Mind Ergonomy for the Knowledge Economy : software Neuroergonomics and Biomimetics for the Knowledge Economy. Why? How? What?

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Mind Ergonomy for the Knowledge Economy

Software Neuroergonomics and Biomimetics
for the Knowledge Economy
Why? How? What?

Dr. Idriss J. Aberkane

Abstract. Could we flow knowledge faster and better? Why is this a problem in the first place? How can we tackle it technologically? What could be a prototype solution? This work unifies these questions in the outline of a single, refutable and improvable paradigm of noodynamics - the study of knowledge flows - and nooconomics, the knowledge economy. This paradigm will answer the question "Why". Neuroergonomics ("brain ergonomics"), and biomimicry, will be summoned in answer to the question "How". Their contribution will follow from the knowledge flow equations proposed in this work. Two original optimisation problems are also posed in software neuroergonomics and biomimetics: the Mindscape and Serendipity Problem. A case of theoretical neuroergonomics, or neuroergonomics *ex ante* is proposed with the study of *Hyperwriting*, a written grapheme-loceme association, or a glyphic method for externalising spatial memory. Its application to the design of user interface will finally found neuroergonomic design, or *neuromimicry*, with the example of a collegial interface to augment multiscale knowledge flows: *Chréage*. The anatomy of this prototype mindscape will be the technological conclusion of this work, and its answer to the question "What"?

Keywords : software neuroergonomics - software biomimetics - user interface - knowledge economy - artificial writing - biomimicry - neurotechnologies

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Prof. Francis Rousseaux - *Président*

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Mind ergonomy for the Knowledge Economy

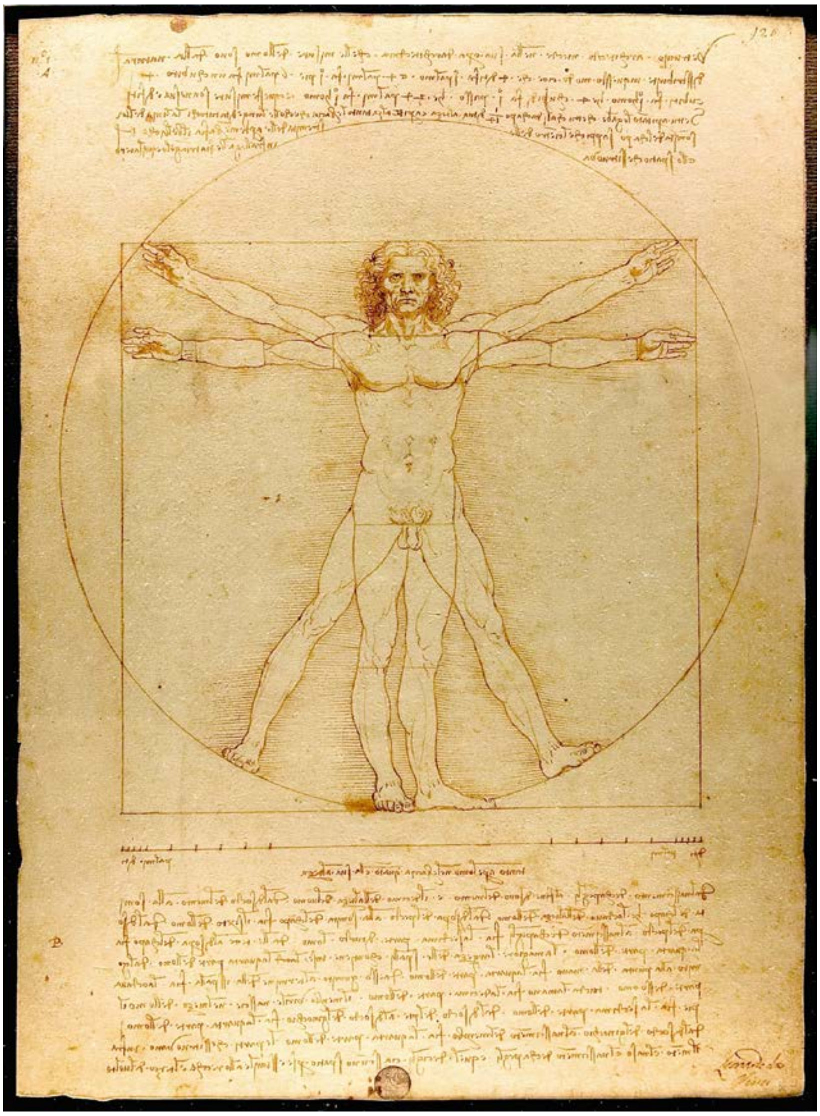

Fig. 0 Da Vinci's interpretation of the Vitruvian Man.

There is something Vitruvian in this research, in that Vitruve attempted to fit man-made cities to the human body, and this work attempts to fit man-made mindscapes to the human mind.

Excerpt from chapter "tradition and state of the art" section "regarding the question what?"

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Thy thought to Thee an Empire be

Introduction

> *As recently as 1987, AT&T was still projecting that it would take until the year 2010 to convert 95% of its long distance network to digital technology. Then it became pressed by the competition. The result? AT&T made its network virtually 100% digital by the end of 1991. Meanwhile, over the last decade the price of interstate long distance service for the average residential customer declined over 50%. Now it is time to take the next step. We must open the local telephone exchanges, those wires and switches that link homes and offices to the local telephone companies. The pressure of competition will be great -- and it will drive continuing advancements in technology, quality and cost. One businessman told me recently that he was accelerating his investment in new technology to avoid ending up as "roadkill" on the* ***information superhighway****.*
>
> —Al Gore (1994)[1]

Could we flow knowledge faster and better ? Why is this a problem in the first place ? How can technology tackle it ? What would be a prototype contribution ?

The purpose of this work is to break new ground to answer all these questions in an inter-related manner, within a single, refutable and improvable paradigm and with the bringing of a simple prototype. Its method is **software neuroergonomics**, and its objective is the theorising of the “fiber optics of knowledge exchanges”. Just as there are already high-bandwidth information pipelines indeed, there could be high-bandwidth knowledge pipelines. From a political point of view, Zbigniew Brzezinski (1970) had well understood the importance of what Al Gore would later popularise as “Information Superhighways” or “Infobahn”, a rhetoric that succeeded very much in capturing public attention in its time. Brzezinski theorised “America’s role in the technetronic era” which Gore applied by expanding the ARPANET and turning it into a civilian network, making one, among others, decisive contribution to the adoption of the Internet, and reinforcing the infrastructural leadership of the USA over Internet and information technologies altogether. The High Performance Computing Act of 1991 (Pub.L. 102-194) also known as the “Gore Bill” is remembered as a legislative landmark of those “information highways” and, indeed, “America’s role in the technetronic era”. The USAPATRIOT Act of 2001, on the contrary, is the manifestation of a disastrous counterpart to the enthusiasm, idealism and freedom of this age…

Now that we have information superhighways, however full-spectrum snooped and wiretapped they may be, **our next challenge is thus to develop Knowledge Superhighways or *Noobahn*. Knowledge superhighways are the very purpose of this work**. Gore opened his March 21st 1994 speech before the International Telecomunications Union with the very notion of a “Global Information Infrastructure” (GII). Thus

[1] Speech before the International Telecommunication Union. March 21st 1994

the founding notion of this work is that of a Global Knowledge Infrastructure (GKI), and this where neuroergonomics is necessary.

Indeed, the problem of building a Global Knowledge Infrastructure is particularly challenging, because flowing knowledge requires a plugging to the human brain : most computers cannot handle knowledge, just information. Elucidating the ergonomics of such a plugging is a difficult task. The *parti-pris* of this work is to look for a non-invasive, natural and ergonomic plugging : natural neuroergonomics, because it believes that it is not for technology to modify the human brain, but it is for the brain to modify technology. Equally, it assumes that technology should not use the brain, but that the brain should use technology, and remain its absolute master at any time.

Therefore, just as biomimicry advocated that “nature is a library, and we should read it instead of burning it”, this work advocates neuromimicry, which equivalent message is “we should read our nerves rather than burn them”. Hence, its view on software neuroergonomics is that **we should not fit the user’s brain to softwares, but we should fit softwares to the user’s brain**. This, in essence, is a manifesto for software neuromimicry, and this entire work.

Why is the endeavour of flowing knowledge faster essential ? This will be the subject of an original, synthetic theory of the knowledge economy, commencing this work. One concept in particular is central to all the questions addressed here : **Mind Tools**. From the carved silex to the space shuttle, Man has designed many tools for the body, and language is already a tool for the mind, but how could we systematically inform the design of mind tools? This is the very purpose of this work’s tapping into neurotechnologies. The conception of mind tools, the founding of such a field as **mind tools design**, with the purpose of **augmenting the cognitive span of working minds** is its entire *raison d’être*. Just as one can define a *fitsful* then, what must be a *mindful* ? If the fistful is the working span of the human hand, the mindful must be the working span of the human mind. Studying its ergonomics and augmenting it can have immense consequences on absolutely all the aspects of human production, from diplomacy to politics to economics, philosophy, arts, and, of course, science.

The essential difficulty in establishing high-bandwidth knowledge transfers is that computers may process information, but they may not process knowledge yet, and especially more so regarding self-knowledge, which has been the most classical and stable definition of the highest quality knowledge there is, namely wisdom, which is yet inaccessible to machines, and has little perishability.

Indeed on the short term, information is very perishable (a daily newspaper intrinsically decays in value within 24 hours), knowledge is less perishable (an academic handbook should be reedited every five to seven years), and wisdom is virtually imperishable (Marcus Aurelius or Sun Tzu would still have precious comments and decisions to offer our contemporary world). One may define knowledge as Plato, the intersection between belief and reality, or as Bacon, that between experience (which, in Bacon's time, included first-person experience) and reality, and therefore scientific knowledge becomes the interaction between theories and phenomena; experimental science having no access to the *noumena*, the non-manifested, but theories having access to any possible noumena, while remaining, so far, unable however to decide whether a given noumenon is verified in our world.

Knowledge implies cognition, and human cognition involves the human brain. Improving the flow of information between computers is a matter of "computer ergonomics", which regards algorithmic optimality. What would be the equivalent for the human brain? Posing this question immediately calls for a certain scientific humility, as it would probably be sterile to apply wholesale paradigms developed for computers, to something that is essentially more complex, the human neurocognitive system, so much more complex actually, that we are yet extremely far from being able to retro-engineer it.

There is however, a dedicated field of research for the study of practices that "fit" the brain, and this field is neuroergonomics, the study of the human brain "at work" that is, not necessarily in a controlled setting. Neuroergonomics has been practiced essentially "ex post" (Parasuraman 2003), but the original interest of this work is to practice it "ex ante". Such an enquiry is founding the fascinating new field of neuroergonomic design. Here it is mainly applied to software design.

As Biomimicry is already an endless source of inspiration from agroforestry to industrial design to architecture, supply chain management or even governance, the emerging, corresponding Neuromimicry is the art of fitting our systems to the human brain rather than fitting the human brain to our systems. It could be equally fertile and lead to the creation of objects, systems and services of remarkable value. Neuromimicry and Biomimicry are the two most essential answers that this work uses to address the knowledge flow problem. But again, why is this really a problem in the first place?

The first part of this work, answering the question "Why ?", is an enquiry into the immaterial wealth of nations, and a new testable and peer-improvable paradigm for nooconomics. The second part consists of the summoning of neuroergonomics and biomimetics to inform the design of new, high knowledge flow user interfaces, and it will be this work's answer to the question "How ?". One application of the neuromimicry described here will be the hypothesis that such a thing as "hyperwriting" is possible, namely, a glyphic grapheme-loceme association to turn the method of loci, an art of memory, into a proper, intersubjective writing. The combination of neuromimicry and biomimicry will also allow us to outline a biologically-inspired theory of the noosphere from the perspective of its multiscale complexity. This work will also pose two original problems in the design of user interfaces, the Mindscape and Serendipity problems, having described earlier why their posing is of economic relevance.

Combining purpose and technological means, the third part of this work will describe the anatomy of a novel Mindscape, *Chréage*, a collegial interface for the knowledge economy in Web 3.0. Chréage is a prototype mindscape to map mental objects onto a virtual space, facilitate their sharing, browsing and navigation. It is an outline of the "fiber optics" of knowledge that this work is calling for, designed to augment knowledge flows at the micro, meso and macroeconomic levels. It is intended as a typical example of software neuroergonomics. Eventually, the entire objective of this work is to research into the scientific extension of human mental operations, and **span augmentation** in particular. It thus attempts to answer those three questions :

Why should we design mind tools ?
How should we design them ?
What are they exactly ?

Why is this work different ?

We need men who can dream things that never were [2]

—John Fitzgerald Kennedy (1963)

I believe in intuition and inspiration… At times I feel certain I am right while not knowing the reason. When the eclipse of 1919 confirmed my intuition, I was not in the least surprised. In fact I would have been astonished had it turned out otherwise. Imagination is more important than knowledge. For knowledge is limited, whereas imagination embraces the entire world, stimulating progress, giving birth to evolution. It is, strictly speaking, a real factor in scientific research.[3]

—Albert Einstein (1929)

Asking the good questions is infinitely more valuable than diligently answering ill-posed or weak ones, **however data-driven the effort**. In establishing a paradigm it is essential to “tread lightly” and be extremely prudent, before summoning data, as to the nature and the scope of the questions that should be posed. It is a pity, therefore, that such a majority of contemporary researchers have been turned into unimaginative “data zombies”, while we need a complete synergy, not castrating, null sum, mutually exclusive competition, along the scientific value chain, between data, models, concepts and even intuitions and dreams. Billions of exabytes of data with no model, concept or purpose are of no value ; in fact, maybe the value of data is correlated to its product with purpose, itself derived from concepts. Then, an immense amount of it multiplied by zero purpose, zero concept, zero idea, is worth nothing. It is, however, the type of decaying flesh that some - fortunately, not all - scientists pride themselves to have an appetite for. Ideas change the world more surely than data ; they always have, and always will. One can conduct research without data - Edward Witten, Albert Einstein, and any mathematician always have - but one can positively not conduct research without ideas, period.

Yet, the quantitative - not the qualitative - majority of scientific research operates within the comfort zone of well-established paradigms, allowing it to collect large amounts of data, smaller amounts of information, smaller amounts of knowledge, smaller amounts of ideas and concepts, and only a trace amount of novel paradigms or even more rarely, wisdom. Yet, a civilisation that is producing a lot of knowledge and very few wisdom is doomed. We must maintain at all time an excellent ratio between knowledge and wisdom, lest we destroy our own humanity.

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[2] John Fitzgerald Kennedy in Kennedy, J.F. (1964). Public Papers of the Presidents of the United States: John F. Kennedy, 1963: (Best Books on). p 534

[3] Albert Einstein in Einstein, A., and Shaw, G.B. (2012). Einstein on Cosmic Religion and Other Opinions and Aphorisms (Dover Publications).
p.97

So the quantitative majority of research produces data, information, some knowledge, and almost no wisdom. There could be many explanations to this phenomenon in terms of cognitive biases ; Man is reputed to favour his comfort zone over the search for the truth, be it moral or scientific : whenever the majority is faced with the dilemma of leaving their comfort zone and embracing the truth or rejecting the truth and reinforcing their comfort zone, it is the latter we must expect to be chosen. Worst : those who have been courageous and sincere enough to leave their comfort zone, will be decried by those of their very peers that have been most lacking courage and originality themselves.

A teaching-story of Mollah Nasruddin illustrates this phenomenon, all-too destructive in the academic world : the Mollah is seen searching for his keys outside at night, within the light cone of a street lamp. “Where did you lose the keys in the first place” “at home, answers the Mollah” “Why would you look for them here then ?” “Because, here, there is more light”. Researchers tend to follow the exact same bias, searching for novel answers within either worn-out or inadequate paradigms. The approach of this work is different : it has the ambition of founding an original, though simple paradigm for the guiding of further data-driven research, but it commences with concepts, and assumes concepts are more precious than data at this very stage of the scholarly value chain, for they inform their purpose, without which data has no value. Before there is such a thing as data-driven research indeed, there must be concept-driven, idea-driven, paradigm-driven research. Of this alas, no matter how often History will brilliantly and boldly remind Humanity of the unfathomable value, data-zombies deny the very existence.

Today data is overabundant, and has clearly begun slipping away from the hands of academics. When the FAT GAS BAM (Facebook, Apple, Twitter, Google, Amazon, Samsung, Baidu, Alibaba, Microsoft) collect and handle more data in a day than the entire academic world in a decade, even the noble astronomic data of a Kepler mission is promised to be left, *in fine*, to such companies as SpaceX and ArianeSpace. The oil supermajors of the past are being substituted in importance (entrepreneurial, financial, political and even diplomatic altogether) by data supermajors, able to extract, refine, value and sell data. What will be left to academic research then ? What computers cannot collect, namely, ideas, knowledge and wisdom. These categories, overlooked in the last four decades of research, especially more so with the emergence of the pseudoscience of academic rankings and bibliometrics, themselves correlated to the capacity for data extraction and analysis overall, are becoming the most precious commodities of scientific research in the 21st century.

There is an endless debate as to the importance of acquiring new data prior to founding a new paradigm, and a probably even more sterile debate as to the importance of citing existing paradigms to establish new ones. Why are these debates sterile? Why is the forcing of academics to review all of the existing paradigms before contributing their ideas very far from being a best practice ? Simply because brilliant scholars in the past have repeatedly demonstrated that one could produce outstanding research without obliging themselves to these petrified routines. Da Vinci did not quote his peers, and was unable to cite most of them, handling neither Latin nor Greek, and while he is today considered the archetype of the Renaissance Man, was thus never awarded the title of "Humanist" in his lifetime, for he did not master the Humanities of his time. Rather than citing peers and masters he merely acknowledged "I am Leonardo, the disciple of experience".

Darwin's model, the cornerstone of contemporary biology, was not at all data-driven at the time of its publication : it was backed by mere subjective observation, and contained not a single reproducible experiment; it would prove to be the father of pretty much all reproducible and peer-reviewed experiment in biology for a century and a half, yet it received horrible peer-review in its time. Einstein's works were theoretical in nature, and would have to wait for more than fifteen years before they were backed with some data. So were the speculations of Fritz Zwicky over neutron stars or dark matter, so were black holes, so was Lemaître's theory of a "primordial atom" (which would become better known as the Big Bang Theory, a term that was supposed to turn it into derision), etc.

Descartes' works received such a negative and suppressive peer-review in their time that the French philosopher had to spend half of his life in exile. Adam Smith's enquiry on the wealth of nations did not contain any data, consider any experiment or contrast any direct citation. Newton's notions of *fluxions* were amply rejected by Berkeley. So were Cantor's theories, firmly opposed by an authoritative clique of well-established mathematicians, including Kronecker ; Hilbert and Poincaré endlessly antagonised each other over their views on the foundations of mathematics, while they were much more than opposing, they were complementary.

Bertrand Russell and Alfred North Whitehead could not find a way to publish their *Principia Mathematica*, other than paying themselves for their printing, a practice that is still considered infamous by the contemporary academic world. As it is, one of the most important works of 20th century logic, just as the single most important work in economics (the Enquiry) and in biology (the Origin of Species) had thus not at all fit contemporary academic standards. The *Principia*, however rejected by its peers, inspired two major scholars among others, Ludwig Wittgenstein and Kurt Gödel, showing once again that it matters not how many people cite you, but *who* does.

As for Wittgenstein, there is not a single experiment, not a single data and not a single canonic citation in his *Tractatus Logico-Philosophicus*. How come it was such a groundbreaking work then ? Possibly because it was groundbreaking both in form and content. Scientific research is much vaster than its organisational form, which is therefore suboptimal ; should it surprise us then, that it had been repeatedly possible to procure remarkable thought away from its oligopolistic supply chain ? Should it surprise us that this process subsisted, and even thrived, in our times still ? Benoît Mandelbrot is yet another example of a disruptive outsider whose works encountered immense academic opposition before they were adopted in a triumphal manner.

"I am trying to think, don't confuse me with facts !" is a famous quote by Plato, defended by Richard Francis Burton "Facts (…) are the idlest of superstition". The same should apply to an original work "I am trying to invent, do not confuse me with the thought of my peers". This, would be ideal creativity ; this work however, has not the depth, the richness, the genius and the creative impetus of a Descartes, a Smith or a Wittgenstein. Citing is a help, and as such, should never be obligatory, and it has been a trademark of many a great mind to cite as little as they could. Paul Cohen, who triumphed over one half of David Hilbert's First Problem, prided himself of not reviewing or citing any of his peer's earliest works, so that he could transcend them rather than ground his thought to theirs ; the same acumen for independent research animated Andrew Wiles, Alexander Grothendieck, John Nash or Ytang Zhang.

Did the Wright Brothers perform any thorough literary review prior to successfully flying their plane ? Not at all ; such a review could have even prevented them from succeeding; countless scholars were busy reviewing previously published materials on the possibility of flying planes. Unencumbered by such a castrating exercise- which here, they well proved counterproductive - the Wright Brothers proceeded with trials and errors until they succeeded. "We are Orville and Wilbur Wright, the disciples of experience", could have been their conclusion.

Rather than endlessly spiralling over the bit-by-bit contributions of one's peers, which the standard "publish or perish" inclines to pusillanimity in the very same manner than a strict quarterly corporate governance can discourage long-term managerial vision, breakthrough originality, the engineering of a paradigm shift, must be commenced away from "where there is more light". There is no doubt it is sometimes necessary to clearly depart from existing models, because they tend to establish both a form and a scholarly comfort zone that ends up limiting. Paradigms are the only things that define the possible and the impossible, and the establishment of complex scholarly constructs, however excellent it may sometimes seem, and however fertile in new results exploited from it, is also a limitation *per se*. Such limitations becoming so usual to the scholar's mind, one tends to defend the "impossibility" to solve such and such problem, merely because it is inaccessible to the current paradigms. Here we have once again a manifest propensity for preferring one's comfort zone over the truth, however beautiful and exalting it may be, from flying a plane to admitting to a universe populated by something - dark energy and dark matter - that we know virtually nothing of.

Hence, established thought is a shelter for the mind. It is made for exploitation, but is inimical to exploration. Yet, exploration is the very purpose of an original work, and therefore it could avoid established thought as much as possible. In searching for new forage zones, one must first leave the shelter. Most researchers, however, prefer their shelter over a new discovery, and that is why peer-review has proven so repeatedly inimical to paradigm shifts, from Copernicus to Galileo to Descartes to Darwin to Planck to the Wright Brothers, etc. Demanding that research be formally placed within existing paradigms is demanding that the scholar extract oil from the same field as them. This being well understood, one can perfectly deduct the natural consequences of such a prerequisite. An original work, is searching for new, unexplored oil fields. With this goal clearly established, its methods and scopes will not appear unorthodox anymore to the practical researcher.

Mind ergonomy for the Knowledge Economy

In balancing exploration and exploitation in scientific research, we are not quite as aware of the topography of unknown knowledge, as we are of geography. Simply put, we are conscious of geography, but vastly ignorant of noography. There are phylomemies however, and the excellent work of Chavalarias & Cointet (2008, 2013) is worth mentioning here. But phylomemies are but observations of existing literature, their main shortcoming is that they can only be based on what has been published, and thus map the *terra cognita* at its interface with only some very limited *incognita*, that must be in immediate contact with the published world. The *incognita* at large, that is not adjacent to the *cognita*, science mappings, agregators, phylomemies and the like have simply no access to.

As it is with many fields and the limitation of human consciousness, most scholars will tend to believe such areas are either inaccessible or, for some obscure pseudo-scientific reasons, should simply be avoided. This belief has not been proven however. That scholarly research need be completely connective paradigm-to-paradigm, that it be not recommended to establish novel, non-connective paradigms, this is indeed a merely unproven belief, and as with all unproven beliefs, a mark of obscurantism, from which, eventually, scholars are not any more immune than non-scholars.

It is interesting, eventually, to consider to which extent scientific research is stygmergic, that is, to which extent scholars reinforce each other's scientific paths, and suppress deviant ones. Stygmergies are made for exploitation, this is exactly how ants self-organise them in foraging for food. This is also how the human brain works in reinforcing developing pathways. Changeux has developed the fascinating notion of a "neural darwinism" to describe the way spontaneous activation in utero stabilises critical neural pathways. The consolidation of the pathways of reading in the human brain are also typical stygmergies. General Systems theory has taught us to consider scale-invariant organisation principles, and it is interesting to see how humanity is becoming a collective brain, reinforcing and suppressing certain connections, and how scientific research is essentially stygmergic, and therefore, exploitative. The difference, however, between neural and academic stygmergies is that the first are nature-proof while the others are simply reinforced by dogmas and unverified assumptions.

Peer-review is essentially peer-pressure. And of course, peer-pressure can bring nothing good to research, or just as Richard Feynman would often vehemently say, quoting his sister, "what do you care what others think ?". We have entered the 21st century with a research of the 19th, peer-review having been critically developed by the rapidly-industrialising Germany to accelerate the adoption of industrial standards, and thus not for fundamental, disruptive research. The problem is now so pervasive and global that even the Times Higher Education has been publishing a clear call for an all-out abolition of peer-review *ex ante* in scientific research, in favour of it *ex post*, as it has always been.

> *Earlier this year, the former British Medical Journal editor Richard Smith called, in these pages, for pre-publication peer review to be abolished.*

> *"Peer review", he wrote, "is supposed to be the quality assurance system for science, weeding out the scientifically unreliable and reassuring readers of journals that they can trust what they are reading. In reality, however, it is ineffective, largely a lottery, anti-innovatory, slow, expensive, wasteful of scientific time, inefficient, easily abused, prone to bias, unable to detect fraud and irrelevant."*
>
> *Far better, he said, to just publish all papers online and let "the world…decide what's important and what isn't" (*"Ineffective at any dose ? Why peer review simply doesn't work*", Opinion, 28 May).*[4]
>
> *If the majority of referees like your research, you can be certain that you are doing boring work. To push forward ideas that will matter to the world, you and I may as well accept that we are going to have to upset people and crawl through the trenches of muddy carping and explosive criticism. All referees – and I suppose that must include me – are subconsciously looking for manuscripts that play back to them ideas they already find familiar and palatable, and ones that lend support to their own prior research. That is bad and sad. However, it also happens to be human.*[5]

A more general trend is peer-improvement, which, if it is sincere and always performed in good faith, can truly help science. The problem is that human science, as any human activity, has a physical counterpart, namely the complex and suboptimal structure of credits, grant committees, promotions, tenure and the terrifying behemoth of academic social autopoiesis with its mountains of ego etc. This system is highly competitive, and thus, highly inimical to collaboration, which is still the only way to make excellent, far-reaching research (and the CERN may be such an example).

In *Behind the Mirror* Konrad Lorenz simply considered automatic thinking, or what Sufi psychologists like Idries Shah or Robert Ornstein have called "mental petrification" a disease of the mind. If there is a mind ergonomy, it implies there are postures of the mind. Confining our mind to certain postures only could indeed cause postural diseases, comparable to their bodily counterparts. This Dan Pink and Ken Robinson have also well explored. One problem is that while we may easily see our own bodies, we do not easily see our own minds, and thus are unaware of its wrong and malignant postures. Even worse, while an outside observer may easily detect a wrong bodily posture, the same could only observe a wrong posture of the mind under certain circumstances, because the mind does not manifest itself passively but only actively, not at rest, but under stimulation, unlike the body.

Ill-being is probably the most salient symptom of a wrong posture of the mind. Then, one could study the immensely widespread ill-being of Ph.D students for example. Why is it, indeed, that Ph.D students around the world are so chronically unhappy ? Is it

[4] *The worst piece of peer-review I ever received : Six academics share their experiences before delivering a verdict on the system* Times Higher Education Aug. 6th 2015.
[5] Andrew Oswald, in the same article.

related to a more general trend, that opposing fulfilment and productivity ? Or is there something particular to the condition of Ph.D candidates that is creating such a reproducible phenomenon of mental pain and ill-being? In any case, it must be a problem of mind ergonomy : why do Ph.D students suffer so much?

Having written three Ph.D thesis myself, my personal opinion on the matter would be that the general ill-being of candidates is at least caused by a mixture of cognitive dissonance and material servitude. Together they create disillusion, disappointment and incertitude, which can but only manifest into ill-being. The Ph.D condition indeed, is much too often a very effective scissor effect between material and intellectual servitude.

Intellectual servitude comes from that Ph.D students are most often encouraged to become data zombies, into a process, painful and unwholesome, that will achieve such a powerful hold on their intellect that it will self-organise into a disastrous hazing, by which the minds who have already castrated themselves of their dreams, ideals, and intuitions in favour of a strict automatic data-drive will despise and suppress those who haven't, calling them childish or unprofessional.

Automatic data-drive however, is the very opposite of the enthusiasm Ph.D candidates initially embraced research for. What most early researchers want to produce, precisely, are groundbreaking works, the like of Newton's, Cantor's, Darwin's, Wittgenstein's or Chomsky's, which are precisely the ones that the academic condition will most forbid today, for they are mere "opinion pieces", something that does not even warrant doctoral graduation nowadays. One must never forget, however, that Chomsky's response to Skinner's theory of a conditioned acquisition of language was just an opinion piece publishing no data at all. It was, thus, surely not "data-driven" but "idea-driven". Great researchers have always valued ideas over data. The reason behind that is again simple, and worth repeating : it is possible to produce great research with no data, but it is impossible to produce great research with no ideas.

Thus data-driven and nothing else, students who embrace the career of researcher to contribute their creativity, their ideas, their intuition, their concepts and even their dreams, that is, what is most beautiful and most human in their mind, must turn themselves into data machines, and suppress all that is not data in their intellect. This transformation can only be but an alienation, for it turns a human being into a lesser thing, and makes this suppression a virtue, while it is most surely a vice. Nobody has put it better than neuroergonomist Jorge Cham in his "Piled Higher and Deeper" comic strip.

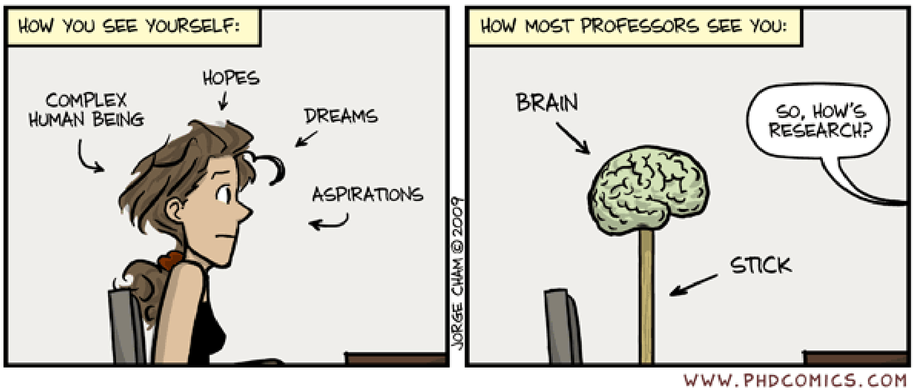


Fig 1. "Piled Higher and Deeper" by Jorge Cham www.phdcomics.com

Since the transformation from a complex human being into a data zombie is essentially a mental castration, it may foster the dynamic of social autopoiesis through painful rites of passage. The Ph.D becomes such a rite, and the pain sustained, a confirmation of the social autopoiesis. Richard Francis Burton once wrote "the dream of the slave is not to be free, but to have a slave of his own". The dream of the data zombie, methinks, is not to become human, but to become a necromancer himself, that is, someone who makes, and has zombies of his own. Research, however, is not the path of limitation, but that of expansion. The purpose of the researcher is to augment his intellectual humanity, not to reduce it to mental petrification and automatic thinking. This, maybe, makes for a very powerful cognitive dissonance between the dreams of paradigm shifts that a prospective Ph.D candidate harbours, and the reality of everyday lab life. One embraces research to change the world and therefore work on world-changing questions, but the Ph.D researcher ends up working on a field with extremely narrow implications, and which he did not choose himself. Yet, a thesis should not chose its student, a student should choose his thesis !

Is it a virtue to bridle the dreams and aspirations of Ph.D researchers ? Surely not, as whether or not they are data-driven, they are truly change-driven. What the data zombie has not, is the impetus to challenge the status quo, that to plant his dreams into the world and make a profound intellectual difference. Economically, by bridling this very impetus, we deprive our society of its vitality, and this is a tragic phenomenon, which, again, we call a virtue. The intellectual ill-being of Ph.D students, I believe, is fuelled by this painful collision between their dreams and the intellectual austerity of the system. Who is right and who is wrong in it ? Surely, the system is wrong and Man is right, for Man is greater than any of his creations, and dreams are greater than data.

The material servitude of Ph.D students is manifold. First, as Marx had understood of the proletariat, and as Berardi well understood in our time, they form a "cognitariat", a class of people who own not the means of production and must sell not their body, but their minds to operate it. Hence, the means of production dictate how the cognitariat should use their minds rather than their minds dictating how the means of production should operate. We end up with a system in which the industry operates humans and not humans operate the industry. This is profoundly nefarious, and, unsurprisingly, mentally painful.

Ph.D researchers do not own the means to produce data. Yet, they are made to believe that, in research, anything that is not data is worthless. They must hence submit themselves to data and not submit data to themselves, which they can't, because they cannot produce it themselves anyway. Hence again, the system ends up choosing how it uses human beings, not human beings how they use the system. The cognitariat, by not owning the means to produce data, which are increasingly more centralised, ends up having no bargaining power against them. Even more : Ph.D researchers being extremely docile because they have been graded for so long, and eager to compare each other's grades and alienate those of their fellows who did not graduate from a university as prestigious as theirs, naturally limit themselves into an attitude of very low bargaining power. They are very poor bargainers indeed, either regarding wages, precariousness or working conditions, and can very easily become a disposable workforce that is simply unable to look after its own interest. Unlike the proletariat even, the owners of the means to produce data do not even have to split them and impede their sense of brotherhood, for they are enforcing an anti-brotherhood attitude themselves, again, mocking those of their fellow with lower grades, supposedly lesser data, lesser track, lesser citation composite indices etc. Poor bargainers and fanatical individualists with a natural and strongly reinforced propensity for trolling each other… this makes for a perfectly disposable workforce indeed. And then, the data industry operates brains, not brains the data industry, and academia is ruling over men, not men ruling over academia. Man creates systems to pilot them, and ends up being piloted by them.

This is particularly true of the adoption of two rather recent and socially nefarious practices : the spreading of postdocs and of bibliometrics. A postdoc, initially, was a privilege for those who sought spare time to focus on research, away from administrative and teaching duties. Today, it is a form of employment blackmail, by which researchers are confined into precariousness at wages that are ridiculously low compared to their qualifications and for periods that are next to unprofessional and disrespectful to their very age. Regarding bibliometrics, it is nothing but a pseudoscience : a system that one cannot contradict and is forced to adopt regardless of its correlation with the fine grain of reality. In both cases, those practices are recent, and their adoption has been due to a mixture of bandwagon effect and academic self-discipline.

If I had to make recommendations for a happier Ph.D life, I would first encourage Ph.D researchers to systematically oppose intellectual and physical servitude, the most important being the intellectual one. Researchers should choose their field, not their field choose them. Research is an intellectual mariage, and the choice should be driven by love, not by mere reason. Most doctoral mariages however, are driven by necessity and reason rather than by love and passion. Then, a researcher should always admit this very simple principle : dreams are more precious than data. Profound, world-changing research is not data-driven, it is dream-driven. Hence, data should not be driving humans, humans should be driving data. The same apply to ideas and dreams : they drive data, not the other way around.

Both materially and intellectually, Ph.D researchers should be made to cooperate and respect brotherhood over individualism: there should be joint Ph.D programs by which units of, say, around five students would defend a very large project together, thus fostering bonding, a shared sense of purpose and the mutual exchange knowledge and experience. But that Ph.D researchers have been graded over such a long period of time makes them believe that individualism is a virtue. This is somehow reminiscent of the excellent *attitudinal portrait* that Richard Gabriel made of the Cold War soviet soldier : being trained to precisely avoid brotherhood and bonding:

> Soviet military units appear to have failed to develop strong primary-group attachments among the soldiers and between leadership elements and their men. This represents a potential for instability and fragmentation under combat stress. Therefore the effectiveness of Soviet military units in prolonged battle, when quick victories are not forthcoming (…) is open to question. Soviet military units could well begin to unravel if pressed hard enough in a conventional battle environment. From this perspective, Soviet units contain a great systemic weakness.[6]

Or as Idries Shah commented on this study in his novel *Kara Kush*, the leadership of those “new red legions” actually *feared* bonding, which could only occur by accident within military training. The result was an ineffective army, which soldiers went easily AWOL, if they could find bonding and brotherhood with the enemy. The atomisation of research and of students has produced a comparable effect, and it is probably why Academia is the only industry in which such practices as *trolling* and *name-dropping*, of which a preteen youtuber would already admit the nefariousness, are actually considered best practices. One could conclude, as Gabriel does of soviet units, that Ph.D researchers, as a class, contain a great systemic weakness. So does Academia at large : it maintains an attitude which is individualistic and inimical to collaboration, originality and change.

How could we avoid the many professional diseases of the human mind then ? Regarding those disease of the social mind, as they especially emerge in education, I could only but recommend the advice of the Renaissance *bottega*, at which Da Vinci was typically educated, and which Tai Lopez summarised as the law of the 33% : spend one third of your time with people who can mentor you, one third of it with yourself, and one third with people whom you can mentor.

I have no doubt that fulfilment and productivity should not be opposed. The same goes for the opposition between nature and the industry. These two oppositions are inherited from the Industrial Revolution and have matured throughout the 20th century : for post-war South Korea for example, there was little doubt that a generation had to sacrifice itself to improve the standards of living of the coming one. These oppositions, however, are being increasingly more challenged in the 21st century, a century in which fulfilment should be the sine qua non condition of productivity, not as a principle, but simply because there is no more excellent, and profitable productivity than the meaningful one

[6] Richard Gabriel. The New Red Legions. Vol. 2 an attitudinal portrait of the Soviet Soldier Greenwood Press, 1980

of fulfilment, and in which nature and the industry should work together, in full synergy, rather than oppose each other.

Ex-Google Eric Schmidt's 70/20/10 model for resource management, and in particular that of intellectual resources, should be encouraged in Ph.D life, just as that of Tai. First, Ph.D researchers should be encouraged to spend, indeed, one third of their time with students they can mentor, one third of their time with themselves, and one third with a mentor of their own. Second, they should, as Schmidt recommends, they should adopt the habit of dedicating 70% of their research time to their very thesis, 20% to related questions, however interdisciplinary and away from their expertise, and 10% on anything recreative, that is completely unrelated to their thesis but that is fascinating them enough to warrant the spending of their intellectual time. These two rules of course, I have been fortunate enough to apply to my own research time, through all the three Ph.D research projects that I have conducted, and which, also, I was fortunate enough to choose myself. Interestingly enough, Jorge Cham, who is a neuroergonomist, advocated "the power of procrastination", and indeed, recreation etymologically rhymes with creation.

In a nutshell, my piece of advice for fulfilled Ph.D students and Postdocs would be

- never despise dreams, intuitions and pleasure in research: good research does not exist without them
- prioritise and protect them over anything, including data and publication conformity
- never become a data zombie: always collect data if it is motivated by a purpose, a concept and, even better, a dream, never just for the sake of it. The same goes for citations.
- never despise brotherhood and friendship: research is intrinsically collaborative, not competitive. "Hold Humanity one Man" as Burton chants, and remember to always challenge this blatant lie that graded people tend to internalise deep in their mind : that success or failure are individual phenomena. This may be true for unimportant things - a graded exam for example - but is not for truly important ones : from hunting mammoths to building the pyramids to landing in Normandy, success or failure has always been a collective process for Humanity, and it always will. Do not think that Academia is smarter than Humanity, for it is smaller, and less important.
- equally, any *Homo* that is not *sapiens* is an alienation. *Homo academicus*, *Homo geopoliticus*, *Homo economicus*, *Homo industrialensis*… however tempting they may sound, and look, are but mere limitations and alienations of *Homo sapiens sapiens*.
- do not consider the castration of your mind, of any of its dimensions, a virtue. Your mind comes from millions of years of evolution, and there is nothing genuinely useless in it. Dreams, hopes, aspirations, creativity, ideas, speculations, should not be skimmed off research, they are research, and always have been.

- Research, and especially Ph.D research, is a mariage, and should be driven by love, not by data, not by reason. If you do not love your subject, do not marry it.
- Precisely as Jobs said, which is true for any trade, including research, “have the courage to follow your heart and intuition” and do not prostitute them for a mere drive for data.

and hence, remember that

> there is no such thing as conformist, peer-pressured and obedient innovation.

Innovation is disobedience

—Serge Soudoplatoff

1. Tradition and state of the art

> ***Ideas[7] are what power sur economy.*** *It's what sets us apart. It's what America has been all about. We have been a nation of dreamers and risk-takers; people who see what nobody else sees sooner than anybody else sees it. We do innovation better than anybody else -- and that makes our economy stronger. When we invest in the best ideas before anybody else does, our businesses and our workers can make the best products and deliver the best services before anybody else.*
>
> —Barack Obama (2013)[8]

1. Regarding the question "Why ?"

This work, however original, is no *Codex*, *Wealth of Nations*, *Principia*, *Discours* or *Origin of Species* and it can cite and contrast peers, showing that the noems, the mental objets and streams it presents, are not so far away from existing others in the noosphere. However, I claim citing is not a virtue, but just a help. The principal subject of this work are knowledge flows. They have been rather poorly theorised in economics so far. Although Beck and Davenport (2013) underlined the essential role of Attention, they did not establish a simple theory of it as a critical element of purchasing power in the knowledge economy. They understood the importance for entreprises to capture attention and defined it as a "currency of business", but did not clearly establish it as one of the most basic currencies of the knowledge economy, along with time. Considering that time and attention be the most fundamental currencies of nooconomics, and that knowledge exchanges, unlike properties exchanges, are flows, will be one of the most novel contributions of this work.

Essential to the founding of my theories on the importance of knowledge flows have been the works of Gunter Pauli (2009), themselves comparable to those of Ellen Macarthur, albeit more enterprise-oriented. The idea that waste-free production systems could be more profitable than waste-producing ones is inseparable from that of flowing ingenuity and innovation faster in industrial clusters. In a way, the paradigm of the Blue Economy is the best and most recent illustration of the importance of knowledge flows in economic systems, not only from the point of view of information asymmetries, transactions and contracts, but from that of paradigm shifts.

Another inspiration to this work are the theories of George Kozmetsky, and the seminal symposium of Smilor et al. (1991) *The Technopolis Phenomenon*. Kozmetsky's question "how can we create prosperity in zero time ?" echoes Pauli's industrial ecology and bio-inspired industrial theory in that nature does indeed produce "prosperity", as

[7] Data Zombies take notice: data without ideas are worth nothing. Ideas without data can still change the world; they have in the past and will keep doing it in the future.
[8] Barack Obama - Remarks on the BRAIN initiative April 2nd 2013.

defined by a diversity of added value, from initially lifeless plots, using only what is available on the spot. Nature does not willingly import materials, it captures them ; in nature, importations are emerging (self-organised without a designed intention) and public, in our economic systems, they are planned and private (akin to intelligent design at the mesoscopic scale). There are many other comparisons that we could consider between nature and our economic systems ; probably the most essential is that in nature, individual behaviours do self-organise into a collective good. Nature is the best embodiment of Smith's Invisible Hand, before economic systems.

That any value be reducible to a natural good or service is also an essential idea, uniting biomimicry and economic theory. It is owed to the Physiocrats, Quesnay being the most famous, but the physiocratic thought having originally spread across the Atlantic through Benjamin Franklin and Dupont de Nemours ; economy and ecology of course, share the same etymology, and this connection is being all the more confirmed in the 21st century, with the works of Pauli, Macarthur and Benyus among others.

Pauli wrote that nature would surely deserve an MBA (a "Master of Brilliant Adaptation" precisely) because its managerial practices are incredibly more advanced than ours. Benyus would add, comparing it to supply chain analysis, that nature has a remarkable ease at organising such a complex event as "Spring", which, from the point of view of supply chain coordination is an incredible feat, when such major companies as Apple have to postpone the release of products for lack of a working supply chain (two examples being the Apple Watch and the Macbook of 2015, the latter having been postponed due to a delay in Intel's delivery of it's Broadwell "core M" technology).

"Whatever is good for you and the environment is expensive. Whatever is bad for you and the environment is cheap. Who is in charge of this system ?". This is the major question in bio-inspired economic paradigms, posed by Gunter Pauli and reiterated by Janine Benyus. Nature, more than an MBA, well deserves several Bank of Sweden Prizes in Memory of Alfred Nobel : it has established the only economic system in which, for every supply, there is a demand. It has established a way of producing both cheaper and in larger quality and quantity. Anything that is good for us and the environment is cheap in Nature, while again, the opposite applies to our current, suboptimal systems. And in Nature indeed, individual self-interests self-organise into that of the community, so that there is a seamless continuity between microeconomics and macroeconomics. There are however *zeitgeberen* (time-givers) in nature, such as the Earth rotation around the sun and its axial precession.

1.1 Conceptual landmarks for the classical economist

Humanity has been exchanging knowledge long before it ever exchanged goods and surpluses. The knowledge economy, therefore, is not a novel phenomenon ; what is new is its awareness, and its systematic theorising. In it, I also owe a lot to technologist, entrepreneur and former IBM researcher Serge Soudoplatoff, for having formulated what is probably the most fundamental social consequence of knowledge exchanges, and which, in this work, I call "Soudoplatoff's law".

This law in itself, as I will underline later, is but an alternative expression to the well-known notion of “rivalry” in the economy of goods and products. Although the rivalry of immaterial goods is actually subtler ; rivalry is usually considered within “normal” conditions of use. For example, a bridge is not a rival good as long as the crossing of it by someone does not impede the crossing of it by someone else. There are hence regimes under which some goods may be rival, and others under which they may not be. This will be explored in more detail in Chapter 1 which was initially written for a more general audience, but will be supplemented with clearer marks for the working classical economist.

At least, although the notion of “rival” goods was notably developed by Lawrence Lessig, the inventor of the Creative Commons licence, I found it had been developed earlier by Serge Soudoplatoff at IBM, though not popularised in academic circles at the time. A common academic ancestor to the theories presented here and classical knowledge economy is of course Peter Drucker ; I will be drawing on his KID (Knowledge-Information-Data) nomenclature to develop my work.

Considering the state of the art in classical knowledge economy, one must understand that this work’s objective is entirely focused on theorising early “knowledge superhighways” and thus concentrates on the act of flowing knowledge, either at the micro, meso or macroeconomic scales. Hence again my drawing on Beck and Davenport to develop the notion of “At” or “@“, defined later as one hour at full attention (from a scale ranging from 0 to 1) as the fundamental currency of knowledge exchanges. This has the merit of allowing to establish an early knowledge econometric that would not only be estimating knowledge flows based on the exchange of patents. Patents indeed are rival goods, in the sens that one patent can rarely be fully owned by two entities at the same time. In nature, the very notion of patent is based on relative exclusivity. The propagation of the practical knowledge of fire-making, on the other hand, which we may consider one of the landmark cases of the knowledge economy, was non-rival, in the sense that a single tribe, or man, was able to distribute it to many others successively or simultaneously. Patents, in essence, are artificial ways to turn a non-rival good into a rival one. One may also remember the mnemonic expression :

viral => non-rival

which very well applies to the spreading of online contents and especially memes. Mems however, commercials and the like, do compete for human attention, which is limited and finite, as living organisms may compete for a niche, and this again Richard Dawkins has very well theorised.

All in all, this work is to be taken as an improvable heterodox contribution to classical economy that is driven by the sole perspective of theorising knowledge superhighways and in that, the end justifies the intellectually heterodox means. As I have also learned from Serge Soudoplatoff, beyond orthodox and heterodox, there is *hyperdox*, the transcending *doxa* that is, which is the fruit of perspective. Hence, whenever needed, the usual concepts of marginal cost, economy of scale, purchasing power and null-sum exchanges will be used. In other situations, ad hoc notions, which may or may not end up convertible in classical ones, may also be added. This is, like any academic work, is a work in progress, and its flaws are affordances for the constructive mind, stridence for the destructive mind, of which, of course, I am not responsible for.

2. Regarding the question “How ?”

Neuroergonomics, in its modern practice, is owed to Parasuraman, and describes the science of fitting the brain “at work”, or even augmenting its performances in a rather controlled manner. Classical neuroergonomics is mostly practiced *ex post*, that is, deducted. Its origins are related to military research, with Parasuraman being commissioned by the US Air Force to conduct studies on the neuroergonomics of flights. Avionics and neuroergonomics work naturally well together. With the high cost of both the hardware and training of pilots, the potential value of neuroergonomics in avionics is well matching the cost of their research. France has thus also created an institute for research into neuroergonomics and avionics (neuroavionics), in Toulouse, and it is likely that there be an emerging global race for neuroergonomics at large, considered the productivity leverage it can muster.

Such as there is a theoretical physics, theoretical biology and theoretical neurosciences, there is a theoretical neuroergonomics. One can predict models and the existence of previously unknown phenomena, before the experimental means are available to test them. Again, Fritz Zwicky predicted the existence of dark matter and neutron stars way before there were any means to observe them. This is exactly the *parti pris* of this work: one of theoretical physics, but in neuroergonomics, attempting to predict the existence of certain cases of neuroergonomics, before they can be tested.

The most groundbreaking of such predicted phenomena is hyperwriting, a way to write with the method of loci. The method of loci, mnemotechnics at large, are early cases of neuroergonomics that were discovered through the finest and most scientific way of conducting research: intensive trial and error. In the case of the method of loci, it has been well described by many scholars across the ages, not the least among them Giordano Bruno; world memory champion Nelson Dellis and Paul Stammets use memory palaces to achieve their high performances, suggesting that our common ways of handling mental objects are far from optimal. After all, olympic athlete Dick Fosbury demonstrated that our ways of jumping high obstacles, however reiterated across generations, had not been optimal either.

If there are new stances to discover in track & field, where the external human body is well visible to anyone, would there not be optimal stances to the human mind as well ? Could we consider these stances mental algorithms in a way, and question their relative power ? What if we were all underusing the leverage of our brain ? That we “only use 10% of our brain” is both a myth and a non-myth : it is true that one uses not all of the hand’s surface when typing for example, and that one could type faster and better still. The question is not whether or not we use “all of our brain” at any time, but rather if we use the good mental strategy to handle such and such task. It is possible to grab mental objects and problems with different parts of our brain, or in different ways altogether. It is possible to redistribute the cognitive weight of a given task over many different cortical areas and functions of the modular mind. This is founding Mind Ergonomy, the art of distributing cognitive weights over the modules of the mind in an optimal manner. This work, unsurprisingly, owes to those scholars who have researched into the modularity of the mind, not least among them Jerry Fodor, Ned Block, Michael Posner, Zenon Pylyshyn and Antonio Damasio.

Pesenti et al. (2001) have demonstrated that prodigy calculator Rudiger Gamm, who is able to mentally compute the real value of prime ratios up to the sixtieth decimal, was critically tapping into his episodic memory to achieve his performances. From the perspective of computer sciences, this seems comparable to the GPGPU technique, by which Graphical Processing Units, which are normally made to excel at massively parallel computing, are used to fulfil routines normally attributed to the CPU. Episodic memory and spatial memory, as Rudiger Gamm uses them, allow to achieve much larger performances than working memory, with its well-known usual limitation of 5 +/-2 objects (Miller 1956). Now that we have a neurophysiology of many mental tasks, we can begin to question its optimality, and this enquiry is precisely one of ergonomics.

Most situations which are physically inergonomic we can be aware of, because our body is visible to us. Bodily ergonomics has been a technological achievement still, and it is far from completed, but it has at least passed in global awareness. Our brain and mind, however, are not naturally available to our thought. They are an exciting new barrier to ergonomics : could we see our working mind, we could project it, in the Latin etymological meaning, have it before us, and diagnose its best or worst practices. Isolating some mental best practices, is it not a fascinating endeavour for applied cognitive sciences ? In such a quest, however, one must maintain a humble stance, because success is not a proof of optimality ; the working neuroergonomist should at all time abstain from claiming that such and such mental states, stances or methods are rigorously impossible. Neurosciences having surely not been axiomatized, since physics is not axiomatized either (that is, Hilbert's sixth problem is still open), it is not yet accessible to us to establish impossibility theorems in neurosciences.

What Pesenti *et al*. have shown is that one can tap into episodic memory to create an all new mental gesture; their study in Positron Emission Tomography has been one mode of observing the brain in the way one can observe the human hand, and is a fine example of neuroergonomics, before the name was popularised by Parasuraman. This study has been an essential influence of this work, because it has posed the question of ergonomic gestures of the brain, a founding enquiry of all the theoretical material that will be presented here.

Four other works in cognitive neurosciences have been of seminal importance to the present one. Charles Tijus' application of the theory of an *empan cognitif* (cognitive span) in the observation of images in perspective has been an important influence to the notion of hyperwriting. The introduction of perspective in writing could open a vast diversity of new and ergonomic mental gestures, because it would redistribute the *span* (a notion that is a cognate to that of "cognitive load" Sweller 1994, Sweller et al 2001) in a different way.

I have followed the works of Stanislas Dehaene extensively. From their study of the notion of core knowledge with Elizabeth Spelke, Véronique Izard and Pierre Pica to their observation of the mental number line (see also Boroditsky & Ramscar 2002) and the SNARC effect, they have provided me with interesting insights regarding the fundamental intuitions, recycling and correlations of the idea of space in the human brain. Dehaene is also interesting for his model, with Jean-Pierre Changeux, namely the Changeux-Dehaene Workspace model, inspired itself from the various cognitive workspace theories, and from which, with Sackur and others, was established a testable taxonomy of the conscious access, which in turn I cite to suggest early ways to measure and grade the flow of attention in the knowledge economy. Finally, Dehaene's research into the physiology of reading is essential to establish a putative, *ex ante* physiology of hyperreading and hyperwriting. If there is a precise, very frequent and robust in spite of the natural human polymorphism, neural pathway of reading and writing, with the critical contribution of the visual word form area, could there be such a stable pathway for hyperwriting, with a critical contribution of the hippocampus and entorhinal cortex ?

I am therefore also grateful to the life's worth of research of O'Keefe, Moser & Moser who were awarded the 2014 Nobel prize for Physiology or Medicine. It is because we have such well-identified notions as place cells and grid cells that one can in turn establish and neurally correlate the notion of *loceme,* the spatial equivalent to graphemes. Simply put, Changeux-Dehaene, with their global cognitive workspace model, provide me with a very stable base to found the neural correlates of noems. Moser, Moser and O'Keefe provide me with a very sound base for the notion of loceme.

There are precise neural fields for numerosities, and one can indeed suppose a loceme-numereme association in Rudiger Gamm, or in world champion Alexis Lemaire, who can mentally extract the root 13th of a one-hundred-digit number in 3.62 seconds. With some neural correlates of noems, locemes and numeremes established on the one side, and some of the grapheme-phoneme association on the other, and the neuroergonomics of reading and writing *ex post* precisely, I could begin developing a testable theory of hyperwriting *ex ante*. These were the giants on which shoulders I stood, because again, this work is no *Codex Atlanticus*, and does not proceed from pure revolutionary imagination out of naive experience. The latter, however, is the noblest of all scientific research, which this work, and hopefully any of its readers, shall never forget. The impact of this work, therefore, will not be as remarkable as that of genuine paradigm-shifters.

Three other scholars have provided me with excellent scientific bases for the establishing of neuroergonomics *ex ante* in regard to hyperwriting. The first is Francisco Varela, with his paradigm, confirmed experimentally by Lutz et al (2002), of neurophenomenology, namely the possibility for an experimenter in a brain imaging interface with a good time resolution - ElectroEncephalography (EEG) or MagnetoEncephaloGraphy(MEG) in our times - to observe precisely the neural correlates of a mental shift, and to use first person data to guide such an observation.

Neurophenomenology is a en essential contributor to the neurosciences of awareness, and commences bridging a fascinating gap, that between objectivity and subjectivity in neurosciences. Neurosciences can use subjectivity, just as mathematics can use intuition. People who developed mental routines themselves, such as memory athletes, or “mind magicians” and “mentalists”, did perform a very serious research in neurosciences. It was published, since their purpose is to show novel aptitudes (yet not necessarily how they achieve them) but not through the narrow-minded *imprimatur* of the academic world. The curious scholar cannot ignore them, for their knowledge, however subjective and personal, is the fruit of experience, just as was that of Da Vinci. I believe we will cross more and more first-person data with second-person data in the future ; in neurosciences, their combination is vital to the field of wearables electronics, and man-machine interaction in general. Combining the subjectivity of the user with the predictability and reproducibility of the worn device could bring us fascinating new discoveries in augmented reality, personalised medicine, gamification, and of course neuroergonomics at large.

I owe a lot to the works of Bach-Y-Rita on sensory substitution. Research into neural control is also essential to neuroergonomics, from those of Jose Delgado to those of Nagel et al (2005) on C. elegans or Schroll et al (2006) on D. melanogaster ; the research into Blindsight (for example, in the works of Gazzaniga) is also an essential inspiration. It was very disruptive and innovative to explore sensory substitution in such a systematic fashion as Bach-y-Rita did ; it paved the way to the study of “Plan B” neurosciences, or the science of rerouting damaged neural pathways in a mode that was not made canonical by evolution but that is working still, and this is essential to reeducation for example. Other inspirations have been the profound first-person experience of neuroscientist Jill Bolte-Taylor, now reported in her marking TED talk “my stroke of insight”, which spread the more general insight of crossing, indeed, first and second person data in neurosciences.

Thus, “Plan B neurosciences” would be the study of alternative neural routes to perform a certain task. This is again a typical case of ergonomics : how does a painter with no hands use is or her mouth, or feet to paint ? What is the dynamic, and topography of this second route that was taken. Reeducation is full of such problems ; the spectacular functional recoveries observed by Aguayo *et al.* were among the most important breakthroughs of the field in the 2000s. Thus, their study has many practical implications. Hyperwriting is a case of healthy “plan B” that would be achieved without the need to reconstruct a normal mental function, but to re-engineer a new one. Knowing that such a neurocognitive equivalent of “bypass surgery” existed, with Bach-y-Rita among its finest practitioners, I could begin theorising a novel form of bypass, or in a way, build a case for the domestication of neural routes.

If neuroergonomics and “plan B neurosciences” can compare to open heart surgery, it is very fertile to obtain a map of confirmed neural correlates of mental tasks. The best of such maps available to me has been the excellent research aggregator LinkrBrain of Yves Burnod, Jean-Philippe Cointet, Selma Mesmoudi and others (Mesmoudi *et al.* 2015), without which this work could not have been assembled. The more neural correlates we know, the better we can theorise, and later, test, pathway engineering, which is equivalent to developing a general theory of the neurophysiology of writing, a general theory of man-made neural associations, namely, a general theory of “neowriting” or “artificial writing”. Such a framework will go beyond operant conditioning, because it will be considering cognitive associations, not those purely based on coincidence and reward, even though our brain is a good correlator and coincidence tracker. The impossibility for language to have been acquired only through operant conditioning has very well been debated by Chomsky in his most famous article against Skinner (Chomsky, 1959) and this argues well enough in favour of a clear distinction between conditioning and neowriting. A general theory of man-made neural associations, a general theory of neowriting, would be something at once new and in clear continuity with the current state of the art regarding the physiology of writing. Regarding neurosciences and neuroergonomics, it is the most important contribution of this work ; just like a certain theory of computing machines was purely speculative when it was published by Alan Turing, a complete theory of neowriting - which is however beyond this work - may appear unorthodox, daring or all-too-speculative to the strict data-driven scientist, but its intellectual fertility could be tremendous. It would have to be predictive of course, and evolve through trial-and-error against first and/or second person data indeed.

A general theory of neowriting could be one of mental algorithms. Again, one could metaphorically consider Rudiger Gamm's tapping into episodic memory a mental algorithm comparable to the GPGPU procedure in computing. But the idea of a mental routine developed to better share the cognitive load of a task brings the notion of cognitive tools, or mind tools. Such tools are the core of this work : rather than "Mind ergonomy for the knowledge economy", it could have been titled "mind tools". The art of fitting a mental object to the human mind is precisely that of mind ergonomic, and it is just as new as the art of fitting a hand axe to the human hand was in prehistorical times.

Fitting a hand axe, or a mouse to the human hand (and I borrow this simile from Matt Ridley) has been rather intuitive because we can see our hands before us. Yet, even in spite of the consciousness of the form and limitations of our body, it took very long to develop a science of ergonomic, and a biophysics of the human body. What could we say of our mind then ? We do not see our own mind, we are not aware of it at work, and do not see its form and limitation directly. Yet, such limitations exist, and they are appropriate and inappropriate ways for the mind to grasp mental objects. The more we know about the mind, and its biophysical correlates, the better we can learn to fit mental objects to it. After all :

Thought is the work of brain and nerve,
in small-skulled idiot poor and mean;
In sickness sick, in sleep asleep,
and dead when Death lets drop the scene.[9]

Physical tools extend our physical reach, that is, our kinesphere, the sphere of our possible actions. Mind tools should extend our cognitive reach, that is, our reach within the noosphere, the sphere of all possible human mental objects: they should be means of transportation to explore this universe, which may be vaster than the known physical

[9] Richard Francis Burton, in Burton, R.F., Bock, V. (1883 -> 1945). The Kasidah of Haji Abdu (Peter Pauper Press).

one. Mind tools allow us to think better, faster, deeper, and most importantly, collectively, for collective thinking is going to be one key to the human progress of the 21st century. Augmented reality is already among them, and there will be many others. However, one should never forget the existence of the law of the instrument, that is, as Abraham Maslow put it, “when all you have is a hammer in your hand, you see all your problems as nails”: this will be even more true of mind tools. René Guénon already understood that, while we developed potent quantitative tools for the mind in the 19th century, we also ended up being used by those tools rather than using them : for Man designs tools, structures, organisations and systems to serve himself, and ends up serving them instead. In designing mind tools, we must always remember that the human nervous system is sacred, that man is superior to any of its creations, and that its creations should always serve him, not the other way around. This is a manifesto of neuromimicry. Let us design tools to use them, and not to be used by them, which still happens too often.

My research is also owing to the works of Green & Bavelier (2003) on the interaction between attention and video games, and those of Janata (2005, 2010) on the neural correlates of music-evoked autobiographic memories, another inspiring benchmark for theoretical mind ergonomics. I may also cite Simmon-Sterns et al. (2010) and El Haj (2012) for their study of the memory enhancing properties of music. This all relates to the fascinating field of gamification, for which I acknowledge a clear influence from Jane McGonigal. Deterding *et al.* (2011) have also produced a good review of the general use of game design outside gaming contexts. Serious gaming is a clear application of neuroergonomics, and the latter should study it closely, because games are remarkably fitting many pathways of the human brain, hence the addictions they can cause while preserving a very high flow of attention and even a high cognitive load.

Regarding bio-inspired design, most of the precedents I could find regarded hardware control (e.g. Frasca *et al*. 2004). For the design of bio-inspired softwares then, beyond Benyus and Pauli again, my main sources of inspiration came from architects, among which Jacques Rougerie (1973 ; 2010), Michael Pawlyn (2011) and Vincent Callebaut (2008). The excellent work of John Dabiri (Nawroth et al 2012 for example) at Caltech has also been a very inspiring source of applied biomimetics

Finally, the notion of a Merleau-Pontian Universe, which I originally coined at a “CogLunch” talk at Stanford University on May 30th 2007, was later also developed by Heurtebise (2011). The work of Antoine Le Bos *et al* at the European Film Lab *Le Groupe Ouest* has been very inspiring : more practical, less academic. They show it is possible to envisage media that tap more into the dorsal stream of vision, the way of the “How” rather than the “What”, something which Mesmoudi and Burnod (Mesmoudi *et al* 2013) had very well understood and expanded in their fascinating discovery of a “dual intertwined ring architecture”, of which the crossing point lies within the parietal lobe.

This work of Mesmoudi *et al.* deserves a thorough citation, as it has been one of my most essential influence to postulate a neuroergonomics *ex ante* for hyperwriting, and dorsolateral writing simulants (“neowritings”) in general.

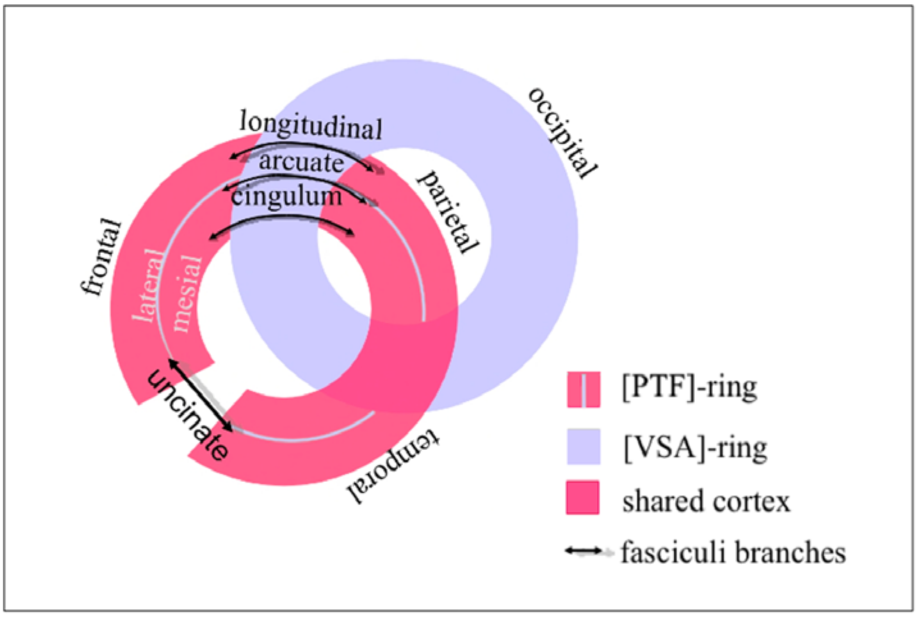


Fig 2. From Mesmoudi et al. "Schematic representation of the principle of intertwining of the VSA ring and the PTF ring within each hemisphere, thanks to the major long-range tract fibers. doi:10.1371/journal.pone.0067444.g007". The authors analyse and cluster a large set of Resting State fMRI data to propose a dual, intertwined architecture for the cortical default mode network, the associative Parieto-Temporal-Frontal (PTF) ring and the auditory-visual, visual)somatic and auditory-somatic (VSA) ring, overlapping within the Parietal cortex.

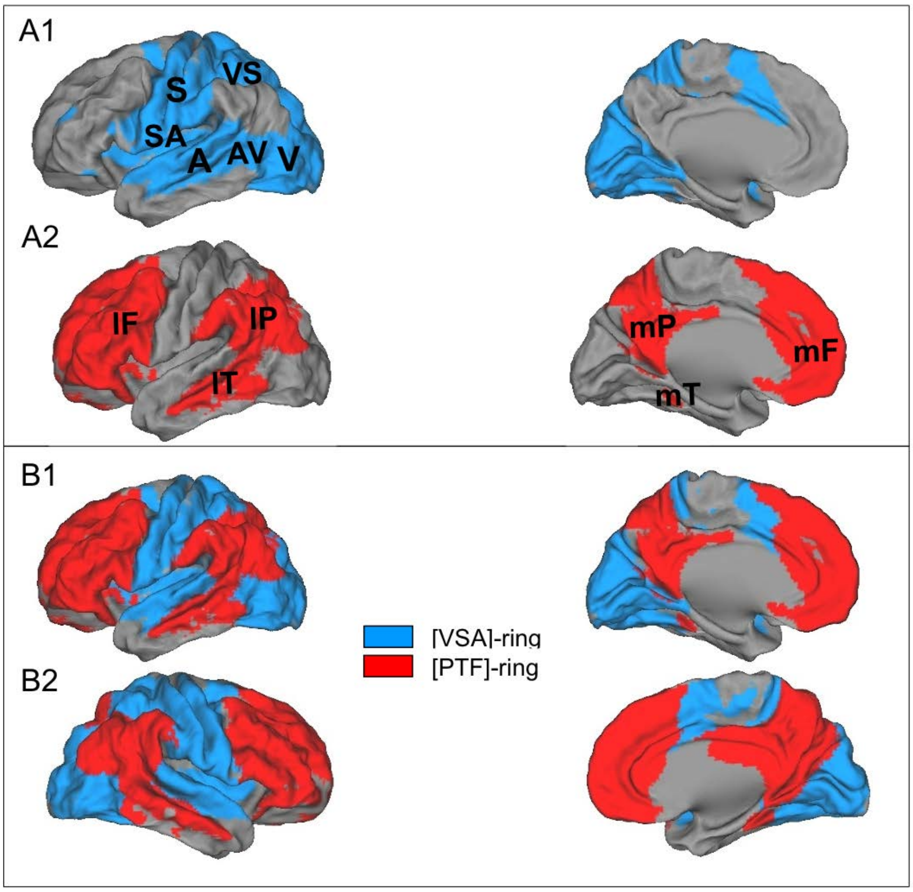


Fig 3. From Mesmoudi et al. 2013 "(A1) The VSA ring, in blue, forms a continuous cortical ring organised around primary cortices: visual (V), auditory (A) and somatomotor (S) with interspersed bimodal regions: visuo-somatomotor (VS), auditory-somatomotor (SA) and visuo-auditory (VA). (A2) The PTF ring, in red, forms a ring discontinuous over the cortical mantle but closed by major cortical fiber tracts (see Fig. 6), with 3 regions, parietal, temporal and frontal on the lateral (l) aspect of each hemisphere (lP,lT,lF) and 3 regions parietal, temporal and frontal, on the medial (m) aspect (mP,mT,mF). (B) The two rings are intertwined: the PTF ring, in red, is placed in foreground, to show that it is not continuous over the cortical mantle but interrupted by the VSA ring and is closed by major cortical fiber tracts passing below the VSA ring, as shown in the next figure".

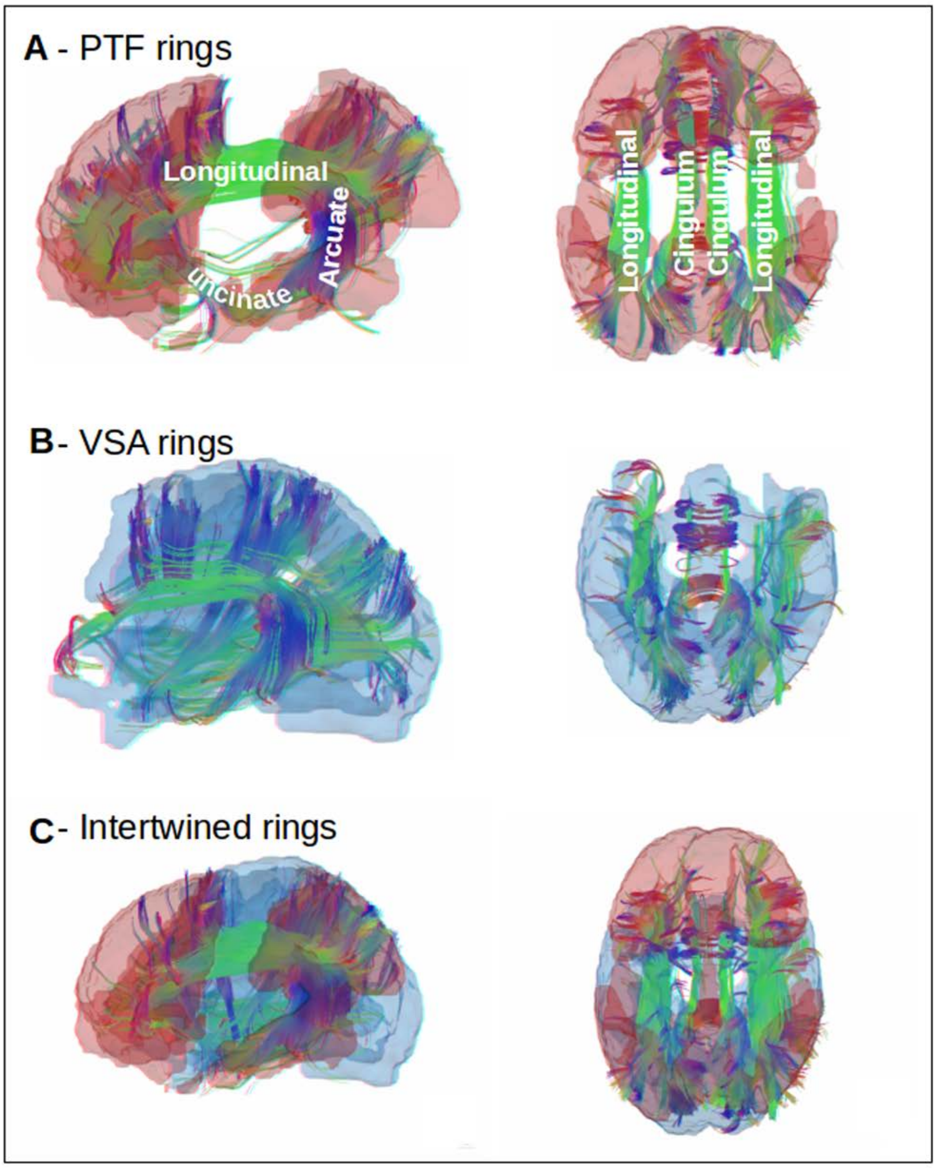


Fig 4. From Mesmoudi et al. 2013. "Comparison of the topography of the two rings (lateral and dorsal views), with superimposed major cortical fiber tracts (see text for details). Mapping of major long-distance fiber tracts on the 3D mask of the PTF ring (Fig. A) and VSA ring (Fig. B). Long-range connections on the VSA ring and the PTF ring, mapped together (Fig. C). doi:10.1371/journal.pone.0067444.g006"

Altogether, Mesmoudi et al. 2013 established a breakthrough model in large-scale, integrative (meso/macro) cognitive neurosciences that very solidly and elegantly complemented Global Workspace theories, among which the Changeux-Dehaene global workspace model.

The Changeux-Dehaene model is a liquid long-distance network of excitatory and inhibitory neurons that is intended to represent the flexibility and fluidity of the working attention and human consciousness, making very interesting predictions regarding its span and limits, including those observed in the resolution of the Wisconsin card sorting task (from Berg 1948 and others), the Tower of London test (Shallice 1982) and inattentional blindness. It can also be used to establish a testable taxonomy of the various states of human consciousness. In the theory of visuo-attentional span and attentional span altogether, this model provides very useful concepts to understand the ergonomics of the working human consciousness, including the relation between long-term and short-term memory during mental planning or free thought, and has been one of the basis on which I have constructed an initial theory of hyperwriting.

Thalamocortical resonance is the basis of to the Changeux-Dehaene global cognitive workspace model. The authors isolate certain behaviors of their model, including a sort of self-organised criticality, with a supercritical behavior engendering multistability through a clear-cut Hopf bifurcation that could separate, they argue, the various levels of consciousness. This would lead to another publication (Dehaene et al. 2006) establishing a testable taxonomy for levels of consciousness : subliminal, preconscious and conscious, of testable interest in the priming paradigms in particular.

Another remarkable discovery is that of Onur Güntürkün, Monika Güntürkün and Constanze Hahn (2015) that an ancient Turkish whistled language, still in use by more than ten thousand people today, taps into both hemispheres of the human brain for its comprehension. This discovery supplements that Carreiras et al. (Nature 2005) on the Silbo Gomero language, used by shepherds of the Gomera Island (Canary). Their discovery had already been that “the language-processing regions of the human brain can adapt to a suprisingly wide range of signalling forms”. This flexibility argues very much in favor of hyperwriting, as a way to write, using glyphs, with the method of loci.

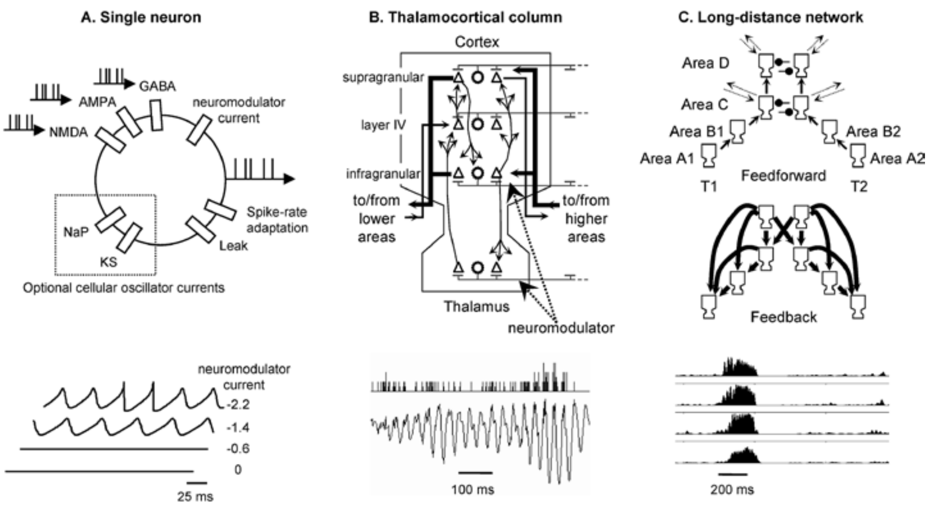


Fig 5. 3 levels of complexity of the Changeux-Dehaene model: a spiking neuron (deterministic), a thalamocortical column of glutamatergic neurons and inhibitory interneurons and a long-distance network critically involving a reciprocal interaction from Van Economo areas . The mutually inhibiting emergent behavior of thalamocortical columns creates an attentional bottleneck that can represent inattentional blindness. From Dehaene et al. 2005. The model displays several interesting emergent behaviors, including rich multistability and self-organised criticality.

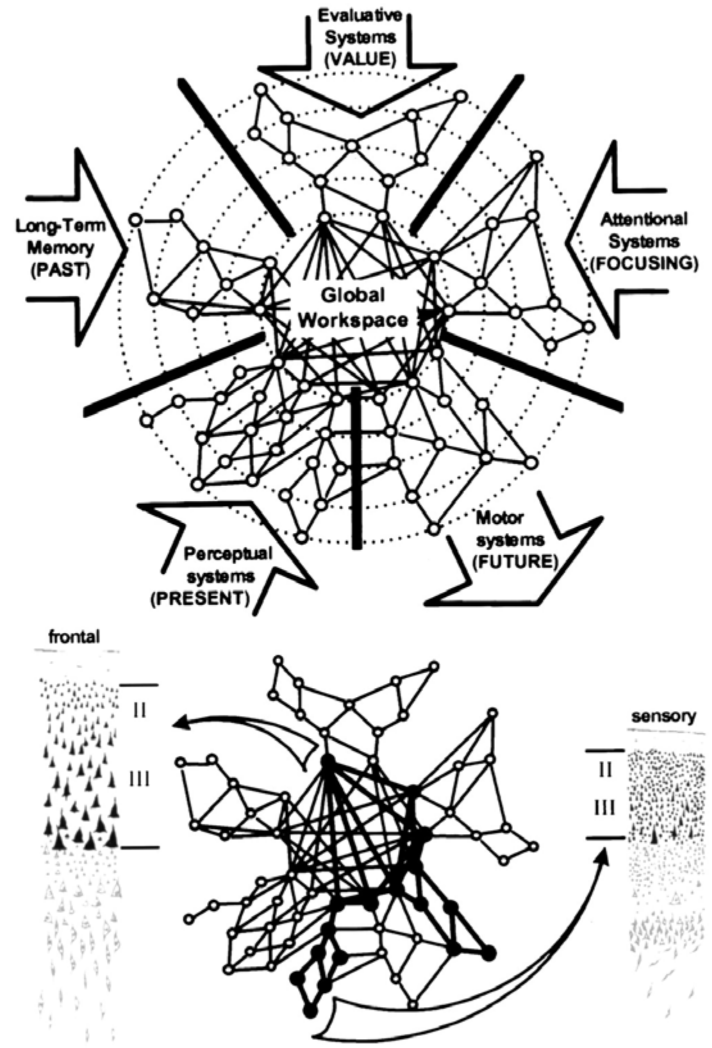


Fig 6. (From Dehaene & Changeux 1998), a cytoarchitectural model (inspired from Mesulam 1998) of the Global Cognitive Workspace. This is one the best models of the neural correlates of noems (objects of intentional thought) and their fluid multisensory, representational network . The interaction between long term and working memory is very interesting for the neuroergonomics of hyperwriting (ex ante). The model also gives a sound basis to represent the general neuroergonomics of noems, some of the transformations they can undergo and the metrics of their span. All in all, this model is one of the most useful to represent the span of a "mindful" (ie. "a handful of the human mind") or what the human mind can grasp mentally. It is very precious in neuroergonomics.

The Nobel Prize in Physiology or Medicine 2014

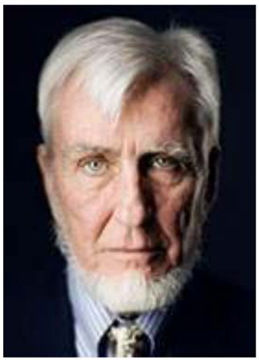


Photo: A. Mahmoud
John O'Keefe
Prize share: 1/2

Photo: A. Mahmoud
May-Britt Moser
Prize share: 1/4

Photo: A. Mahmoud
Edvard I. Moser
Prize share: 1/4

The Nobel Prize in Physiology or Medicine 2014 was divided, one half awarded to John O'Keefe, the other half jointly to May-Britt Moser and Edvard I. Moser *"for their discoveries of cells that constitute a positioning system in the brain"*.

Fig.7 The research conducted by the laureates of the 2014 Nobel Prize in Physiology of Medicine was the cornerstone of the neuroergonomics advocated in this report. It is with the clear isolation of grid cells, border cells and place cells that the notions of loceme and a fortiori, hyperwriting, could be developed here. Copyright The Nobel Foundation 2014.

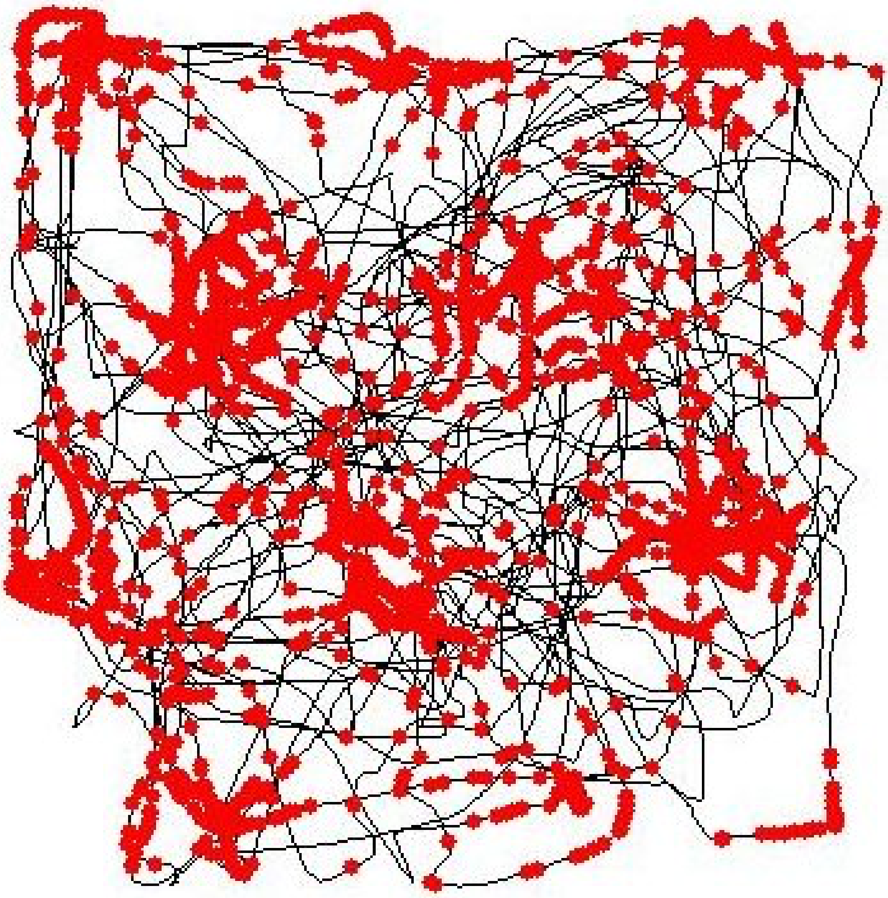


Fig. 8 Spike activity of Entorhinal cortex grid cells in a mouse (CC 3 Torkel Hafting 2006 Wikimedia Commons). The black line represents the trajectory of the mouse, and the red dot a recorded spike from a single neuron

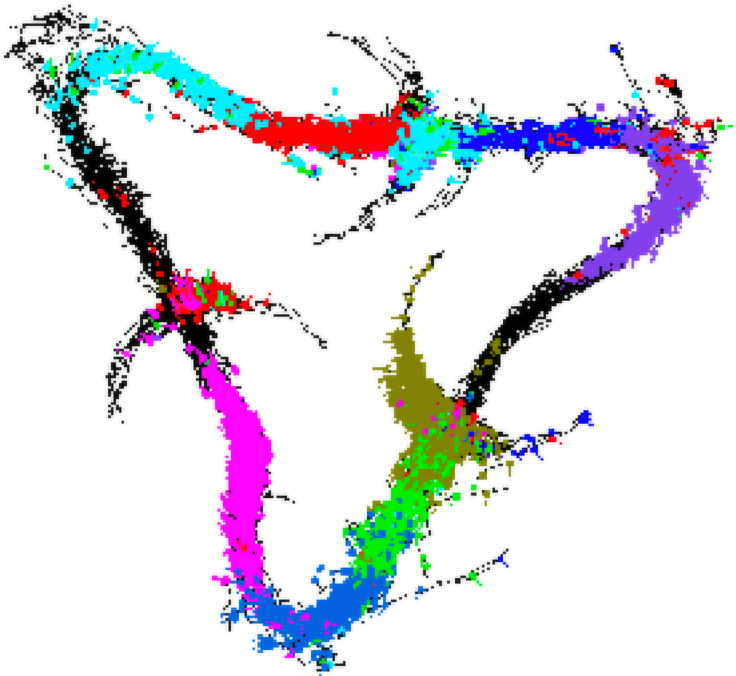


Fig. 9 Receptor fields of CA1 place cells in a mouse exploring a maze several hundreds of time. The black dots indicate the position of the mouse's head and the coloured dots registered action potentials from seven different cells. One can clearly observe a correlation between each cell's activity and the position of the mouse in the maze. (Image in the Public Domain, created in 2008 by Wikimedia user Looie496)

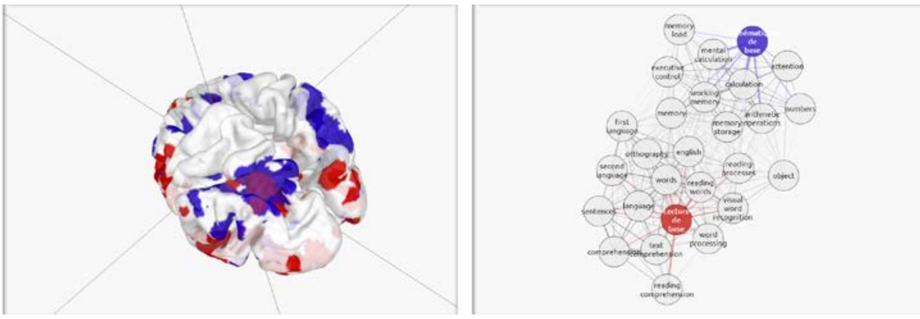
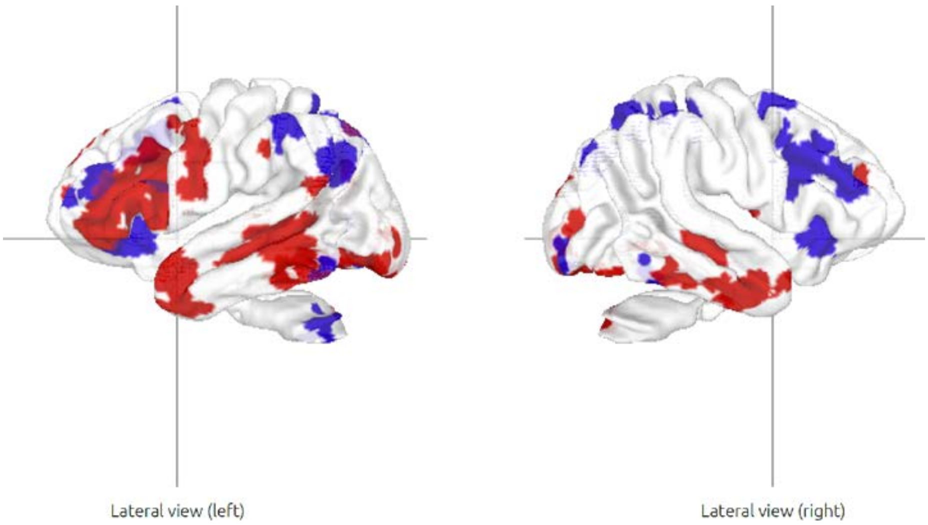


Fig. 10a (up) representation generated with the Linkrbrain bibliography cruncher (Mesmoudi et al. 2015) of confirmed activations correlated with basic mathematics (precisely, arithmetics, calculation and mental calculation), in blue, and reading, in red. The left representation is displaying the left intraparietal sulcus on which both sets of skills heavily draw (hence the blue/red overlap). On the right : a graph representing known correlations with other tasks.

Fig 10b (down) left and right lateral views of the same representation, showing the larger left-sided lateralisation of the reading pathways.



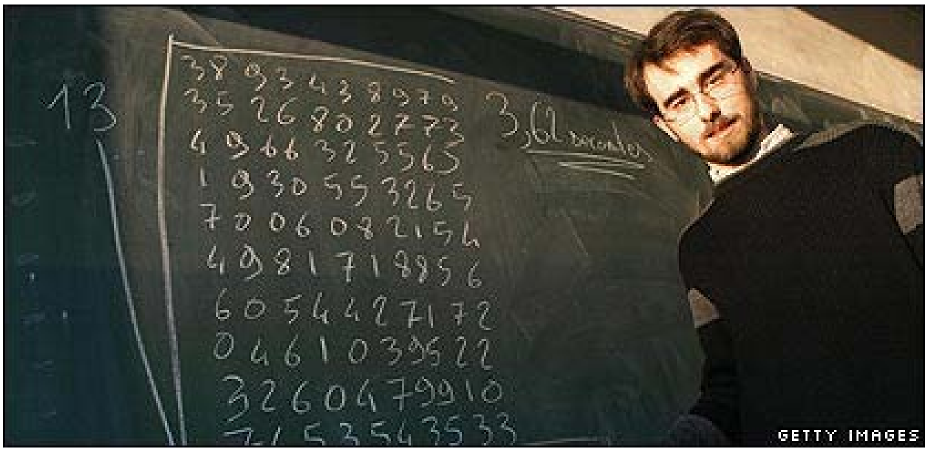


Fig 11. Prodigy calculator and world champion in mental calculation Dr. Alexis Lemaire is able to mentally compute the 13th root of a hundred-digit number in 3.62 seconds, and also that of a two hundred digit number. His case, as that or Rudiger Gamm which was studied by Pesenti et al. (2001) gives remarkable insight into the neuroergonomics of serial mental operations, and the hijacking of the dialogue between episodic and working memory. Photo : Getty Images.

Fig 12. Artists Stephen Wiltshire popularly known as the "human camera" is able to reproduce an entire skyline by heart after having seen it once in a helicopter flight. He is seen here drawing the Dubai skyline. His works provide a fascinating manifestation of the ergonomics of extended "mindfuls", that is, the art of extending the working span of the global cognitive workspace, and in particular, the ergonomics of the dialogue between episodic and working memory. image credit http://www.stephen-wiltshire.co.uk/Dubai_Panorama.aspx

3. Regarding the question "What?"

This is a work of applied neuroergonomics, and its applications regard User Interface. One of the most excellent manifestations of such an interaction have been the works of Pranav Mistry : his "Wear your World" (WUW) concept has been considered industrially fertile enough by Samsung to entrust him with the senior role of Global Vice President of Research. The field of Natural User Interface at large has provided me with a solid conceptuel base to study what, here, I call "Mindscapes". My contribution will be to go from "Wear your World" to "Wear your Mind" (WUM) ; my approach of mind ergonomy is based on the idea of seeing one's own noosphere at work, before oneself. This is, after all, the etymological sense of the word *reflexion*.

Thy Thought to thee an Empire be;[10]

It may be anecdotical, although it is part of a broader, global trend for neurotechnologies, but *reflexion* is precisely what is proposed by Anatole Lecuyer in his "Mind Mirror" interface, and this is a manifestation of the zeitgeist, Man's current interest in his own mind. Mind Mirror is a device of EEG designed with feedback in mind, displaying ongoing activity before the user so he can learn to modulate it. Its applications could be numerous. Neuroergonomics and gamification have also been very successfully applied to medical education by Alexandre Mignon and Antoine Tesnière at Paris-Descarte University. It is part of the trend of computing, by which we may review the history of user interface since Vannevar Bush's seminal *As We May Think*, in which the scientific administrator famously outlined what would become the hypertext.

As We May Think is a central piece for this research, so much so, it could have been titled "As We May Think in the 21st Century", and this would have perfectly defined its scope. What Vannevar Bush provided was what today's ultra-scholastic academic categories would have called an "opinion piece", something of little scientific value people would believe. Yet, it was the fruit of a long experience as a scientific administrator at the Manhattan Project, and this experience, a human, embodied one, was invaluable. As Leonardo, to his detractors, Bush could have said "I am Vannevar, the disciple of experience".

The scientific administrator clearly had mind ergonomy for objective: how could we facilitate our mind's workflow, he asked himself, working in one of the most "mind-intensive" projects on the planet. From Sumer to Wikipedia, across Giordano Bruno's arts of memory and Tim Berners Lee's development of the World Wide Web, anybody who has every successfully improved the flow of the working mind has changed the entire planet, the entire Humanity. Why is that? Because it is in the fundamental nature of human beings to exchange knowledge, and the more they do, the healthier Humanity. It is as if, in a way improving the individual and collective knowledge flow were like natural history's invention of myelin. Myelin is a critical component of what we could call the *infrastructure* of the nervous system of tetrapods. Mind ergonomics are critical components of Humanity's knowledge infrastructures.

[10] Richard Francis Burton - The Kasidah *IX*

Mind ergonomy for the Knowledge Economy

What Vannevar Bush envisioned, was simply the possibility to access the meaning of any unknown word directly, by pointing to it. This, fifty years later, would evolve into the hypertext, within a global trend in facilitating knowledge exchanges: larger than the Manhattan project, there would be the European Organisation for Nuclear Research (CERN), another knowledge-intensive endeavour that fostered the emergence of the World Wide Web, there would be the Arpanet before that, one of the ancestors of the distributed network we today know as the Internet, and after the World Wide Web, there would be Wikipedia. All of these projects had in common a profound and meaningful interest in facilitating the flow of knowledge, from human beings to organisations and systems. This is a profoundly noble endeavour, and anybody who conducted successfully changed the world indeed, Jimmy Wales and Tim Berners Lee among them, but also those who endeavoured it privately, like Sergei Brin and Larry Page, or Alan Kay, Elon Musk, Jobs and Wozniak, etc.

The structure of Brin and Page's research at Stanford University, which would lead to the emergence of the Google search engine, has been a central industrial influence to the structure of this research, and its attempt to prototype the Chréage mindscape. Google was a case of mind ergonomy that I want to contrast here, not oppose, but complement. When Google emerged, the majority of investors, entrepreneurs and even more so, academics, vouched that the future of the Web had only one name: Portals. The working web had not even ten years of existence, that there existed already an entire ecosystem of arrogant specialists - the scholars not the least arrogant among them - to establish peremptory rules about its interface with the masses, before any perspective had been achieve on its Business-to-Consumers (B2C) user scenarios.

In 2015, first-generation portal services like AOL, Altavista, Lycos or MSN are dead, and Yahoo is far below Google. On the one side, so-called specialist had predicted that, to make sense of such a complex thing as the world wide web, one would need a guide, assuming people hardly know what they want (which is, paradoxically, very much verified by Apple's success at introducing the Apple stores). Thus, portals rich in content were created, to showcase the Internet. The Google boys had another vision in mind: a "no-chrome" (a notion that would later be essential to the chrome search engine) interface, with a search bar and nothing else. This system was made for exploitation and succeeded, portals were made for exploration, and failed.

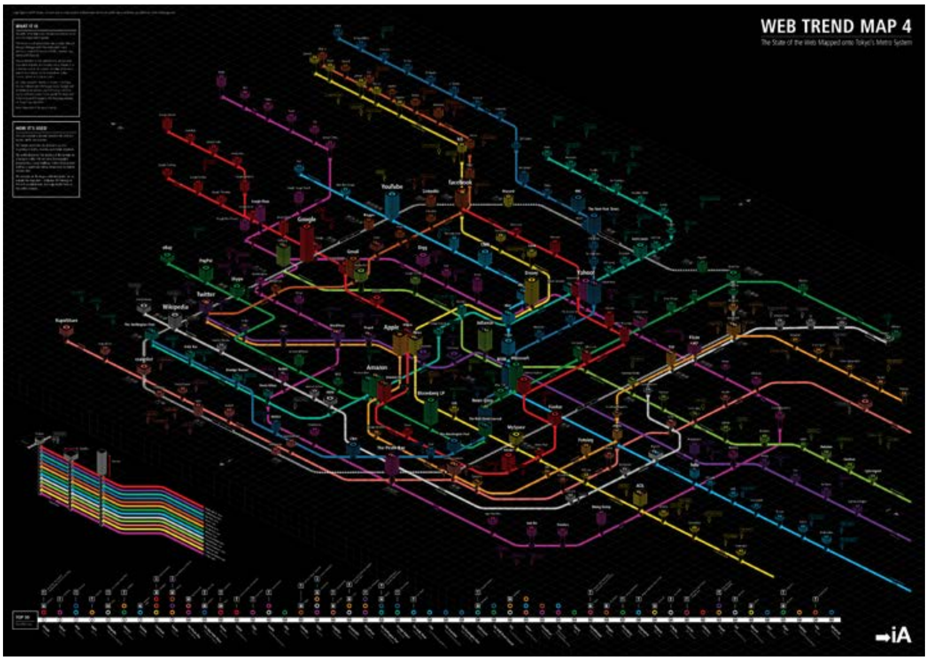


Fig 13. Web Trend Map 2007 Copyright Information Architects ia.net. This infographics loosely maps trend-setting websites and influencers along lines of the Tokyo subway system, each representing a certain field.

Does the Google case mean that the Web should not be envisioned with wanderlust and exploration in mind ? Surely not : Amazon and Apple, again, demonstrate otherwise. amazon.com experienced a backlash in the late 1990s precisely because consumption behaviour ended up different online than in real stores. If people are given a shopping list and have to stick to it, they simply consume less. Modern supermarkets are organised in a way that favours exploration and serendipity, precisely to augment consumption. If we could do the same, not with polluting excess goods, but with knowledge, would also increase its consumption. The tension between exploration and exploitation is present in any user-collection interaction, and solving it is not trivial.

The main reason Apple introduced its store system was that Jobs had precisely experienced with this tension himself: countless market studies had forecasted the failure of the personal computer in the late 1970s and early 1980s, just as even more studies would find the iPhone and iPad doomed. What Jobs had a first-hand experience with, was that, first, market studies should never be trusted for a product that does not exist yet, and second, that people know that they want a new product not when it is theoretically presented to them on paper, but when they can directly interact with it. Hence, the

Mind ergonomy for the Knowledge Economy

Apple stores, the world's most profitable retail stores by square meter, twice more than the second, namely Tiffany & Co.[11]

The history of computing is one of ergonomics. From World War II to the current Cold War 2.0 we have gone from Military Computers (MC) to Wearable Computers (WC). It would have been hard to imagine indeed that one day a single wristwatch would have more computing power than the advanced cryptographic bombs of Bletchley Park. Wearing those cumbersome computers could only have been a fancy of the most imaginative minds. From them, industrial computers evolved into the BC era (Business Computers), hence IBM selling them : International Business Machines.

For a maker of pure Business Machines then, the idea of a Personal Computer could only be laughable - the device would be a gadget at best. One says that if failure is an orphan (nobody wants to acknowledge paternity of a failed project), success has many fathers. The ancestor of the Personal Computer as we know it, that, is, with an intuitive mouse-driven Graphical User Interface is mostly considered to be the Xerox Alto, which was in turn the most decisive influence over the Apple Macintosh, and the Windows interface.

From then, computers would increasingly become more and more personal: the PC era was followed by the Post-PC era, with, for the business world, the Network Computer era or NC, which was at the heart of Oracle's success, and with the wearable industry we have entered the Post-Post-PC era. Computing is growing more ubiquitous and intimate. However, there is no intimacy without vulnerability.

With Google, now the Alphabet holding, researching into computers-in-a-pill, we could be moving towards not only wearable computing but physiological computing (PhiC). What I have learned from Pranav Mistry, Steve Jobs, Alan Kay or Sergei Brin and Larry Page are invariants in the acumen for interface ergonomics, and a fundamental intuition that the human mind should never be subservient to technology, but rather technology should always be subservient to the human mind. This is what the Linux community has blatantly failed to understand - with the notable exception of Mark Shuttleworth and the Ubuntu distribution - in that Linux is remarkably machine-ergonomic and terribly human-ergonomic.

[11] fortune.com March 13th 2015 Apple Extends Lead in US…

Fig 14. An internet meme: a typical example of the geek culture. Internet memes are viral partly because of their vulgarity (which is extremely attention-ergonomic and should be honestly acknowledged as such). This one reminds that Alan Kay, at Xerox, had long envisioned a flat personal computer with the ergonomy of a book in mind.

In software design this tension between machine-ergonomy and human ergonomy has remained permanent. Microsoft has long embodied poor machine ergonomics and a so-

so human ergonomic. Linux has represented excellent machine ergonomic and horrible human ergonomic (there is no pride in reducing the richness of one's mind to the spartan limitations of a computer terminal) and Apple, above all, the very best of both world, if, of course, we do not consider the enormous problem of open source softwares, backdoors and the like, and just focus on ergonomics.

A general phrase was popular among computer scientists since the seventies, that "user-friendliness is for wimps anyway" and the very word "WIMP" standing for "Windows, Icons, Menus, Pointers", the fundamental categories of Graphical User Interface since the Xerox Alto. This phrase can explain in itself why computer science is way too important to be left to computer scientists ; people who prided themselves of their ability to operate at very low ergonomics, could often not at all understand its importance for the masses. This, Jobs understood, Shuttleworth understood, Brin and Pages understood, and this Elon Musk surely very well understood. This, most of the Linux community never understood however, which is all the more tragic given that Linux, being open, remains the most secure of the commonly accessible operating systems and should therefore encourage its massive adoption. Today there are a very few smartphones available off the shelves with a Linux distribution, that is, even eight years after the introduction of the iPhone. Linux is thus poorly entering the Post-PC era, and far from being operational in the Post-Post PC one, where the people, paradoxically, most need it! For intimate computing should be safe and protected, which is what Linux was supposed to be all about. Maybe it is for this reason that Canonical (the parent company of the Ubuntu services and distribution) recently teamed with IBM to propose full-Linux Mainframes (August 2015)

We must therefore observe that specialists have the very negative tendency of priding themselves of their lack of ergonomy, of their ability to contort their mind at work, and tend to despise those who wish to contort technology to their mind and not the other way around. The crystal-clear influence that I must acknowledge here, is the lifelong experience of all the technologists I have cited, that it it should never be for man to contort his mind to technology, but for technology to contort itself to fit the human mind. After all, the human mind is not a human invention, hence man cannot synthesise it yet. And Humanity, fundamentally, is superior to any of her inventions.

The technological state of the which this work is built upon also regards the generations of the Web, and technologies of video gaming. In late 2015, we are still in Web 2.5. Facebook is ten years old, and its massive adoption established the clear entry into the 2.0, or social web era, which many others had pioneered without manifesting it at such a massive scale. Web 1.0 was founded on the hypertext, it was the embodiment of Vannevar Bush's vision at another collegial project, the CERN, and the meeting of Bush's understanding of "the mind at work" with Lee's understanding of computer networks at work. Hence, the *ht* and *f* transfer protocols.

These protocols however, would prove more machine-ergonomic than mind-ergonomic for consumers, who demanded the exchange of much richer contents than was permitted by both technological limitations (bandwidth included) and the limited user scenarios of working academics. Some researchers and so-called futurologists even considered that there would be no reason to call for a bandwidth above a few hundred megabytes per second. This is a typical attitude of those who love contorting humanity to technological limitations rather than stretching technology to the endless dreams of Humanity.

Wikipedia was a triumph of Web 1.5, it tapped magnificently into the hypertext technology of the Web 1.0 and created one of the web's largest community at the same time, clearly blending hypertext and social networking. Hypertext, after all, had been an answer to the collegiality of knowledge, and thus was conceived to fit certain cases of social ergonomics. Its success at crowdsourcing also inspired other ventures which would later contribute to what Jeremy Rifkin would call the zero marginal cost society, and the emergence of social-based sharing services like Uber and Airbnb, all part of the web 2.5 trend.

With this perspective on the generations of the world wide web, and although we are very far from being able to forecast or even envision such things as web 4.0, web 11.0 etc, or the reality that there will indeed be, one day, an archeology of the Web (an Old Web is still inconceivable to many) what would the Web 3.0 trend encompass? The World Wide Web Consortium consider the Semantic web to be its most essential dimension. Additional ones include connected objects and web 3.D. Beyond the semantic web, one could also envisage a semiotic web. If we consider the trend of internet-based communication, started with simple protocols, its contents have become increasingly richer in affects, emotions, and complex media, all the while crossing the limitations of simple language. Going from syntactic to semantic, one could believe the web will go from semantic to semiotic, therefore transcending the language diversity of its contents. English is not the lingua franca of the Web anymore, the Europpean Alphabet is far from being the only one in use, with the explosion of Chinese, Arabic and Russian among many others. If we created a web based on signs rather than letters, or even symbols, parts of which could be entirely language-free, we could solve another "Babel problem". Solving such problems was at the very origin of both the HyperText and the WorldWideWeb : for either Vannevar Bush or Tim Berners-Lee, the problem was to have people who did not speak the same intellectual language communicate better, so that they could achieve something that none of them would have endeavoured alone. With such projects as space colonisation, Babel problems will arise more often in the global society, that is why it is essential to find reliable non-verbal ways to exchange contents.

A Semiotic Web would have to be ecological in sense of Von Uexkhüll ; ecological design is a form of ergonomy, and this is where Web 3D must be called. Crossing the chasm from 2D to 3D in computer environments has been a difficult task. Anand Agawarala designed the Bumptop interface in 2009, a clear attempt at "ecologising" the desktop metaphor, but although it was purchased by Google a few years after its release, the multinational did not achieve massive adoption for it, which we could assume was a manifestation of that the technology was not mature enough. In the technology adoption curve, it seems clear today that ecological interfaces are within their "chasm". Yet, if they are, it also means that when the technology is mature and cleanly ergonomic, it should meet very little resistance to adoption anymore. Projects such as Yoowalk, Second Life or Bumptop have shown that there were an interest in 3D productivity, and all emerged before its adoption gap.

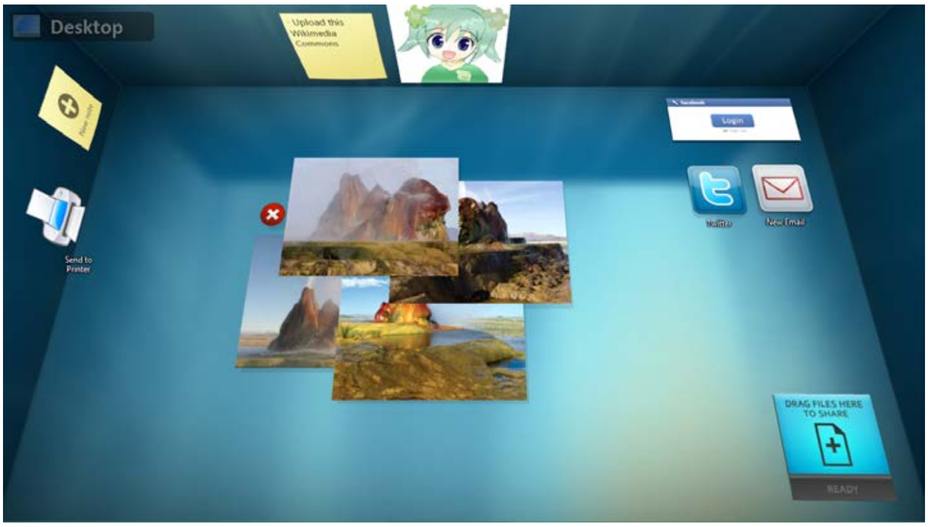


Fig 15. The Bumptop Graphical Environment (Google Inc. Apache License 2011)

For technology is mature for cloud-based 3D productivity, especially more so when it comes to collegial work. There is a Web3D Consortium, best practices have been established (among which the COLLADA format) on both the side of the industry and that of enthusiasts, and excellent libraries exist for plugin-free embedded rich 3D contents: WebGL and its second-order libraries among others, Babylon.js, Node.js and Tree.js. Two game engines developed early native HTML5 compatibility : Shiva 3D and Unity 3D, the latter influenced by the former. I owe Bourry (2013), Bourry & Van Lancker (2013) and Ronce (2013) their excellent WebGL programming standards, which were used for the early proof of concept of Chréage.

An emerging technology of gaming that proved excellent for Web 3D is Procedural Generation. It allows to generate precise multiscale landscapes on the fly, thus solving the problem of having to store complex and heavy 3D models, and even textures sometimes. Procedural generation makes for complex and precise objects with very little memory, and it is exactly what should be seeked after in the Web 3D revolution I believe. Interestingly enough, procedural generation is typically biomimical, in that nature uses it all the time, precisely because it allows for complex shapes to emerge from very simple instructions. Procedural generation, from an industrial point of view, can be very lean. It is also at the core of Lidenmayer Systems (L-Systems ; Lidenmayer 1968), which are used to generate complex trees on the fly, among many other applications.

Peytavie (2010) provided most of the background I needed to employ it in mindscape generation. Amit Patel (2010) of Red Blob Games also provided an excellent and very portable algorithm for procedural island generations. In general, the most recurrent and basic techniques in landscape generations include simplex noise, voronoi mapping, and, for the sake of designing semi-realistic biome maps, moisture/elevation charts (all used by Patel). Those techniques are useful in the sense that they help generate *topoi*, or loceme, complex mental objects related to space, and this on the fly. Generating convincing topoi on the fly requires the ability to generate landscapes and especially hydrographic maps. This Bourry performed modelling complex flows and precipitations with Saint-Venant equations, and achieved computing optimality by performing most of the procedural generation in General Purpose computing on Graphics Processing Unit (GPGPU).

Barabasi has been one of the most central references regarding scale-free networks for mappings of the World Wide Web (Barabasi et al 2000, Barabasi 2009, Albert et al 1999) but I have preferred the more practical work of Barret Lyon (2005) globally known as “the Opte project”, because as the author defines it, it was conceived essentially as an aesthetical experience. This is exactly the philosophy of an “art of memory”. I also owe a lot to Paul Bourgine, he has been instrumental in helping me refine the notion of Hyperwriting (writing with the method of loci), and to tap into scale-free networks and especially recursive systems and L-systems to develop a prototype writing with the method of loci (which I called “Curvy A”)

Finally, regarding Basic User Interface ergonomics, the iOS 7 user guideline has benen an important influence for two simple principles : 1) “defer to contents” and 2) “use a lot of negative space. In that I owe a lot to Craig Federighi’s philosophy of clean user interfaces. This is also what Sergei Brin and Larry Page had in mind in their “no chrome” philosophy of search engines. The research of Cynthia Breazeal at the MIT media Lab, on human-robot interaction, has also been instrumental in my developing a theory according to which man-made technology, especially in a Business-to-Consumer (B2C) interaction, should optimally find itself at the interaction between cuteness and power (ie. “cute x powerful”). This is very much embodied by the success of Apple products in general, from the first Mac to the Ipad Pro, which is typically cute and powerful and the same time, and, in the case of Breazeal’s research, the Jibo homebot. In terms of business model, the “Million Dollar Homepage” (Alex Tew 2005) has been an interesting case of how virtual real estate could be generated and sold in a pay-per-placement scheme, a structure that would be reused for Chréage.

Other influences regarding neuroergonomic design have been the notion of Ma (間) in Japanese Garden Design, the base of Federighi recommending the use of a lot of negative space in his interfaces. French Gardener André Le Nôtre, and the architects of the renowned “Round City of Baghdad” have also inspired my research into ergonomic mindscapes. **Generating ergonomic mindscapes is a “neo-Vitruvian” quest, in the sense that, if Vitruve wanted to fit man-made cities to the human body, the purpose of this work is to fit man-made mindscapes to the human mind**. Other influences have been the arts of memory of Giordano Bruno, Aristotle’s treatise on memory and, today, the hackerspace/makerspace culture, its trial-and-error philosophy being reminiscent of that of the cathedral builders of the Middle Ages or that of the Renaissance *botteghe*.

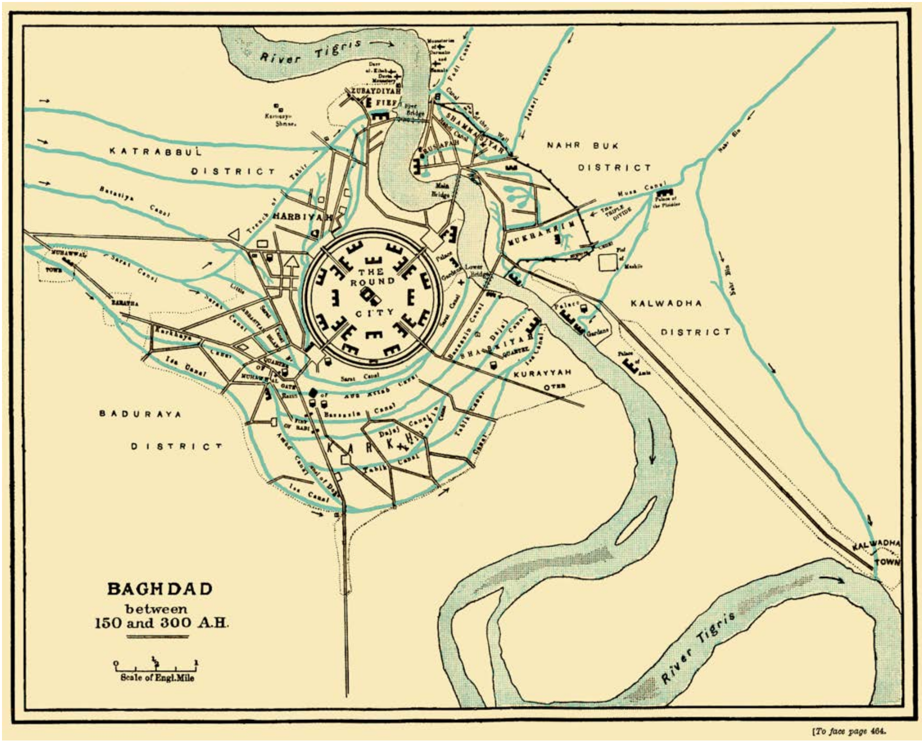


Fig 16. The Round City of Bagdad, from Muir 1883-1915[12]

[12] Muir, W. (1892). The Caliphate: Its Rise, Decline and Fall, from Original Sources (Religious tract society).

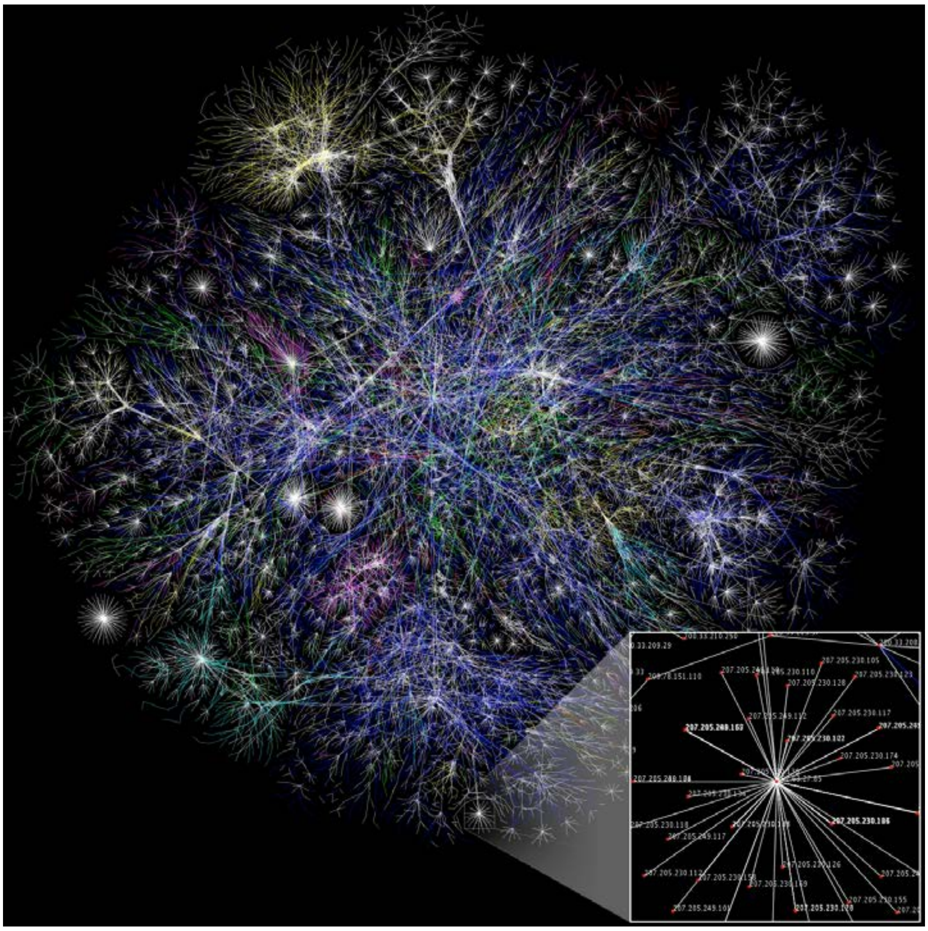


Fig 17. The Opte Project, 2007, scale-free mapping of single IP addresses CC 2.5 Barret Lyon 2007.

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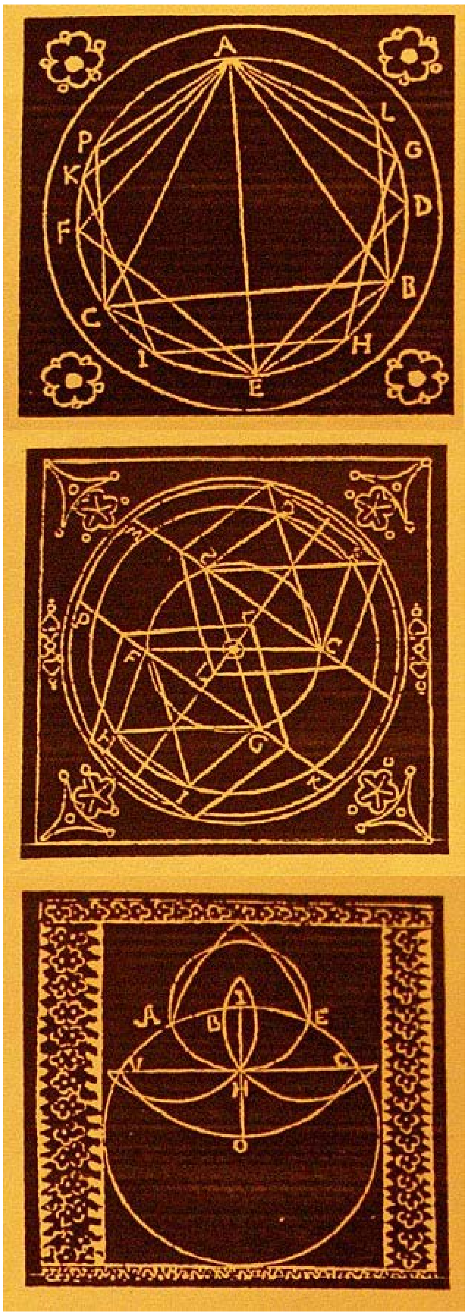
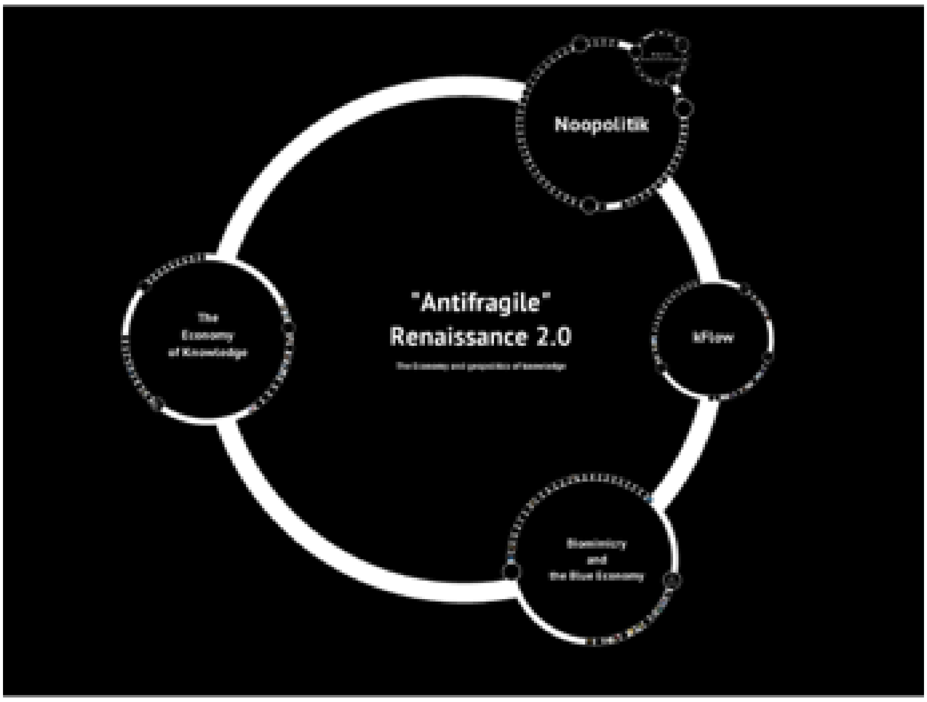


Fig 18. Arts of memory from Giordano Bruno's De Umbris Idearum, his most renowned treatise on the Art of Memory.

Mind ergonomy for the Knowledge Economy



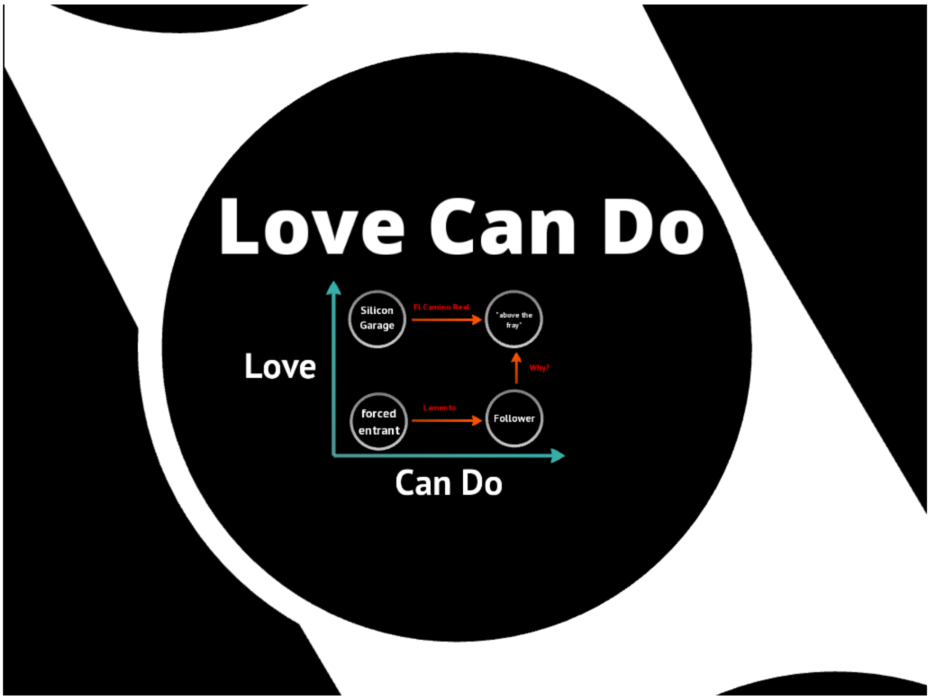


Fig. 19 (a,b,c). 3-scale art of memory conceived by the author, under the Prezi software, during this work, for the Mazars "nExt MBA" program in Silicon Valley. It is an early case of mapping noems both in a neuroergonomic way (using the method of loci) and in a biomimetic way (considering streams of noems and a corresponding noome, the noetic equivalent of a genome). This art of memory, thus, already maps noems onto space and generate noetic strands, two precursors of the Chréage concept. This art of memory was created using the Prezi software (Somlai-Fischer & Halacsy 2009) which, by bringing perspective to the stream of consciousness, represents a fundamental leap forward in the neuroergonomics of digital mental tools, a leap comparable to the non-digital arts of memory of Giordano Bruno in their time. Prezi was an essential piece of the state of the art to develop Chréage

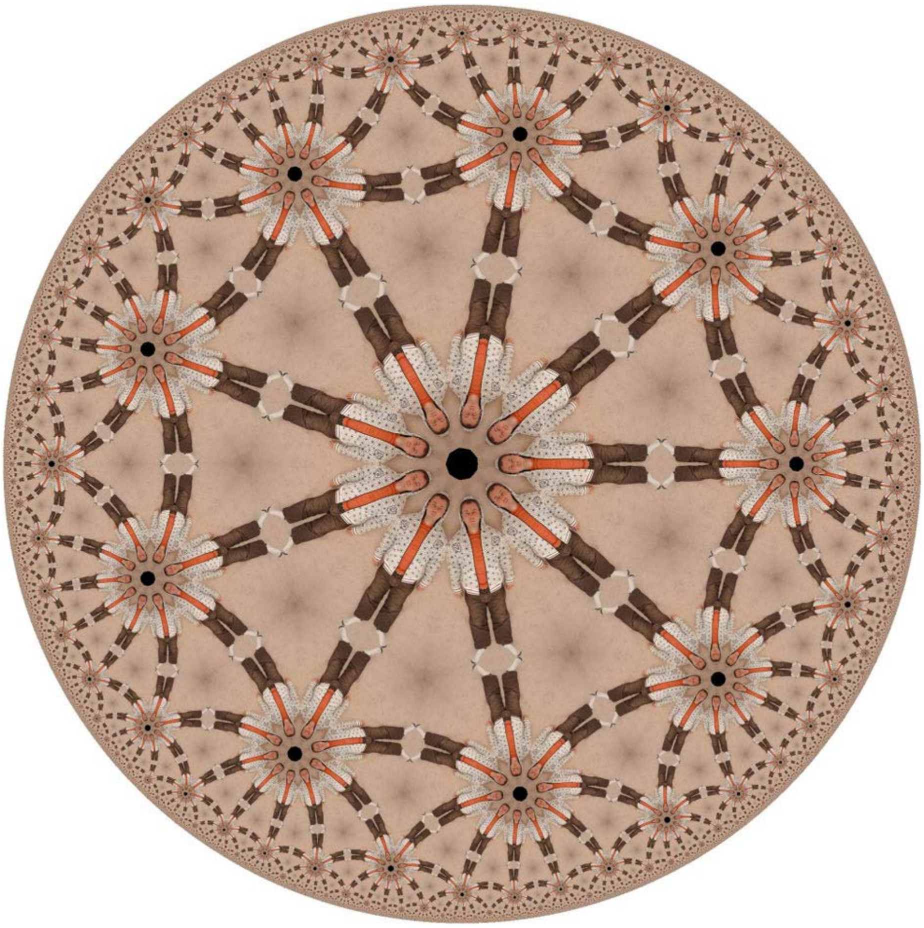


Fig 20a. From Boguna et al. 2010. A Hyperbolic mapping of the publication's third author (Dmitri Krioukov). Original publication caption : "The exponentially growing number of people lying on the hyperbolic floor illustrates the exponential expansion of the hyperbolic space. All people are of the same hyperbolic size. The Poincaré tool developed by Bill Horn is used to construct the tessellation of the hyperbolic plane in the Poincaré disc model with the Schläfli symbol {9, 3}". Note that the scale-free network of Barret Lyon in figure 16 was NOT hyperbolic, unlike this one.

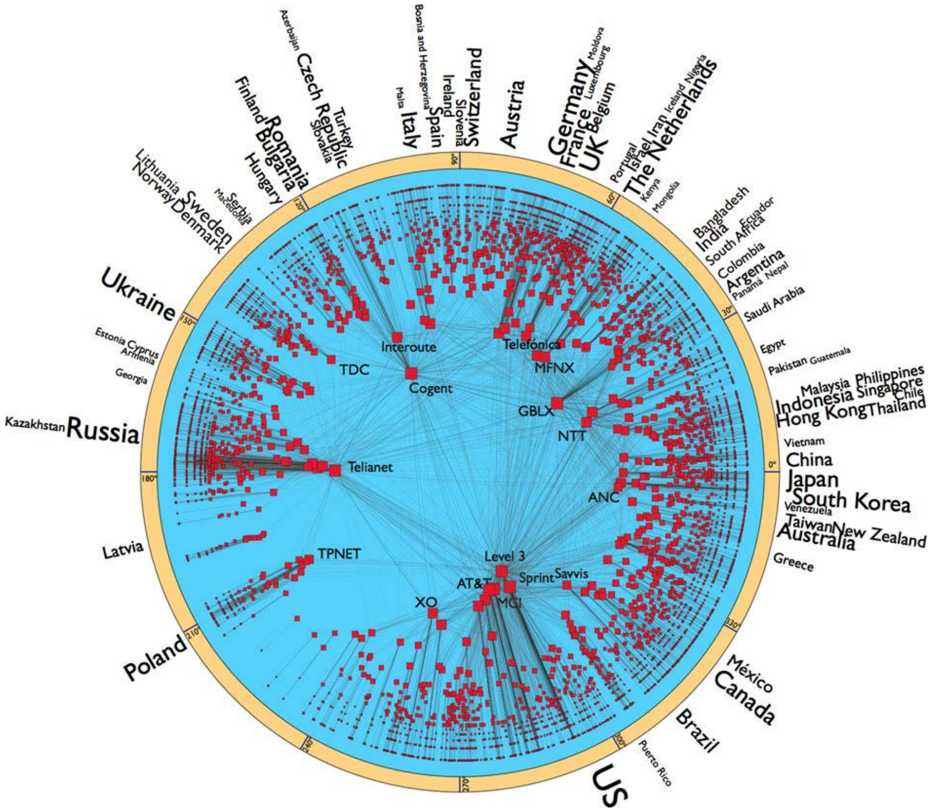


Fig 20b. From Boguna et al. 2010. hyperbolic Atlas of the Internet, mapping Autonomous systems (as in Figure 20b) for example networks under the same provider or host, up to three levels of complexity. The size of each eutonomous system is proportional to the logarithm of its degree. Among the discoveries of Boguna et al. was the observation that the hardware scalability of the Internet was much more robust than expected.

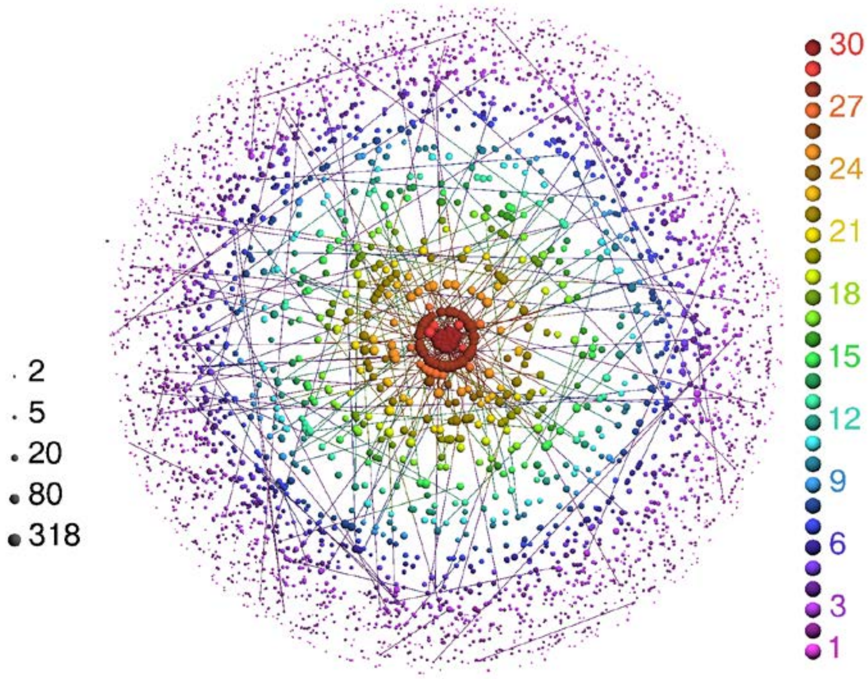


Fig.21a scale-free hyperbolic mapping of worldwide airports "Each node represents an airport and each edge is a regular flight between two airports. Colors are assigned according to the coreness: vertices with coreness 1 are violet, and the maximum coreness vertices are red, following the rainbow color scale. The node degree scale is also displayed, showing the maximum degree of the network"[13] José Ignacio Alvarez-Hamelin, Alain Barrat, Alessandro Vespignani, Luca Dall'Asta Mariano Beiró and others)

[13] http://lanet-vi.soic.indiana.edu/gallery.php

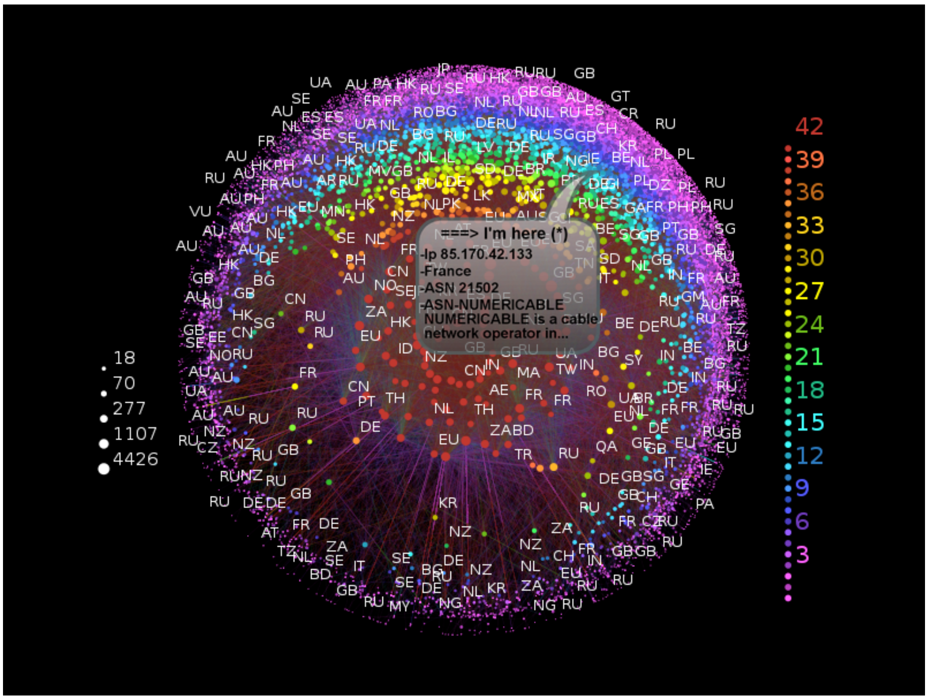


Fig. 21b "I am here", another scale-free hyperbolic visualisation of the Internet, this time clustering autonomous systems (eg. sets of networks under the same internet provider) J. I. Alvarez-Hamelin, D. Anunziata, M. Beiró, A. Barrat, L. Dall'Asta, A. Vespignani 2011.

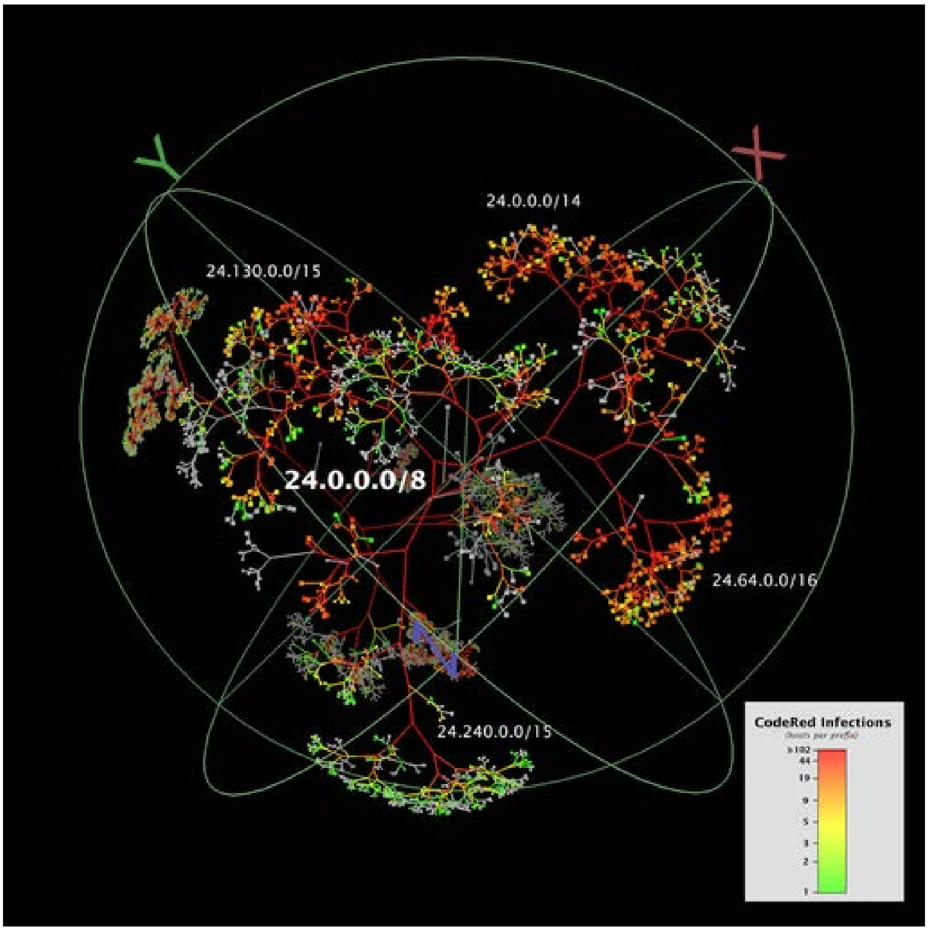


Fig 22 Element of a WALRUS visualisation output (here: representing the dynamic of infection of single IP addresses by the CodeRed worm which infected White House computers on July 2001). WALRUS was developed with the help of the Defense Advanced Research Agency (DARPA) as a CAIDA project of the University of California San Diego's Supercomputer Center. Credit Young Hyun
David Moore, Colleen Shannon, Bradley Huffaker

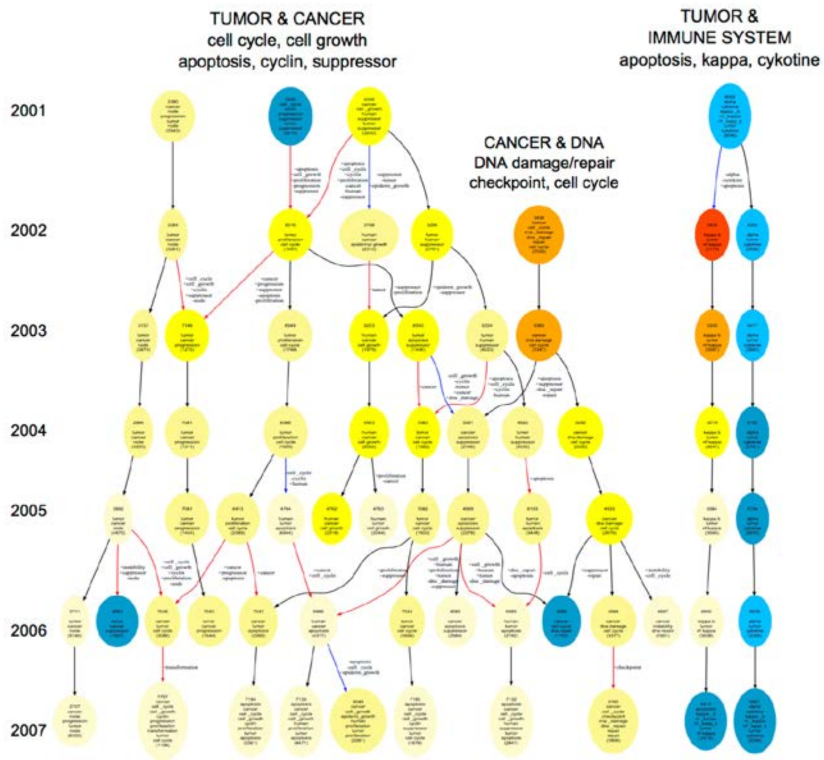


Fig.23a Quantitative epistemology from Chavalarias & Cointet 2013. Original caption: "Detail of the sub-phylogenetic network related with cancer studies. Colors of the circles, from blue to red, maps the growth rate of the pseudo-inclusion index. Red links indicate the introduction of at least one new term. Note that this index is increasing along most of the branches (warm colors) although its growth rate is decreasing with time. Fields are labeled with their most generic term, except for the beginning of a branch or for the most recent period, where all terms are displayed. The labels of inter-period arrows indicate which terms have been lost or gained between two periods. In cluster labels, the number on first row indicates the cluster id and the number on last row indicates the number of articles mentioning all terms of the cluster."

Fig.23b A larger Phylomemy from Chavalarias & Cointet (2013) Original caption: "The phylomemetic branches naturally cluster the scientific fields into large areas of research. The branches presented in this figure have been labeled by their most commonly occurring terms (gap junction, extra cellular matrix, etc.). Time flows from left to right (from 1991 to 2010). Color coding has been used to highlight the existence of emerging terms (in red) or recombinations (in yellow) in clusters (cf. the Results section): a term associated with two **stars indicates that it is emerging, whereas one *star indicates that it is a recombination."

Fig. 24. Pranav Mistry's gestural interface, as part of the "Wear your World" (WUW) suite places affordances at the center of software and hardware design. A projector and a camera track hand gestures and interpret them, while projecting contents on any surface, including one's own hand.

Fig 25. Senior Disney Animator Glen Keane demonstrates his "step-into-the-page" interface: a drawing is converted into a virtual world in which the author and readers can walk through the Oculus Rift interface. This is a remarkable early case for a self-made Merleau-Pontian Universe and Hyperwriting, in the sense that it is a way to "write" using the method of loci.

Fig. 26 The Million Dollar Homepage Copyright Alex Tew 2005-2015. Tew's idea, revolutionary in its execution, was to sell pixels from a 1000 x 1000 webpage at one dollar each.

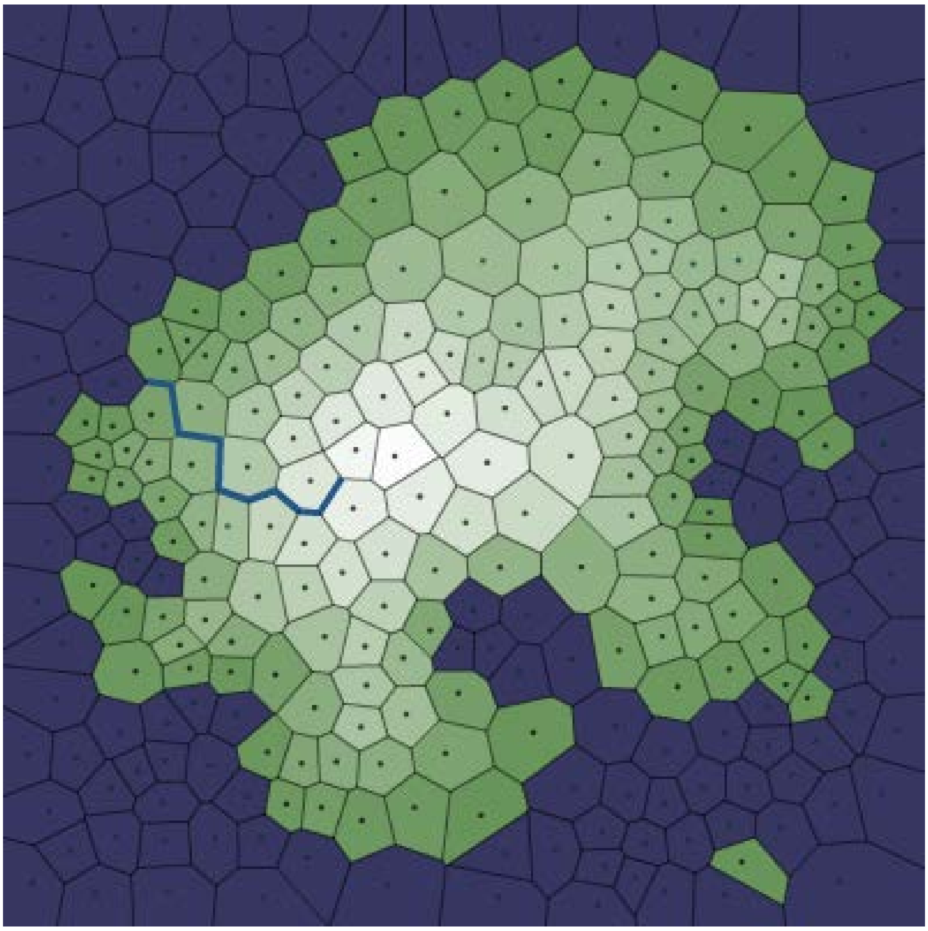


Fig 27 a. From Amit Patel (2012). Early phase for a Voronoi-based island generation

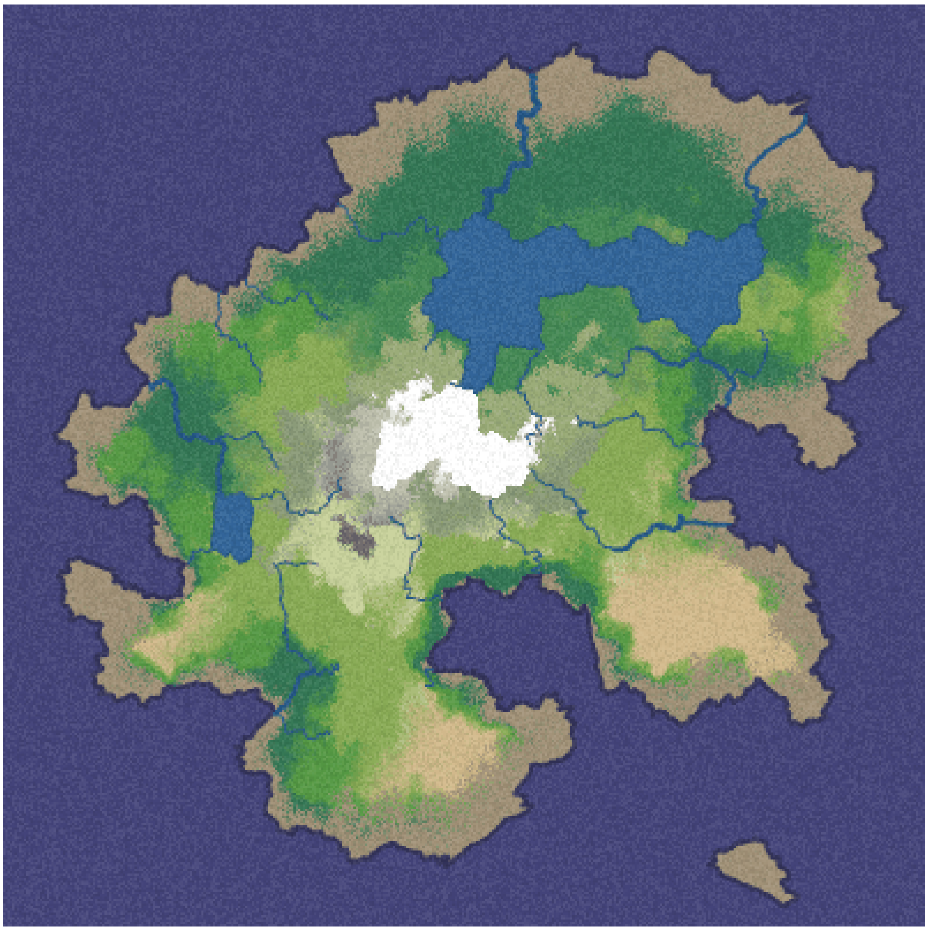


Fig 27 b. From Amit Patel (2012). Intermediate phase : rivers are procedurally generated and biomes determined from a simple matrix crossing elevation and moisture.

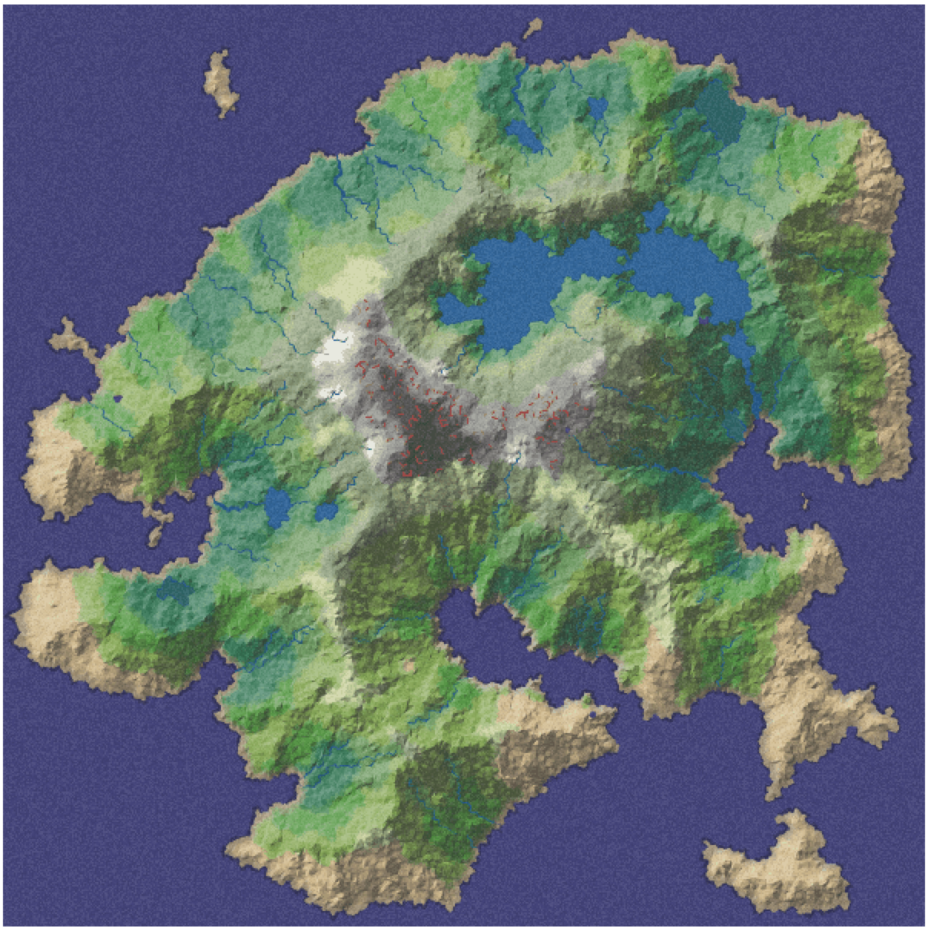


Fig 27 c. From Amit Patel (2012). Final result for a procedurally-generated island with biomes and rivers. This island however, is generated in vector graphics and is not generated within a full 3D game engine.


FLASH MESSAGE
D0053
INTERDICT
Destroy the Plateau's HQ.
Bravo
Echo
Kilo
Lima
Juliett
India
Charlie
00 40 15
HQ
INFO UNITS
DISP ZONES
AUTO ZOOM
SAT VIEW
Objective Alpha secured.
Objective Foxtrot secured by an enemy.


FLASH MESSAGE
D0065
00 40 24
HQ
INFO UNITS
DISP ZONES
TRACK CAM
AUTO ZOOM
SAT VIEW
Objective Alpha secured.
Objective Foxtrot secured by an enemy.

Fig 28 a,b,c. Three levels of zoom from the excellent Iriszoom game engine, developed by Eugen Systems, and implemented here in the Wargame Real Time Strategy game series. The game engine allows a smooth, seamless zoom from the symbolic map to the single unit. Copyright Eugen Systems (2012-2014).

Fig 29. Watch OS App Launcher, first publicly released version. The Watch OS App Launcher, combined with the method of loci, provided me with a working basis for the front-end design of the Chréage Mindscape launcher.

Fig 30. The prototype Solu Operating System (2015), a collegial interface for the knowledge economy, forked from the Android Operating System, and project-oriented in its design philosophy.

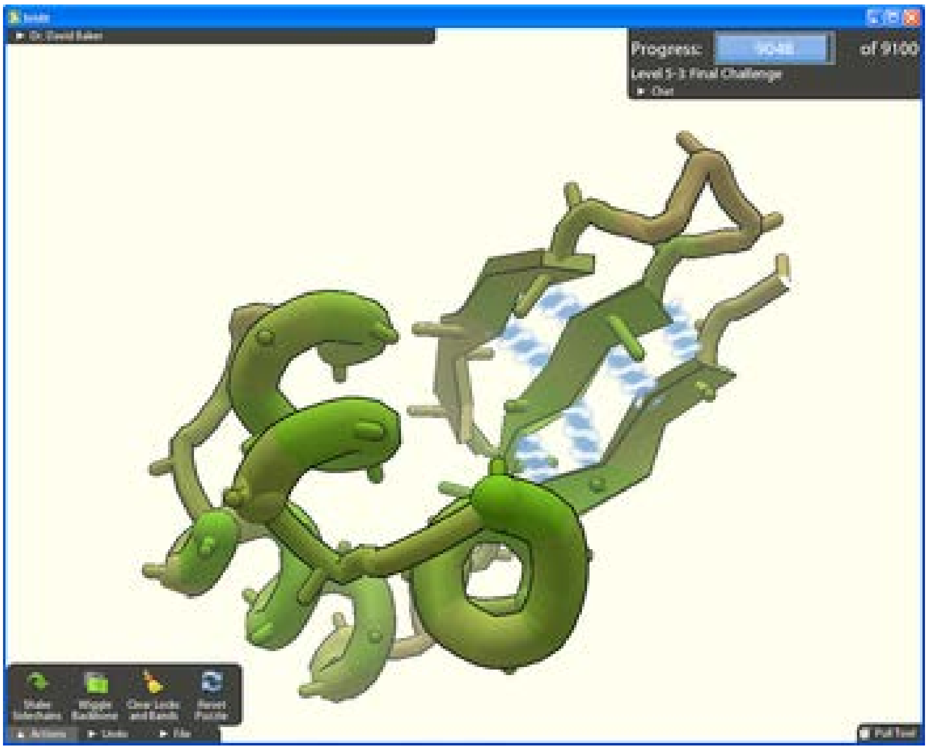


Fig 31. The FoldIt serious game, created by David Baker with Seth Cooper as lead game designer, gamifies a critical part of the research on the 3D structure of proteins. It was instrumental in my speculating on the idea of an “ATLASER”, that is, a game focusing a massive amount of “At” (a unit of attention multiplied by time) on open scientific problems to break them in a novel way.

4. Synthesis of the influences & contributions

> The most powerful computer in the world isn't nearly as intuitive as the one we're born with.
>
> —Barack Obama

Essential Influences[14]

Why ?

Smilor, Kozmetsky, McKenna, Pauli, MacArthur, Benyus, Beck & Davenport, Drucker, Carter, Benyus, Brzezinski, Gore, Shariq

How ?

Parasuraman, Changeux & Dehaene, Janata, Green & Bavelier, Burnod, Cointet, Chavalarias Mesmoudi, Bach-y-Rita, Varela, Benyus, Rougerie, Pawlyn, Callebaut, McGonigal, Giordano Bruno, Bolte-Taylor, Bourgine, Dabiri, Collet,

What ?

Kay, Jobs, Mistry, Belhassen, Soudoplatoff, Bush, Berners-Lee, Thorvald, Shuttleworth, Bourry, Patel, Tew, Brin, Page, Federighi, Breazeal, Serlet, Gassé, Le Dressay & Le Dressay, Guillemot, Agarawala, Somlai-Fischer, Halácsy & Arvai, Keane, Cooper & Baker

Essential Contributions[15]

Why ?

Outline of a theory of knowledge flows (general noodynamics)
Outline of a Micro and macroeconomics of knowledge

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[14] this list is not exhaustive
[15] not exhaustive either

Extension of the Blue Economy with the notion of “kwaste” and the “GDK/GDW” ratio
Comparison between Physiocracy and Silicocracy
An analysis of Smilor et al.’s “technopolis phenomenon” through the Love Can Do matrix and the Cute x Powerful matrix.

How ?

Posing the Hyperwriting Conjecture
Posing Curvy A, a conjectural prototype for a glyphic hyperwriting
Posing the Mindscape and Serendipity problems
Outlining Noomics
Posing a theory of Merleau-Pontian Universes.

What ?

kFlow a Platform as a Service spatial interface for collegial knowledge flows
Chréage a prototype neuroergonomic and biomimetic software for the knowledge economy in web 3.0

From this section onward chapters are presented as individual standalone contributions with their own abstract, bibliography and numbering as often as possible. This is to ease the practical consulting of the entire report, which is made at the comparatively negligible cost of some repetitions. Repetitions, from a neuroergonomic point of view, are actually more practical : in fact Western music works by this very means, and if there can be beauty in the repetition of streams of phonemes, could there not be such a beauty in that of noems? Besides, how exemplary would a work on mind ergonomics be that would not make any effort at being slightly more mind ergonomic than an average academic work itself ? This of course, requires a certain challenging of the status quo *of the otherwise unchallenged manuals of style. Better late than never…*

Mind Ergonomy for the Knowledge Economy

Part 1

“Why ?”

1. The Knowledge Economy : Why ? How ? What ?

This section was peer-reviewed and published in French, English, Chinese and Korean by Fondapol (Paris), May 31st 2015. It was augmented and edited for this version

Abstract. The Knowledge Economy is extremely different from classical economy. While it is often considered the newest however, it is actually the oldest, in that human beings have been exchanging knowledge long before they exchanged services, or even materials and tools. It is an economy whose main resource is infinite, and an economy endowed with an intrinsic form of justice, one that facilitates and rewards sharing, and where the unemployed concretely boast greater purchasing power than those in work. The synergy of knowledge also makes it an economy where 1 and 1 makes more than 2, and, more importantly, an economy in which everyone is born with purchasing power and where, ultimately, each individual has potentially total control over his or her purchasing power. Nooconomics – the economics of knowledge – captures the essence of sustainable development and may allow us, in just a few years, to trivialize problems that Humanity has considered unsolvable for millennia. This section will answer three questions : Why practice nooconomics?, How do we practice it?, and What is it exactly?

1. Introduction

1.1 General outline

Imagine an economy whose main resource is infinite. Imagine an economy endowed with an intrinsic form of justice, an economy that facilitates and rewards sharing, an economy where the unemployed boast greater purchasing power than those in work, an economy where 1 and 1 makes 3, an economy in which everyone is born with purchasing power and where, ultimately, each individual has total control over his or her purchasing power.

Just as stupidity, knowledge is infinite. This inherent potential of knowledge has very profound economic implications. Firstly, if knowledge is infinite then, by indexing growth to knowledge, the former also has the potential to be infinite. We know that this is not the case for growth indexed to natural resources which – even when they happen to be renewable – will always be finite, due to the finite nature of time itself. Infinite growth is impossible to achieve with finite resources. However, infinite growth linked to knowledge is not only possible, but rather simple. Consequently, nooconomics captures the essence of sustainable development, which is to say the immense richness of its applications.

Conceptually, the economics of knowledge is not a continuation of the classic economics of raw materials, work or capital. It represents a revolutionary change from the latter, a genuine paradigm shift. Although this notion appears ad nauseam in the world of mass marketing, it really does represents a return to the very roots of the word "economics", to the age of the Physiocrats, for whom all economic value could be reduced to natural goods or services. The prefix "eco-" is, of course, common to both economy and ecology, and it is exactly this link that is emphasised by the economics of knowledge.

This chapter addresses three questions: Why ? How ? and What ? Why should we practice nooconomics? How do we go about this, and – in particular – on which theoretical basis? And finally, what are its essential applications? The latter includes biomimetics, probably its most spectacular application. This treatise addresses political and economic decision-makers. A citizen is both, entitled to vote both politically and – more importantly – economically, the latter being exercised via the citizen's choice to grant money, attention and time to any given company, even if that citizen is only rarely conscious of such decisions nowadays.

1.2 For the working classical knowledge economist

As this chapter is intended for a general, non-specialist audience, and in particular for policy-makers, this subsection is added to orient the classical knowledge economist more easily. It will thus anticipate some of the notions that will be presented later, with which the working economist may already be familiar.

This work does not exactly depart from those of Peter Drucker, George Kozmetsky, Lawrence Lessig and Beck & Davenport, it rather supplements and, sometimes, contrast them. It is however a work in progress, an open paradigm that may be contrasted, contradicted or refined. Any more precise notions are welcome to enrich it.

What this work contrasts with, among other notions, is the idea that knowledge flows may be only represented with such measurements as patent transactions and the like. The purpose of this work is to establish a theory of knowledge, what Bourgine (2001), Varela (2001), Dupuy (1997), Chavalarias & Cointet (2013) and others have brilliantly called an "applied epistemology", that should be ultimately, collectively evolve into the knowledge equivalent of Shannon's information theory.

The econometrics of patent flows is interesting, but what this section focuses on is the exchange of knowledge for a single individual. This is necessary before the "knowledge superhighways" can be theorised, and these are not mere patent purchases.

When purchasing a patent indeed, the transaction is essentially instantaneous (after negotiation that is), the patent is transferred from the assets of company A to those of company B, and since patents are mostly rival goods, as they were intended to materialise something immaterial, company A and company B may not own the same patent at the same time (unless it is a shared holding). Ideas, concepts and the likes remain non-rival goods: company A and company B may hold and apply the same views, ideas and cultures at the same time, although the competition will usually encourage them to differentiate each other.

The notion of “rival” and “non-rival” goods I have substituted here with the simpler “Soudoplatoff Law” which was developed by technologist and cartographer Serge Soudoplatoff in 1984 at IBM, and formulated a well-known piece of wisdom, that had been defended by Sufi master Amadou Hampaté Ba for example.[16] regarding purchasing power I have based my model on Attention and Time, expanding Beck & Davenport into an early, albeit rudimentary model with some econometric implications that will be discussed in the following chapter (“discussing nooconomics”). The joint expenditure of attention and time is defined here as the most essential currency of the knowledge economy, without taking such subtle notions as resonance and dissonance into account. This joint expenditure can later be indexed as a revenue, and this index may orient future policies, either macroeconomic or microeconomic. The idea that incoming knowledge may resonate constructively or negatively with existing knowledge, the idea that most human beings, when faced with the exclusive choice of embracing the truth or remaining in their comfort zone, will choose the latter, could be related to behavioral economics and finance.

Just as the notions of action, energy and work, originating from classical physics, could all be transferred fruitfully to the grander paradigm of quantum physics, the notions of maximising agent, limited rationality, marginal cost and Pareto-Optimality could all be transferred, equally fruitfully, to the paradigm of nooconomics. The same would apply of the categories of finance and cognitive finance in particular. One, however, should not forget that it would always be limiting to attempt to fit knowledge-based phenomena into paradigms developed for material-based cases ; above all, nooconomics is not the most recent of economies, it is actually the most ancient : human beings have been exchanging knowledge long before they did material goods. The transmission of fire is one of the most fascinating examples of such knowledge-based economic phenomenon. Let such phenomena expand older paradigms, and not older paradigms limit the understanding of such phenomena. If the knowledge economy is the most ancient, its awareness is the most recent. It would, however, be childish to confuse awareness with existence and especially to limit the latter to the former. This, however, is a well-known scientific bias : “what I don’t know, doesn’t exist”.

Of particular interest to the classical economist will be the idea that knowledge exchanges are positive sums : I can give away knowledge to whoever I want, repeatedly. This, however, is not true at a subtler level : giving away knowledge is spending away time, which is limited, and as such, the activity of giving knowledge is rivalled with others. The activity of purchasing knowledge, is also rivalled with entertainment ; after all, attention is limited. Further developments of nooconomics should improve this paradigm into a subtler precision, just as, say, femtochemistry has improved classical chemistry into the understanding of subtler phenomena. Paradigms must evolve from coarse to fine-grained and nooconomics is no exception. This, again, is a coarse yet seminal paradigm. Its merit is not necessarily in what it predicts, but also in what it

[16] in the form “knowledge is the only good that can be shared without diminishing it”

does not represent, which is at least equally interesting. Again, it was because classical chemistry did not capture femtoscopic phenomena that femtochemistry ended up such a brilliant paradigm. The microcognitive phenomena, encompassing cognitive resonance, risk aversion, fear of change, confined thinking, or other manifestations of what is known as the ego, could all be studied in extremely fertile offshoots of the paradigm presented here.

2. Why practice nooconomics?

2.1 Knowledge is infinite

There is one simple and essential reason to practice nooconomics: because knowledge is infinite. And also because any resource or energy management issues can be reduced to that of managing a future knowledge in the making; that is to say, the issue of not thoughtlessly using up and wasting a resource in a trivial manner today, when tomorrow the knowledge exists to use it in a better and more profitable way. As will seen in the third part of this treatise, biomimetics is a very elegant realization of this principle, the reason for its emergence as a global techno-industrial avatar of sustainable development.

Nooconomics captures the entire essence of sustainable development, because knowledge has the potential to render problems that Humanity has considered unsolvable for centuries redundant, in the space of one generation. One kilogram of mud contains enough mass energy to meet the entire annual demands of mankind, but it is due to a lack of knowledge (ignorance, or negative knowledge) that we are unable to materialize its potential. Antimatter could be a revolutionary fuel for the aerospace industry, yet it is because of a lack of knowledge that it is not used on a mass scale today.

The knowledge economy can underlie a healthy, are infinite growth that absolutely no other paradigm can offer in today’s world. In order to prevail, however, it requires the creative destruction of our existing economic paradigms, based on scarcity, division and Malthusianism. In other words, paradigms still trivially grounded in material rather than immaterial realms of thought. Yet these paradigms, inherited from the industrial revolution, are proving to be very durable because they have normalized[17] our very system of education, teaching yesterday's ideas to tomorrow's generations, measuring the possibilities of the future against the past. Ensuring that the ways of the past do not impinge on the future is a fundamental theme of sustainable development.

The toll taken as a result of the process of creatively destroying the economy of capital, work and resources in favor of nooconomics is represented by a protracted political

[17] Interestingly enough, France's state-run schools for teachers, formed during the industrial revolution and historically known as a decisive rival of the Church, are still called “normal”, the “Ecole Normale Supérieure” being the most famous at the time this treatise is being written.

struggle. Although its premise dates back further, the modern beginnings of this struggle can be pinpointed to the year 1977 when Jimmy Carter, as part of a fascinating speech during which he declared the energy crisis to be the “moral equivalent of war”, made the following calculation: if we keep indexing the US dollar to raw materials, its potential is great but limited; were we to index our currency to knowledge, its potential would be infinite. We know beyond any doubt that this ideal has not been achieved over the following forty years. The proof is there to be seen in the millions of deaths resulting from various wars in central Africa and the Persian Gulf, still the world's most volatile region due to its abundance of cheap hydrocarbons. The strategic doctrine pushing the United States to secure the Persian Gulf’s oil deposits at absolutely any cost is still ironically labeled “the Carter doctrine”, even though it diametrically opposes the vision outlined by the president vision in 1977. Indeed, every politician can tell the story of an ideal that has gone missing in action. Yet, while dreamers may be killed, their dreams never can be.

By way of a caricature, yet one with a strong grounding in truth, this profound political struggle between resource-based (material) and knowledge-based (immaterial) power could be reduced down to the opposing visions of Jimmy Carter and Dick Cheney – the latter easily caricatured as the partisan oilman, the embodiment of domination by resources. Today, dollar remains the trading currency for all raw materials, and unfairly so. Whether you wish to trade wheat, frozen concentrated orange juice, gold, uranium, bauxite, cotton, crude oil, natural gas or lean hog futures, ultimately the purchase will be made in dollars. This is perceived as an immense economic injustice by the BRICS, and drove them to push for the advent of a new global reserve currency indexed to gold and special drawing rights held by the IMF, at the G20 summit in L'Aquila in 2009. Although Dominique Strauss-Kahn backed the BRICS at the time, their initiative has subsequently borne no fruit.

Only seven years after that 1977 speech, the emergence of the “Valley Heroes” – from Steve Jobs to Sergei Brin, from Mark Zuckerberg to Elon Musk – proved to just what extent knowledge had become the country’s most essential economic resource. In 1984 Steve Jobs, having launched the legendary Macintosh and sold the idea of the personal computer[18] to the world, met with French President François Mitterrand who, in view of the investment of several hundred million dollars that Apple had just made in France, asked him if his country could witness the emergence of its own Silicon Valley. Jobs' response, the epitome of clarity and conciseness (and which, as a Frenchman, I consider more valuable to the French economy than ten years’ worth of École Nationale d'Administration graduates), is now preserved in the audiovisual archives of the French national channel “Antenne 2” and available on Youtube. Most significant of all is his prophetic utterance: “Software is the oil of the 80s and 90s”. This idea had been considered inconceivable for at least a decade at IBM, who – following a now-legendary

[18] A significant part of Jobs' genius was cultural, as well as technological. Even if Jobs did not invent the PC, he still won the battle with Bill Gates as the first person to make – within a single generation – the concept of a computer in every home a reality. IBM, on the other hand, had long considered the very term “personal computer” to be an oxymoron, a natural consequence of their 'B2B' (Business to Business) culture (IBM of course stands for International *Business* Machines).

meeting between Bill Gates, Paul Allen and Steve Ballmer and the American company in the 1980s – famously claimed "we know there is no money to make in software". Today, the man considered by the mass media to be the world's richest is not an oil magnate but a software magnate. And today Apple, born in a garage, just like Amazon, Google, HP or Disney, is sitting on a pile of cash comparable to the entire GDP of New Zealand. So yes, software is indeed the new oil. And, more broadly speaking, knowledge is the oil of any given age, just as Richard Francis Burton described Paradise – in other words Eternity or the one true "end of history" – as the place "where every knowledge shall be known". If time is indeed Plato's mobile image of an immobile eternity, its mobility can only be traced in the evolution of human consciousness and, as a last resort, of wisdom (knowledge of the self) and knowledge (of the non-self). Nooconomics is itself a pragmatic and elegant branch of nooscience, the knowledge of knowledge, and its political challenge is to explore, exploit and distribute those two vast oils: wisdom and knowledge.

Barack Obama can be seen a kind of successor to what I call the "the true Carter doctrine", that of nooconomics. Obama is actively courting the geeks of his country and has held meetings with Mark Zuckerberg. Facebook now holds more economic value than a Total or a BP, and the firm enjoys more influence over governments than the oil companies of yesteryear did when they went about funding *coups d'état*. The company also has a market capitalisation comparable to theirs and, although the latter is still largely speculative, it has achieved all of this with one hundred times fewer employees. It may justifiably be said that the productivity leverage of knowledge is colossal, and it is for this reason that mathematics could be a most wonderful instrument to drive development in Africa. Unfortunately Africa, as of early 2015, is still of all the continents the one least involved in nooconomics, although this is of course foreseen to change.

Obama also met with Elon Musk, the founder of SpaceX and Tesla Motors. The former company has been able to win over fans with its proposals for the private refueling of the International Space Station and the provision of mass space tourism, in just five years. The latter company concentrates all of its production in the USA and is valued today above the PSA-Peugeot-Citroën group. It has made a mockery of the low-cost, de-industrialization politics that have prevailed for too long among the strategies of the austerely and mechanically orthodox French automotive industry, which remains capable of predictable administration but intrinsically incapable of unpredictable disruption. It is to such a mentality that France owes the death of the "Watch Valley" in the Jura region, among other failures.

SpaceX, an exceptionally agile and visionary company, subject to relatively small levels of bureaucracy compared to its industry counterparts, is the nemesis of Arianespace. The two companies' DNA are radically opposed, one being as fundamentally idealistic and disruptive as the other is the result of an upbringing rooted in rationality and predictability. It also bears mentioning that Tesla motors recently declared that it would not sue any competitors who choose to replicate its patents in good faith, something that would still be unthinkable for the European automotive establishment. Not only has the price of Tesla shares not dropped following the announcement but, from October 2012 to August 2014, it grew by a staggering 765 %! When was the last time a

French, or even European, business leader was deservingly referred to as disruptive ? Is bureaucracy not diametrically opposed to disruption ? Can the term “disruptive state” ever be anything other than an oxymoron? What can we say about the French “National School of Administration”, itself administered by the state? Must it not be the stage for the least disruptive thought on Earth?

Barack Obama is also courting Taylor Wilson, the young prodigy who produced a DIY deuterium fuser in his parent's garage while he was still attending high school. Better still, the president has set in motion a tradition of entrusting the extremely strategic Department of Energy to geeks, such as Nobel prizewinner Steven Chu and professor Ernest Moniz. Originally created by Jimmy Carter, the position at the head of this department had traditionally been the reserve of seasoned intelligence or oil experts. Let us remind ourselves of the brilliant quote from Sheikh Yamani, Saudi Arabia’s legendary Minister of Oil and Mineral Resources from 1962 to 1986, at the time of the oil shocks: “The Stone Age did not end for a lack of stone, and the Oil Age will end long before the world runs out of oil.” We should avoid the fallacious interpretation here that “stones are abundant, and hydrocarbons will remain so”. Instead, it should be seen as an assertion that Humanity, through its ingenuity and cultural maturity, remains free to accelerate the advent of a technological revolution via a process of creative destruction, so dear to Schumpeter. Before the American Civil War, one of the essential economic consequences of the abolition of slavery in most northern states was a massive acceleration in the industrialization process, because the steam engine was more effectively adopted once the old model of slave-based manual production had been destroyed legally, ethically and then culturally. The American automotive industry was destined to flourish forty years later in the North rather than the South, whose industrialization had experienced a decisive delay. The end of the slavery model is an elegant precedent of the creative destruction needed in order to impose nooconomics. Let us just hope that this transition will not result in a conflict in any way comparable to the American Civil War.

2.2 The curse of raw materials

When Brazil discovered the subsalt oilfields of Tupi and Iracema, geologically similar to those of the Gulf of Guinea, President Lula da Silva declared that they were “Brazil's second independence” (the Tupi oilfield has since been renamed “Lula”). However, the really noticeable trend among the BRICS is that the fewer raw materials they possess per inhabitant, the quicker they are to wholeheartedly embrace nooconomics. Let us compare, for example, the raw exports of the Russian Federation with those of the Republic Of Korea, which experimented with setting up a Ministry of the Knowledge Economy. Despite a territory 171 times smaller than Russia’s and a third of its population, South Korea exports more than the Federation because, instead of being held back by the mental sloth that an easy access to raw materials inevitably encourages, it is forced to export knowledge and expertise.

The export matrices of the BRICCA (Brazil, Russia, India, China, Canada and Australia) all demonstrate a great dependency upon raw, agricultural or geological materials, and this dependency is sentencing these countries to remain attached to the paradigm of material economics. These are also the world's largest countries, with the exception of the USA, the only one to possess the geographical attributes of a superpower as of early 2015, namely both a large interconnected territory and population. China, precisely due to a notable lack of hydrocarbons per inhabitant, is, of all the BRICCAs, the most involved in nooconomics and as a result the one country that encourages its children, from kindergarten, to read the fables of Gunter Pauli, the father of Blue Economy.

Geopolitically it must be noted that sometimes, for an individual or for a country, “what doesn’t kill me makes me stronger”. By limiting China's access to the hydrocarbons that it craves, the Organization for Economic Cooperation and Development (OECD), which is under clear American leadership, has actually made this nation more innovative and somehow saved it from the debilitating economic diabetes that an easy access to cheap raw materials would have otherwise caused, and which can be clearly observed in a few other countries, Russia and Algeria for example.

Consequently, in Brazil, the discovery of new oil fields could prove to be more of a disguised curse than a blessing, for it can prevent the country’s entry into the knowledge economy. In this sense, surely it does not represent “Brazil's second independence”, as it renders the country more dependent upon the export of raw materials. For countries and individuals alike, two desires may coexist: that of the ego, demanding “give me what I want!”; and that of the true self, more quietly begging “give me what I need!”. It is strange to observe that states persist in behaving like children, coveting territories and resources out of a vain sort of greed, like children craving an overload of sweet treats that will inevitably make them sick, while they should instead be coveting wisdom and composure. I am dedicating a separate Noopolitik treatise to this fascinating observation.

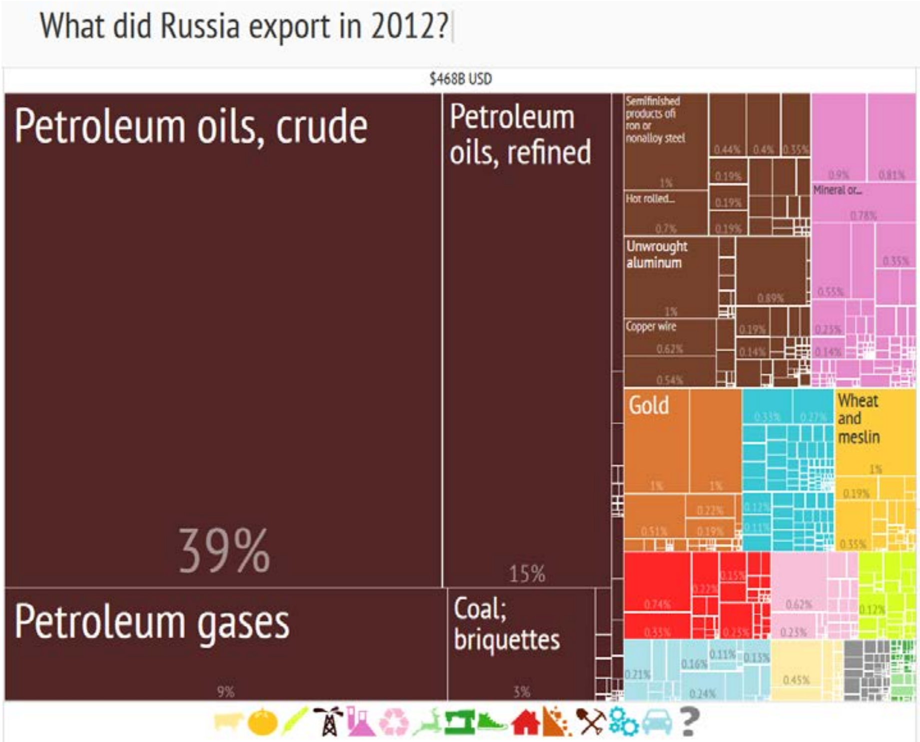


Fig.1 Raw Exports from the Russian Federation in 2012 (total volume: USD 468 billion)[19]

[19] Source: "The Atlas of Economic Complexity," Center for International Development at Harvard University, http://www.atlas.cid.harvard.edu.
http://atlas.cid.harvard.edu/explore/tree_map/export/rus/all/show/2012/

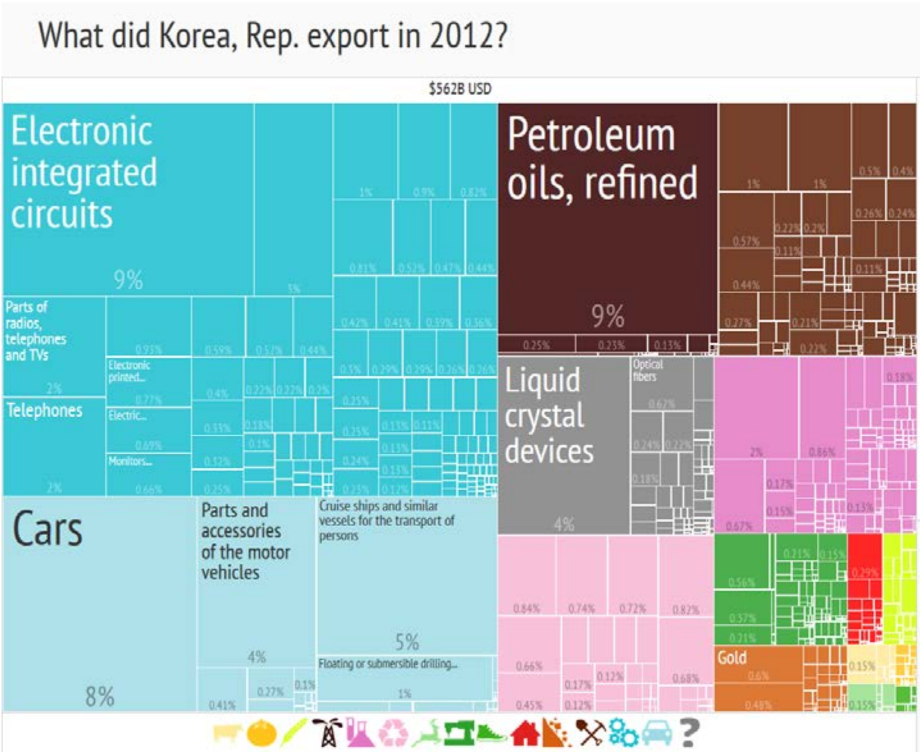


Fig.2 Raw Exports from the Republic of Korea in 2012 (total volume: USD 562 billion)[20]

The fact that the French-Brazilian Artur Ávila was awarded the Fields Medal in South Korea in the summer of 2014, and that Brazil will host the 2018 International Congress of Mathematicians, are both somewhat discreet economic events that are nevertheless much more influential for Brazil's economic potential than the discovery of deep sea oilfields or the painful soccer World Cup of 2014 (when the country was the generous host of its own humiliation).

Let us dwell for the moment on the notion that an abundance of raw materials is to states what candies are to children: sweet, yet harmful. A comparison of raw exports from Morocco and Algeria once more demonstrates it beyond all doubt. Algeria's economy is diabetic; the country suffers from a sort of hydrocarbon diabetes, the clearest symptoms of which are an absence of innovation a total lack of diversity in its exports.

The story of Johann August Sutter – the subject of Blaise Cendrars' Gold and a possible inspiration for Sergio Leone's Once upon a time in the West – perfectly illustrates how,

[20] Note that the overall volume of South Korea's exports is superior to that of the Russian Federation in 2012, as is its proportion of technological exports. The contribution of mineral products to South Korea's raw exports is largely made up of those products circulating and being transformed within its borders, rather than those originally mined there.

for a smart entrepreneur, the discovery of raw materials can be a terrible curse. Although he had created a very valuable business in California thanks to his singular ingenuity and use of renewable locally-sourced materials, Sutter was ruined by the Californian gold rush of 1848 and the stupidity and injustice that it brought about. A few centuries earlier, the Spaniards had ruined themselves by attempting to exploit the Potosí silver mines (then in Peruvian territory, today in Bolivia) while later many states of the Persian Gulf, Saudi Arabia chief among them, would prove to be incapable of actively and effectively participating in the knowledge economy, because of the political and mental sloth that an easy access to raw materials inevitably encourages. Men and states alike must understand that the brain is a philosopher's stone that is more valuable than all the world's gold. It is better to be born poor and smart than rich and stupid; this is particularly true of states, and ably demonstrated by the adventures of Sutter, 16th century Spain or, in contrast, the successful "forges de Buffon" in 18th century France.

Fig.3 Raw Exports from Algeria in 2012 (total volume: USD 69.8 billion)

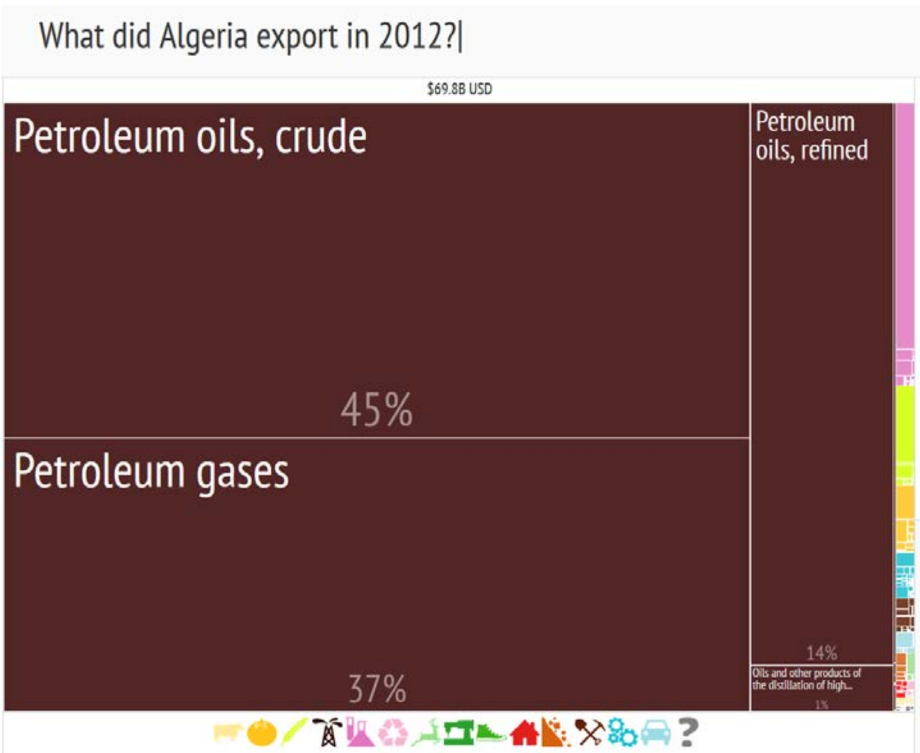
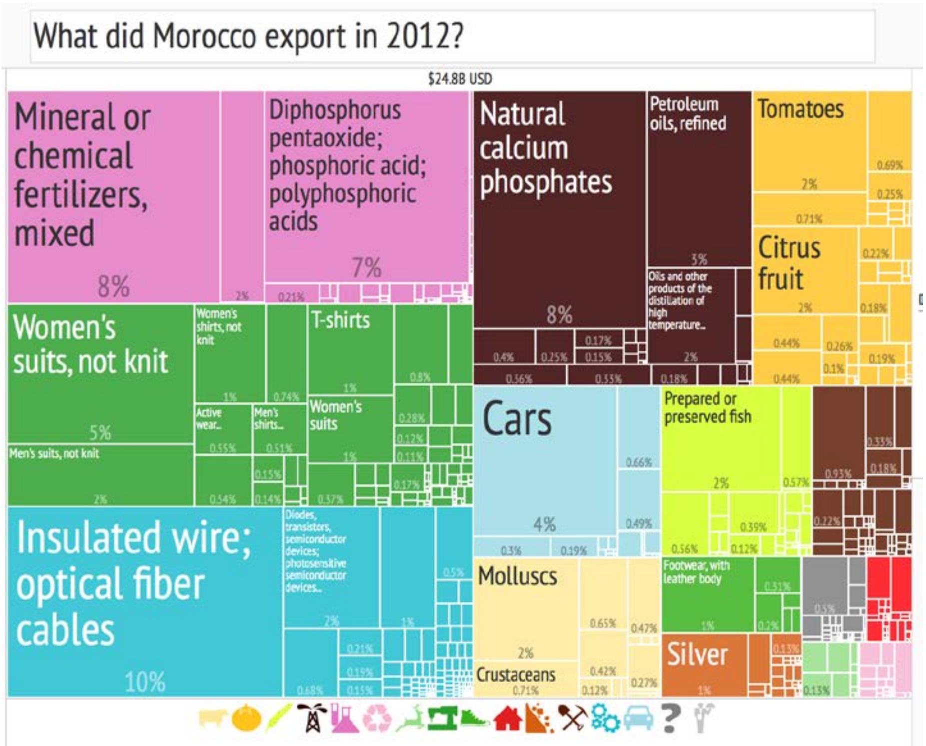


Fig.4 Raw Exports from Morocco in 2012 (total volume: USD 24.8 billion)



2.3. The dynamic of socio-technological revolutions

When it comes to a socio-technological revolution, the cultural dimension – which is to say, the unavoidable element of the zeitgeist – must not be underestimated. Mankind does not embrace new technology or a paradigm shift (the structure of scientific revolutions, according to Thomas Kuhn) because they are objectively better and more efficient. Such an act would imply rational humanity, which behavioral economics has clearly demonstrated to be a myth. Provided that the choice is available, a revolution is adopted only when mankind no longer fears it, which is entirely different and explains the success of Apple. Apple did not invent the PC, but was able to make it “cute” (or acceptable and, above all, harmless) in the eye of the public. Even today, the firm's trademark designs preserve this culture. Yet we must remember that mankind already possessed the following technologies in the past: an analog computer, the Antikythera mechanism, in the 1st century BC (therefore more than 1,700 years before Blaise Pascal's analog computer); Zhang Heng's Houfeng Didong Yi seismographer in 132 AD; a working electric battery or a galvanoplastic device, the “Bagdad Battery”, in the 7th century at the latest; smallpox inoculation (variolation) in 16th century China at the latest; and a working steam engine, the Aeolipyle, in 1st century Alexandria.

Thus, as a prelude to the question “how to practice nooconomics?” we can already observe that the widespread acceptance of any revolution, of any ingenious idea in history, necessarily passes through three stages - the comprehension of this process is usually attributed to Schopenhauer.

Stage 1: it is considered ridiculous, and above all unfeasible. This is a result of mankind’s natural instinct to measure the future against the past. Abolishing slavery and allowing women the right to vote were considered ridiculous and unfeasible in their times. Today the same applies to the eradication of pollution. However, Gunter Pauli shows that it is not only feasible but also highly profitable, in the same way that the abolition of slavery accelerated the Northern states’ industrialization and subsequent adoption of a much more economically profitable paradigm.

Stage 2: it is considered dangerous. The suffragettes, after having been ignored and ridiculed, were tortured, sectioned, imprisoned and, in some cases as a last resort, killed.

Stage 3: it is considered obvious. Nowadays women can vote. So what ?

It should be noted, therefore, that a revolution is never actually considered as wonderful, but instead passes directly between the “dangerous” and “obvious” stages, which subsequently both encourages mankind to regard it somewhat cynically and prevents us from reacting more constructively to the next revolution: tomorrow's reactionaries will base their certitudes on yesterday's revolutions, without ever being aware of the origins or historical dynamics of these certitudes. Despite history being full of scientific and political revolutions that were once considered impossible but that are part of our everyday lives today, we are still incapable of anticipating the next ones, like the elimination of pollution. The latter will seem just as self-evident to our descendants as the abolition of slavery is to us nowadays. According to Cheikh Aly N'Daw, founding father of “economics via peaceful means”, the art of attaining a “crystal-clear subjectivity” may be a cure to this condition of collective human consciousness.

Any revolution elicits cognitive dissonance, and man will naturally react with denial and violence up until the point that the revolutionary ideas are assimilated into collective patterns of thought. As we have already seen, when faced with a paradigm shift, Man is effectively confronted by a cognitive dilemma: one choice is to disown his past and abandon his comfort zone by stepping into the unknown and embracing the truth, and the other is to remain in his comfort zone – which is to consciousness what a shelter is to a body – and to reject the truth. It is normal, and to be expected, that people tend to prefer the comfort of a lie to the discomfort of unknown truth. However, the latter is better for them than the former: this is another case where the ego leads humans away from what is beneficial. Politicians and citizens alike can act to combat this harmful mechanism of the individual and collective ego; patience and exemplarity are the best weapons in this struggle, for the use of force and lies will antagonize the ego and strengthen its resolve, thus making it even more resistant to changes for the better. Eternal leaders are those able to subtly charm the ego, those motivated by a transcendent beneficial love of the unknown. In the words of Gandhi: “in a gentle way, you can shake the world”. Gandhi also very clearly outlined the fundamental stages involved in adopting a revolution, having himself experienced such changes at first-hand: “first they ignore you, then they laugh at you, then they fight you, then you win”.

It is for this reason that the deepest and most durable revolutions must be non-violent (as opposed to examples such as the Algerian and French revolutions, which were rushed, imperfect and the result of a historical fracture that leaves humanity with no other choice than that of violence), like Martin Luther King Jr.'s Civil Rights movement, which did infinitely more for racial equality than the Black Panthers or the Nation of Islam put together. Violence in support of a revolution is counter-productive because it antagonizes the ego and strengthens the public’s conviction that such change is dangerous, thus preserving a collective mindset that is stuck in the metastable state of “dangerous” rather than “obvious” (and therefore, consensual). There is nothing more counter-productive, in the context of a negotiation or a revolution, than to antagonize the ego of a person or a nation. Such a notion should be taught in the Middle East: let us consider the idea of a peaceful territory, with Palestinians and Israelis sharing one single multicultural, flexible and globally beneficial society, and constitutionally committing themselves to protecting each other. Today, this idea is considered somewhere between “ridiculous” and “dangerous” by both the Israeli and Palestinian elites. It is not angelism, but merely a simple observation in “social thermodynamics”[21], to deduce that only through non-violence will we be able to change the status quo. This hints at the diplomatic interest of nooconomics, and in this case noopolitik, as applications of the economics and politics of wisdom. It is a serious oversight that nooconomics is not taught to decision-makers in the fields of diplomacy and administration, because the culture of transcendence, revolution and disruption that it presupposes is of exceptional diplomatic value.

In conclusion to this first section, let us remind ourselves why we should practice nooconomics. Because knowledge is infinite, and because infinite prosperity is an inherent feature of the knowledge economy, unlike any other economy. A culture of transcendence is also inherently present, which represents a genuine treasure for Humanity. Finally, it contains a universal protocol that transcends material, zero-sum conflicts and is instead concentrated on immaterial, positive-sum, outcomes, as we will see in the next section.

[21] Christian Borghesi et al. have proved that there is a statistical physics to voting crowds, with a simple empirical law regarding ballot participation: the more a voter feels that his/her vote will be diluted, the less likely he/she is to participate in the ballot. Hence in many countries from Israel to France, the mean abstention rates for municipal elections are positively correlated to the size of the city. C. Borghesi, J. Chiche and J.-P. Nadal, , “ Between Order and Disorder : A ‘Weak Law’ on Recent Electoral Behavior among Urban Voters ? ”, PLoS ONE 7(7), e39916, (2012).

3 How to practice nooconomics ?

3.1 social properties of knowledge

Nooconomics differs from classic economics to the same extent that quantum mechanics differs from Newton mechanics. Yet its axioms are at once simple and elegant. First, knowledge has two fundamental social properties: it is collegial, and it is prolific.

Collegiality means that everybody possesses a share, and nobody possesses it all. A consequence of this property is that if we do not learn collectively, we will no longer learn at all: the hypertext[22], the Internet[23], the Web and wikis are technological manifestations of this collegiality. States and organizations who wish to increase their flow of knowledge and wisdom (an essential process) must ensure that their population is "group literate". In other words, their education and activities must be focused on the group and on the ability to work as a group, rather than on the individual. However, the ego prevents human beings from cooperating and acting in a coordinated manner.
The second fundamental social property of knowledge is its prolificity. It is estimated that the quantity, but not the quality, of global knowledge – which is to say, the number of open problems that are closed – doubles about every seven to nine years[24]. It means that Humanity, at least in terms of quantity (as paradigm shifts, relating to transcendent knowledge and therefore qualitative in nature, are not taken into account), now produces the same volume of knowledge in seven to nine years as it has managed in the rest of its history.

The prolificity of knowledge poses one obvious logistical problem that all organizations around the world must address: knowledge is growing exponentially, but continues to be distributed in ways that are essentially linear against time (language, text, video). It does not take an expert in supply chains to identify the problem here. However, supply chains of knowledge are scientifically fascinating, and the problems they pose are probably just as significant as Monge's transport theory.

Let us thus sum up the two fundamental social properties of knowledge:

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[22] The Hypertext is considered to have been theorized by Vannevar Bush in his work as an administrator for the Manhattan Project and in a famous 1945 article in *The Atlantic Monthly*, entitled "As we May Think".
[23] At first the Internet was decisively influenced by the Arpanet project, a product of the US military-industrial complex. Yet the World Wide Web had essentially been a civilian project, just like the earlier Transmission Control Protocol (which was adopted by the Arpanet).
[24] It is essential to understand that this estimate does not take paradigm shifts into account, for they are qualitative and not quantitative. In *The Technopolis Phenomenon. Smart Cities, Fast Systems, Global Networks,* edited by David Gibson, Georges Kozmetsky, Raymond Smilor, Regis McKenna estimates that the time taken for world scientific knowledge to double is under ten years.

Property 1: knowledge is collegial
This property means that "truth is a shattered mirror"[25], everybody possessing but a small piece of it, and advances can only be made to mankind's collective consciousness by pooling all of these pieces of knowledge. The force obstructing this process is the ego. Yet contemporary academic research, repeating the mistakes of the medieval scholastic method, has become a vast professional cult in thrall to the latter. Who knows what fascinating discoveries would await us, if only academics abandoned their egos?

Property 2: knowledge is prolific
This property is another way to say that knowledge production is self-driving: the more knowledge we have, the easier it is to obtain. The same is true of capital, the difference being that knowledge is infinite. While the "writable" volume of knowledge *(i.e.* the number of open questions that we answer) is currently doubling every seven to nine years, this growth does not include paradigm shifts and intellectual revolutions that could be summed up in one sentence, yet would equally be capable of disrupting millions of other existing phrases.

3.2 The three principles of noodynamics
It is possible to define noodynamics – the dynamics of knowledge exchange – because all knowledge exchanges adhere to at least three simple principles, by which they are fundamentally opposed to the exchanges of capital and raw materials.

Principle 1: knowledge exchanges are positive-sum
Principe 2: knowledge exchanges are not instantaneous
Principe 3: the combination of knowledge is not linear

Principle 1: knowledge exchanges are positive-sum. If I give you twenty dollars, that money is no longer mine. However, if I give you knowledge, I still possess it at the end of the transaction. "When a material good is shared, it is divided; when an immaterial good is shared, it is multiplied," explains Serge Soudoplatoff, who also reminds us that the knowledge economy is an economy of flow, unlike the economy of work, capital and raw materials, which is an economy of stock. The economy of knowledge is also an economy of abundance, which is based neither on scarcity nor on speculation. This holds true in principle, although in reality the speculation of knowledge is extremely tempting, for example with degrees or patents. The chivalrous and visionary decision taken by Elon Musk to grant his competitors free access to all Tesla Motors' patents, which flabbergasted the automotive industry around the world (particularly in France and Japan), is a specific example of this fascinating sign of the times. This will prove to be another idea that Musk transforms from "ridiculous" to "obvious". People like him are economic treasures.

[25] "Truth is the shattered mirror strown in myriad bits, while each believes his little bit the whole to own", sings R.F. Burton in *The Kasidah of Haji Abdu El-Yezdi*, which is taken from Rumi.

Principle 2: Knowledge exchanges are not instantaneous. Above all, they are not scalable[26], unlike property exchanges. Handing over the ownership of 20 dollars or 20 million dollars takes more or less the same amount of time, equal to that required for a written or electronic signature. The same goes for trading material goods: trading of 20 or 20,000 tons of rice takes virtually the same amount of time, which makes high frequency trading possible. Knowledge, on the other hand, cannot yet be distributed at high frequency, even if neuroergonomics and MOOCs (Massive Open Online Courses) will one day allow it to be exchanged at a much faster rate. But for the time being, I cannot give you the theory of quantum chromodynamics as fast as I can give you 20 dollars.

Principle 3: The combination of knowledge is not linear. Possessing 20 dollars and 20 dollars means possessing 40 dollars. Yet knowing two things together means more than knowing two things separately. It is the definition of positive non-linearity, which we may express as: K(A and B) > K(A) and K(B), where K is the « know » operator. We can term the difference between knowing (A and B) and knowing (A) and knowing (B) separately as the serendipity of A and B. Thanks to this serendipitous quality, one manifestation of the prolificity of knowledge, we can affirm that, in a sense, in the knowledge economy 1 and 1 make 3. Here, we can once more note an essential difference between the economy of knowledge and that of capital and raw materials, even though ideas, knowledge and innovation may also be generated by the combination of two material objects.

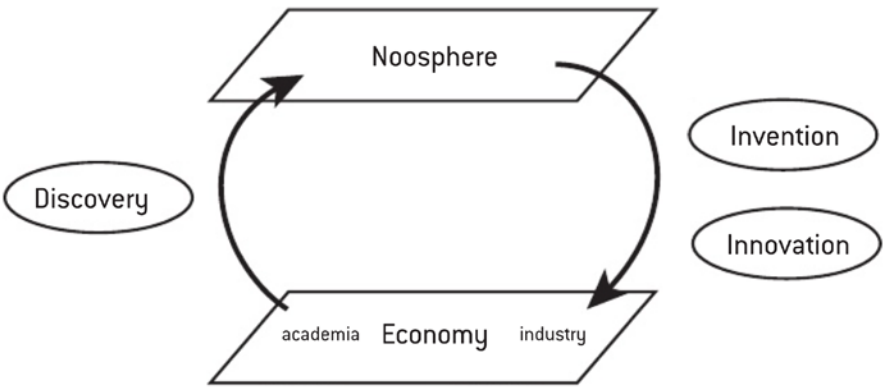
The interaction between industrial economy and the knowledge economy can be illustrated as a water cycle featuring the “rain of innovation”. The noosphere is the sky of all fundamental knowledge which we may simplify as being open and accessible to everyone. In this metaphor, the publishing of discoveries as a result of fundamental research is akin to the evaporation of knowledge towards the noosphere. This knowledge is then precipitated from clouds in this sky, down onto the material economy, in two steps: firstly that of invention, or the prototype of an application of knowledge; secondly that of innovation, a product that is accessible to everybody in direct exchange for money, rather than for expertise or learning (the product of attention and time). Not all inventors are innovators, and vice-versa: Nikola Tesla struggled to commercialize his brilliant inventions, while Steve Jobs transformed non-ergonomic and clumsy prototypes of personal computers (inventions) into products that were simple, universal and user-friendly (innovations).

In a similar way, states do not always reap the returns from the fundamental research carried out on their territories. France can serve as an example: France discovered optical pumping, but is by no means at the forefront of the LASER industry as a result. The discovery of giant magneto-resistance, and important breakthroughs regarding liquid crystals, were made within its demosphere (the sphere of its people), on its territory

[26] In the start-up community, “scalable” is usually synonymous of “sublinear” and will mean here that doing ten things at once will take less time and resources than doing one thing ten times. Transferring possessions is fully scalable, since transferring one million dollars is faster than transferring one dollar a million times.

and with its money, yet France is a world leader in none of their industrial applications (such as LCD screens, mass data storages, etc.). While contributing to the noosphere is an art in itself, there is also an art in reaping the benefits of such contributions. It is tragic that states are able to contribute so greatly to the creation of such brilliant clouds of fundamental knowledge, without ever the benefitting from the subsequent rainfall. France is a specialist at committing this costly error while, on the other hand, Silicon Valley appears to be out on its own as the place where the time-lapse between discovery, invention and innovation is at its shortest. China seems to have learnt its lessons, advancing from "Made in China" to "Innovated in China", which is a clear strategy of knowledge politics (noopolitik). It had already been in a perfect position to do so, given the evidence of its numerous discoveries and inventions throughout history.

Fig 5: The nooconomic cycle - legend below



The R&D cycle of nooconomics is comparable to the water cycle. Scientific discoveries evaporate from research sources into the noosphere, from where they are precipitated back on to industry in two stages: invention and innovation. However, states and organizations whence discoveries and inventions originate are not necessarily those that reap their innovations, or the only ones that enter in direct contact with the markets. Xerox invented both the Graphical User Interface and the mouse, but did not commercialize their innovations. France discovered giant magneto-resistance and excelled in the field of liquid crystals, but never managed to attract the respective industries onto its territory. The evaporation produced by a discovery is the fruit of the Research (R), representing the exploration in the R&D cycle. The precipitation produced by innovation is the fruit of the Development (D) representing the exploitation. The slogan for Research should be "KICK" – standing for "Keep it Crazy, Kid!" – as Research should essentially be disruptive and explorative, to which creativity, craziness and a refreshing childlike mentality are all conducive. The slogan for Development is be "KISS" – standing for "Keep It Simple, Stupid!" – for it is all about exploitation, simplification, rigor and not pure creativity anymore.

3.3 The Knowledge flow equation

The basic equation used to describe knowledge flow is equally simple and elegant, yet its social, political and economic implications are vast. Right now, we are carrying out knowledge transaction: by reading a book or watching a video, by listening to someone or playing a game, you are receiving knowledge yet also giving something in return. Above all, you are spending your attention and your time. Knowledge exchanges are the inverse of attention exchanges (he/she who gives knowledge receives attention) and are therefore the result of a psychological consolidation which has some interesting social implications, since knowledge exchanges are also a means to social cohesion. The following equation illustrates this principle, according to which the total flow of knowledge is proportional to attention multiplied by time (instant bandwidth being proportional to attention):

$$\varphi(k) \propto At$$

Which socio-economic implications can we infer from this equation? Firstly, as for Beck and Davenport, we can observe that, while data, information and knowledge are all very abundant nowadays[27] (since their volume doubles every seven to nine years[28]), there is indeed an "attention economy" since attention (and time, for that matter) are not limitless commodities for each individual. The result is a global competition, particularly among mass marketing executives and above all on the Internet, to attract and captivate our attention. From a historical perspective, this competition is at the interface between the old economy, that of scarcity, and the new economy, that of flow and abundance.

It should also be noted that time and attention are intrinsically in flux, since they evaporate away (are spent) by default and cannot be stored. Their conversion into money induces a certain entropy – in the thermodynamic sense, meaning "non-recoverable energy" and thus "irreversibility" – for one can convert time into money but cannot buy raw time from money. At best, we can reduce the time taken up by a task in exchange for spending more money. Time, *in fine*, is more precious than money, and is spent by default. There is also an intrinsic compromise between wealth in time and financial wealth: the time-wealthy but financially poor individual is ready to spend a lot of time to earn a little money, while the time-poor but financially wealthy individual is ready to spend a lot of money to save a little time. It is also an extremely serious shortcoming for a state to force its citizens to spend their attention and time on its complex or inefficient bureaucracy : this bureaucracy will drain away two infinitely precious resources that would be much better invested in the real economy.

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[27] In Peter Drucker's "KID" paradigm, "Information (I) is Data (D) endowed with relevance and purpose. Converting Data into Information thus requires Knowledge (K)"

[28] One may agree upon the following simplification: starting from data, information is a perspective on data, knowledge is a perspective on information, wisdom is a perspective on knowledge. Information is then comparable to a derivative of data against time, and knowledge the corresponding derivative of information (or an acceleration of data in a way). The exponential function being invariant by derivation, it follows that the transformation of information into knowledge theoretically preserves the doubling time, under the hypothesis, which is not at all met by reality, that any piece of data is indeed transformed into information.

We must also present an approximate, although efficient, way to distinguish between information, knowledge and wisdom. Information, as in the case of military intelligence, is heavily dependent upon time and space. “The Allies will be landing in Normandy on June 6th” is a piece of information. Knowledge, in short, adheres to the fundamental laws of the universe and depends upon neither time nor space, remaining true in any era and in any location. Wisdom, finally, does not even depend on the universe but only on itself, for it is drawn only from self-knowledge, with the universe acting merely as an aid. The distinction between data, information, knowledge and wisdom is nevertheless not cut and dry, for the elements form part of a continuous spectrum. Progress along this spectrum is driven by integration, in the neurophysiological sense, which means transcendence: information integrates data, knowledge integrates information and wisdom integrates knowledge. The more we progress along the spectrum, the more we liberate ourselves from the constraints of ages, civilisations, time, space and the universe. This is why the fear, insecurity and exhaustion of the journalist, who handles information, are far worse than those of the wise man, who handles propositions that remain true at any place or time.

Let us also be clear that the knowledge flow, from an economic point of view, is proportional to the *product* of attention and time: if you read this document or listen to a speaker with all your concentration, but only for one minute, then the transfer of knowledge will be relatively small. If you dedicate an hour of your time to a subject, but without properly paying attention, transfer will be similarly small.

In the sense that purchasing power in the knowledge economy is the product of attention and time, its structure is very particular. Individuals are not born into the world with 1,000 dollars in their pockets – which should nevertheless be a human right – but all human beings are born with both attention and time to spend. Even if access to knowledge remains unequally distributed throughout the world, we can still affirm that everybody is born with purchasing power in the knowledge economy (just not the same choice of stores to shop at, depending on one's location). This is not at all the case in the economy of capital, work and raw material. In this sense, and assuming equal access, prisoners and the unemployed also virtually hold more purchasing power than those who work, having more spare attention and time to spend acquiring knowledge.

Another fascinating consequence of the structure of purchasing power in the knowledge economy emerges when we consider the conditions that lead an individual to freely spend that purchasing power. Put another way, under which circumstances do we give all our attention and all our time to a person or a subject? When we are passionately in love with it, of course! The flow of knowledge is not at its greatest when the objects of our attention and time are imposed upon us (by the state, for example, through compulsory education), but when a passionate appetite for the knowledge has already been developed. Thus, as well as boasting an intrinsically fair dimension, nooconomics also features a personal purchasing power that depends only on the individual, who sees those who are in love benefitting from an inherently greater purchasing power!

4. What does it mean to practice nooconomics ?

4.1 Knowledge infrastructures - "nooducts"

We have looked at the fundamental rules of the knowledge economy, and why they make up a revolutionary paradigm. We have also seen that, at the beginning of the 21st century, the key for mankind and its organisations is to increase their knowledge flow (kFlow), something of much greater value to mankind than, for example, cash flow. If knowledge is indeed the new oil (and a lot more, besides), developing the ability to allow it to circulate faster is crucial, and knowledge pipelines will assume inestimable strategic importance.

Since Knowledge is collegial, it must be shared in groups, and education must therefore be built around the group rather than just the individual. This would represent a vital evolution of our educative system, which has been inherited from the industrial revolution and is focused on assessment rather than self-fulfilment, on the individual rather than the group. Given that purchasing power in nooconomics is equal to attention multiplied by time, two adjustment variables emerge by which society would be able to increase its knowledge flow: the first, time, regards the group; and the second, attention, the individual. Ultimately, the love of knowledge is the best way to circulate it, in the same way as the heart pumps blood around.

The case of Massive Multiplayer Online Games (MMOG) provides a constructive example of how attention and time may be used to adjust the flow of knowledge. They involve remarkable levels of both attention and time and, without them, the popularity of Massive Online Open Courses (MOOC) would not have risen as sharply. From 2004 to 2014 for example, Humanity accumulated more than seven million years playing World of Warcraft, which is over fifty times move than the overall amount of time that people spent working at Apple from 1976 to 2014. Video games are able to capture attention on a huge scale and, in this sense, MOOCs have a lot to learn from them because a MOOC that is unable to attract attraction is effectively dead. Furthermore, if we compare video game learning to compulsory learning, and if we metaphorically consider that our brain is a car running on the gas of motivation, in compulsory learning, the car will consume gas when the key is turned in the ignition and then throughout the ride. With video game learning, the car will only consume to stop! Guess which, out of compulsory learning or passionate, playful learning is more competitive in nooconomics? This is the importance of gamification in the knowledge economy.

As attention is an individual adjustment variable of the knowledge flow, cognitive neurosciences can contribute a lot to nooconomics, for they are the most qualified disciplines to understand the structure and, above all, the potential of human attention. For this reason, the fascinating field of neuroergonomics, which at this stage remains overly confined to military applications, should be studied in depth by states and organizations, because it has become evident that our individual and social cognitive abilities are under-employed in our knowledge exchanges. Put simply, the latter are not neuroergonomic enough. And why would they be? Our education methods, inherited from the industrial revolution, date back to a time when we knew next to nothing about the human brain.

Neuroergonomics, MOOCs and MMOGs – which can all be bracketed under the concept of gamification – are all contributors to knowledge infrastructures. As explained by Bruce Cahan, if knowledge exchanges are based on infrastructures then they must be subject to an infrastructural investment policy. As you will recall, there are two attributes of a superpower state, the first being geographic and the second demographic. A superpower must have a vast territory and a vast, interconnected population. This is why India is attempting to embrace the "Post-PC" era on a mass scale, and why tablets, smartphones and other instruments of this era are promising tools for development in Africa, along with mathematics, the science offering the highest returns on investment.

Its capacity to drive peace and development offers another application for nooconomics. It is interesting to note that Silicon Valley could only emerge long after the Californian Gold Rush, and that this socio-technological wonder sprung up between San Jose and San Francisco, rather than alongside NASA and a host of oil refineries in Texas, as expected. As has already been noted, natural resources can prove to be a decisive obstacle and public deterrent to the emergence of a technopolis.

Given that knowledge can enable what George Kozmetsky describes as "prosperity in zero time" (instant prosperity), its contribution to global peace is succinctly summarized in the Constitutive Act of UNESCO which declares that, in essence, increasing the knowledge flow between peoples is an instrument of peace, and perhaps even the most profound such instrument. It is for this reason that the Kozmetsky Global Collaboratory of Stanford University is experimenting with the idea of a Professional School for Shareable Prosperity.

4.2. Disruption and Silicon Valley's "Love Can Do"

The cultural identity of Silicon Valley is a perfect example of how nooconomics maximizes the purchasing power of those who are in love. All the companies that revolutionized the valley, having started out life in a garage, have had one subtle thing in common: a passionate and absolute love for what they do. Those companies that rise above leadership to a status "above the fray" in their industry, just like Apple at the time of writing, are those whose work involves what they both know and love. When asked why they design their products and services, they never give the obtuse, commercially-driven answer "because there is a market", but rather the sincere, visionary answer "because we want to change the world!"

Thus Apple initially prevailed over IBM, which was still one of the most powerful companies on earth, and over the deceased French "Minitel" which, although not lacking components or over means, was not as well-endowed in passion and vision. Google in turn beat AOL, a company with superior levels of capital and talent. By the end of the 20th century, the difference came down to two things: passion and motivation. The Google boys loved their job, before they even knew how to do it.

The evolution of disruptive companies in Silicon Valley is very often identical: entrepreneurs start out in a new industry not because they know how to do the job and have read the manuals, but because they have an immense desire to do so and because they love it, even without being experts. Only love can keep someone working in a garage, without any reward, for months on end. Disruption cannot be expected from those who excel at reading manuals and taking exams. While the followers read manuals, the leaders write them. And above all, leaders are people who, knowing comparatively little of the industry when he starts, can exclaim in the face of competition: “sorry, I didn’t know it was impossible!” Elon Musk is one such leader. “Like David, he changes the rules without telling Goliath,” observes Gunter Pauli.

The LCD Matrix (standing for “Love x Can-Do”) can be used to represent the cartesian product of the two most important entrepreneurial components of Silicon Valley: love for the job (Love) and the Can-Do attitude. This matrix attests to the fact that, when founding a start-up, someone who loves the job but has no experience is worth a lot more than a depressed expert. The former will still be able to learn, while the latter will not. Expertise acquired through love is much more valuable than expertise acquired through obligation. Finally, expertise that is acquired from scratch is necessarily more disruptive than that which is prescribed by schools and manuals. The latter is in essence conservative, since schools are the conservatories of knowledge. Leonardo da Vinci adeptly illustrates this principle.

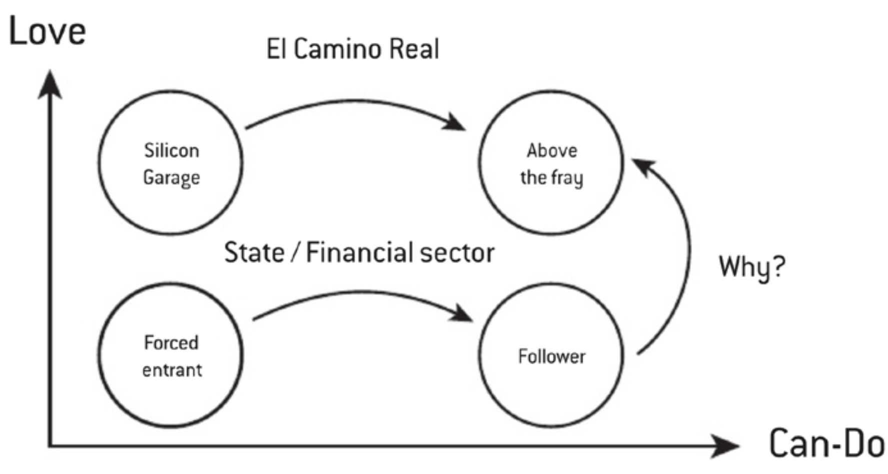

Fig. 6: The Love Can Do Matrix

The LCD matrix features four distinguishable types of companies. The company found “above the fray” is the one that practices both what its people passionately love and do very well. In 2014, this is the case at Apple, Tesla and Hermès for example. Followers have essentially the same industrial know-how as those “above the fray”, but none of the same love of the product. Its products and services show this absence of love: they are less captivating, less sexy, they show much less attention to detail and do not glow with culture. They betray reality: that their *raison d’être* is neither inspiration nor disruption, but profit. They were designed by administrators rather than by visionaries, which will never escape the attention of the connoisseur. Nowadays, Samsung typically falls within this category. Samsung certainly did not turn its attention from refrigerators to tablets with a view to changing the world, or out of a manifest love of the product. Consequently, people will never spend weeks camping out in expectation of the release of a new Samsung product. The same is true of Microsoft.

All those companies that started out in Silicon Valley garages and later became multinationals entered their industries out of passion and, just as importantly, with comparatively minimal know-how. These are essential conditions for disruption: the professor, limited by his dogmas and manuals, is necessarily less disruptive than the pupil. As the Chinese proverb goes, “in the beginner's mind there are many possibilities, but in the expert's there are few”. Because expertise, which is exploitation, is very often synonymous with confined thinking. The masters of the Russian martial art Systema are one such case in point. The essence of Silicon Valley was not created by valedictorians – the CEO of Apple before Jobs’ return, who insisted on being addressed as “Dr. Amelio”, amply demonstrated as much. All things being equal, you should expect more disruption from an under-qualified former Hippie like Jobs our outsider like Wozniak, than from an administrator, civil servant or doctor.

The very worst position within the LCD matrix is that of the forced entrant. Unbelievably certain companies can be observed to occupy or have occupied this position, one of the most notable being STMicroelectronics in Europe. The forced entrant does the job out of obligation. Industry does not represent a burning passion but a chore. Of course, socio-economic dynamics will always ensure that such a company attracts a certain level of passion and talent, but its capacity to professionally fulfil them is very limited when compared with the leaders. The company ends up curbing that passion and creativity, crushing it rather than encouraging it to blossom.

These companies are born above all out of obligation. To take the case of STMicroelectronics (or Bull) the situation is as follows: Europe cannot afford to import all of its semiconductors, hence the need for a company to carry out this task. A company was thus created with very little experience, which is not bad in itself, but with no passion and no vision. This is tragic: today, Taiwan boasts several major semiconductor manufacturers, such as UMC and TSMC, not to mention Silicon Valley with Intel, AMD or Nvidia.

Transitions are still possible between the different states of the LCD matrix. If the follower wants to move “above the fray”, he must ask himself why he is doing his job, as Simon Sinek understood it, and the answer to this question must never be “because there is a market !” Those found “above the fray”, like Tesla and Apple, are extremely profitable because they think beyond profitability, with a panache that is unimaginable and, more importantly, illogical to their competitors. Such as when Tesla offered open access to all its patents free of charge, or free supercharging to all its customers. This is not irrational behavior, but behavior that transcends rationality and demonstrates a profound understanding of why the company is operating.

The transition from forced entrant to follower is always the result of an external constraint: the choice of a state or an institutional investor who does not know anything about the business and only invests because it represents a market opportunity. Finally, the transition from garage to global cultural leadership – as was the case with Apple, Google or Amazon – is made when the acquisition of expertise is motivated by passion and nothing else. Not by a grade, a salary, a vain regional or municipal prize, not by the artificial attention of an incubator that will paternally administer the entrepreneur, not by the laurels of a Ministry, but only by the very love of the work. Such an entrepreneur is following what I term “the royal path”, from the name of Silicon Valley's boulevard, El Camino Real.

4.3 Biomimicry: an application of the knowledge economy

A last fascinating perspective on the knowledge economy is that it captures the entire essence of Sustainable Development. The latter is all about teaching mankind the art of not wasting its future through the incorrect use of its resources: the art of not trivially spending goods today, if their absence will come to be felt in the future, when richer and more elegant uses may emerge.

For there is a resource, plentiful and elegant, that mankind has been spending with infinite stupidity over the last millennia of its history. Thanks to the industrial revolution, which induced even faster and more irresponsible spending, today we are beginning to realize the extent of such wastage. The physiocrats, the first “economists” (for economics, before Adam Smith, was a term owed to the physiocrats), felt the most profound respect for this resource. It is of course Nature. And if Nature is a veritable library, biomimetics is the science that advises “read it, don't burn it!”

Humanity indeed, from the moment it became urban (for this principle seems not to apply to native civilizations), considered nature as a source of raw materials and spent it as such. We know today that nature, besides the ecosystem that it provides and that we are only now learning to appreciate, represents a source of knowledge rather than a source of materials. Biomimetics is a science founded on the extraction of knowledge from nature, something much more profitable than the simple extraction of raw materials.

Humanity has a propensity of spending precious resources in a trivial way. Nature is one such resource, and it should be spent not as a source of raw materials but as a high tech library, full of technologically delicate solutions: from nanotechnologies to material science, pharmaceutics, organisation sciences, from dynamic and ergodic systems to fuzzy logic. Today when we consider, for example, French architect Jacques Rougerie’s visionary SeaOrbiter project, we observe that humanity is ready to develop not only platforms for the extraction of raw materials, but also for the extraction of knowledge from nature. Maybe our descendants, studying our oil rigs, will tell themselves that we spent our time and attention mining the wrong things from nature, that the flow of knowledge was actually more important than the flow of oil. A different treatise on biomimicry and policy will be dedicated specifically to this vision.

Of course, we are not defending the total abolition of the material use of nature. Case studies by Paolo Lugari and Gunter Pauli demonstrate the extent to which the latter, so long as it is elegant, can be decisive in the 21st century. We are simply advocating a better balance between the material and immaterial use of nature, a better equilibrium between the material and the immaterial economy. A constructive dialogue between the two must be established, in place of mutual exclusion. What is for certain, politically speaking, is that only the immaterial exploitation of nature can compensate for its excessive material exploitation. Let us conclude simply by observing, in agreement with 13th century Sufi poet Hakim Sana'I, that “Humanity is weaving a net about herself”, which is precisely the subject of sustainable development.

And regarding mass education which, inherited from the industrial revolution, continues to set the agenda for this era, its mistake is that it destroyed love which, according to the (although limited) teachings of the humanists, was the most sacred ingredient of learning. Our contemporary education system does not teach for the sake of gross domestic happiness, but for gross domestic product, hence the immense importance it puts on grades. We are no longer teaching for the purpose of being self-fulfilled, but to be economically useful, which is strictly inferior (any fulfilled man is economically useful, while any man that is economically useful is not necessarily fulfilled). If only we managed to reconcile the love revered by humanists with the mass education made possible by the industrial revolution – a reconciliation that neuroergonomics could very well enable, but only as a result of a collective choice made by our civilisation – then surely we would start the construction of a marvellous economy of knowledge, and would bequeath to future generations magnificent nooducts, just as impressive and inspiring as the aqueducts of our ancestors.

Ultimately, adopting the economics of knowledge is just a matter of an evolution of individual and collective consciousness: will Humanity be based on materiality or on wisdom? Will we be *Homo sapiens materialensis*, or, as we decided to define ourselves, *Homo sapiens sapiens?*

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2. Discussing nooconomics

Abstract. Drawing from the idea that the fundamental currency of the knowledge economy is the joint expenditure of attention and time, this section outlines a simple microeconomics and macroeconomics of the knowledge economy. It further develops the notion of knowledge flow not only from an economic but from a neuroscientific point of view, and underlines the strengths and weaknesses of the simplest theory of knowledge flows to facilitate its further improvement. From an economic point of view, an interesting consequence to study is the structure of purchasing power in the knowledge economy, that of the willingness to buy, and that of the willingness to sell. From a neuroscientific point of view, an interesting phenomenon to study is that of the resonance between existing and acquired knowledge, which is not taken into account in the simplest knowledge flow equation. This question, which encompasses cognitive dissonance, outlines a more general theory of knowledge flows, and may also explain the interest of design in technological adoption.

Keywords : knowledge flows, econometrics, attention, purchasing power, revenue, zero marginal cost, cognitive dissonance.

1. Introduction

In the previous chapter, I outlined a simple theory of knowledge exchanges from an economic point of view. In this section, I intend to underline its strengths and weaknesses in order to facilitate its further improvement. In particular, I would like to discuss the theoretical and empirical consequences of considering the joint expenditure of attention and time the most fundamental currency of the knowledge economy.

In this section, I thus explore some emerging behaviour of an economy of which the most fundamental currency would be attention multiplied by time, a unit which I call an "at" and will denote with an @. This unit will be defined later in this section, expanding the remarkable insights of Beck & Davenport (2013). The latter already modelled a few phenomena in a newly satisfying way; among others, the reality that, say, a University football manager will reap a much larger salary than the provost of the same University, precisely because the former will also attract more attention; therefore, a correlation between the drawn attention and the drawn money can be observed in a reproductible manner and is a phenomenon of the "Attention economy"[29]. This attention economy can be supplemented with that of "Attention x Time", namely the "@ economy" which I discuss here.

[29] In a personal communication the alumni of the Mazars NEXT MBA program in San Francisco in October 2015, Peter Coffee, the brilliant VP for Strategy of Salesforce, remarked that some

2. An early model with strengths and weaknesses

In the previous section I introduced the equation

$$\varphi(k) \propto At \qquad (1)$$

which was the simplest equation to describe naive knowledge flows from an economic point of view. From an economic point of view indeed, it meant "an exchange of knowledge requires an expenditure of attention and time". This should already be supplemented by another, more precise equation, to avoid any confusion between the neuroscientific and economic interpretations, namely, that since attention is what neurosciences describes as the very span of conscious access to the global cognitive workspace, then "the instant flow of knowledge is proportional to attention" or equivalently, the "conscious knowledge bandwidth is attention":

$$\varphi_i(k) \propto A(t) \qquad (2)$$

which is not to be confused with the previous equation (1), which holds from an economic perspective, that was equivalent to the statement "a transfer of knowledge depends (only)[30] on the expenditure of attention and time". This clarification being made, let us focus on the economic point of view, because the idea that the product of attention and time could be the most fundamental currency of nooconomics has many non-trivial consequences.

In the previous section we saw that the idea that the most fundamental currency of the knowledge economy was the product of attention and time had a few interesting social implications : the unemployed will tend to enjoy a higher monthly revenue of attention and time than those in work, and hence, more a purchasing power. Those who love what they learn will be more eager to spend their attention and time, and also to increase their revenue of it altogether, and hence, love maximises purchasing power. The fact that one "@" is a product of attention and time has dramatic implication for education policy, which even today, still limits most of its considerations to how many *hours* pupils should spend on each field per week. We can spend hours at school learning French or Mathematics for years and not end up any proficient in these fields anyway, because schooling does not control attention, but only time, which, alone, is not the unit of knowledge purchasing power.

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automative companies had explored the possibility of lending cars for free and monetizing instead the attention span collected from (among others) onboard services.Describing the business model of French TV Channel TF1 Mr. Lelay, then heading the channel, acknowledged casually that he was in the "trade of available human brain time".

[30] That is, again, in this first, naive equation. As we will see, there are many phenomena of nooconomics where it may not hold, but it is still a very practical base to start theorising nooconomics and its product of predictiveness and simplicity is encouraging.

So which economic reality did Equation (1) attempt to represent ? Typically, reading a book, listening to a talk, watching a video online etc. For example, this equation can well represent the way a reader will learn from Wikipedia and is, in a way a “Wikipedia equation” or a “MOOC equation” in that it will also represent the knowledge learned by an attendant from a Massively Open Online Course : an amount that is proportional to the product of spent attention and time. It should be inferred that a MOOC that is unable to capture attention is essentially a dead one.

From this perspective, the knowledge economy is also one of fluxes and not of savings, and indeed there are no savings in the knowledge economy because time naturally flies. Another interesting consequence is the comparative study of purchasing behaviour in a regular supermarket and in a knowledge supermarket. In a regular supermarket, especially in economies where supply is greater than demand, the limiting factor to a purchase is not desire, which marketing tends to maximise, but purchasing power itself. In a knowledge supermarket, nowadays at least, the first limiting factor is not purchasing power but desire. If one has one hour of full attention to devote do something, and has to choose between a Wikipedia page on mathematics and a video game, the latter is more likely to be actually purchased. The reason is that knowledge marketing is still rather poor, in the sense that most knowledge purchases remain the result of a (usually professional) necessity rather than pure desire, passion or interest. We seldom spend our free @ revenue on knowledge, but more often on entertainment, although knowledge and entertainment are not mutually exclusive.

From a macroeconomic perspective, it is very fertile to consider the average @ revenue, either individual or that of organisations (governments, NGOs, enterprises) because the individual and collective purchasing power in the knowledge economy is very much overlooked today. @-based economic indicators could pave the way to an early “nooconometrics”, the econometrics of knowledge flows. At all scales (micro, meso, micro) such a tool could bring new technical nuances to the study of productivity, and of the wealth of nations : one could study the knowledge flows and the @ revenues of households, of regions, of states etc.

We have seen that what maximises the willingness to buy knowledge is love, or passion, and below it, addiction and that therefore games (either video or not) have the potential to command a high willingness to pay @. Another interesting dimension is the willingness to sell knowledge. Humans can appreciate receiving attention, and trades of attention are a rich anthropological phenomenon. Since any trade of knowledge is also a reverse trade of attention (whoever/whatever gives knowledge receives attention in exchange) there can be a fundamental incentive to deliver knowledge, even beyond monetary reward.

The emerging properties of collective expenditures of @s are also non trivial, and they regard the phenomenon of crowdsourcing. I posit here that there is absolutely no problem, be it technological, political, diplomatic, scientific etc. that can resist the focused expenditure of human attention and time, if this expenditure is not self-destructive (eg. the ego of researchers can often lead them to destroying the work of each other rather than catalysing their constructive cooperation). Any entity that can focus a large and protracted amount of @s in a non-destructive way, on a certain problem, can find itself in the position of attacking, and ultimately breaking, any problem.

Therefore, any organisation that is able to focus large amount of synergistic attention and time can find itself in the position to generate an equally large amount of value, new products, new services etc. In economic competitiveness, but beyond, in the global productivity of a unified Humanity facing the immense challenges of inhabiting planet Earth in the wisest possible way, and of colonising other planets, there is a technology that we should focus time and attention on already : the one consisting of domesticating time and attention for technical reasons itself. This technology is still at its very early stage, but holds fantastic promises for the future of humanity.

Finally, the idea that one @ is the most fundamental currency of the knowledge economy can also be put equivalently that one @ is the currency of the “brain’s app store”. It could be possible to label any skills (from pastry to calculus to systema martial art to painting to playing the piano) in @, among all the possible skills a human being can learn in his life. Then again, any human being would be born with a non null monthly @ revenue, and become increasingly more motivated in spending them once he knows in advance how many @ such and such skill will cost.

Ultimately, the product of attention and time may be to the noosphere what momentum, the product of mass and speed, may be to the kinesphere. In that we may remember the famous quote of Napoleon :

> The strength of an army, like the momentum in mechanics, is estimated by mass times its velocity[31]

Hence, when we consider the geopolitics of knowledge, to which I will dedicate the next section, we must understand that one way of exploring the noosphere in a far-reaching manner is to dedicate a lot of attention and time to it, and again, that the “quantity of motion” in noosphere is dependent upon the expenditure of attention and time. This consequence could be further developed to define strategy and logistics in the geopolitics of knowledge.

3. From a neuroscientific point of view

From a neuroscientific point of view, Equation (1) presents many opportunities for further improvement. It must assume an appropriate flow of knowledge from the sender, so that the coupling between the sender’s knowledge and the receiver’s attention can occur. It does not take into account ongoing mental activity, which does control access to consciousness. What could be added to it also, for further refinement, would be the many subtleties posited by Dehaene et al. 2006 : that there is a testable taxonomy between conscious, preconscious and subliminal processing. Then, three constants, c1,

[31] Rose, J.H. (1912). The Personality of Napoleon (G. P. Putnam’s sons). p.119

c2 and c3 could be adde to the model, each representing a different level of cortical arousal, so as to clearly distinguish, among others, subliminal learning from conscious learning. And since attention, just as numbers and knowledge, is hardly well-defined *per se* today but rather in its relation to other scientific objects such as consciousness (with which it may one day be fully united scientifically), one may, for the moment, simply scale the attention factor (A) from zero to one.

A full attention (1 on the scale) would correspond to that level of cortical arousal that is so high that a subject will be indifferent to any other stimulus. It may be related to the sate of "hypnosis" in the sense that a full attention will typically correspond to a situation where, say, the reader of a book will be sufficiently absorbed by it to miss a train station. The unity of attention in the naive knowledge flow equation could be called a "Posner" or a "Dehaene" but this will be left to the community. Still, from an neuroscientific point of view, we could measure attention with a correlated measure of foveation (eye-tracking) and cortical arousal. There are probably simpler ways to extract reliable empirical measures of attention from an economic point of view. The key to their finding will surely be to distinguish between collective (macro), where the law of large numbers may apply, and individual (micro) attention, with the study of the mesoscopic scale representing a very exciting problem of nooconomics. The microscale could again rely on eye-tracking.

Also note that Equation (2) implies the following :

$$k \propto \int A(t)dt \qquad (3)$$

again, assuming a situation of coupling between ongoing and content. In this metaphor the incoming content is like a flowing river, and the ongoing attention like a pipe of a dynamically variable width. In reality, which this equation does not yet take into account, ongoing cerebral activity can interfere with incoming knowledge, in either a destructive or a constructive way, and hence, add to it possibly.

Thus again, Equation (1) does not capture any kind of flow. It lacks a notion of synergy: what if entrant knowledge resonates with already existing knowledge? Surely one should consider this case, in which the knowledge flow could exhibit a form of positive feedback. Attention could either increase or decrease through time, but surely attention is in itself a function of time, which this initial equation does not consider. Thus, one could probably suggest the following equations instead (also adding that Attention is intrinsically dynamic and thus substituting A with A(t)

$$\varphi(k) \propto A(t) + Syn(k,t) \qquad (4)$$

Where Syn (k,t) would represent the synergy of entrant and preexisting knowledge at a given time. Just as some enzymes may be "michaelian" or "non-michaelian", some knowledge flows may be simply captured by the non-synergic regime, and others not. It is probable that a more general theory of noodynamics be eventually captured by equations in the form of:

$$\varphi(k) \propto A(t)\ (\mathrm{Res}\ (Sp, Ev)) \qquad (5)$$

Where the flow of knowledge is proportional to the resonance (Res) between the spontaneous (Sp) and evoked (Ev) activities of the brain, or the learning system at large (thus, why not, considering the knowledge flow of such other cognitive systems as the immune system for example, and not only the sentient brain). In such an equation however, both the Res operator and variables Sp. and Ev. remain to be defined.

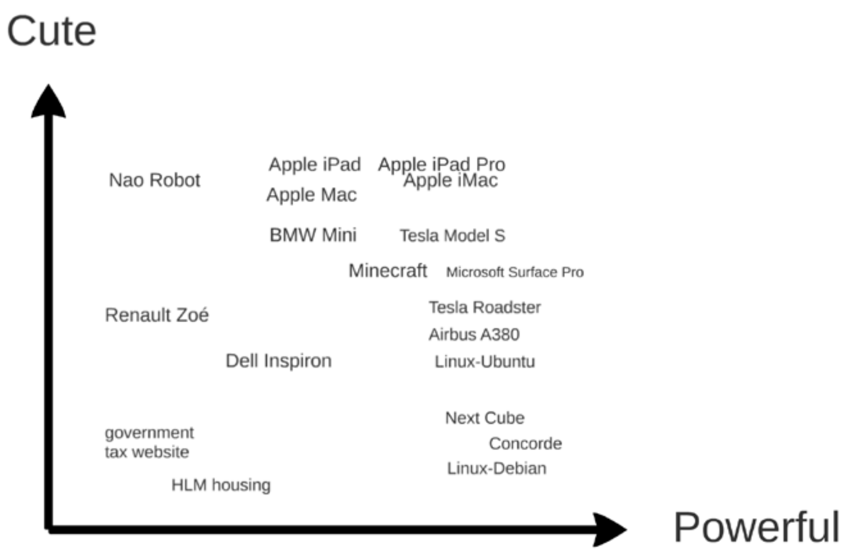
4. Conclusion

The idea of a resonance between existing knowledge and incoming knowledge implies many practical predictions in nooconomics, especially regarding the phenomenon of cognitive dissonance. A much debated question in the history of innovation and its management, is whether or not it is useful to have reviewed the entirety of existing knowledge before endeavouring to innovate. Often, innovating with zero initial knowledge is not recommended, but attempting to innovate only after having mastered the absolute entirety of precedents in a field is usually the best way to end up doing nothing. Surely virtue is in the middle, but can this be represented or inferred from the previous models ?

Interference can be destructive or constructive, and models of interference may apply to the phenomenon of cognitive interference. This is where models of quantum cognition (for exemple, models similar to those of Aerts & Gabora 2005) could be useful to represent the interaction between incoming and established knowledge. In any case, this interaction is not trivial. A prime interest of a resonance-based theory of knowledge flows would be to represent constructive or destructive cognitive interferences and possibly analyse their manifestation at the macroeconomic level. For example, when a start-up company that is less knowledgeable than its established competition succeeds where the established fail, can it be partly explained by cognitive interference ? Is there such a thing as a long-term cognitive encumberment, by which holding old knowledge could prevent the acquisition of fresh knowledge, and would this partly explain the dynamism of start-ups ?

Other interesting questions will regard the macroeconomics and political economy of knowledge flows. For example, if global knowledge has a dynamic, non-decreasing doubling time, and that the individual knowledge flow is in the form of Equation (1), what does it predict in terms of the macroscopic equilibria human groups (such as organizations, or states…) should achieve? Should states aim to equate their variation of the knowledge flow with the velocity of knowledge, or with the size of the human noosphere (global knowledge) itself? From a microeconomics perspective, what does the fundamental attention-knowledge transaction of individual agents imply (namely, any knowledge-giver is an attention receiver), especially in terms of cognitive and behavioural psychology? Could we eventually develop a working paradigm for mesoscopic nooconomics?

Finally, the notion of cognitive interference could partly explain the obstacles in adopting innovation. I may conclude on a purely speculative theory that the ideal innovation, to be adopted, should therefore be "cute and powerful", and map some innovations along a Cute x Powerful diagram. Batra et al. (2015) have already been going in this direction to explain the psychology of technological adoption (which is not rational at least). Cuteness, as Batra *et al.* and others can confirm, is neuroergonomic in essence, and may explain some of the success of the Apple products. Cutness thus, implies an absence of threat, and power, on the other hand, implies leverage, and also perceived affordance. The interaction between affordance (implying a low barrier to entry), cuteness (an absence of threat) and power (leverage) could also expand this simple,



speculative diagram

Fig. 1. Speculative Cute X Powerful diagram, mapping products depending on their subjective "cuteness" and "power" relative to their own industry. The idea is that an optimal disruptive technology, in order to succeed, should be Cute and Powerful at the same time. Cute products that offer little leverage may not be adopted on the long term, and powerful product that seem threatening may not be adopted on the short term. But cuteness and power, ultimately, are neuroergonomic variables.

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3. A simple paradigm for noopolitics, the geopolitics of knowledge

This section was peer-reviewed and published under the same title in the issue of Oct. 15. 2015 *of e-International Relations*.[32]

Abstract. Geopolitics is a complex system. Let us define it as the interaction between land and power, and *noopolitics*, the interaction between knowledge and power. The contribution of knowledge to the protraction or transcendance of conflicts has seldom been codified. Here I pose a few simple principles for the founding of noopolitics as a paradigm, exploring the way knowledge alters the dynamic of conflicts. Contrary to the view of classical realism, I pose that states never know their interest, and that the pursuit of it is not the initial but the final logical aspect of their interaction as cognitive agents. One can thus define a more general "cognitive politics", of which one consequence is that states are antifragile (in the sense of Taleb). I then define the noopolitical "fog of war" and conclude with a notion of "state stoicism" positing that the ultimate form of power for a state is power over itself.

Keywords : geopolitics, noopolitik, conflicts, peace, knowledge management, realism, antifragile, cognitive politics

1 Introduction

Arquilla and Ronfeldt (1999) developed the term *Noopolitik* as a political strategy focusing on the use, and denial thereof, of knowledge and information. The term, reminiscent to Realpolitik, was informed to establish a policy, that of "Being in Athena's camp". What it did not, however, is codify a more general geopolitics of knowledge, in which power would not be subserving knowledge, but rather knowledge subserving power. The development of such a paradigm is the purpose of this article.

Geopolitics is a complex system and could be studied as such. It can be defined as the interaction between land and power; indeed, there is no geopolitics where there is no idea of power. Geopolitics routinely manipulates notions such as power and interest as if they were almost self-evident, yet nothing could be further from the truth. The entire assumption of contemporary geopolitics, especially from the practical perspective of modern decision-makers, is that there is such a thing as *Homo geopoliticus*, a fallacy comparable to that of *Homo economicus*. Indeed, there is such a thing as behavioural and cognitive geopolitics, and there are many cognitive biases in geopolitics and history. The essential idea of this article is to codify not the interaction between land and

[32] Another, larger publication expanded this section and was published in French under the title "Noopolitique: le pouvoir de la connaissance" Fondapol (Paris) Nov. 2nd 2015.

power, but the interaction between knowledge and power. Its two founding categories are noosphere and kinesphere.

2 On kinesphere

In the study of proprioception, kinesphere is defined as all the possible reach of a body. One could simplify it as the set of all one's possible movements with at least one foot remaining in contact with the ground. Here, let us simply define the kinesphere as the set of one's possible actions. The noosphere, in turn, will be the set of one's possible thoughts, including one's possible knowledge. I will call "the noosphere of a state" that of its actual knowledge and thoughts, and simply "the noosphere" the universe of all possible thoughts and knowledge, which is considered the same for any state.

Strategy, as defined by Xenophon, is the art of maintaining one's liberty of action. Brzezinski has compared classical geopolitics to a "Grand Chessboard" (1997) and this comparison has many accurate historical correlates: the most strategic part of a chess-board, all things being equal, is its center. Thus, controlling the center of continents as remained an essential strategic goal to empires throughout the ages, hence MacKinder's (1905) classic "Heartland theory" and hence the very reproducible balkanisation (division between many sovereign and if possible, competing states) of the centres of strategically-important zones by empires: from Central Africa to Central Asia to Central America, all extremely balkanised and therefore volatile. That empires seldom fought over Australia made it such a unified continent. That the United States of America ended up cohesive although their territory had been so much disputed by powerful empires from France to Spain to Great Britain to the Netherlands was an essential contribution to their sense of "Manifest Destiny". They are the only modern of exception to this simple geopolitical rule: any area over which empires have fought has ended up balkanized. That the Treaty of Tordesillas had only be en decided between two competing empires limited, but did not prevent the balkanisation of South America. That the Portuguese-speaking territories of South America ended up all united politically in spite of History's many complexities, also contributed to a geopolitical sentiment comparable to Manifest Destiny in Brazil.

If strategy is the art of preserving one's initiative, it is also that of damaging the one of the opponent. In those terms, geopolitics is more reminding of the Go game, in which effective containment is key to success. Much has been written about this art in geopolitics, and it is at the very core of the current geopolitical doctrine of the OECD, under the leadership of the United States, towards the Shanghai Cooperation Organisation: limiting Beijing and Moscow's initiative and degrees of liberty in the economic, media, political and of course geographical spheres while at the same time attempting to preserve their liberty of action.

Classical geopolitics is essentially seen as a game of power, an arm wrestle by which the bargaining powers of states and various other entities interact with each other in a non linear manner. Contrary to a regular game of arm wrestle, however, the expenditure of subserving an opponent tend to augment in degree of the level of subservience, as long as hard power is concerned of course. It does not cost the same to impose an embargo on an opponent, as it does to occupy it fully: expenditures then escalate almost exponentially as one nears total submission, because, as Sun Tau very well understood, cornering an enemy is tantamount to despairing him, and despair leads to suicidal decisions.

Still, classical geopolitics ressembles the endless and reciprocal interaction of kinespheres over what are usually null-sum exchanges (territories, natural ressources, stable markets, trade routes, etc.). In this interaction, classical doctrine posits that it is in the interest of states to achieve maximum power over others. This is precisely the current attitude of the OECD leadership, namely the USA: attempting to acheve "full spectrum dominance" over anything politically organised that is outside its kinesphere. The collision of kinesphere, its pendulum effect of defeat and revenge (eg. the occupation of either Lorraine or the Ruhr on either side of the Rhine river in Europe) has always defined geopolitics. There is, however, a very clear, transcendent escape route to this self-destroying phenomenon by which Humanity, and states, are regularly self-organizing their own annihilation. This route is that of the noosphere, which transcends the kinesphere.

3 On noosphere

The noosphere is an expression popularised by Teilhard de Chardin, which I use here to define the universe of all possible human thoughts, including knowledge and pure speculations devoid of connection with the phenomenal world. An interesting part of it, the universe of all possible human knowledge, is clearly infinite, unlike raw materials, allowing for an infinite resource for human growth, especially economic, to tap into. The interest of elements of the noosphere is well defined by Soudoplatoff's law, a very clear formulation of an otherwise more confusedly known principle by geographer Serge Soudoplatoff:

Soudoplatoff's law (1)

when one shares a material good, one divides it. When one shares an immaterial good, one multiplies it.

which one can reformulate as that knowledge exchanges are positive sum: when one gives away, say an ounce of gold, one does not have it anymore. When one gives away knowledge, or an idea, one still has it. In the immaterial world, one can have their cake and eat it too. This is good news of course, since possession of oil deposits, trade controls, freshwater reserves or, of course, territories, is not positive sum at all. In classical geopolitics, win-win agreements are but the exception, not the rule, and when it comes to sharing a territory, it is a null-sum game as usual, for which there must be a winner and a loser. Transcendance, as defined by Galtung and others, is of course a way to go beyond the null-sum game, and the early construction of the European Union could be seen as an example of it, just as the reunification of Germany, or Korea, or the Levant.

If the old adage that “sometimes you win, sometimes you learn” is true, that is, to the cognitive individual who is investing enough attention and time in the study of their failure to achieve an objective, then whatever states may lose in their kinesphere, they can recover, and beyond, in the noosphere: this is the base of the (4) observation I will make here. This is apparent even outside the time of armed conflicts: it is interesting to remember that South Korea is, today, exporting more than one billion USD more than the entire Russian Federation, with three times less population and 171 times less territory, because it is exporting original know-how, which it is free to create wherever it wants, independent from its geological destiny.

The noosphere is a strategic ocean to which absolutely every nation can have an access. Better: while a foreign nation may indeed deny another nation’s access to the sea by blockading it, the single most efficient noosphere blockade is self-imposed. Countries themselves are their worst enemy in noopolitics, because in the geopolitics of knowledge indeed, one’s most stubborn opponent is one’s own ego. We may define self-knowledge as wisdom, and whatever is not self-knowledge, simply as “knowledge”. Then one can define the “fog of war” in the war against war as the ignorance of the means to transcend a conflict.

Noopolitical fog of war (2)

Any conflict is a mixture of knowledge and ignorance. It takes the knowledge to wage war, and the ignorance to solve war.

Simply put, any conflict needs the knowledge to deal harm to one’s opponent, and ignorance to deal harm to the conflict itself, to one’s ego among others, to transcend the conflict. As a consequence then :

Noopolitical positivism (3)

In total knowledge, including total self-knowledge, there would be no war

Besides, the interaction between knowledge and power shows an interesting paradox defined by Nassim Nicholas Taleb (2012) as antifragility, and simply captured by the saying “what does not kill me makes me stronger”. The more a state is pressured in its kinesphere, the more it is pushed towards the exploration of its noosphere, so much so that a geopolitical victory can end up a tremendous noopolitical defeat for the attacker, and vice-versa for the defender.

Noopolitical victory (4)

A geopolitical defeat can be converted into a noopolitical victory

This is precisely the current situation of the confrontation between the OECD and SCO, a geopolitical constraint to the SCO yet a dramatic noopolitical expansion at the same time. States are cognitive, and there is such a thing as cognitive geopolitics.

Classical geopolitics posits that states know their interest. This is plainly wrong. The moments in which they come close to their true interests are transient and exceptional. All the rest of geopolitics is made of unrealistic desires, geopolitical, life-costing cravings. States, as individuals have an ego, a "commanding self", the very opposite of their "true self". The "commanding self" asks "give me what I want", while the "true self" asks, infinitely more rarely, "give me what I need".

Commanding Self (5)

Very often, states crave not what they need, and need not what they crave. States have a "true" and a "commanding self" (an ego). The first asks "give me what I need", the second "give me what I want". As a result, states, as human beings, rarely know their true interest

This fundamental observation has been completely left out of classical realism, and it is what should most clearly separate Noopolitik from Realpolitik. However, a fundamental flaw in Arquilla and Ronfeldt's original Noopolitik is that it still supposes a control of power over knowledge. Here I defend exactly the opposite: "Noopolitik" should be an internal policy of flowing knowledge as much and as fast as possible for a state, a policy of knowledge and wisdom, as Edgar Poe would put it "where deep thoughts are a duty". "The worst of sages is a visitor of princes, the best of prince is a visitor of sages", the sufi proverb perfectly captures genuine Noopolitik, as the art of wisdom to precede power. In true Noopolitik as well, there is a certain "knowledge panacea doctrine", as statement (3) gives a particular importance to knowledge flows, to the art of producing and flowing transcendent knowledge in general.

4 Conclusion

The interaction between knowledge and power reformulates very simple geopolitical principles, that have been all-to-often forgotten by classical realism, and that were known to such enlightened princes as Marcus Aurelius and Gandhi. One of its clearer formulation is that states should not strive to achieve power over others, but rather power over themselves, which is the ultimate form of power.

State Stoicism (6)

It is in the interest of states, just as of humans, to seek not power over others but power over themselves. Self-power is the ultimate goal of international relations.

the mission of flowing knowledge internally, along with proposition (2) of this paper's principles of noopolitics, also leads to the idea that there is more profit to make in the peace industry than in the war industry. Every time a military technology has made it to a civilian application it has changed the world, from semiconductors to radars to computers to jet propulsion to the Internet etc. It is possible for Man today to turn a blue planet into a red planet, but nobody has the technology to go the other way around. Such "weapons of mass construction" would surely yield much more power than those of mass destruction. This observation founds the Peace-Industrial Complex.

Peace-Industrial Complex (7)

Maximal peace profiteering is infinitely superior to maximal war profiteering. Military technology and ingenuity should always be allowed - or even forced - to develop into civilian applications. There is more power in weapons of mass construction than mass destruction.

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4. From waste to kwaste : on the multiscale synergy of Blue Economy in terms of knowledge flow

This section was peer-reviewed and published under the same title at the CS-DC'15 World e-conference Oct1st 2015.

Abstract. Introduced by Gunter Pauli, Blue Economy, namely bio-inspired industrial ecology or self-profitable circular economy, is a remarkable example of the way knowledge flow can fundamentally alter micro, meso and macroeconomics, and be converted into cash flow. Its reception is also a case of limited rationality in management and economics, and of resistance to change in general. Here I simplify Blue Economy to the following equation: waste + knowledge = asset. I then explore the implications of this equation in terms of venture capitalism (microeconomics) accounting (micro-mesoeconomics) and in terms of GDP (macroeconomics). I finally discuss its possible impact on politico-economic decision-making and its clear continuity with the knowledge economy. One fertile question thus arises : what could be the micro-meso-macro-economic stygmergies of the Blue Economy?

Keywords : Blue Economy, biomimicry, knowledge flow, synergy, industrial ecology, sustainable development, economy of knowledge, stygmergy, mesoeconomics, self-organisation

1 Introduction

Currently, Blue Economy may be the most sophisticated biologically-inspired economic theory, and at the same time the most practical. It is a paradigm considering that waste-free production can be more profitable than current industrial production. Contrary to the so-called Green Economy, it does not consider that the solving of pollution will inevitably impede growth, but rather that there is a paradigm shift to transcend the conflict of interest between growth and sustainable development. This paradigm shift is fundamentally bio-inspired and synergistic, and may be summed up in the sentence :

Axiom of Blue Economy (1)

We should not ask nature to produce like our economy, we should ask our economy to produce like nature.

2 Bio-inspired economics

Nature has poorly been studied as an economic system in its totality, rather than in the limited consideration of its tradable outputs (eg. fisheries), but were it investigated as such, its ingenuity and multiscale optimality would surely deserve several Nobel prizes, and expand the field of bioeconomics. In Nature, waste as an exception, as it exists only at the micro-ecologic scale, for the ecosphere, globally, is in homeostasis, and does not accumulate any particular chemical. On the other hand, our economic systems are not in homeostasis, and do accumulate various products. The point is that for anything that Nature produces, there always ends up to be a demand.

Macroeconomic optimality of Nature (2)

For anything that the ecosphere currently produces, there is a demand from the ecosphere itself

Let us note however that this optimality is global (macroeconomic) for it does not always apply at the ecosystem level. It is also time-dependent, at equilibrium precisely; as we will see, the ecosphere may have been seen to have produced waste in the past. In human systems on the other hand, most value chains end up producing waste, which are not an exception but the rule of our industrial production, and which accumulate globally. We are probably the only species to produce things that nobody wants. Waste can indeed be defined as products for which there is a negative demand, products that one would accept only with a payment. Nuclear waste clearly fall under this category, so do persistant organic pollutants (pop) or even, intriguingly enough, most of the world's output of used ground coffee today, although this is rapidly changing.

Macroeconomic suboptimality of Humanity (3)

Humanity produces things for which their is a negative demand, at both the microeconomic (local) and macroeconomic (global) levels

If we were producing any of our goods and services in the circular way of nature indeed, there would be no waste. This observation has been made by many such as Ellen MacArthur, Janine Benyus, Fritjof Capra and of course Gunter Pauli.

Comparative optimality of Nature and Humanity (3)

In Nature, macroeconomic optimality is the rule; in Humanity, it is the exception. Nature achieves economic optimality faster than Humanity, at any scale. Nature is the best representation of the Invisible Hand, before human-made economic systems.

Trial and Error v. Planification (4)

Man is more risk-advert than Nature. Nature's route to market optimisation is multiscale trial-and-error. Man's route to market optimisation is planification at the micro, meso and early macroscopic levels : individuals plan their decisions, enterprises plan *their decisions, states plan their decisions, and so do central banks. Nature does not plan, it tries, regrets not the past, fears not the future. Man's fear of the future and regret of the past is the essence of Humanity's multi-level suboptimalities.*

Sustainable Development is essentially a Man-made answer to Man-made problems. Without Humanity, there would be no sustainable development, for ecosystems are fundamentally converging to sustainability. Better, any ecosystem suboptimality is transformative in Nature. It could be so of Man-made markets, and this scientific ambition founds biologically-inspired econonomics.

How about the kinetics and the thermodynamics of a transition between a linear and a circular (bio-inspired) economy however ? The contribution of Gunter Pauli regards both the equilibrium state, for which MacArthur has already well argued that it is in favor of circular economy, and the activation energy or barrier to entry for a Blue Economy retrofitting. This article studies the latter : the micro, meso and macroeconomic interests of a conversion to Blue Economy, and their cognitive barriers among others. It also studies both its possible stygmergies from the perspective of a "Technopolis Phenomenon": Silicon Valley indeed, the best known contemporary technopolis, self-organized through entrepreneurial stygmergies, that is, the phenomenon of constructive peer-inspiration. Cannot a global conversion from linear to self-profitable circular economic go the same way, especially more so with the network effects allowed by both crowdsourcing and the Internet in general ?

3 Why Blue Economy ?

Pauli named "Blue Economy" not only in reference to the oceans, but primarily in the idea that "blue is the new green", in the sense that blue economy, unlike the green one, must be profitable in itself, because Nature is both a waste-free industrial system and still cheaper, leaner, and more effective one than ours. It is thus not ridiculous to consider that pollution-free production could be more competitive than current production, without subsidies or even externality taxes.

If Pauli defined "blue" as simply "green 2.0" I may add another metaphor to understand the origin of this "blue" name. Has Nature produced waste in the past, or is its current state of globally waste-free ecosystem production an attribute of even the earliest ecosystems? Nature has indeed produced some waste in the past, the most dreadful of all being… gaseous dioxygen. Dioxygen did provoke a relative extinction of biodiversity that was greater, by several orders of magnitude indeed, than the one that the very simultaneous release of absolutely all man-made pollutants would ever cause. The Great Oxygenation as it is referred to in geology was, in relative biodiversity, the greatest extinction of all the biosphere. Yet, it is thanks to oxygen that planet Earth is this "pale blue dot" we know of, and is green as well. If the very worst waste of natural history could be turned into a blessing, ours, even the most dreadful, are just trivial in comparison.

Transformative nature of wastes (5)

In Nature, wastes induce forward-leaning transformation. In Humanity, they induce backward-leaning conservation.

If we consider that human societies are antifragile (in the sense of Taleb 2012) then adding a constraint to them does not necessarily imply impeding their development ; one could rather verify the opposite throughout history, an observation that was at the heart of Leibniz's optimistic theodicy. One such case of industrial anti fragility was the abolition of slavery during the US Civil War : far from being a handicap to the Union, it ended up an economic blessing, because it accelerated the industrial adoption of the steam engine on the short term, and the advent of a consumer economy on the long term.

One usually (wrongly) attributes to Schopenhauer the three stages of the adoption of a revolution in Human history, be it scientific, philosophical, technological, political or moral :

"Schopenhauer's" three stages of revolutionary adoption (6)

first it is considered ridiculous, then it is considered dangerous, and then it is considered self-evident.

Gandhi defined a similar dynamic : "first they ignore you, then they laugh at you, then they fight you, then you win"[33]. That any revolutionary idea, such as the founding principle of quantum mechanics, the marginal reproduction of mature neurons or the existence of a cerebral lymphatic system, among many others must first be considered ridiculous and then dangerous also explains the well-known suboptimality of academic peer-review, which is but peer-pressure in essence, and thus fundamentally inimical to paradigm shifts, normative in nature.

Blue Economy is surely crossing the three stages of revolutionary adoptions. If the abolition of slavery was a moral, industrial, political and intellectual challenge of the 19th century, and the abolition of apartheid of the 20th century, the abolition of pollution should be the one of the 21st century. Probably the only way to achieve it is to demonstrate that this Pareto optimum can also be a Nash equilibrium. What allows for such a dramatic phase transition is knowledge economy : if one demonstrates that the game of prosperity has much different rules than the ones we took for granted, then one could establish a clear demonstration that pollution zero is not only Pareto-optimal but also a Nash equilibrium. I believe that Blue Economy is the most promising paradigm in this direction. It shows that prosperity is a game with dynamic rules, and I may formulate it as the simplest possible equation :

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[33] Gandhi, M.K. (2000). The collected works of Mahatma Gandhi: (21 October, 1936 - 24 February, 1937). (Publications Division Ministry of Information and Broadcasting Governent of India).

Simplest formulation of Blue Economy (7)

$$waste + knowledge = asset$$

If in any economic game, holding waste were equivalent to a loss, holding waste plus the adequate knowledge could be a win. The knowledge flow can dramatically alter the dynamic of economic games regarding wastes, at the microeconomic level of individuals or small groups holding wastes, at the mesoeconomic level of enterprises, for which the knowledge flow could alter their accounting in the non-linear way of turning liabilities into assets, and finally at the macroeconomic level, where states could consider waste as an opportunity for growth.

4 In terms of knowledge flow

Imagine sustainable development were a proper subfield of the knowledge economy? One could define sustainable development as the art of not trivially wasting resources today, that could be better used tomorrow. Biomimicry is thus a perfect example of sustainable development, as it consists of considering nature not a source of raw material but a source of knowledge. Blue Economy posits, in the same way, a certain "knowledge panacea doctrine". There is surely more than a synergy between noöconomics (the knowledge economy) and Blue Economy, the latter being rather an industrial and managerial subfield of the former.

One should first consider Blue Economy in microeconomic terms. I have reminded of the conservative cognitive bias towards the adoption of revolutions, and it has a decisive impact on the individual knowledge flow. If we were to consider industrial decision-makers as purely rational agents of course, we would expect them to convert all the useful knowledge available to them into action, and in particular that all the knowledge relevant to profitable waste transformation be used to that end. Individual behaviour is not that rational however. First, for a given knowledge to be adopted, it needs to resonate with the existing paradigm of the receiver, otherwise, no matter how well it is demonstrated, it will be rejected.

Of the most significant cognitive biases I should underline in the study of the Blue Economy in terms of knowledge flow is the bias of conformity. When faced with the dilemma of adopting the truth and leaving one's comfort zone or staying within one's comfort zone and rejecting the truth, most human beings will choose the later. An evolutionary reason that is often invoked to explain this phenomenon is that we, contemporary humans, are mostly the descendent of the weak-minded humans who survived by preferring to remain in their tribe and reject the truth every time they were faced with a dilemma. The others have died. For, between leaving the group and adopting the truth and leaving the truth and remaining in the group, be it in the savannah or during the Ice Age, the latter meant survival, and the former quasi-certain death. Although the adoption of disruptive knowledge is not really equivalent to death anymore, our brain has evolved to discourage it as much as possible, as long as it goes against in-group favoritism. Hence the following strong proposition that Blue Economy should be "won in the middle":

Mesoscopic synergy of Blue Economy (8)

The adoption dynamic of Blue Economy, in terms of knowledge flow, does not favor the microscopic but rather the mesoscopic scale. Blue Economy will be all the more successful as it targets neither individuals (micro) nor nations or even cities (macro) but groups and groups of groups (meso).

It is a testable hypothesis that the adoption dynamic of Blue Economy should give a premium to the mesoscopic scale, for it is the scale in which the all-or-none mechanism for the adoption of disruptive knowledge could prove the least disruptive. Groups, and groups of groups - not individuals - should be the targets.

If knowledge holders are to be modelled as biased maximising agents, as in regular economic, then one should study the social conditions under which they will be *willing* to maximise their knowledge flow. For in nooconomics (the economy of knowledge), the willingness to acquire knowledge is the very first bottleneck of knowledge logistics (applied noodynamics). From a macroeconomic perspective, one should observe that statement (7) implies that economies producing a lot of waste and at the same time a lot of knowledge could most benefit from Blue Economy in terms of GDP. This alone of course, could explain the political interest of China for the field. The general statement is that the best way to manage waste is not to bury it deep in either dirt or water, but in knowledge.

At the transition between the meso and macroeconomics of the synergy between waste and knowledge many business models could be developed, as, for example lines of services in the accounting and auditing businesses, because if statement (7) becomes a standard industrial observation, then knowledge and externalities should be accounted for in a completely different manner in financial terms. Maybe generally accepted accounting practices could also very well benefit from a retrofitting in Blue Economy. From the high mescoscopic point of view of multinational firms, this would be a novel, readily available though untapped well of profitability, and boasting a genuinely operational "Blue" label (which could become the trade of *ad hoc* rating agencies) could end up a critical success factor for any publicly-traded company. This is exactly the kind of mesoscopic effect that the Blue Economy should seek. From the lowest macroeconomic level then, that of national or regional administrations, one could observe that such a behaviour would encourage corporations to internalise their externalities as systematically as possible. Why externalise waste indeed if these liabilities, once blended with the appropriate knowledge, end up being assets? This possible mesoscopic behaviour seems rather intuitive, but it is merely the outline of the more thorough economic model one should develop to systematise the synergy between nooconomics and industrial ecology.

Macroeconomic indicator of Blue Economy (9)

We could define such indicators as Gross Domestic Waste and Gross Domestic Knowledge. One message of Blue Economy is that Man should not bury their waste in nature anymore, but in knowledge. Thus, the problem is not to produce waste, but to produce the adequate knowledge, and the art of turning waste into kwaste. A macroeconomic indicator could be the knowledge/waste ratio (k/w). A high ratio is good, a low one is bad.

5. Conclusion: in terms of stygmergy

Peer pressure is a normative phenomenon. One of its emerging effects is social inertia, but also social stabilisation. Thus at the beginning of a revolution, peer-pressure is what encourages an idea to be considered ridiculous and dangerous, but then it is also what helps revolutions to move towards self-evidence.

Stygmergy is the self-organisation of a pathway, usually at the mesoscopic scale (that of groups and groups of groups) through various forms of reinforcements. The self-organised stabilisation of the shortest pathway through pheromone signalling in anthills is the textbook example of stygmergy. Economic systems typically display stygmergy as well, be they destructive (like a bank run), constructive, or neutral. The history of Silicon Valley was typically one of stygmergy, based on constructive peer pressure, e.g. “if I succeeded, why would you not”. The opposite of course, destructive peer-pressure would be “if I failed, why would you succeed ?”

The dynamic adoption of Blue Economy poses the question of its entrepreneurial stygmergy, especially at the mesoscopic scale (that of small and medium enterprises). If the emergence of Silicon Valley was a typical “technopolis phenomenon” by which the enthusiasm of novel project holders self-organised along the fresh trails of earlier successful entrepreneurs, could there be an identical “Blue Technopolis Phenomenon”? How would the man-hill of blue entrepreneurs self-organise ? Would it reach homeostasis, expand - by converting new entrepreneurs - or collapse ?

Here I discussed how the knowledge flow can alter the meso-economic dynamic of Man’s interaction with waste, along the general idea that, in the 21st century, Man will learn to bury not this waste in either dirt or water but in knowledge. If waste+ knowledge = asset (proposition 7) then the entire interest of the Blue Economy is to catalyse the conversion of waste into “kwaste”, that is, appropriately paired bits of waste and bits of knowledge. Surely crowdsourcing could benefit such a global catalysis, especially considering that human knowledge is intrinsically collegial. The crowdsourcing of the collectivisation of knowledge (Wikipedia being the clearest example of it) can encourage stygmergy and the emergence of common sense. Should an equivalent “kwaste” platform be established, to maximise the interaction between waste and knowledge ? Nature’s way to deal with waste is to surround it with trial-and-error. Man’s way of dealing with waste should be to surround it with knowledge. As the No Free Lunch theorem establishes that there is no more efficient optimisation strategy than a random search over all types of optimisation problems, maybe trial and error is actually the very best way for the ecosphere to incorporate novel molecules into its many cycles. Should it also be that of Man ? If yes, how could we accelerate such a kinetics of trial-and-error over waste ?

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5 Botcrafting and Botbreeding: a simple economics of evolutionary algorithms

Abstract. Let us consider the industrial and economic impact of genetic programming and its generic availability to the masses. Is the interaction between genetic programming and the so-called "cognitariat" the beginning of a "genetic revolution" in the industrial sense? Can we theorise a genetic marketplace, based on the dynamic of bids and ask for genetic algorithms to be made-to-order and leverage any daily routine, thus trading value? Can genetic algorithms be cross-bred to achieve a phenomenon similar to animal domestication, and can such a pressure for domestication percolate to macroeconomic value? Which economic marketplace would allow such an economic phenomenon to happen and percolate least impeded? Here I consider the economic implication of evolving genetic algorithms to address any repetitive human task, within a grand genetic marketplace composed of bidders and askers that would be using, evolving and breeding genetic programs ("bots") and manipulating them as "bot breeders" to leverage their own economic output. I define a cryptocurrency on the buyer's side, conceived to represent a unit of genetic purchasing power, which I call a "botcoin".

Keywords : Economy of Knowledge, bitcoin, botcoin, evolutionary algorithms, self-organisation, theory of value

1. Introduction

The purpose of this article is to outline an *ad hoc* economic paradigm for genetic programming. If programs represent economic value, self-writing and self-evolving programs may imply self-generated or automatically-generated value. This poses fascinating scientific questions, especially for the economist. Simply put, the economy of genetic algorithms is non-standard.

The rationale is quite simple : genetic algorithms can generate value, and this value is special. Hence, how will one trade it ? These are some foundations of the economic study of genetic programming. Its interest of course, is to lead to innovating economic theories, for the economy of genetic programming could be quite different from that of other commodities. Let us here investigate some of its possible microeconomic, macroeconomic and financial principles.

Knowledge workers, as Davenport (2013) put it, are those who "think for a living". Berardi (2004) using marxist concepts and historical materialism, referred to lower class and middle-class knowledge workers as a "cognitariat", namely a loosely-defined group of workers whose only tradable work is cognitive. In the same way that the proletariat would sell their arms, the cognitariat would sell brainwork, with almost no bargaining power, and therefore, at the smallest possible price. The remuneration of Ph.D students and postdocs in the academic world, barely equal, and very often inferior, to the GDP per capita of their country anywhere in the world, is a textbook example of this disciplined social class, highly educated though very poorly aware of the socio-economic injustice of its status.

2. Knowledge workers

The definition of the proletariat held in that they did not own any share of the means of production, be they land, herds or factories. This has been generally true of the current cognitariat, owning not any share of their laboratories, office space, servers etc. Technological revolutions have increased the occurrences of enterprises with a relatively low barrier to entry (e.g. “garage entrepreneurship”) but the scalability of such businesses has remained highly dependent upon capital. This order of things has seemed rather impossible to change. However, the advent of cryptocurrencies has demonstrated the possibility of establishing a fiat currency from scratch, independently from central money suppliers and governing bodies, with a relatively low volatility on the medium term. Peer-to-peer capital, encrypted furthermore, can profoundly challenge the supremacy of centralised fiat capital in the economy. But as any revolution, it must be first considered ridiculous, then dangerous, and eventually self-evident, if and only if entrepreneurs, not inventors, make it “cute”, that is, simple and adoptable. For cryptocurrencies to become mainstream, their best message should be “don’t be afraid !”.

If there is a category of workers who think or write for a living, software developers must clearly belong to it, and own only a very limited share of the global means of production, that is, a few computers. Genetic programming however, can profoundly alter this socio-economic order of things, with at least two disruptive elements :

Genetic way out of the cognitariat (1)

a genetic programmer does not only write for a living; their software also writes itself. If software is sellable, genetic programmers can own “herds” in silico. *They can create and expand capital out of nothing. The same could be true of knowledge workers altogether, but the ability to back a solid fiat cryptocurrency on the value of such silicon-based “herds” opens up the possibility of an associate complex* in silico *finance, and hence the access to up a possible substitute to regular fiat capital.*

The novelty of genetic programming, for the cognitariat, is that you not only write, but also “breed” for a living, with software husbandry an equivalent of animal husbandry etc. This, in a way, could be the beginning of a massive, highly disruptive, silicon agriculture, with the concept of a “genetic domestication”, the domestication of genetic programs, and later, entire genetic ecosystems. In this article, I call this phenomenon”botbreeding”. It immediately underlies the concept of *in silico* harvest, which one can suspect may not display seasonality (or could they?), taylor-made crops, serendipitous crops etc.. The behaviour of such botbreeders, and their *in-silico* herds, this entire

Silicon agriculture, is surely an exciting new paradigm with non-trivial anthropological significance, that may compare with that of agriculture and domestication.

3. From Physiocracy to Silicocracy

Self-organisation is not new to economics, which is historically the science of *oikos*, namely the environment. Physiocracy is at the origin of the term *economy*, and is the doctrine according to which any economic value is reducible to natural value added with knowledge. The advent of contemporary biomimicry, circular economy and Blue Economy, among many others, is fulfilling this doctrine in a surprisingly modern way, that economists could not have anticipated just a few decades ago.

Thus, in a way, *nove sed non nova:* there was a biology to economy and then there is a biology to software. Steve Jobs famously reminded, in 1984, that “software is the oil of the 80s and the 90s”; evolutionary programming is adding two critical dimensions to this statement, however: software that write themselves and software that produce human-competitive results, that is, solutions that are either comparable or better than human-established ones. The “Humies awards” are one salient manifestation of this trend; genetic programs can produce value that would compete with that of the cognitariat, just as the steam engine did compete with the value of the early proletariat. Ultimately, this value could “free” the cognitariat from certain of their tasks and allow them to become a sort of meta-cognitariat, that is, a supervisor of cognitive automata.

So, software is a type of oil ; and indeed, the man considered in 2015 to be the richest by some media is a software mogul, not an oil magnate. The new dimension of genetic programming is that now there is a biology to it. The suspected economic consequences must be partly comparable to that of physiocracy. Another self-made value for the cognitariat would be productivity leverages : there are still, today many repetitive tasks to knowledge workers, from very simple cases of office or laboratory life to more complex collective ones. Since advanced full-spectrum software literacy is not quite achieved in any economy yet, any cognitarian faced with a repetitive task could not write their own piece of software to remedy to it. If softwares were fully tradable however, or, more importantly, software generators, then one could specify precise constraints for genetic programs to evolve towards practical adoptions in working conditions, for such programs to evolve towards maximal ergonomics, etc.

Programs evolving towards maximum productivity and maximum adoption could be economic game changers. So could be programs evolving with much less constraints, or unexpected ones, yet proving serendipitously to be of economic or even, more surprisingly, of emotional value.

Botcrafting (2)

Botcrafting is the activity consisting of designing made-to-order genetic algorithms, for example to automatie a human task for a given client.

Botbreeding (3)

Botbreeding is the activity consisting of evolving genetic algorithms without a precise order, or with one's own set of constraints, in hope of selling them.

The founding principle of Silicocracy is therefore that one may evolve an ecosystem of algorithms, *in silico*, of which one may extract piecemeal value. Holding a universe of fitness landscapes and genetic algorithms *in silico* could become equivalent to holding acres of forest, arable plains or herds of cattle. The next step, of course, would consist of extracting and selling the value of these goods, or cross-breeding them with codes evolved from other landscapes, in hope of achieving heterosis (hybrid vigor). The expectation of such an algorithmic heterosis, in itself, could make software markets more liquid by providing a strong incentive for exchanges. Trade, in general could be defined as the negotiated exchange of value between breeders, with such familiar effects as comparative advantages and limited rationality likely to emerge. Now that we have expressed such micro and meso-economic Silicocracies, we may outline some aspects of their macroeconomics.

4 Soft markets and soft finance : trading places for algorithms

A complete financial ecosystem could be compatible with the idea of silicon-based agriculture ; once one considers the possibility of turning genetic algorithms into cash crops, and their massive commoditisation altogether, one can consider their more advanced, derivative physiocracy. Rather than raw materials of course, such an agriculture would directly produce services, and thus possess some aspects of the service industry (its elasticities, for example) and some aspects of the primary industry (its adhesiveness, possibly). Again, it is expected to be not seasonal, thus having a rather continuous harvest, with technological improvements dramatically improving the profitability of such or such algorithmic search, others making it irrelevant, etc.

What could be some derived products of *in silico* harvests? Which insurances, which futures, which options, which bonds and which shares? Could there be cooperatives, or mutual genetic funds sharing computing capability? Surely one of the most essential resources of such a "silicoculture" would be floating operations per second (flops), but also the human ingenuity of the breeder. The ability to maximise value out of a given "head" (an evolved program) would also be an art in itself: pieces of code could be traded separately, possibly with other codes to determine the optimality of their piecemeal trading…

The mercantile exchange of genetic algorithms or algorithmic material would immediately pose the problem of their fungibility, which is fascinating in itself: to which extent will one bit of code be considered equivalent, and thus financially interchangeable ,with another? Could the quality of bits of code, or systems, if they come to be sold as well, be assessed and guaranteed ? Which composites could ensure the standardisation of the intrinsic diversity of a large spectrum of genetic materials, and would it even be desirable ?

For the moment, let us suppose that a sufficient clarity has been achieved in the posting of algorithmic specifications for a market to be established between bidders and askers. Bidders would be botcrafters (sellers with a precise target in mind) and botbreeders (sellers having developed their algorithms without an initial target among askers) having fresh algorithms to offer, each fitting precise enough specifications, either made-to-order from the specifications of askers (botcrafting) or anticipated or serendipitously emerged from the art of botbreeders. The creation of a novel breed of code could end up comparable to that of a novel breed of, say, wheat, rice, cattle, etc. It also seems that demand should establish and distinguish the different algorithmic markets, for which a possible basic unit would the family of task to automatise. Caffeinated drinks, for example, establish a family of commodity markets (from tea to maté to coffee). The same could go for a large diversity of tasks normally performed by knowledge workers.

The market between askers and bidders will ultimately need to evolve beyond barter, and this is where an *ad hoc* currency would be needed. A cryptocurrency seems the most adequate to fit this need, but the rules of its supply and value would remain to be decided. The rate of exchange of bitcoin, for example, is established by the flow of exchanges between it and regular currencies, usually the US dollar. It is not backed by knowledge *per se*, but by mining, which is correlated with computing power (in flops) or ingenuity : for example, it is possibly to hijack computing power from the Web, through zombie machines recruited on massively multiplayer online games, to achieve competitive bitcoin mining without having to amortise a costly proper computing infrastructure.

Huang et al. (2014) have called “botcoins” the monetising of stolen computing cycles. The “botcoin” I introduce here however, is not comparable :

Botcoin (4)

a fiat cryptocurrency representing one unit of purchasing power on trading places for algorithms

Holding botcoins would represent the ability to purchase algorithmic value. Since this value would also represent saved time, money etc, it could remain convertible, just as bitcoins. One difference with the most widely used cryptocurrency however is that there would not necessarily be a need for miners, or a fixed asymptotic money supply (as is the case for bitcoins). The money supply of botcoins could be established by consensus, pegged to the volume of exchanges, or established in any other way so as to preserve the liquidity of markets and, of course, discourage excessive hoarding. The founding purpose of botcoins would be to increase the liquidity of trading places for algorithms and to facilitate the commoditisation of programs by establishing a trustable intermediate between made-to-order programming and *en passant* purchases, that is, purchases executed by a third party, of value that was created for another client.

Botcoin could also be correlated with another currency theorised by Pierre Collet (personal communication), the ECU for Evolutionary Currency Unit, representing, on the bidder's side this time, one unit of evolutionary computing power. The joint creation of currencies to standardise and liquefy purchasing power on both the bidder and asker's sides would be designed to accelerate even more the commoditisation of softwares.

5. Conclusion

Although it may seem revolutionary, the economy of evolutionary algorithms, unsurprisingly, seems relatively close to physiocracy. Its consequences remain non trivial, because the breeding of algorithmic value, a value that writes itself, that has the intrinsic potential of surprising its breeder, and that actually represents a service rather than a material - although physiocracy as been overlooked as a theory of services rather than of materials, as the advent of the notion of ecosystem services has quite clearly demonstrated - remains novel in itself.

The commoditisation of softwares, accelerated by the technology of genetic programming, is a very fertile case study for the economist. It may pose at least three questions: why achieve it? how to achieve it? what kind of economy will emerge from it? For example, what could be the emerging elasticity and cyclicity of such novel "botmarkets". The consequences of the commoditisation of softwares on microeconomic, mesoeconomic and macroeconomic productivity should also be considered.

The present outline leaves much room for improvement, which was precisely its purpose, but it has attempted to establish enough clear concepts to found the study of *in silico* economics or "silicon agriculture". Is the domestication and cross-breeding of self-writing "herds" of software, and the mercantile exchange of either them or their genetic material, akin to the agricultural revolution of the Neolithic? One can already see many applications to such a "silicon cattle": many industries are constantly in need of "bots" to automatise tasks that are performed by humans, for example level design in video gaming, which is beginning to be automated by procedural generation. Genetic procedural generation could already be a fascinating field of study in computer science, but so would be genetic art, genetic cinema editing etc…

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Mind Ergonomy for the Knowledge Economy

Part 2

"How ?"

6. Hyperwriting, or multiscale writing with the method of loci

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Abstract. Let us suppose that any media is the outsourcing of a mental function; writing, then, is the outsourcing of working memory. For Dehaene and others, writing is neural recycling through which populations specialised in shape recognition are associated with sounds, thus forming a simple grapheme-phoneme association. Could there be other forms of writing then, or "neowriting", and could they externalise other mental functions, such as say, episodic memory? Here I propose a multiscale form of symbolic writing based on the method of loci, consisting of a loceme-noeme association endowed with a proto-grammar, which purpose is to externalise episodic memory, and allow for the mapping of noems onto space. I add that hyperwriting is not the only possible form of neowriting, thus posing the problem of the neuroergonomic optimality of existing media depending on their contents and cognitive purpose, and discuss its epistemological continuity with hypertext.

Keywords : neuroergonomics, writing, neural recycling, method of loci, episodic memory, mind maps, knowledge maps, hypertext

1. Introduction

What if any media was nothing but an extension of a cognitive function? The historically decisive contribution of writing would then be represented as the mere extension of working memory. Writing is a technology by which one can provide an external structuration of mental objects, each loaded in working memory, thus creating a stream of intentional mental objects that is coded outside the body. Writing, in essence, is but a partition to the human mind.

Taking Husserl's definitions of noems (objects of intentional thought), could the learned association of phonemes, graphemes and noems of writing be generalised through other associations? We know for example that writing is essentially a "ventrolateral" media, in that it taps into both the ventral stream of vision, that which cognitive sciences may simplify as the path of the "what", and the left hemisphere. Since writing is a very specialised yet, from an evolutionary point of view, relatively artificial form of association, could there be other such forms? In particular, could one establish a "dorsal-bilateral" form of writing, that would tap into the dorsal stream of vision, and be space-based in nature? Could one engineer such a writing with the aim of externalising not only working memory, but some aspects of proprioception, and episodic memory?

Therefore, could it be possible to engineer *de novo,* exotic forms of writing beyond the grapheme-phoneme association, but, for example, a loceme-noem association, namely a writing that would consist of the systematic association of space and thought, and be endowed with a natural grammar based on the transitive inclusion of places in natural space? The speculation into such a form of writing is the purpose of this article. It provides the prototype of a form of hyperwriting, a zoomable writing based on the method of loci, that is, the art of memorising large collections by mentally mapping them onto space, also known as “memory palaces” or “memory galeries”. In the same manner that writing systematised and externalised the strategy of learning by heart, hyperwriting should systematise and externalise the strategy of building memory palaces. It would be the art of writing with space, and attributing meaning to space, so as to form a working language. This language, however, would be a silent one: it could not be articulated yet, or spoken, since it would not integrate phonemes. It would remain a structured language still, and a language of the mind, as it would integrate noems. Its main shortcoming in terms of communication would simply be that it could not yet be shared orally but only visually. The purpose of this paper is to discuss the interests of such a media, exhibit a possible early form of it, and consider its continuity with Vannevar Bush’s early conception of the hypertext.

2. On the method of loci

The method of loci is a mnemotechnic tool consisting of mapping mental objects onto a mental space. Usually, this mental space is a familiar place, thus easing its storing by episodic and autobiographic memory. The general idea behind this intuitive “technology of memory” is to use memories of the environment, which are much more resistant to decay and intrinsically non-verbal, to structure the stream of consciousness and in particular that of working memory. The method of loci may be considered a structured dialogue between episodic and working memory, one with a very large long-term storage capability, and the other with an access to what Baars, Dehaene and others call the “global cognitive workspace”. In a way, during the particular episodic retrieval of a memory palace, one could consider episodic memory a Read-Only Memory, and working memory the Random Access Memory of the brain.

Pesenti et al. (2001) have demonstrated that prodigy calculator Rudiger Gamm was extensively tapping into episodic memory networks to achieve his high-performance mental calculations, such as computing divisions of prime numbers down to the sixtieth decimal for example. Mathematical skills at large tap into many visuomotor networks, including cerebellar networks, as can now be easily reviewed with such integrative platforms as Mesmoudi and Burnod’s https://iscpif.fr/blog/projects/linkrbrain-2/ automatic literature-crawler and brain-mapper.

In general, mnemonists tend to develop interesting mental routines to memorise longer lists of elements than the average limit of working memory can allow for. One of them is very close to the creation of a language, for example in memorising large alphanumeric lists, in that it associates seemingly random series of characters an ad-hoc meaning to facilitate its memorisation. Combined with the method of loci, such ad hoc, pseudo-languages are the most efficient way of memorising large collections for professional mnemonists. It is for example the one used by such memory athletes as Joshua Foer, Dominic O'Brien or Nelson Dellis.

If any media is but the externalisation of a mental strategy, then one could externalise the method of loci into a novel form of artificial writing. The interest of such a media could be immense, in that it would transcend existing writing, and, from a historical point of view, may be just as significant as the introduction of the latter. From a neuroscientific point of view as well, the study of artificial writings could pose fascinating questions as to the "potential wells" of media when coevolving with the cerebral cortex. We know for example that the neural correlates of reading have a very low level of polymorphism in the human population: writing tends to route itself across the left hemisphere, from the early visual areas to the temporal and then frontal lobe in most people. Mathematical skills, being more fuzzy in their definition and practical purpose (from the professional mathematician to the architect etc) tend to recruit more diversified populations of neurons, but almost always tap into the intraparietal sulcus, which is critical to exact arithmetic in humans (Piazza et al. 2004). The fascinating question of course is: would the neural correlates of *de novo* and *ad hoc* writings be always as stable as those of regular writing? Could there be reproducible bifurcations? Is there a general topology of the interaction between neural populations and artificial media? Can one establish a clear landscape of it, just as one can achieve some levels of predictability in hydrology, namely the interaction between geological and hydrographic landscapes? If we consider human mental routines rivers (and *fasciculi* may indeed make the metaphor not too far-fetched) forming in their easiest possible course through the "geology" of the human brain, then indeed the interaction between artificial media and their neural correlates could be, to some extent, studies with comparable tools as those of the complex systems of geology, including catastrophe theory. The extensive research of Bach-y-Rita in sensory substitution is also seminal to the question. Here I attempt to extend it into not sensory but mental substitution, or mental re-routing, by introducing a prototype for hyperwriting, a writing with the method of loci.

3. "Curvy A" : a prototype hyperwriting

The core concept of hyperwriting is loceme-noeme association. Locemes we know are critically correlated to the entorhinal cortex and hippocampus, and in particular with the so-called "place cells" and "grid cells". Them being so well correlated to very precise brain structures, just as the Broca and Wernicke areas correlate with phonemes and visual word form area with graphemes, makes them very interesting areas to target in neowriting engineering, and thus, one could say that they were not picked at random, either by memory athletes, nor for this very study, in that there seems to be a natural level of neuroergonomics to loceme-noeme association, just as there was a certain level of neuroergonomics to grapheme-phoneme association.

In homage to the undeciphered Minoan script "Linear A", I named the first prototype hyperwriting "Curvy A". It consists of a simple way to script landmarks and places, just as writing is a simple way to script graphemes. Dehaene has reminded that the letter A as a grapheme in itself may very well have come from the inversion of the early script of a bullhead. Considering the evolution of regular writing as the simplification of figurative scripts, why not begin with a figurative metaphor to structure locemes as well, and then simplify it? Writing is correlated with civilisation; one of the most easily recognised symbol of locemes in the collective mind of most civilisations are rivers. Mesopotamia, after all, simply means "the land between the two rivers", the Nile has structured the entire Egyptian civilisation, just as the Indus in the Indian subcontinent, etc. Let us then use simplified rivers as the most basic element of hyperwriting's first loceme-loceme association (*i.e.* a place that maps other places onto space, themselves later mapping noems). The structure of hyperwriting indeed can be simplified as :

grapheme —> loceme —> … —> loceme —> noem (1)

The multiscale dimension of hyperwriting comes from that, as the built environment, it is finitely zoomable. However, all the scales of hyperwriting preceding that of noems, the final scale, are locate scales, namely, scales that represent places either containing or being contained by other places. Regular writing, in contrast, as a different descendent complexity, which, for example, may be represented as

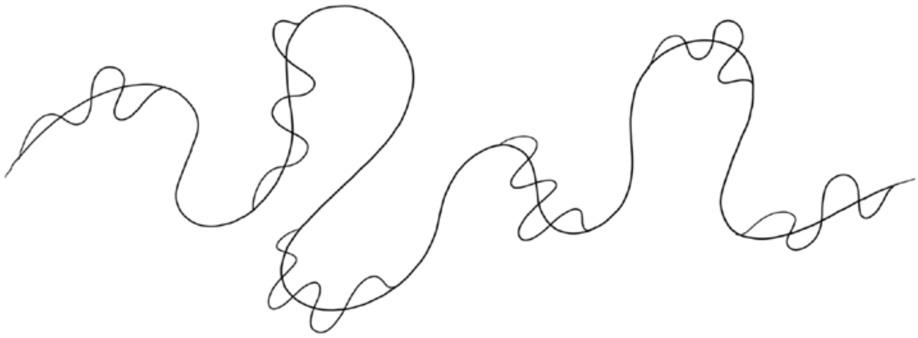
book—> chapter —> section —> paragraph —> sentence —> word —> letter (2)

Both Hyperwriting and regular writing are finitely zoomable, their difference lies specifically in the brain areas they are targeting. A more complex grammar could still be associated with the various levels of complexity of hyperwriting, and this is a possibility that Curvy A already explores.

The fundamental symbol of Curvy A is a stylised river shape, curved, hence the name, which is essentially a Bézier curve (fig. 1). As it turns out, a more complex, asymmetric and packaged curve (that is, with more meanders) is intuitively more memorable, and allows for the mapping of more content in a single view (fig. 2). This river shape is a strand of loci (fig. 3), each being another strand for other loci (fig. 4) which are groups of noems of various shapes so as to facilitate their memorisation. The purpose of Curvy A is to capture some of the aspects of the interaction between long term and short term memory in the method of loci, and to make it writable in a procedural manner. Hence, being an externalisation of the method of loci, it is a media, albeit fundamentally different from writing. Among other things, it is a procedural writing.

Fig.1. Curvy A.1, a Bézier curve is figuring the highest loceme, itself mapping other quasi-self-similar locemes. The lowest level locemes are black dots, which in three dimensions could figure a stylised rock, just like the Bézier curves are stylised rivers. The lowest levels locemes are directly mapping noems, unlike the higher-level ones.

Fig.2. Curvy A.2, first step: the curve is made more complex so as to map more locemes in the same space. As a stylised river, it has more asymmetric meanders, making it slightly more memorable.



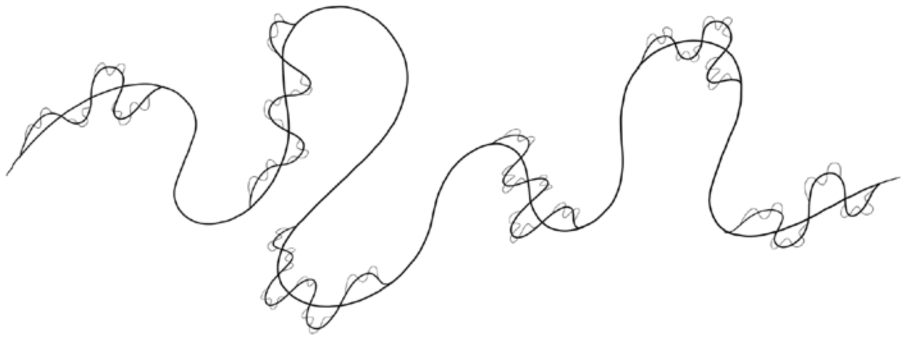


Fig.3 Curvy A.2, second step: other quasi-self-similar locemes are added at the level below the second ones.

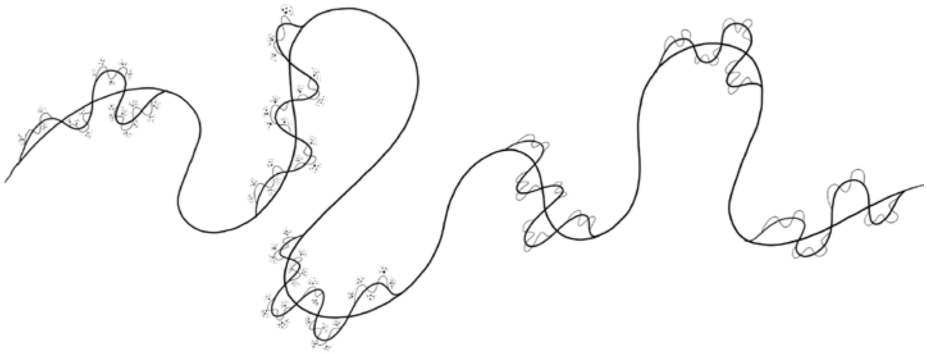


Fig.4 Curvy A.2, third step: half of the locemes have been populated by the lowest level locemes (the dots, stylised rocks) each clustered in groups, and each associated with a single noem. Here the entire script is mapping about 630 noems and could be continued.

Fig. 5. Purus River (above) and the Acre River (below) at the tres frontieras ACRE region radar (Advanced Synthetic Aperture Radar) infrared image.

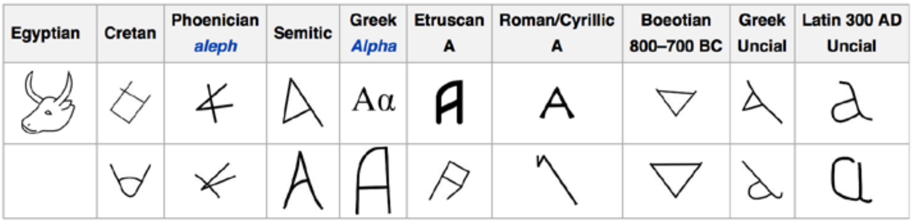


Fig.6 Evolution of letter A from its hieroglyphic-skeuomorphic representation of a bull head to a purely glyphic grapheme, for example in Greek and Etruscan. Hyperwriting attempts to mimic such an evolution by using the representation of a stream or a river as a skeuomorphic proto-grapheme, and then by simplifying it to a purely glyphic grapheme. (CC3 Wikimedia commons). Note that from a media point of view, Hyperwirting fundamentally requires the ability to zoom, which was possible neither on clay tablets not on papyrus or wax tablets, but is easily achieved on a digital slate. A symbolic zoom (eg. by the use of arrows) is still possible on a paper Atlas for example.

4. Conclusion

Reading, for the human mind, is essentially a stream of noems, mental images, which are multimodal in nature. Mental phonemes are of this kind, for example, and essentially monomodal. Phonemes in themselves, can be very good intermediates to noems, although they do not capture all of them, such as pure mental images, smells and pictures, *qualia* in general, which are not verbal by definition yet remain highly correlated to their linguistic counterpart. The entire interest of hyperwriting is to propose not a substitute for writing, but a higher-level, synergistic form of writing to supplement and enrich it. The practical purpose of hyperwriting is to enrich regular writing and allow for a mapping of it onto space.

It could be interesting to further the development of hyperwriting by developing *ad hoc* pseudo languages to specifically map locemes and phonemes, *i.e*. to give names to the natural grammar of space that would not be logical constructs (eg. “A is in B”) but single words. Another function of hyperwriting, that of the method of loci in general, is to allow the reader and writer not only to ask themselves “what was the keyword of this thought again?” but also, more importantly and more mnemotechnically “where did I leave this thought again?”. This, in essence, is an early form of both dorsal and episodic process, in that hyperwriting intrinsically suggests to develop *affordances* for thought, namely the art of reaching them, and of placing them in a mental space so as to give meaning to their reaching. This could further be developed into a proper grammar, but a dorsal grammar, based on affordances.

Curvy A and hyperwriting in general naturally provide for a grammar of inclusion as well. There are levels of complexity in regular writing, as we have seen, and the next step to the development of hyperwriting would be to seamlessly entangle them with the natural levels of complexity of the mental space. Here my interest has been to suggest that an artificial writing based on a loceme-noem association could recruit very precise areas of the brain, act either in synergy with existing writing or independently from it.

The epistemologic contribution of hypertext has been to create both a grapheme-grapheme and eventually, a noem-noem association. This has enriched the way one can explore, and understand large collections of words, especially by giving a lateral, intertextual dimension to them. One epistemologic contribution of hyperwriting is to facilitate the mental grasping of large collections of contents, its memorising, and at the same time the capturing of it in a writable form. Another interest of de novo writing is to pose the question: has man domesticated writing or has writing domesticated man? The wilful domestication of both our dorsal visual stream and the neural correlates of our episodic memory could lead to the development of fascinating new media, of which "Curvy A" is but a very early suggestion.

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7. Noome and noomics: towards a genetic of the noosphere

Abstract. Memetics has brought a practical theory of the resemblance between viral blocks of genetic code and viral behaviour or ideas. It evolved to produce the science of phylomemy, allowing us to consider the equivalent of a connectome for human thought. If enough perspective has been achieved on the concepts of genetics, proteomics, connectomics, physiomics and memetics, this papers introduces that of a noome, the noetic equivalent of the physiome. I define noetic strands as streams of noems, just like DNA strands are streams of genes, and the peer-to-peer exchange of noetic strands as a phenomenon comparable to lateral transmission in bacteria, which is also semiconservative. I conclude by considering noosomes and noome packaging, in the fashion of chromosomes and DNA packaging, and their possible implications for social User Interface.

keywords: Noetics, noosphere, phylomemy, physiomics, noomics, noem

"In terms of the Internet, it's like humanity acquiring a collective nervous system. Whereas previously we were more like a... collection of cells that communicated by diffusion. With the advent of the Internet, it was suddenly like we got a nervous system. It's a hugely impactful thing."

—Elon Musk,
upon the first Dragon docking with the International Space Station, April 26th 2012

"for almost 150 years, people has aspired to fulfill Hawthorne's vision--to wrap nerves of communications around the globe, linking all human knowledge."

—Al Gore (1994)

1. Introduction

Let us consider Husserl's definition of noems as "objects of intentional thought", and simply, here, expand it to "objects of thought" in general, leaving volition and intentionality aside. The purpose of this article is to outline noomics, the study of noomes, structured collections of noems. If one defines the physiome of an organism as the entirety of its physiological traits through time, from birth to death, the noome of a human being is the entirety of its mental objects from birth to death. The collective noome, in turn, becomes the entirety of the mental objects of humanity, from birth to death as well

- and of course the noome of Humanity is yet to be discovered. Since Humanity, as a single meta-human being, is mortal, its noome should be finite still.

Here I intend to outline some of the early categories of noomics in a collaborative manner, thus leaving much space for peer-improvement. I do not pretend to establish a self-consistent, ideal theory of noomics. The objective of this publication will be met simply if it clarifies both the scientific interest of such an -omics as that of mental objects and inspires the community with concepts simple enough to establish predictive theories. Thus, the contribution of this article is entirely flexible and contradictable, and the author will welcome its evolution into both a leaner and more powerful peer-improved version.

Furthermore, to avoid any confusion, I named the study of organised noems noomics rather than noetics to clearly distinguish it from the so-called "noetic science" although, on the other hand, I do not deny its continuity with the philosophical field of noetics at large, from Plato to Plotinus to Ibn Arabi etc.

2. Outlining noomics

Either individual noomes or the noome of humanity, which Teilhard de Chardin named the noosphere, are interesting complex objects. The noome of an individual is not merely a stream of noems, but rather a stream of streams, partly coherent and stable in themselves, and structured either intentionally or not. What is the dynamic of these streams of mental objects ? How are they born ? How do they evolve ? How do they survive, thrive or disappear ? This article is a set of flexible propositions establishing a simple frame to answer these questions, and others. It is biologically-inspired in nature.

Noems (1)

Let us define noems as conscious mental objects. One could define them more precisely as conscious objects of the "global cognitive workspace" (Baars, Changeux, Dehaene and others). A noem is the unit of conscious thought, the building block of what William James called "mental life".

Noome (2)

Let us define the noome of an individual as the total succession of his mental objects, from birth to death Surely there will be other relevant levels of complexity between noems and noomes. They are precisely what noomics should study: how are noomes structured? For there is no doubt that noomes are intrinsically complex.

Noosphere (3)

Pierre Teilhard de Chardin's noosphere, in turn, is the collection of all noomes, past, present and future, of all possible mental objects accessible to Humanity.

Noems, noomes and the Noosphere should be among the fundamental categories of noomics. From an epistemological point of view, one can also consider its continuity with the social metaphor of the "China Brain Experiment" (Davies 1971 and Block 1978), the idea, that had actually been posited much earlier in different traditions, and in the West by Gabriel Tarde, that Humanity may be compared to a brain of which individual human beings would be nerve cells. A central interest of noomics and noetics then, becomes the way human beings build, organise, exchange and evolve noetic material. In this comparison, noomics is the equivalent of genomics, and noetic the equivalent of genetic. One of the essential methods of genomics is sequencing; what would be the equivalent in noomics?

3. Expanding noomics

In developing the genetic metaphor to explore the scientific complexity of noetic material and its dynamic in particular, one of the first steps should be to establish the mesoscopic scale. Let us, by convention, establish this scale at that of a single human mind. In Gabriel Tarde and Auguste Comte's idea that Humanity could be a multicellular organism, noetics thus becomes comparable to cellular biology, and the upper scale, physiology. Let us therefore explore the scales right below and above that of a single human mind, and further develop the genetic metaphor. Phenomena of scientific interest in genetics and genomics include transcription, regulation, large-scale interaction and evolution. There are very comparable phenomena in noetics and noomics.
A very fertile comparison between genetics and noetics, genomics and noomics, is that indeed the human mind does *package* his thought. Noetic packaging is omnipresent in the creation, transmission and evolution of human thought. One of its origins is the distinction between long term and short term memory. Long term memory may be seen indeed as holding a much larger diversity of noems than short-term memory. Mnemonists, or "memory athletes", use various techniques to alternate their mnemonic retrieval between long term and short term memory, the most widely used being the "method of loci" also known as "memory palaces", the art of mapping mental objects onto space so as to facilitate the dialogue between spatial and immediate memory in memorising and retrieving large collections.

The interesting metaphor of noomics, then, is that noems held in long-term memory are packaged ones, and noems held in short-term memory are unpackaged or expressed ones. Thus, all the noetic code of a an individual, constantly rearranging, is partly defined by what is expressed, unpackaged, and what is not. We package our thoughts a little bit as we package our personal belongings. We can confine them in a certain mental volume, to move along with them, and then we can expand them to study, or showcase them to others, in further detail.

noetic packaging (4)

some of our thoughts are expressed, others are not. We could compare short-term memory to expressed noetic material, and long-term memory to packaged noetic material. a grand set of packaged noetic material may be called a noosome, and we may have sufficiently distinct ones to extend the genetic metaphor.

It also follows that one may ultimately compare the human brain to a cell, and systems of the brain, in particular of the cerebral cortex, as organelles. The hippocampus and entorhinal cortex for example, would be certain organelles, and the frontal cortex another set of organelles, critical in the construction of the global cognitive workspace, and in short-term memory in particular. The scientific metaphor is not at all far-fetched, when we consider that the sum of our current knowledge in cognitive neurosciences is comparable to that of our current knowledge of cellular biology.

noetic strands (5)

our mind assembles not only thoughts but streams of thoughts. These streams are highly unstable and volatile, almost as RNA is much less stable than DNA in a way. Let us call these noetic strands "CNA" for "Complex Noetic Acid".

Beyond mere scientific fun - humour and bewilderment remain vital componen ts of research - and that "CNA" is practically more memorable than "Noetic strand", such a comparison immediately brings that, very fertile, of transcription, translation and also of sexual reproduction, polyploidy etc.

general noomics (6)

We may compare the loading of a noem from long-term to short-term memory to genetic transcription (the conversion from DNA to RNA, that is). Short-term noetic strands are very unstable and volatile indeed. In this metaphor long-term memory is the nucleus, and short-term memory outside the nucleus.

lysogeny, sexual reproduction, lateral transfer (7)

T*he external world, which includes media (man-made signs carved out of the external world, designed to interact with our senses and intellect), can interact with our noome and modify it either on the short term or long term. in the genetic metaphor, long-term modification is comparable to viral lysogeny. Short-term modification could also be compared to polyploidy, the making of double-stranded noetic material, the coupling of one strand, external, with another, internal. Also, human minds may share noetic material, and this seems very much comparable to lateral transfer.*

translation (8)

Just as translation allows the single cell to express its RNA into another material, thus contributing to the emergence of a phenotype, the single mind may translate *noems into other materials, such as graphemes (writing), phonemes (speech) or many other things. One observation is that although the complexity tends to dramatically increase from RNA to proteins, it often decreases from noems to, say, phonemes. It does not when one considers the complexity of human creations at large, say, literature for example (graphemes) because the memory space that the external world allows seems greater than that of a single human mind. Unlike cellular translation too, the human brain has more than aminoacids at its disposal : it has graphemes, phonemes, gestures etc.*

The collision of noems is a way to serendipity or fortuitous discovery, and noomics immediately poses the question of the multi-scale dynamics of single minds, as physiology does with single cells.

4. Conclusion

It is scientifically fertile to consider the entirety of the mental objects an individual may handle from birth to death. Such a “noome” is a very complex object, for which the genetic metaphor also provides an interesting (albeit surely contradictable and improvable) scientific angle of attack. In this paper, I have deliberately placed individual intellects at the mesoscopic scale, and compared them to single cells. The modular parts of the human mind, in turn, I have compared to organelles, and individual noems, to individual genetic bases. Streams of noems I have called “CNA” and unlike RNA, although they are single-stranded material, their building blocks are mental states, or states of the “global cognitive workspace”, which are much more diverse than individual genetic bases, thus reaching one interesting limit of the genetic metaphor.

The latter metaphor is just an angle of attack of course, and should be peer-improved into a standalone testable theory of noetics and noomics. In this collective effort, simplicity should remain a guideline ; this article’s purpose is to break enough new ground to sparkle such an effort. For many questions remain open : what are the steps of translation, and of transcription ? What is the “alphabet” of thought ? The latter could be a risky metaphor indeed, as language is strictly less powerful than thought : any sentence may be expressed by thought but surely not every thought may be translated into a sentence. The search for “atoms of thought”, building blocks of thoughts in a way, has been a long investigation, with such scholars (from a Western point of view) as Leibniz, Ibn Arabi, Luc Benoist, Bergson, and even Wittgenstein - much-too-often considered to have heralded the superiority of verbalisation over unverbalised thought, which is but a reduction of his contribution - have all considered to be the founding problem of noetics. Noetics, ultimately, is the science of describing thought with thought. The challenge is stimulating; in founding genetics as a system of verifiable thoughts, we used thoughts to describe matter, but in founding noetics, self-description is inevitable.

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8. Posing the Mindscape and Serendipity Problems

Abstract. Many fertile problems remain to be asked in the neuroergonomics of User Interface. Here I attempt to pose two of them, the Mindscape and the Serendipity problems. Both are complex optimisation problems, calling for an evolutionary solution with non-trivial technical implications. The question is whether or not such a solution can be better than a random search, for either of the two problems. The Mindscape problem is the question "given a list of contents - for example a pile of documents - is there a better way to achieve an overview of them (*i.e.* a "Mindscape") than just throwing them all in front of me?". The Serendipity problem is then more complex: although serendipity is by definition a fortuitous, unexpected discovery arising from the interaction between several bits of knowledge, could it still be engineered? More precisely, if one approximates the n-serendipity of a given knowledge vector as the difference between the knowledge of its elements taken separately and that of its elements taken altogether, how could we maximise it in a user-collection interface?

Keywords : Self-organization, User Interface, Artificial Intelligence, Collections, Engineered Serendipity, Natural User Interface, evolved interfaces, evolutionary algorithms

"You've got to start with the customer experience and work back toward the technology - not the other way around."

—Steve Jobs
World Wide Developers Conference 1997

1 Introduction

The purpose of this paper is to outline two fertile problems in the design of self-organised, evolved user interfaces. With websites able to build themselves, self-organised product displays and showrooms, or natural user interfaces, the interaction between contents and users is growing not only in quantity but, more interestingly, in quality. This trend is increasing both the creation and consumption of contents. The bandwidth of exchanges between collections and users is constantly growing.

Internet entrepreneurs, Soudoplatoff among many others, have reminded that the value creation of technologies lied primarily in their usage rather than in their initial purpose and design. As Pranav Mistry also underlined, the aim is that technology serves human beings, not the other way around, so that we do not end up "being machines in front of other machines". Technology can either narrow or enrich human experience, but as contemporary user interfaces are necessarily specialised, and therefore limited, we must either end up limiting our mind to them, or enriching them to fit more and more of our mind. Again, machines serve Man, not the other way around. Thus, it is legitimate, as Steve Jobs put it and as Alan Kay had earlier clearly understood, to limit not the user experience to what technology can currently offer, but to stretch the technology towards a more daring user experience. This is particularly true of the interaction between users and large collections of contents. With the exponentiel growth of "mind contents" (contents that are consumable by the human mind), yesterday's user interface cannot address tomorrow's problems. Yet, should we mindfully design interfaces for case studies we do not yet understand, or should we let them evolve continuously to fit our needs? The purpose of neuroergonomics, in user interface design, is to clarify that, it is not for our brain to reduce itself to any interface, it is for interfaces to fit our brain better and better. Our brain is more complex than any user interface. Beyond complexity actually, it is the "simplexity" of the human brain that strikes us. We must aim to achieve such a simplicity in user interfaces. What could be better than coevolution to achieve such a goal ?

2 "Collections are for collisions"

Neuroergonomics is the study of the brain in natural working conditions, that is, neither in a pathological situation, nor in a controlled task. As Parasuraman (2003) put it, it is the study of the "brain at work". User interface is such a situation, and the neuroergonomics of both Information Technologies and education are still a vast scientific *terra incognita*.

Mixing evolutionary algorithms and neuroergonomics could be extremely fertile. The former is the science of fitting technology to the very most complex system of organs known to Man, the latter are rapid search and optimisation systems, precisely designed to fit complex landscapes in general. Simply put, neuroergonomics is the art of designing gloves, or glove-like tools, for the brain and mind. Indeed if natural tool design has originally consisted of conceiving handheld tools, then :

neuroergonomic design (1)

neuroergonomic design is the art of designing "brainheld" tools

On the other hand (pun unintended), evolutionary algorithms are a way to evolve such tools through trial, error and natural selection, until they simply fit best. Such as there are already "evolved antennas", there are "evolved user interfaces", which purpose is to fit usages as closely as possibly. Evolving ergonomics can inform both physical and software design, proposing original solutions as long as one has clearly posed problems to submit to them.

Thus, just as we can evolve satellite communicators (evolved antennas), handheld tools (evolved ergonomics), we can also evolve brainheld tools (evolved neuroergonomics). The idea of evolved neuroergonomics is an extremely exciting one from both a scientific and a user's point of view. Without the technology of evolutionary algorithms, man has essentially designed tools through low-frequency trial and error. With evolutionary algorithms, frequency, and selection can be dramatically increased, thus "crunching the time" of technological evolution.

In the interaction between users and collections, online for example, Bell (2014) has brilliantly reminded that "collections are for collision". Considering two elements of a collection together can bring about ideas that would not have emerged by handling them separately, which is the motive behind interdisciplinary studies, but a much broader principle in general, probably lying in the fundamental prolificity of knowledge. We may simplify the notion of serendipity by expressing it as the difference between knowing two things together and knowing them separately.

Approximate serendipity (2)

$$S\,(A \wedge B) := K(A \wedge B) - K(A) \wedge K(B)$$

let us define the serendipity of two bits of knowledge as the difference between knowing them together and knowing them separately

The purpose of proposition (2) is, above all, not precision, but simplicity. There are therefore many factual scenarios it may not capture: first, serendipity is person-dependent: the collision of two bits of knowledge will not provide the same result with two different persons. Second, it is unlikely that serendipity covers all of the difference between knowing *n* things together and knowing *n* things separately. Here however, it remains a practical simplification.

Let us consider such a collection as Wikipedia for example. For a given user, (and at a given time), the serendipity of two pages is the difference between considering them together and considering them separately. We could therefore generate an evolutionary algorithm designed to maximise the serendipity of pairs of pages for a user: the program would be designed to produce pairs of pages, and the user would kill those pairs that do not inspire him, and give positive reinforcement to pairs he would consider fertile. The question of course is, "is there a program that will be significantly more efficient than a random generator of pairs of contents"? This is the base of the serendipity problem, in collection interface. We may also note that for any collection, its potential, total serendipity is inscribed not within the collection itself, but within its powerset. In an ideal theory of collections and serendipity then, if we suppose that the serendipity of any *n*-plet of elements is non null, then any collection has an infinite serendipity, because the serendipity of its powerset can generate another serendipity. Simply put, if serendipity has no fixed point, if the serendipity of two elements themselves generated by serendipity generates another serendipity, any collection has a potentially infinite serendipity.

Now that we have considered the intrinsic value of serendipity in collections, let us consider that of the so-called "overview effect", that is, the idea that the overview of a collection is qualitatively superior to the consideration of its elements taken separately. This already seems epistemologically close to serendipity, but in terms of user interface, it can generate a much different optimisation problem.

3. From oligorama to panorama

There is a contemporary trend towards gesture-friendly user interfaces. After all, the graphical user interface (including the mouse) brought about the massive adoption of computer sciences in a business-to-consumer model, something revolutionary in its time. The general design philosophy, again, is that there is no particular nobility in reducing the human mind to language and usage of a computer, but that there is tremendous value to extract in the act of expanding computers to the human mind. Thus again, let us not fit the human mind to computers, let us fit computers to the human mind.

The concept of natural interfaces is very interesting epistemologically. We could consider it a bifurcation in interface design: how would computer sciences have evolved if they had been more influenced by, say, Henri Bergson and Maurice Merleau-Ponty rather than by Russel, Church, Turing and Wittgenstein? Pranav Mistry's concept of wearable gestural interfaces, now summarised in the "wear your world" (WUW) design philosophy, are bringing about this idea of advanced ergonomic user interfaces.

Still, from an epistemological and aesthetical perspective, there is a technique that the current Web (also known as "Web 2.*x*", the *2* standing for "second generation" and especially "social", and the *x* standing for that we do not know exactly which sub-generation of the social web is currently in progress) has yet to learn, and it is that of *perspective*. Beyond the ability to increase the number of collisions in collections, is the ability to overview large collections, and have a general, meaningful perspective of them. This is a typical task for mind ergonomic : how can we design collections to fit the mind rather than bend our minds to fit poorly-designed collections.

Panorama etymologically means "the vision of everything", from the root *Pan* - everything - and *orama* - vision. It could be very interesting for the human mind to interact with *panoramic collections*, namely, collections designed with the overview effect in mind. The complementary of a panorama then, is an *oligorama*, etymologically, "the vision of a few". The human mind seems naturally inclined to alternate between panorama and oligorama, and thus naturally needs both. Panoramas are probably better fitting episodic, long term or spatial memory (made for the hippocampus and entorhinal cortex for example) and oligorama, fitting working memory. Metaphorically, a panorama could be the landscape of an entire library, and the oligorama the opening of a single book. The interaction between panorama and oligorama is comparable with the interaction between *packaged* and *unpackaged* thought.

The current web is typically *oligoramic* and not *panoramic*, and so are most computer-based collections, partly because it has been a propensity of many computer scientists to find nobility in the ability to reduce the human mind to computer interfaces rather than to enrich computer interfaces towards the much more complex human mind. Computers do not need panoramas, hence we seldom developed any in computer-based interfaces. Besides, oligorama very well fits *exploitation*, from a cognitive point of view. In the trade-off between *exploration* and *exploitation*, the current Web is essentially exploitative. Panoramas, on the other hand, are made to fit exploration.

Google, for example, is a typical AI-mediated oligorama. It is made to narrow the immense collection of the Web into a mentally digestible shortlist, that is fit for working memory. Episodic memory and spatial memory, on the other hand, are not Google's trade. If we master AI-generated oligoramas however, how do we master AI-generated panoramas? This is the essence of the Mindscape Problem.

4. The Mindscape and Serendipity problems

Panoramas and oligoramas are not meant to compete with each other for human attention, but rather to form an ergonomic synergy in the user interface of collections. Surely a Panorama of web-based collections would facilitate exploration, while still requiring the ability to generate oligoramas on the fly, preferentially in a procedural manner.

Contemporary scientists are certainly not lacking data. Data, information and even knowledge are over-abundant. What they are lacking is perspective on all these collections, the overview effect. It is sincerely despicable that some scientists come to consider scholarly life as mere automated data collection, and Ph.D students data collection automata. Today the GAFTAM (Google, Amazon, Facebook, Twitter, Apple, Microsoft) generate more data at any time than the entire scholarly community. Let Data be essentially the realm of Artificial Intelligence, and let their purpose and their perspective be that of Humanity. One way of maintaining an exponentially-growing collection within one's visual field is perspective. And we may very well, also, equate wisdom with the perspective on knowledge. Perspective, it seems, may be something genuinely human.

Mindscape (3)

A Mindscape of a collection is a panoramic perspective on it. Panoramic is here used in the etymological sense: "the vision of everything".

Hence :

Special Mindscape Problem (4)

for a single *viewer, given a collection of one-paged documents, stacked in a single pile, is there a better way to achieve a Mindscape on it than merely throwing them before oneself (which is the etymologic definition of "projection")?*

Can there be self-organised Mindscapes, self-organised panoramic projections of collections? Can there be panoramic projections of collections that would be more ergonomic than random projections? The human brain and mind are surely very precisely specific landscapes and randomness seems not, intuitively, the best way to fit them. Yet, solutions to the Mindscape Problem could also prove very counter-intuitive. Still, optimal mind ergonomic, one expects, should carry a lot of information, and therefore be quite the opposite of randomness. Also, in the art of fitting the brain and mind, one would expect to find a certain art of knowing them as well, for as many a designer would acknowledge, ultimately, *fitting is knowing*.

Is there a better way than a random projection to fit the human mind's ideal perspective on a collection? This is an expression of the Mindscape Problem. The Serendipity Problem, on the other hand, becomes:

Special Serendipity Problem (5)

Is there a better way to maximise the serendipity of a collection, for a single viewer, *than a random projection?*

General Serendipity Problem (6)

Is there a better way to maximise the serendipity of a collection, for n viewers, than a random projection ?

Distinguishing between a Special and a General Serendipity Problem is particularly interesting : could there be such a thing as "mindprints", just as there are "fingerprints", making the optimisation of serendipity beyond randomness possible for an individual and increasingly less possible when the diversity of individuals increases ? Or would mind polymorphism remain sufficiently bounded to allow for a general optimisation still ? From seemingly very trivial premises, we come to find very non-trivial questions indeed. And thus :

General Mindscape Problem (7)

for n viewers, *given a collection of contents, stacked in a single vertical list, is there a better way to achieve a Mindscape on it than throwing them randomly before all of them ?*

5. Conclusion

The exponential growth of digital collections poses the problem of finding a more optimal surface of contact between them and their users, either individually or collectively. The art of improving the contact between users and contents is that of user interface design. The art of fitting the human mind and brain is one aspect of neuroergonomics. The art of letting interfaces self-organise and evolve is that of artificially-intelligent user interfaces, in which evolutionary programming could be particularly promising.

One of its challenges is to pose the right questions, rather than diligently answer bad or irrelevant ones. I believe two extremely relevant family of questions have been posed here : the optimisation of ergonomic panoramas, and the optimisation of the serendipity of their interaction with a user, or a collection of users, either organised in a network or considered independent from each others.

My personal intuition is that the mindscape and serendipity problems should better be solved together ; one would expect ergonomic mindscapes to also maximise fertile collisions between contents, and therefore their serendipity. I believe these two related families of cross-disciplinary problems (bringing together neuroergonomics, user interface, artificial intelligence, and possibly biomimetics, because there may be biologically-inspired solutions to them) can inform further fertile results in the study of complexity at large, and also further fertile questions, growing in precision. They are after all, but simple premises to a family of interesting problems ; surely this family can grow in complexity, or ideally, simplexity, that is, the art of remaining simple while grasping complex objects. Simplexity is a beautiful ally of mind ergonomy.

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9. Neuromimicry and Natural User Interfaces : a theory of Merleau-Pontian Universes

Abstract. What if User Interface and computer input/output systems had evolved not only from, among others, the thought of Hume, Wittgenstein and Turing but from that of Bergson, Von Uexküll, Merleau-Ponty and Varela ? This section outlines a theory of post-WIMP[34] Natural User Interfaces, and in particular of affordance-based interfaces that would be more semiotic than semantic, and use as little language (ideally, no language at all) as possible so as to avoid the need for translating contents. Consumer electronics has indeed evolved from PC (Personal Computer) to post-PC (smartphone and tablets) and to post-post-PC (including wearables) and the advent of Virtual reality and augmented reality has put more motion, proprioception, affordance and semiotics in our interaction with machines. The prevalence of proprioception and affordance in cognition was theorised by Merleau-Ponty and Varela among others. Drawing from their thought, I define a type of User Interface I call a “Merleau-Pontian Universe”, which has to be affordance-based, habit-proof, and less linguistic.

Keywords : semiotics, Umwelt, affordance, stygmergy, perception, action, Virtual Reality, Augmented Reality

“Vision is a palpation by means of the gaze”
—Maurice Merleau-Ponty[35]

Introduction

If any media is but the externalisation of a mental function, there are many such functions that could still be externalised, and we could systematise the process of generating new media by exploring mental functions. This exploration, also, should be systematic. The scientific premise of this section is that we have seldom been systematic in attempting to externalise mental functions, and that were we to apply such a rigour, we could unveil many different media.

There is little doubt that even today, the neuroergonomics of User Interface (in the narrow sense of Man-Computer interaction) is essentially linguistic. Personal Computers have a screen a keyboard, but this balance between visuo-perception and language is leaning increasingly towards action and vision and less towards language, when Post-PC interfaces (eg. smartphones and tablets) do not always have a keyboard and Post-Post-PC ones have discarded them altogether (eg. the Oculus Rift, the Microsoft Hololens, etc.). Are we therefore returning to a KINDof “Continental-inspired computer

[34] WIMP stands for “Windows, Icons, Menus, Pointers”
[35] Merleau-Ponty, M., Toadvine, T., and Lawlor, L. (2007). The Merleau-Ponty Reader (Northwestern University Press). p.396

science”? What if User Interface indeed, had evolved not from, among others, Analytic Philosophy, with its importance of language, deduction and sequence, but from Continental Philosophy and in particular phenomenology (Bergson, Merleau-Ponty, Husserl), Physio-phenomenology (Von Uexküll, Gibson) and neurophenomenology (Berthoz, Maturana, Varela, Burnod)? This section discusses to which extent the current direction of User Interface design is realising this trend, and how it could be prolonged, theoretically and technologically.

2. “Dorsal media” and the Babel Problem

In the so-called “two stream hypothesis of vision” (Milner & Goodale 1992) and the even more fascinating, and recent, VSA/PTF “dual intertwined ring architecture” of Mesmoudi *et al.* (2013) there are many neural pathways that remain to be externalised. One could consider that writing already partly externalises the “What” visual pathway of Milner & Goodale, and that Hyperwriting attempted to partly externalise the “Where” one. Affordances, as defined by Gibson (1977) may involve the “PTF” pathway of Mesmoudi *et al*. and hence the so-called “Where” and “How” visual pathways. Affordances, in Gibson’s ecology of perception, represent the semiotics of prehension, initially, physical prehension, but one could also define mental prehension: how to “mentally grab” a certain concept or object, and for this, many different perceptual and mental angles of attacks could be offered to the working human mind. This perspective is not trivial, because the angle of attack by which our mind grabs, memorises and uses a concept, especially in mathematics, will influence the further uses of it, in a stygmergic fashion (mental routines may be reinforced, and suppress alternative ones for example).

The advent of real-time and even procedural 3D in user interface, and the further advent of Virtual Reality and Augmented Reality is clearly calling for affordance-based media, endowed with their own semiotics, and that could ultimately avoid the use of language (and therefore, translation) altogether, thus creating a non-verbal way to communicate contents that could be rich and reliable. So far, such a way does not exist: we know no non-verbal non-coded way of forwarding orders in a chain of command for example, or of communicating contents online.

The World Wide Web, however, is growing increasingly divided and no *lingua franca* has clearly emerged on it. Social networks like vkontakte, renren, weibo, naver or kakaotalk will be almost impossible to navigate without a clear proficiency in Russian, Chinese and Korean respectively, and the emergence of the ASEAN as a major provider of digital contents worldwide is reinforcing this trend. Hence, the Web is increasingly facing the “Babel problem”, that of finding a common, intersubjective or interobjective means of communication to coordinate populations that are not using the same language or not sharing the same expertise. The resolution of this problem could call for non-linguistic interfaces. Cinematographer Antoine Le Bos also came to the same conclusions[36] by calling for a new form of 3D-based cinema that would tap into the dorsal stream, by design, and use this new media to change what artists can represent in a motion picture. Maybe in itself, the very notion of a "motion" picture could take all its meaning this way.

McFarland 2002 summed up the differences between the Ventral and the Dorsal streams of vision in this table:

Factor	**Ventral system**	**Dorsal system**
Function	Recognition/identification	Visually guided behaviour
Sensitivity	High spatial frequencies - details	High temporal frequ.- motion
Memory	Long term stored representations	Only very short-term storage
Speed	Relatively slow	Relatively fast
Consciousness	Typically high	Typically low
Frame of reference	Allocentric or object-centered	Egocentric or viewer-centered
Visual input	Mainly foveal or parafoveal	Across retina
Monocular vision	Generally reasonably small effects	Often large effects[37]

3. What is a Merleau-Pontian Universe ?

The general idea is to design a user interface that an illiterate person or a person with definite lesions to their physiology of language could still use fluently. The interest of such an interface would be to solve the "Babel Problem" for online contents, so that an exclusively Chinese-speaking person and an exclusively English-speaking person could exchange contents with an intersubjective or, even better, interobjective way.

Such interfaces are already emerging. Pranav Mistry's "Wear your World' interface is nearing one of them, but the most interesting would be Glen Keane's "Step into the page" interface. To me, Keane's technology, and that promoted by the "Future of Storytelling" group altogether, represent the best state of the art towards a "Merleau-Pontian Universe" (MPU). It is interesting to also note that Al Gore is a member of the advisory board of the initiative. Anybody who has successfully found a way to improve the way human beings exchange knowledge has profoundly changed the world, from the many inventors of writing to Vannevar Bush's speculation over the "Memex" or "memory extender" which would become known as the Hypertext, or Tim Berners-Lee's creation of the World Wide Web.

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[36] Antoine Le Bos "Monde à Plat, Monde en relief" TEDx Rennes June 6th 2015 https://www.youtube.com/watch?v=Hx8xit20swA

[37] eg. motion parallax

I coined the term "Merleau-Pontian Universe" at the "Coglunch" talk at Stanford University[38]. The notion has been further cited and improved by Jean-Yves Heurtebise[39]. They were an evolution of hypertext, with the idea of optimising the trade-off between exploration and exploitation in the interaction between contents and users. I wanted this interaction to be "least linguistic" which would become a fundamental criterion of MPUs, that I eventually defined along those three criteria, which could be summed-up in the ProHaLe memonym :

- proprioceptive
- habit-proof
- least-linguistic

Software that resonates with mental functions would be neuroergonomic in nature. An MPU should tap into the proprioceptive neural pathways, for example Mesmoudi *et al.*'s PTF ring or Milner & Goodale's dorsal stream of vision. "Habit-proof" is a more interesting property: it means that a MPU should, in some way, "reshuffle itself" just enough to avoid the user from losing all of his marks, but enough still, to present him with contents he would not have explored otherwise. The idea is that the collection, the contents, should constantly encourage the user to avoid strict exploitation. Online navigation, nowadays, is essentially keyword-based, and the interaction with unexpected contents made through links or recommendations. If the World Wide Web were a truly navigable ecosystem or a virtual world, users could stumble upon contents they would not have been searching in the first place, not only through their hyperlink proximity. The art of encouraging users to "stumble" upon contents has been considered so crucial that eBay purchased the so-called "discovery engine" StumbleUpon in 2007, an engine that was precisely made to deliver the service of helping users "stumble" upon unexpected contents. The very idea of a "discovery engine" as complementing the regular "search engines" is interesting in itself. Such engines would not be competing with them but rather, again, complementing their service, in the sense that a discovery engine would tap into exploration, from a cognitive point of view, and regular search engines would tap into exploitation.

An MPU is therefore a "discovery engine" by design, that is conceived to also be least-linguistic and proprioceptive, two properties that are not present in the StumbleUpon engine. As a list of structured contents, an could also be the object of its own transfer protocol (namely "mputp" for "merleau-pontian universe transfer protocol". The idea of using MPUs to structure contents online is a "Vitruvian endeavour", in the sens that Vitruve wrote his treatise on architecture, advocating that the urbanist use the various spans of the human body as means to structure a city. So could be done with the structuring of online contents: their architecture could be established not from their own

[38] "Kinesthesia and Cognition: towards the Merleau-Pontian Universes" Idriss Aberkane CSLI Coglunch, Cordura Hall May 31st 2007 12h. A trace of this talk is recorded here http://web.stanford.edu/dept/linguistics/newsletter/v3/v3i29.html

[39] Heurtebise, J-Y. 2011. Penser la danse ou Qu'est-ce qu'un Corps? (Un Univers Merleau-Pontien). In: Penser les matières du corps, S.-A. Crevier-Goulet (Ed.), Paris: Editions Sorbonne Nouvelle, pp. 219-232.

structure, but from that of the various *human cognitive spans*. And since the cognitive span highly depends upon the neural pathways (that of working memory have a much different span than that of episodic memory for example) a founding principle of applied neuroergonomics could consist of structuring collections of contents not (only) on their own metrics, but from the one of the various spans of human cognition. Ideally, the best User Interface would use the inner metrics of contents to fit them to the inner one of cognitive spans ; after all, the two should not necessarily be opposed. This, still, is the Virtuvian endeavour : defining the architecture of contents from the spans of our cognition.

Merleau-Pontian Universes should ultimately merge perception and action, because as Berthoz (1997; 2002) and others (Merleau-Ponty and Bergson among them) have already well understood, perception is an action in itself., something that has been overlooked in the regular computer science paradigm. MPUs should provide affordances to the human mind (conceptual, or “noetic” affordances, *i.e*, constructions to adjust the span of the object to the span of the human mind) and generate a semiotics based on it. The idea that they should be habit-proof means they should resist mental stygmergies. An interesting reflexion I may quote as inspirational in their design is Daniel Wolpert’s one on that “neurons are for movement”, and indeed, the evolutionary emergence of neurons has been not selected out of the ability to communicate but out of that to move. This Bergson had well explored as well. How motion and cognition should interact with each other in the navigation of virtual contents, this is exactly the question that Merleau-Pontian Universes should solve. Ideally, they should solve the Mindscape and Serendipity problems, although this is not necessary ; note already that a virtual universe that would be habit-proof should probably encourage serendipity in itself.

4. Conclusion

There is a wide diversity of new services and softwares to create from the simple reflexion that contemporary User Interface is overly linguistic (Personal Computers have a permanent keyboard, Post-PC interfaces do not, as well as Post-Post PC ones). This leads us to a fascinating reflexion in particular: what would Bergson, Merleau-Ponty, Berthoz, Maturana and Varela have thought of Post-PC interfaces? This goes beyond the simple idea of motion-based interfaces (*e.g*. Microsoft Kinect), because this calls for mental ergonomy just as much as it does for physical ergonomics. A computer mouse for example, abides to the simple ergonomic principles that it should fit our hand. Contents, also, should abide to the simple principle that they should fit our mind. The span of our hand, however, is much less versatile than the span of our mind, our mind is much more modular than our hand. Before we fit contents to the human mind, therefore, we must ensure that they are *routed* properly to the right mental modules, or series of modules. This is the interest of dynamic neuroergomics as applied to User Interface.

Any media is an externalisation of a mental function, so we have much leeway to develop new media, because many mental functions have not been externalised yet. Actually, mental functions that have been externalised are the exception, not the rule, and we have much to win and learn in externalising as many mental functions as we can. Here I have simply outlined a theory according to which we could design new "discovery engines" that should be ProHaLe, namely Proprioceptive, Habit-Proof and Least-linguistic. I have called them "Merleau-Pontian Universes".

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Mind Ergonomy in the Knowledge Economy

Part 3

“What ?”

(Unless otherwise stated by Idriss Aberkane, this section is CONFIDENTIAL until January 1st 2021)

10. General Gamification for the Knowledge Economy : Why ? How ? What ?

Note : This section is CONFIDENTIAL until January 1st 2021, unless otherwise stated by Idriss J. Aberkane. Code was provided by Philip Belhassen under the Shiva 3D Game Engine for the KFlow 3D Interface, and by Serge Soudoplatoff for the kFlow 2D Interface. The Logos interface was coded by Vastpark and Serge Soudoplatoff under game designs by Idriss Aberkane.

Abstract. Discussed here is the interest of gamification as a means for the faster transmission of knowledge at any scale. It is argued that gamification can be an excellent candidate to solve the knowledge flow problem, either individually or collectively, as it is a means to capture focused time and attention, which, combined, are the most fundamental currencies of knowledge economy. In this section I outline answers to three questions regarding gamification for Knowledge Economy: Why should we resort to it? How can we do so? and What could be some practical applications? The latter will consist of two short outlines for a game design document, one regarding the individual knowledge flow, called "Logos" and the other regarding the collegial knowledge flow, called "kFlow".

Keywords : ATLASER, motivation, 70/20/10, gamification, crowdsourcing, stygmergy, cooperation, citizen science, neuroergonomics

1. Introduction

This section is an open, improvable and contradictable opinion piece on the interest of resorting to gamification for Knowledge Economy, supplemented with proposals for game design documents. We do have perspective on the adoption and use of video games in education or for other professional matters, but surely not enough to warrant too many certitudes. What I want to discuss here is to which extent gamification could constitute a critical art in building the "knowledge superhighways" that we so badly need.

This section will then answer the three questions: "Why should we resort to Gamification?" "How do we do so?" and "What may it give us?"

2. "Why": the knowledge superhighways

The first reason to resort to gamification in the knowledge economy is that it can command a large quantity of individual or collective @s (that is, the joint expenditure of attention and time), and @s are to the noosphere what momentum is to the kinesphere (see chapter 4). Gamification therefore has a vast potential for Research and Development, as was proven by crowdsourced video games Foldit[40], Galaxy Zoo[41] or other Citizen science projects as - Polymath[42] which is notably co-supervised by Field Medalist Terence Tao.

This phenomenon I may call an "ATLASER", namely a laser made of @, attention and time. Collective games for the solving of scientific problems have the ability to command, and focus, a very large amont of resonating, coherent (non mutually-destructive, because it is cooperative in essence) attention and time, and no scientific problem can resist the resolute and protracted exposure to focused human attention and time. Economies should learn to develop such ATLASERs if they want to crack important, hard, scientific, technical or political problems. These social devices could become very important technological pieces in the knowledge economy, and critical elements of the emerging global knowledge infrastructures. Any organisation commanding a powerful ATLASER could also yield an equally vast amount of soft power.

Gamification also has the potential to increase commitment and focus, being addictive by design and by business model[43]. Simply put, if gamification is used correctly, and with the full consent of the (*e.g*. knowledge-based) worker of course, it is a way towards excellence and acute competitiveness. Google has been famous for implementing Eric Schmidt's 70/20/10 rule according to which employees should spend 70% of their paid time on the current task that was assigned to them, 20% of it on tasks related to their core business and 10% of it on tasks unrelated to it, even if they are completely creative or even seem futile, such as entertainment and leisure[44]. Many novel product lines, Sergei Brin and Larry Page claimed, came from the last two sections of this breakdown.

Again, a simple way of putting it is that gamification has the potential to increase knowledge flow, which we may call "k-flow" (hence the name of the collective serious game I present in this section) and that k-flow may precede cash flow in many organisations even when they are not necessarily tech-centered. The Flow of novel knowledge, or the ability to crack deep into unexplored knowledge, is that of an ATLASER, of which the critical variables (metaphorically, intensity, the amount of users, and voltage, their expertise) are not yet assembled in a predictive equation.

[40] https://fold.it/portal/
[41] http://www.galaxyzoo.org
[42] http://polymathprojects.org
[43] On January 2015 CNN reported the death of a Taiwanese national after three days of uninterrupted gaming, which, they commented, was the second death of such nature in the island in the last 12 months http://edition.cnn.com/2015/01/19/world/taiwan-gamer-death/
[44] John Battelle (December 1, 2005). "The 70 Percent Solution: Google CEO Eric Schmidt gives us his golden rules for managing innovation". CNN Money magazine.

3. "How": a general art of gamification

A problem with gamification is that it is too much of a case-based craft. Nobody, today, has a general way of gamifying tasks, and hence gamification has not yet entered the industrial age, in the sense that it is not easily reproducible and context-free in its application. Serge Soudoplatoff[45] has defined three principles to gamify contents however: Fun, Collaborative and Engaging. This could also apply to what Clay Shirky's works[46] have lead to call "Github Democracy", the possibility that the people directly edit, fork, share and pass laws without the need for a representative legislature.

Stanislas Dehaene has defined the following "four pillars of learning"[47]:

- Attention
- Active engagement
- Feedback
- Consolidation

and video games indeed can reinforce all four: they easily command attention, being immersive, they invoke an active engagement on behalf of their users, their very dynamic relies on feedback, and being addictive, they call for a repeated use, and even, in the case of "appointment gaming" (a game mechanic consisting of giving an appointment for the user to play at or from a certain date), they precisely encourage consolidation.

A good way to gamify a task then, consists of identifying its modular components (or subtasks) and design a way to have the user repeat them with increased levels of difficulty, in a way that should not disgust but rather engage, and "hook" the user. Another way is that of "side learning", focusing the user on a game which is very tightly correlated to the command of the task that is to be learnt. In this way, the user should not even be aware that he is learning, and simply reproduce a certain task that is inevitably correlated to learning, that is, the fulfilment of which cannot be achieved without mastering the skill that is to be learnt. To put it simply, metacognition can be cumbersome for the learner (knowing that I have learnt can be either discouraging or encouraging) if the learning is rewarding in itself, then metacognition is not needed as a reward anymore, and may not be continuous, so that the awareness that one has learnt can be followed with a sort of more massive "wow effect".

The advantage of side learning is the possibility to tap into other neural pathways than that of regular book-based or lecture-based learning. In general, gamification potentially offers larger flexibility in neuroergonomic design, in the sense that, being multimedia by nature, it is also multimodal, and therefore, offers a larger variety of mind

[45] personal communication
[46] Clay Shirky, June 2012 TED
[47] Stanislas Dehaene Nov. 7th 2013 ParisTech Review http://www.paristechreview.com/2013/11/07/apprentissage-neurosciences/

modules (and their neural correlates) to stimulate. The establishing of a skill in the human brain may not necessarily tap into the same neural pathways for everybody: we know there is a neurocognitive polymorphism even in the skill of reading and writing, even though they are highly constrained by the brain. Other skills, less constrained, could therefore be mapped in a much more versatile way, even after a long consolidation. Consolidation is known to reinforce and focus neural pathways, something that can be observed by how a trained subject may perform the task in parallel and with a reduction of the spillover of the neurovascular response: all things being equal, expertise tends to reduce the contrast of the specific functional signal in fMRI (For example, Erickson *et al*. 2007). All in all, an essential way to resort to gamification is to increase the multimodality of learning, to redistribute the cognitive load of a certain task. This is neuroergonomic in nature.

Another fascinating reason to resort to gamification is that it encourages *deliberate practice*, which K. Anders Ericsson (1993) has defined as the holy grail of expertise. The addiction and seamlessness of games (video or not) very much encourages the behaviour of playing them and training for them deliberately. Deliberate practice, Burnod also points out[48] can be enhanced by mentoring, which is different from regular teaching, in that the respect of a pupil towards a mentor encourages deliberate practice while that towards a teacher usually does not (hence, homework are very rarely deliberate practices: deliberate homework are the exception, not the rule. They should be the rule however).

What Burnod brought to my reflexion then, is that there are still many unexplored At multipliers. Mentors and guides, through cognitive stygmergy can encourage learners to upgrade their knowledge in a more efficient direction, although this may not escape the exploration/exploitation trade-off. For example, a learner of a certain martial art will forbid himself to learn the moves of another, not deliberately, but merely by reinforcing the pathways prescribed by his training. Hence the Sufi: “Truth has no form”. Maybe a formalism inspired by quantum mechanics comparable to that of Aerts & Gabora (2005) could help us represent this sort of “decoherence” (the selecting of a single state out of an entangled infinity) that expertise creates by picking up one actual style out of many potential ones. Learning alone and learning through guides, mentors or peers.
Serge Soudoplatoff also pointed out the interesting experience of Soviet Persimfans or conductorless orchestras, that emerged in the Soviet 1920s. One of their observation was that a conductorless orchestra could perform at the same level of excellence than a conducted one, but that the training for it was much longer. This would confirm Burnod’s idea of mentoring and guiding in the building of expertise.

[48] personal communication

4. What? Outlines for two Game Design Documents

Here I present two cases for neuroergonomics *ex ante* in serious gaming. One, “Logos”, is a putative application of side learning in language education, that is, at the individual level. The other, “kFlow” is a collective game, a collegial interface to increase the flow of knowledge in enterprises. Logos is only a design so far, and kFlow is a game that was already delivered to various multinational companies (including the Jarden group, Mazars, Orange, the French Association Progrès du Management and Amundi), each time with more than twenty players.

4.1 Logos: a game to learn languages in a procedural manner

Logos would be a game to learn any language, based on the architecture of combat games. The mechanics of combat games *(e.g*. Street Fighter, Soul Calibur, Tekken) is based on the exact execution of moves and combinations or moves. Each move is a series of controls on the analogic pad. Each move also, and combination of moves (“combo”) is a subset of a generative grammar. Simply put, the set of all combat moves in a combat games usually forms a simple, generative grammar, at least in the most successful ones.

Hence, the idea is to teach languages through a combat game, in which correct moves are correct sentences, and in which combat “combos” are correct series of sentences. Each character would have to deal damage to an opponent by forming sentences out of words displayed on a touch screen. Words, in this way, would not (only) be interpreted as holding a meaning, but as holding a purpose in the game, that of dealing damages to the opponent. Just as a combat move in a game is a series of say “button A” “button up” “button B”, a combat move in Logos would consist of a series of buttons, each labeled with words. The damages dealt by the move could be correlated to the information of the sentence (classically defined as -log(p) where p is the probability of the sentence to form out of white noise, that is, the Shannonian interpretation).

This would only a typical case of side learning: the learning of language would be correlated not with pure semantic and phonologic acquisition, but with procedural routines. In a way, it would be an attempt to redistribute the cognitive load of language learning (and the motivational load of maintaining a protracted learning situation over several days, one of the most critical steps in learning a new language) over procedural memory. One could end up mastering a language without being able to explain its grammar verbally for example, which is the way a child will learn a language (that is, not analytically, and not being able to explicit its grammar in a declarative way) or the way anybody will learn to walk, or tie a tie, that is, without being able to explain it in a declarative manner.

In short, Logos would be a regular combat game, except that characters, instead of having a set of moves and combos, would load a phrasebook with sentences to train on. These phrasebooks could be fixed or could be edited and improved in a crowdsourced manner, by a social network for example. Players would play on languages that they do not know, or poorly know, and could be guided in their progression either by observing other players, or through Quick Time Events (QTEs, showing the player in advance what he has to do in a game). The interest would be to tap in the great ergonomics of combat games regarding motivation and persistence, and in the equally great ergonomic of procedural learning for contents that are normally learned in a rather analytic way, especially in the case of the adult or continuing education of languages. Ultimately, mastering a certain language would be equivalent to mastering the moves of a character, and delivering blows in the fastest and the most accurate way. Semantic contents could be further taken into accounts, or the prosody of sentences (*e.g.* a rule could be given that to counter a certain sentence, the player must oppose it with a rhyming one, or with one with a corresponding meaning). The video game Monkey Island (LucasArts 1990) had already created a very simple sub-game engine based on semantic matching, in which fighters had to oppose each others with matching insults.

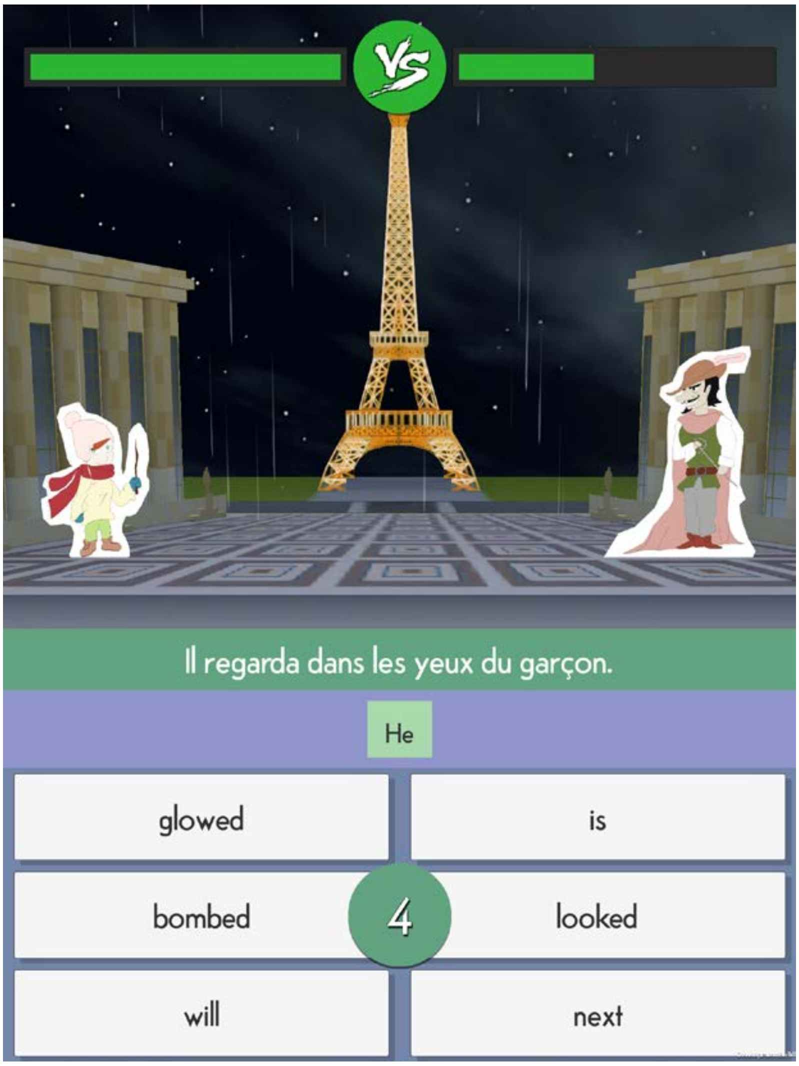

Fig. 1 Version 1 of the Logos Gameplay; a character resembling the Little Prince is fencing with another resembling Cyrano de Bergerac. Rather than being buttons, controls are individual words that must be assembled in correct, and matching sentences. The backoffice of Logos then generates bigrams based on the information (-log(p)) of each sentence. Coded by Vastpark and Serge Soudoplatoff.

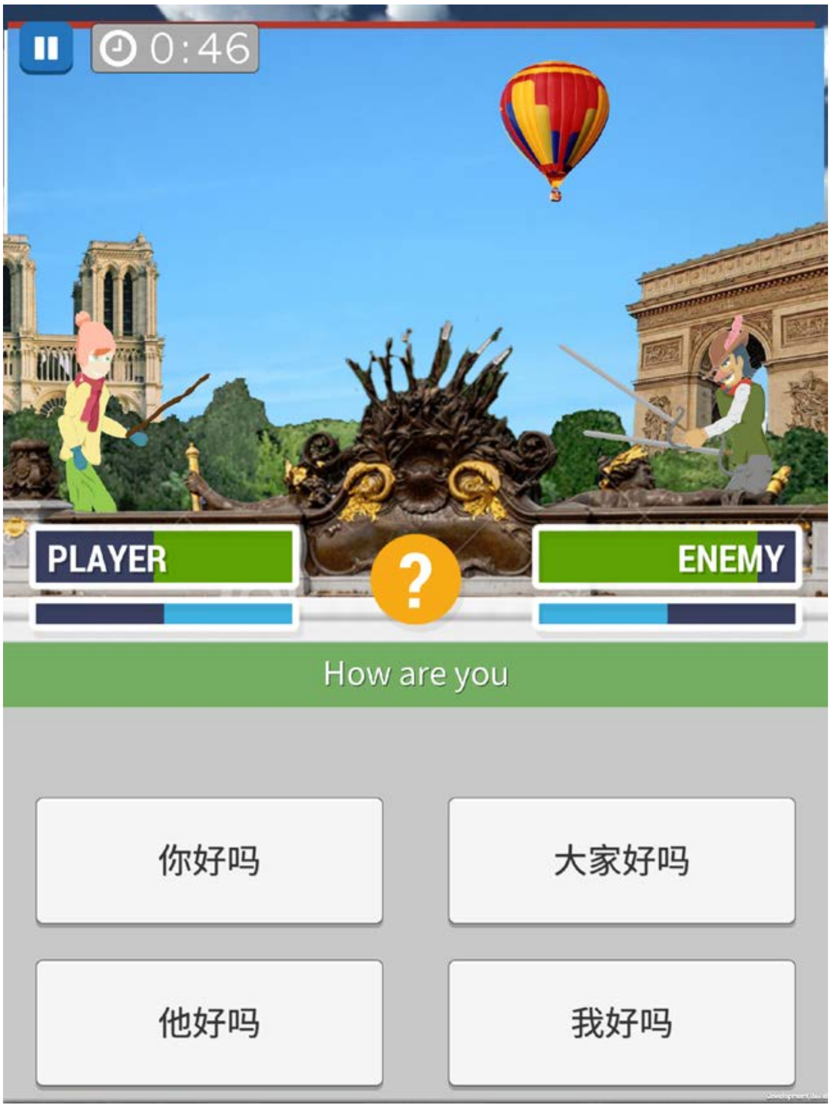

Fig 2. Version 2 of the Logos gameplay, loaded with a Chinese phrasebook and with improved graphics. A timer appears on the upper left corner, defining the duration of the engagement.

4.2 kFlow, a collegial interface to gamify business development

I initially developed kFlow for my Master students at the CentraleSupélec school of engineering, with the first test being conducted with more than twenty-five students in 2011. The idea was to gamify the teaching of business cases, and to be able to teach many simultaneously, by tapping into episodic memory rather than working memory only. The game had to be immersive, and rather than exploring cases one by one, would consist of pitting companies against each other for a better immersion (eg. Google v. Baidu, Apple v. Microsoft, Dupont v. Monsanto[49] etc.).

kFlow is comparable to the game "Risk", it is a real-time strategy game that is played on a map (either Google Maps or Open Street Maps) and in which each team embodies a certain company or organisation and has to achieve strategic objectives by posting two kinds of markers directly on the map: decision or information. These markers are reviewed by a "market" team delivering "likes" to them, and receiving such "likes" will grant the playing team with the initiative to post additional markers. This initiative is represented by an "energy" count, energy as the etymology indicates, representing the ability to act in the game.

The primary objective in kFlow is to accumulate as many likes as possible for one's team, by posting brilliant, disruptive or simply working ideas which have to be pitched to the Market team, either online or physically, in the war room. kFlow indeed is a kriegsspiel or a wargame, in which teams are encouraged to oppose their strengths to the weaknesses or their opponents. The result is a scramble for markets, much like in real-life business development, but where information is much better handled, shared and memorised, as its elaboration is both narrative and collegial.

In a way, kFlow resembles the Google game Ingress, based on Augmented Reality, and in which players must physically meet in the real world to act in the game, except that such a correlation is not (yet) used in kFlow. In Ingress, two opposing teams play on a map based on the Google Maps service, with the game mechanic increasing commitment and perseverance to "hack portals". In kFlow, opposing teams peer-pressure each other into the highest disruptivity and creativity to conquer markets

[49] these were the actual companies studied in the first case

Fig 3. Screenshot from the Ingress game, where two opposing teams compete to control

"portals" represented by the coloured dots on the map (Copyright Google 2011)

Fig 4. screenshot of the 2D kFlow interface (back-end coded by Serge Soudoplatoff, Front-end coded by Sooyoos). Grey markers represent Market challenges, colored markers represent suggestions and responses from the teams. This game was played by the Jarden group in 2014, hence the content of markers is confidential and not displayed here. The game opposed Jarden, Villeda, Dorel and Ansell

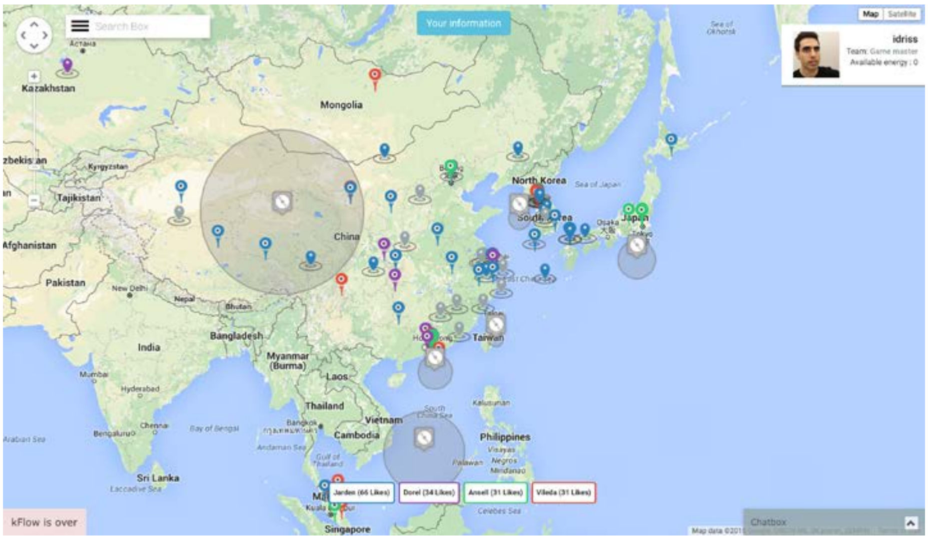

Fig 5. Detail from the same game, contents are confidential

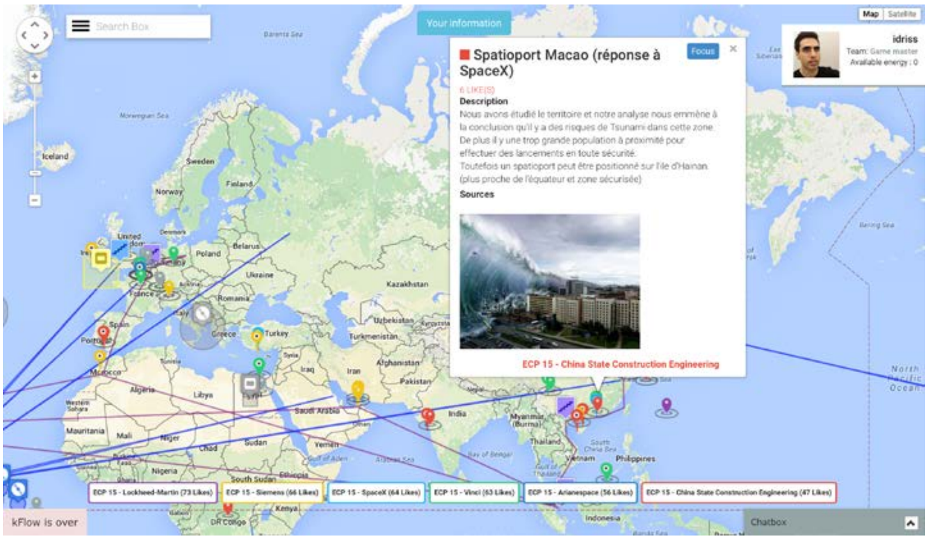

Fig 6. Detail from a game played at CentraleSupélec (Paris-Saclay University) in 2015 opposing Siemens, Vinci and the China State Construction Engineering company on the one side and Arianespace, SpaceX and Lockheed-Martin on the other. The game was played in French, and a marker is open.

Fig 7. Game played by Amundi in 2015, with spare markers on the sides . Contents are confidential.

Fig. 8 Prototype of a kFlow 3D interface (front-end by SaphirProd)

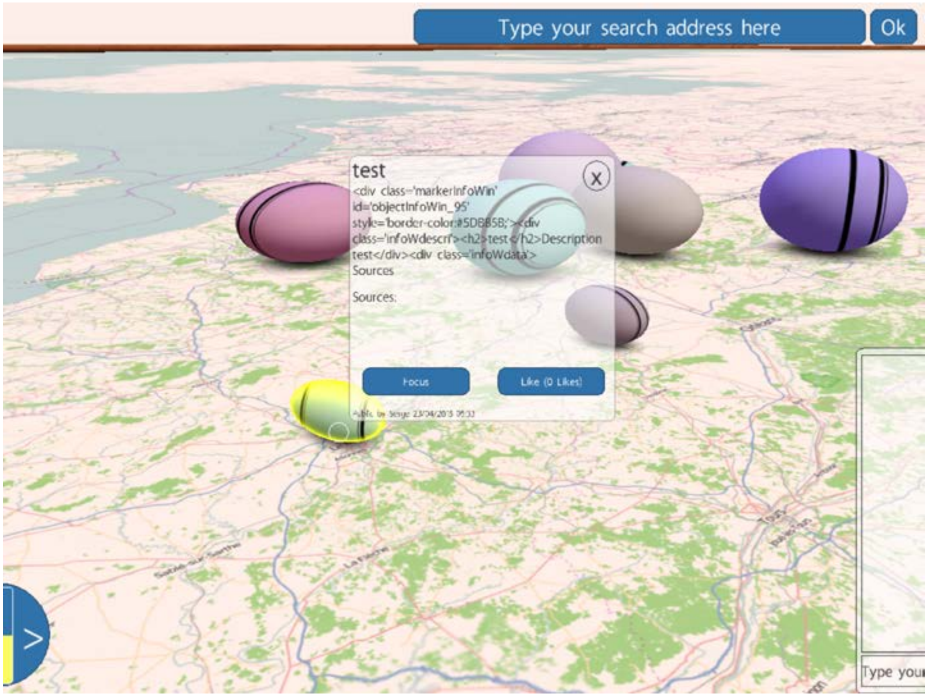

Fig 9. Prototype of a kFlow 3D interface, still inspired by the RUSE interface by Eugen Systems and their IRISZOOM game engine. Taking the expression "mental calculus" quite literally, I represented ideas as pebbles (stones / calculus) to be placed on the map, here Open Street Maps.

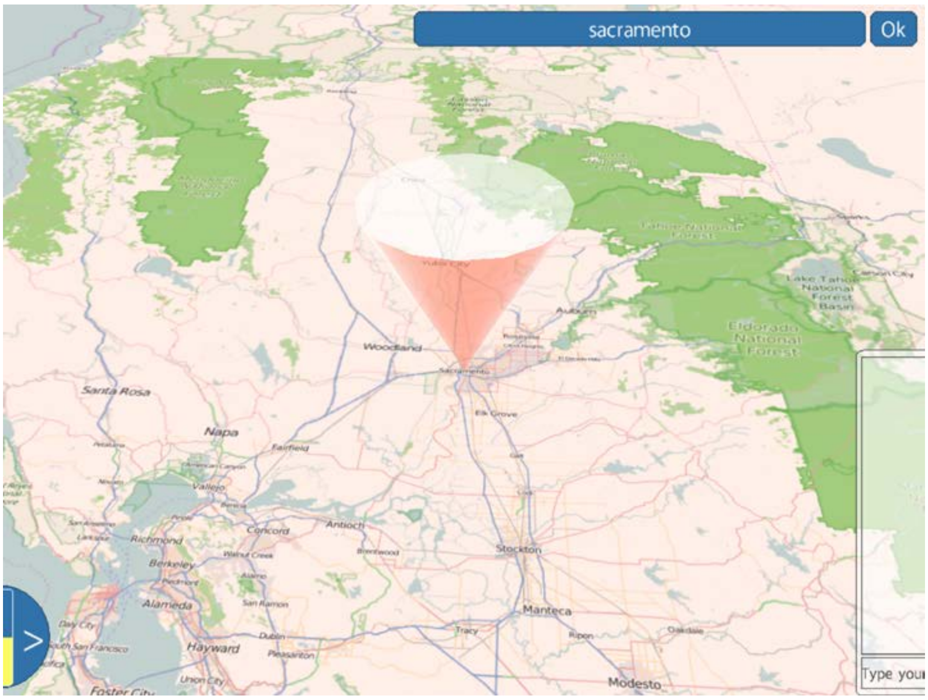

Fig 10. Basic pointer on the kFlow 3D prototype interface. The energy bar is visible on the lower left corner.

Fig 11. An example of a collegial situation in the kFlow 3D interface. Before they are played on the map, ideas are collected within units of players. Small stones represent ideas, medium stones represent players, and large stones represent their unit. A commander could pit certaion units against enemy ones to solve problems posed by the market. Before they are played, ideas are matured in a collegial manner.

5. Conclusion

Gamification is a practical art in increasing knowledge flows and building the much-expected “knowledge superhighways”. Among the reasons to resort to it is that it commands a large amount of @s (attention and time, the currency of basic knowledge flows) either collective or individual. It also increases commitment, focus and therefore excellence and competitiveness. Gamification is also a means to make contents more neuroergonomic, and this in several ways. First, it could act at the volitional level, video games being addictive. Second, it could help route contents to neural pathways that have a larger span, and therefore ease their mental manipulation; episodic memory could be one of such pathways that gamification could tap into. Third, gamification is a natural ally of crowdsourcing, either individual or collective.

With Logos, I have outlined the essential components of a Game Design Document towards a game destined to teach languages by resorting to side learning, and by mimicking the mechanics of combat games, of which moves and combos typically formed a generative grammar in the first place. With kFlow, I have outlined, and experimented a collegial, real-time and open strategy game to gamify business development, especially for multinational companies.

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11. The anatomy of an ergonomic mindscape: Chréage

Note: This section is CONFIDENTIAL until January 1st 2021, unless otherwise stated by Idriss J. Aberkane. Code was provided by Philip Belhassen under the Shiva 3D Game Engine.

Abstract. Described here is a prototype mindscape for the knowledge economy in Web 3.0. Chréage is a procedural memory palace designed to be massive and easy to use. It combines neuromimicry (memory palaces, mind affordances…) and biomimicry (voronoi tesselation, the mapping of noems as loci along a shareable strand, a genetic of noems…) to achieve both leverage and accessibility in a Post-WIMP interface. Its objectives are to map noems onto space on the fly (procedurally) and facilitate the sharing of structured landscapes of noems rather than individual mental objects or URLs. Further functionalities include the mapping of any collections over a structured landscape endowed with an intuitive semiotics, and with scale-free hierarchies. Flexibility, simplicity and collegiality are the main design principles of Chréage, which is intended as a prototype solution to the Mindscape and Serendipity problems together. Above all, its further versions should be "cute and powerful".

Keywords: WIMP, procedural generation, mindscape, neuromimicry, collections, Platform as a Service.

Il semble que la perfection soit atteinte non quand il n'y a plus rien à ajouter, mais quand il n'y a plus rien à retrancher[50]

—Antoine de Saint-Exupéry

1. Introduction

Which standard could transcend the current WIMP (Windows, Icons, Menus, Pointers) interface for Web 3.0? If we design an interface that is neuroergonomic and in particular, that is tapping into episodic memory and the neural pathways involved in the method of loci, it is essential to define a simple, improvable metaphor to navigate contents. This metaphor should be as "affordable" as possible (in the sense of Gibson 1977) and "cute" (in the sens of "unthreatening") so as to facilitate adoption on the emotional side. On the rational side, it should also be powerful, in the sense that it should leverage mental life as much as possible.

[50] "it seems that perfection is achieved, not when there is nothing to add, but when there is nothing to remove". Antoine de Saint-Exupéry. (1959). Oeuvres (Gallimard). p.170

If Hyperwriting is an answer to the technical challenge of a glyph-based leverage of mental life, Chréage is a software-based answer. It is an automatic mindscape generator that is conceived with scalability in mind, unlike Hyperwriting, which, being handwritten (or hand-operated) and not yet adapted to dictation or typing either, is not scalable. Chréage is designed to be a scalable continuation of hyperwriting by the means of software engineering, and this continuation should be as seamless as possible.

2. Critical success factors

On a regular WIMP interface, loci exists in the sense that there is a minimal grid on a desktop metaphor, with a maximal number of positions that first-level contents (*i.e*, those visible from the desktop) can occupy. This metaphor being flat and not contextualised, it taps minimally into the loceme pathways, which are precisely what a 3D interface should target. An intuitive approach to defining the simplest procedural mindscape is to establish what it should critically contain to tap into the neural pathways of allocentric and egocentric orientation, so as to be both personal and interpersonal (and hence, more shareable).

Hence, critical success factors for a good mindscape generator should include the following elements, summed-up in the AMASS memonym, which are further refining the general properties of a Merleau-Pontian Universe.

Affordance
: the semiotics of the ability to interact with contents and loci should be intuitive, language-independent and ideally tap on the neural correlates of action and its planification.

Multiscale
: similar to a directory system, which is intricate, and being comparable to a physical map, a mindscape should be zoomable, and finitely so, to avoid losing the user.

Automatic
: as the purpose of a mindscape is to leverage, and not encumber the user’s mental operations, it should be automatic to generate, and automatic as many tasks as possible during use. Every single action or perception of the user should be interpreted and leveraged as much as possible, ultimately, merging perception and action. The idea is to minimise the “cost-per-click”, that is, make sure that every single action of the user (click or anything else, perception being also seen as an action) is maximally leveraged.

Simplicity
: there should be no barrier to entry in the use of a mindscape generator, it should be ecological enough (in the sense of Gibson) to be easily accessed without compromising automaticity and leverage.

Serendipity
: since “collections are for collisions” (Bell 2014) a good mindscape should maximise the contact between unrelated contents so as to encourage serendipity.

An interesting place to start in the state of the art of user interface design is at the meeting place between the desktop metaphor and the application launcher. This synthesis was successfully pioneered by the iOS operating system, and further perfected in the Apple watch OS, which is simple, finitely zoomable, and extremely “affordable” mentally speaking. The watch OS is today the best available synthesis between an app launcher and “desktop” metaphor.

An ideal collection to map on a prototype mindscape would be a subset of the World Wide Web. Ultimately, the set of all Chréage mindscapes would at least contain the powerset of the World Wide Web, which is its very objective : navigating not only the Web but its powerset. The perspectives of such a navigation, especially when it is combined with social sharing, are really non trivial. The ability to share not single URLs but entire subsets of the World Wide Web, and the ability to fork and edit such subsets opens the possibility of browsing the entire $\mathfrak{P}$(WWW), in which serendipities can be defined.

Another contribution of the iOS and Watch OS user interfaces has been the merging of application launchers and URL icons. Where, on a regular desktop interface, single URLs are mapped as a shortcut to be loaded by a web browser, in a mobile or wearable Operating System, they are substituted with their own application. Today, in terms of raw numbers, websites that have their own application are the exception, not the rule, but, already, they are not in terms of traffic, when Google, Facebook, Twitter and Youtube all have their applications. What if the entire World Wide Web was actually a gigantic launcher then, with each domain being a web-application not by design, but by access? Its mindscape would then be a zoomable launcher, comparable to the Watch OS interface, although it would also tap into episodic memory. This is the ideal Chréage is attempting to achieve, and this would consist of a clear design rupture compared to the Web 2.0 standards.

3. Methods: Hijacking video game technologies

Hijacking video game processes for productivity is a world in itself. Video game technologies are powerful and rapidly evolving because they are enduring an extremely tight natural selection in contact with a very demanding market that is not forced to adopt them. This, paradoxically, has made them extremely competitive : their users adopt them not because they have to, but because they very much like to, and hence, their interface is pressured to be likable. As a result, they are powerful and ergonomic : perfect candidates to leverage mental life, and in particular, its depth, productivity and creativity. They are excellent, among others, at facilitating the overview effect, as video games, competing with each other for the “Wow effect”, have evolved the ability to display an increasingly massive amount of contents within a single scene. This, again, is exactly what a prototype mindscape should aim for.

However, video game technology should be adopted piecemeal, and simplified as much as possible so as to hide its actual potential to the users, and thus, surprise them rather than overwhelm them in technical geekiness. It is better to look simple and user-friendly at first, and then amaze the user with hidden potential, than to announce complexity upfront, with a vast diversity of visible controls and toggles on the interface. This, in a way, is the difference between, say, an Airbus cockpit and an OS X interface, even though the first is clearly conceived as a B2B (Business to Business) interface and the second as a B2C (Business to Consumer) one. It turns out that hidden, surprising power is a value proposition even in a B2B mindset.

Since Chréage consists of the dynamic interaction between contents and places generated dynamically, this interaction better be reciprocal. An ecosystem may be defined as the reciprocal, dynamic interaction between a biotope (a set of organisms) and a biocenosis (a set of niches), and an economic system as a set of markets and a set of enterprises (in the broad sense of the term, including governments and NGOs) a proper mindscape should consist of the reciprocal interaction between contents and loci.

On a regular desktop interface, a place must be specified before a content is added (for example, a new folder, or a new text document must be created) this may be machine-ergonomic, but it is not mind-ergonomic, in that this is clearly constraining the mind to the imperatives of the machine, and adding one operation on the user's behalf when the action could be made more seamless. This is not neuromimical, and should therefore be dismissed, on the premise that mind ergonomy should never be in conflict with machine ergonomy (the main axiom of UI neuromimicry).

I have hence opted for a dynamic surface preexisting to contents, but on which loci are clearly identifiable and selectable. The idea is to provide clear affordances to use loci in order to place contents, without having to create or specify them beforehand. This method is reminiscent of that of city simulators in the video game industry for example.

I have thus tapped into, and simplified, Génevaux et al. 2013, Galin et al. 2010, Peytavie et al. 2009 and Patel 2010, 2013[51] to generate procedural landscapes and map onto them elements of the Alexa web ranking (a global ranking based on traffic). The prototype oscillates between skeuomorphism and abstraction, a tuning that should be optimised by beta testers. I have kept of Patel the procedural biome generation, simply based on elevation for the moment, but with categories that could be further refined in precision based on their interaction, as Patel does, with moisture (eg. closeness to the river) and elevation. Biomes could represent semantic categories or simply be used as landmarks, so as to break the monotony of the landscape.

The prototype mindscape is structured by a river, for which three different types of curves were tried: Bézier, Catmull-Rom and Best Spline, the latter proving ideal. Bézier curves typically minimises jolt (the third derivative of position in time) which made them ideal for hyperwriting, in that handwriting also naturally tends to minimise jolt (Caligiuri & Mohammed 2012 :54; Impedovo 2012:191), but within a video game scene, Best Spline curves will generate a more satisfying river-like natural axis. The

[51] http://www-cs-students.stanford.edu/~amitp/game-programming/polygon-map-generation/demo.html

landscape is then divided by a Voronoi diagram of which the cells should be different enough to avoid monotony but similar enough to facilitate scalability on the user's side.

Different parameters are explored for the spreading of tiles, the general guideline being to optimise cuteness and leverage, which is the most important design tension of Chréage. The result is a Minecraft-like rendering that is somehow "cute", and a massively scalable procedural generator, which is, hence, powerful. Chréage 2.0 should however evolve towards even more simplicity and even more scalability, and offer the experience of a seamless navigation from the "oligoscopic"[52] level of zoom to the "panoscopic"[53] one, so as to better adopt the contours of working and episodic memory in the working human mind.

4. Back-to-Front integration and user scenarii

Chréage is designed as a cross-platform, Platform as a Service (PaaS) software that should be usable on any mobile device, including within a regular web browser, although it does offer some functionalities of a web browser. It thus relies on the Shiva 3D game engine, which has the advantage of being cross-platform, offers a wide range of functionalities and a practical integration of web contents through the integration of the Chromium Embedded Framework which had, however, to be coded *ad hoc* (see next chapter). Another interest of the Shiva 3D game engine is its very early compliance with the PaaS standards, among others, its compatibility with cloud-based integration.

As most neuroergonomic softwares, Chréage is a middleware by design, in the sense that it generates interstitial value by placing itself between contents and users, to add a layer of ergonomy. Again, a game engine is typically made to fulfil this role, hence the choice. The canonical user scenario of Chréage consists of a request to a collection performed by a user, either as a search with a keyword (exploitation) or as intuitive navigation using the zooming interface within an already structure mindscape (exploration). This search or exploration can then be recorded and shared, through social media plugins. Other users can also connect to the ongoing search or exploration and edit it with various levels of administrative privileges, much like in the Prezi interface for example. Being a service more than a software, Chréage is indeed cloud-based and most if not all of its value should be delivered by its servers, not by the device itself. This again, is a reason for delivering Chréage with the Shiva 3D engine.

One of the problems Chréage should immediately solve is the proliferation of tabs and windows when navigating the Web. This proliferation has come both from that of online contents, either relevant or not (since their relevance can only be assessed, *in fine*, by comparing them and thus opening them) and from the increase in performances of even wearable computing devices. The scalability of Chréage allows the opening and manipulation of hundreds of URLs at the same time, and since they are represented as

[52] literally "The view of the few" namely a part of the mindscape
[53] literally "The view of everything" namely the entire mindscape

launchers rather than permanently opened web contents, this manipulation can be performed by even the least powerful devices.

Finally, the most important user scenarii of Chréage are social. Ultimately, Chréage should be a Github of noems, where people can edit, improve and fork mindscapes. Forking sets of tabs and windows would recover some of the time lost by users when they browse the web, perform complex searches and do not share them. For any edited and curated search online, it is rational to assume a certain level of overlap with one performed by another user, either in the near past or the near future. This overlap is not exploited today, even in Web 2.0, although it is reputed to have manifested the social dimension of the World Wide Web. Many emergent phenomena could occur in confronting people not to the search of individual URLs but to curated, evolved, improved subsets of the World Wide Web. These behaviours would include stygmergies among others (self-organised routes that is) because for any search or exploration of the web, it would leverage what others have found before. This could be a very potent service.

5. Conclusion

It seems intuitive, and logical, that the experience of software-based Mindscapes be delivered in a Platform as a Service (PaaS) philosophy. It is the one I have adopted for Chréage. This neuroergonomic software prototype maps collections onto space procedurally (on the fly) by using, simplifying and contextualising video game technologies, in particular, the Shiva 3D game engine, which is versatile, customisable and cross-platform, three essential qualities in a PaaS philosophy.

As always in introducing a novel way of doing things (regardless of the industry) one must, however, never forget that a piece of technology is adopted not when it is functional, and powerful, but when it ceases to evoke fear. The graphic charter of Chréage, therefore, should abide to the principle of cuteness and the “less is more” philosophy of appearing simple and accessible. Video game technologies can be naturally excellent at this, especially those that have been applied to non-segmenting games (games played by any audience) such as Minecraft, 2048 or other mobile games. Above all, Chréage is collegial, and must facilitate sharing. One should share, post, email or broadcast their Mindscapes as one would have a “Gallery of the views” of the Italian Grand Tour.

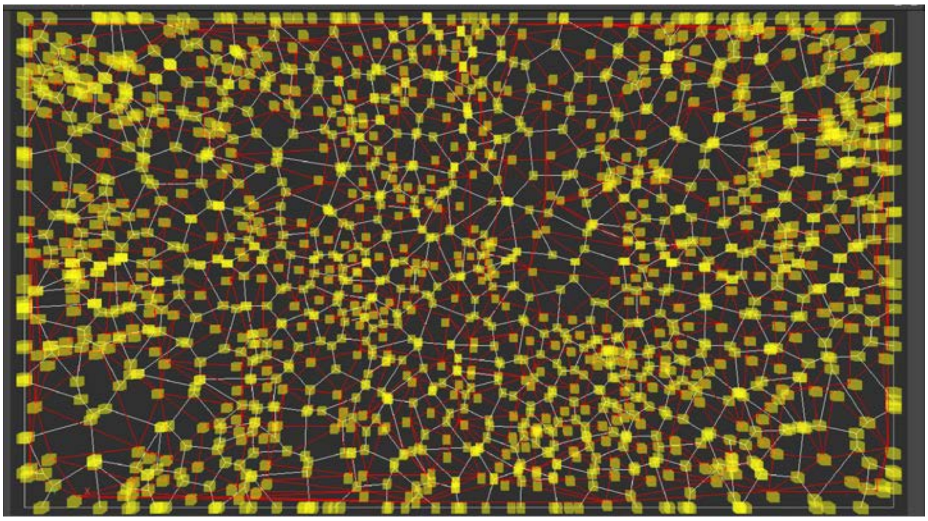
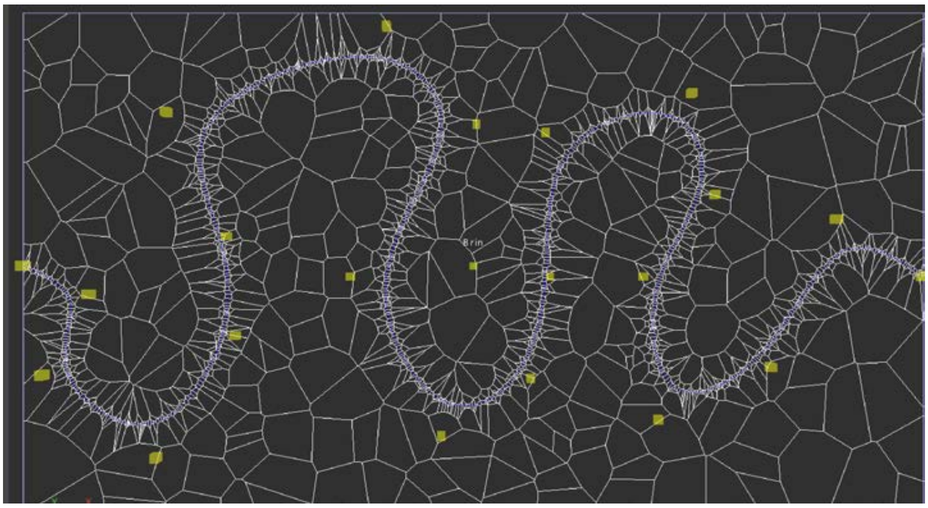


Fig. 1 Procedural generation of a voronoi mapping on a rectangular surface. Yellow squares are Voronoi centers and vertices, red lines correspond to the Delaunay trian-



gulation.

Fig 2. The previous landscape is fitted with a Best Spline curve (yellow squares are its foyers) adjusted to smaller Voronoi cells.

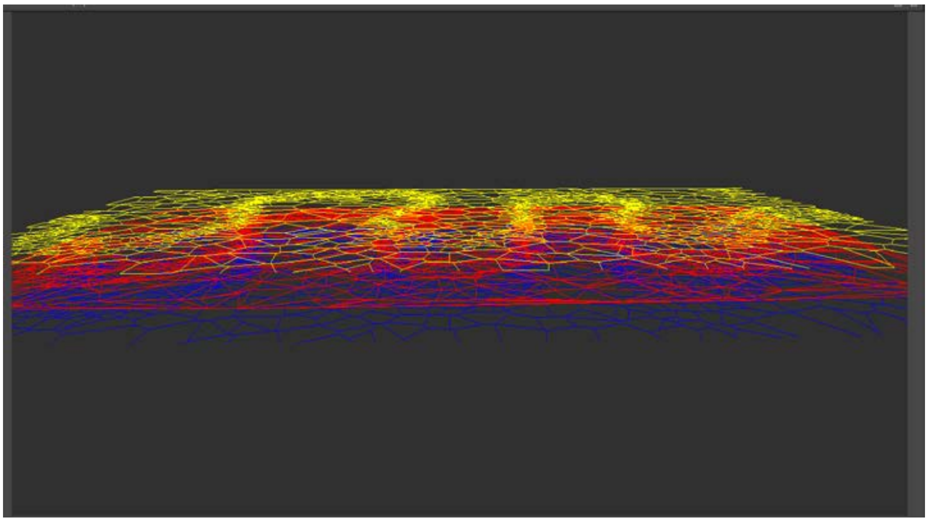


Fig. 3. The three layers superposed: Best Spline, Delaunay and Voronoi

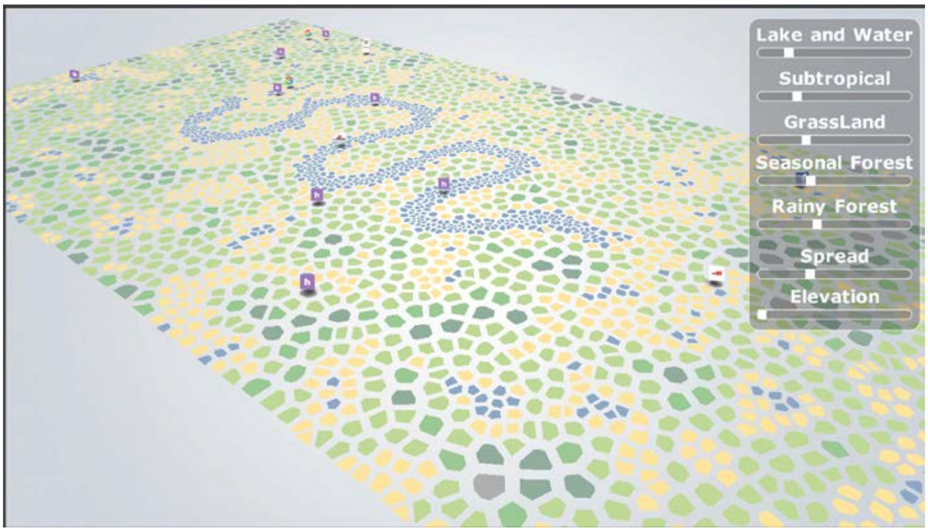


Fig. 4. On a flat surface (elevation zero), each Voronoi cell is colored by a "biome" that is distributed, here, randomly along a Perlin noise of which the seed is controlled by the toggle box on the right (also controlling spread and elevation)

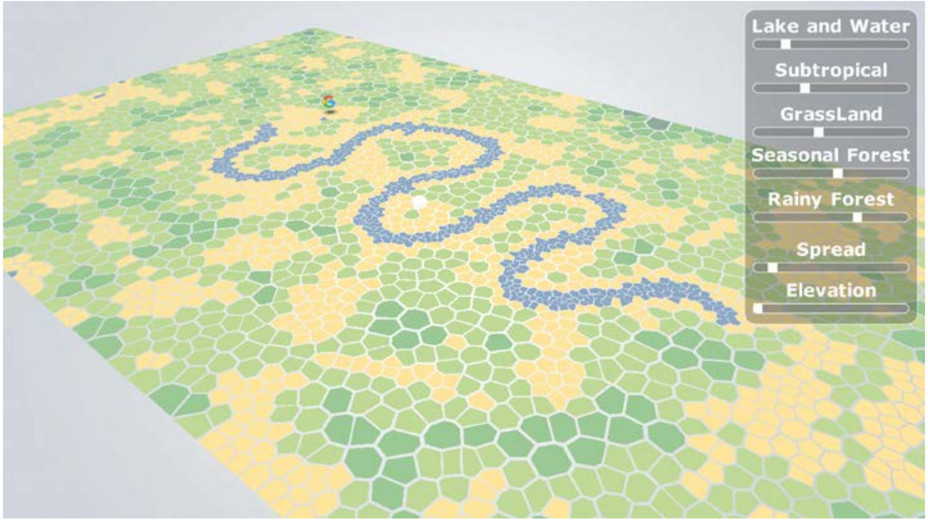


Fig. 5. Flat mindscape with a tighter spread

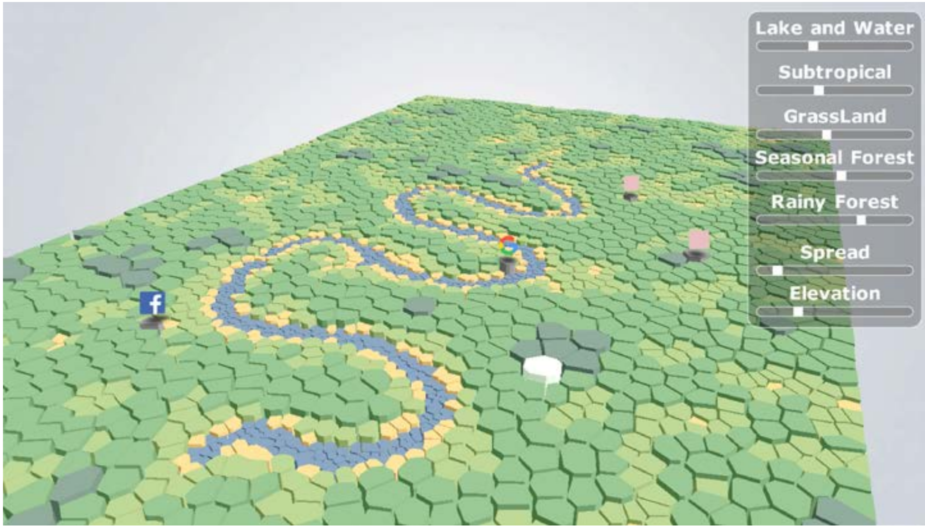


Fig. 6. Flat mindscape with a higher homogenous elevation

Fig. 7 Null spread and more Alexa contents automatically mapped, with favicons generated automatically as well

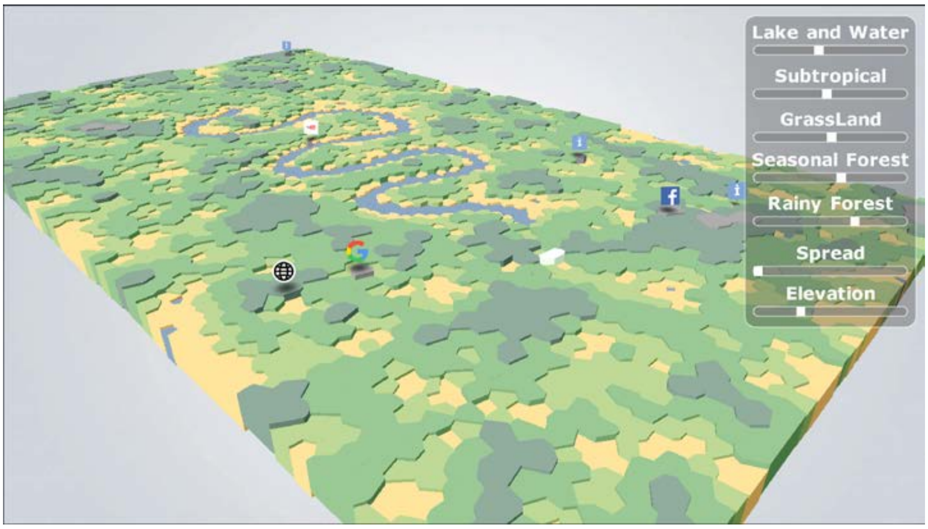


Fig 8. With additional elevation

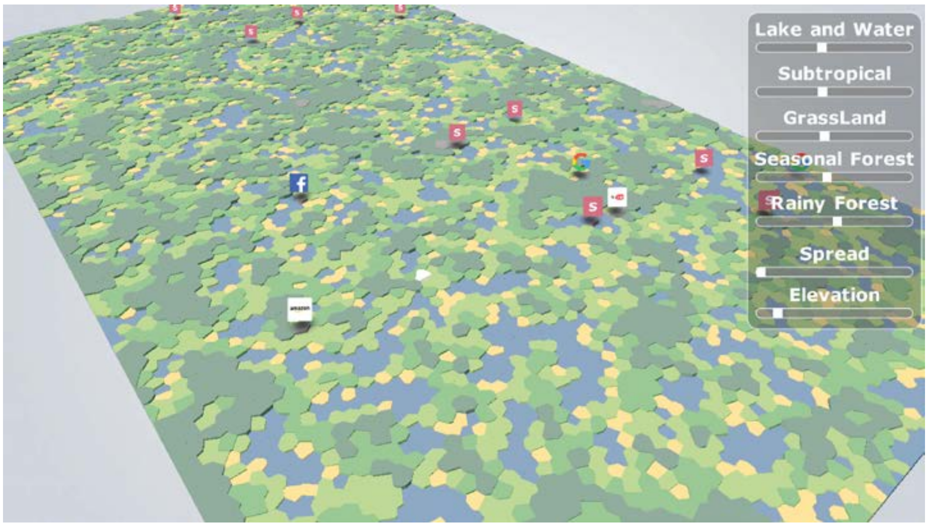


Fig 9. Scalability: ten times more Voronoi cells on a purely Perlin-noisy biome landscape.

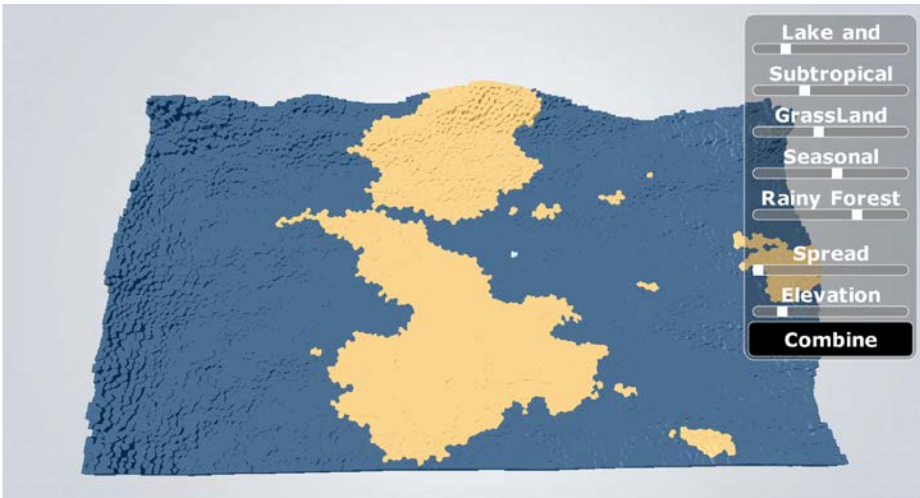


Fig 10. preliminary work for a procedural island generation over 10 000 tiles.

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12. Epilogue : in search for the right technology

Note: This section is CONFIDENTIAL until January 1st 2021, unless otherwise stated by Idriss J. Aberkane.

Abstract. Hijacking video game technology means using components that were intended to serve a certain purpose and applying them to another one. Although it may seem a little unnatural, it is actually the most natural of things, in that biological evolution resorts to this process all the time, duplicating and hijacking functions to serve very different purposes, thus submitting them to a new fitness landscape, and transitioning from the first to the second landscape in a rather continuous way. Searching for the right technology to implement interactive hyperwriting in Web 3.0 is searching for the right fitness landscape. Yet since the fate of a piece of technology also depends on its adoption and serendipitous usages, this landscape cannot be defined in advance. I have found no better way to arrest the right technology for Chréage than trial and error and frozen accident… which have worked in the past (most notably, for Microsoft Windows).

Keywords : game engine, CSS 3D, Web 3D, Web 3.0, WEBGL, Blender, technological DIY, semantic web, semiotic web

1. Introduction

Video gaming technologies have evolved into very high standards of neuroergonomy by opposition with regular teaching for example: they can command a massive flow of @s (the joint expenditure of attention and time) because they evolved under this very constraint. They also encourage deliberate practice, which is the basis of expertise according to Ericsson. Chréage is a first attempt at hijacking them to generate landscapes for the mind (mindscapes). This seems simply put, but while the end result is clear, the serving technology is not quite self-evident, as there are many standards of video game engines that, at first, could have seemed good candidates to implement Chréage.

The best clarifying quote in the endeavour of hijacking video game technologies to serve productivity purposes (which is the main goal of serious gaming, wargaming, serious play etc.) but this time, precisely, to merge regular desktop productivity with gaming or at least, to let gaming inspire it in a non trivial way, has been that of Steve Jobs which I have already quoted in chapter 9 “You’ve got to start with the customer experience and work back toward the technology - not the other way around.”. This in evolutionary terms, we could put as “you’ve got to start with the fitness landscape and then work back the species, not the other way around. In a way, the first is evolution, the second is “intelligent design”, which in this case ends up not so intelligent actually.

The Wright Brothers worked not through initial design but mostly through trial and error to attempt to fit the laws of physics, and this is what prevailed eventually. An emerging software should work the same way, attempting to fit its landscape, which is the user experience. This however, could be designed, transcending debates about the superiority or inferiority of preliminary design over pure trial and error. In human-made products, history well demonstrates that success comes from the mixture of both, even though mental preconceptions can also impede innovation. The best mixture of design and trial and error requires a perfectly fluid/liquid mind, or as Burton put it "indeed he knows not how to know, he who knows not also how to unknow".

This is true of Web 3.0, something that does not exist yet at the time this work is being written, but that is on the verge of existence, so much so that upon its publication this work will already seem antiquated. There are many preconceptions regarding Web 3.0, and many trial-and-error that have updated them. Most analysts agree that Web 3.0 should regard semantic, the Internet of Things, zero marginal cost ("Uberize everything") and Web 3D, and their mutual interaction makes it highly unpredictable, especially more so when one adds the infinite variety of execution to all these grand notions. My modest contribution has been, with the notion of a Merleau-Pontian Universe (chapter 10) to claim that Web 3.0 should position itself towards the emergence of the Semiotic web. The perfect technology strategist would have positioned the PC to point towards the NC (Network computer) or the Post-PC (mobile computers) and then Post-Post-PC (wearables); I believe the perfect technology strategy should position his Web 3.0 services towards the post-semantic, and that the post-semantic is semiotic, where affordance-based neuroergonomics will be of immense help, because it could be possible to design de novo writings that would not need any kind of translation, or even better, that would be self-evident from our very "Core Knowledge" (for example, Dehaene et al. 2006).

2. Trial and Error

In the perpetual tension between "doers" and "thinkers", planners and triers, those of pure design and those of pure action, it seems that the history of technology has placed the optimum towards the doers: Da Vinci and the Wright Brothers had no university degrees whatsoever, and they succeeded where a throng of academics failed. Hence, maybe, Michel Audiard: "deux intellectuels assis vont moins loin qu'une brute qui marche"[54] but again, the walking brute may end up walking in circles, and the tension between the two attitudes remain, so that one cannot deny that virtue is in the middle.

I have experienced that the Silicon Valley attitude, much unlike the recent French one, was "Just do it", and do not bother to have the best CV before you do. Legitimacy is a thing of the Old World, it does not exist in the Valley, and the Frenchmen who end up among start-uppers there must absolutely suffer the reinvigoration of what I call the "Lafayette syndrome", namely, the forsakening of titles and state-owned primacy. No

[54] two sitting intellectuals will not go as far as a walking brute

one cares whether you did a Grande Ecole if you do the job well. Lafayette renounced his titles as well, ultimately, to fight in the American Revolution.

“Fail early, fail often” I have found to be the best guide in arresting the right technology. Try, fail, persevere. And the ingredient of perseverance is love. What have I learned from hijacking video game technologies to prototype knowledge superhighways? pretty much what Idries Shah has reported much better than me in an interview with Elizabeth Hall titled “Psychology Today” in 1975:

> They're not called washerwomen, but if we test them, they react like washerwomen. For example, if you are selling books and you send a professor of philosophy something written in philosophical language, he will throw it away. But if you send him a spiel written for a washerwoman, he will buy the book. At heart he is a washerwomen. Intellectuals don't understand this, but business people do because their profits depend upon it. You can learn much more about human nature on Madison Avenue than you will from experts on human nature, because on Madison Avenue on stands or falls by the sales. Professors in their ivory towers can say anything because there's no penalty attached. **Go to where there is a penalty attached and there you will find wisdom**.

The reason video gaming technologies have turned out to be resilient and efficient has precisely been their accountability, their closeness to “where there is a penalty”, and hence, unexpectedly, to wisdom. The best practices ten to emerge under tight accountability, hence the failure of the Minitel and of purely state-run economies. Tight accountability is also defining nature, and this is why nature has developed among the best practices that we know: the value of biomimicry is a result of tight accountability. This, finally, is also the Achilles’ heel of the academic world, where accountability tends to be increasingly consanguine and artificial, especially more so with academic rankings and the pseudoscience of bibliometrics. Technologies that are accountable, that are pressured to evolve, otherwise our brain will have to fit them, not the other way around…

3. Game engines, Webviews and “frozen accident”

Thus, fail early, fail often, I have found no better way than repeated trial and error to arrest a technology for Chréage. This may still be a “frozen accident”, as the 7-Transmembrane proteins pattern may well be, namely a pattern that works but that could have worked otherwise and that was “frozen” by its selected occurence even though it was not exactly optimal. Microsoft DOS and later Windows after all emerged from such a frozen accident, namely the adoption of QDOS, standing for “Quick and Dirty Operating System”, precisely meaning it was far from optimal, but the massive adoption of which causing a freezing of its evolution.

My long journey through trial and error in search for the fittest technology for Chréage started with the Shiva 3D Engine, and ironically, this is also where it ended, after many detours and attempted alternatives. Initially, I used the Shiva 3D with an implanted "Awesomium" library, which ended up not flexible enough to offer a complete web experience (especially regarding interactivity) within a 3D scene. Besides, the founding company of Shiva 3D ended up in restructuration, with the prospect of the engine not being supported in the future. I then considered Open Source solutions, namely

- the Blender Game Engine
- the Panda 3D Game Engine
- the Berkelium off-screen browser renderer that ended up obsolete in favor of the Chromium Embedded Framework

I also tried plain webGL, in parallel with more advanced libraries Three.js and Babylon.js, and none was compliant enough to merge a clean cross-platform integration, a fast procedural generation and a complete embedded browser experience… This made me return to Shiva 3D which in turn had evolved to perfectly serve the needs I had for Chréage.

The embedding of a full browser within a Shiva 3D scene however remains subject to many options. At the moment the most interesting regards the Chromium Embedded framework, but the ideal would be to tap into the native browser of any device, so as to merely put the regular browsing experience "in perspective" which has always been the founding purpose of Chréage as a good mindscape. This is Vitruvian, this is Renaissance 2.0, this is the contribution of this work: bringing perspective to the web, and to the act of browsing it. Future developments will go beyond the CEF, into the notion of a CSS3D Standard that is owed to Philip Belhassen. Earlier, QT seems a better development framework to embed a browser in a perspective engine.

4. Conclusion

I think a way that Tesla Motors managed to orient itself amid the fluffy complexity of innovation has been its "Love Can Do" attitude and its learning (painfully) that a technology is not adopted when it just works fine but when it is cute, and when people understand why it works (even if this noble why is mere entertainment, after all, the acronym of the successful TED conferences stand for Technology Entertainment and Design). Another guiding light for Tesla has been their slogan: "the end of compromise", and their using their own products, which is always an excellent way to ensure excellence : using your own products is the equivalent of deliberate practice. You don't just do it because you have to, you do it because you want to, and hence, spend more @s on it, which in turn make your product excellent, or at least, better than the competition. Don't just talk about the market, *Be* the market. Then charts, analysis, and the like are irrelevant, because when you decide to Be the market rather than to Have the market, you return to the very meaning of experience, not something detached from yourself, which is the very limited science we much-too-often practice, but the experience in which the experimenter is part of what he experiments (and which, even, quantum physics and sociology are turning mainstream) and which Roger Bacon and

Leonardo da Vinci have both practiced at the highest level. This is also what Bacon truly meant by “experience”, way beyond what we limit it to nowadays.

Thus, what I want for myself in Chréage is total cross-platform interoperability. The noosphere should be in the Cloud, where it naturally belongs, and not on any device at a single time. I want cuteness, seamlessness, and altogether what I summarised in the AMASS acronym in chapter 12: Affordance, Multiscale, Automatic, Simplicity, Serendipity. Above all, Neuromimicry has been my guiding principle, just as it must have been to Tesla and Apple: it is NOT and NEVER for us to fit the product but for the product to fit us. Our brain and mind is greater than any of its creations, and so fitting any of them to a single creation is even more than a limitation, it is an alienation. This is however what we do all the time.

A big trade-off among these various concepts and ideals has been to choose between ergonomy and open source. Both are very important, in that Open Source Softwares, among which UNIX and the protocols of the WorldWideWeb, have always been a treasure for Humanity. Their terrible lack of ergonomics however, sometimes reinforced by a nefarious egotistic attitude sometimes summed-up in the despicable expression “user-friendliness is for wimps anyway”, although it usually stems from the nature of their user base in general and, too often, their lack of a perennial economic model, has made them self-limited, most unfortunately. When I have had to choose between neuromimicry and open source, of course I have chosen neuromimicry. This is what most users do. This has led me to the technological choices that I expose in the final chapter.

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13. Material and methods: technical document for a Chromium Embedded Framework integration in Shiva 3D for the Chréage Mindscape

Note : This section is CONFIDENTIAL until January 1st 2021, unless otherwise stated by Idriss J. Aberkane. It is collective, and established by Idriss Aberkane, Philip Belhassen and Mohammed Knile, from initial Chromium Embedded Framework and Shiva 3D documentation. (Nabeul, Tunisia, 2015)

Abstract. Described here is a protocol for the embedding of the Chromium navigator in a Shiva 3D game engine scene, without resorting to the Berkelium or Awesomium softwares, the first being unsupported and not maintained as of 2015, the second being not versatile, interactive, customisable and complete enough for the purpose of Chréage, and not open source itself. Chréage could be assembled in two ways, the first consisting of plugging in the Chromium Embedded Framework (CEF, version 3) in the Shiva 3D game engine, the second being to use the Shiva 3D HTML5 compatibility for the end side of the backend, within a CEF 3 executable. The first option is explored, and solved, here.

Keyword : Chromium Embedded Framework, Shiva 3D, Web 3D, interactive pebble, embedded webview

1. Introduction

Chréage is a thoughts spatialiser (*i.e.* a mindscape). In application terms, it is a spatialiser of bookmarks and favourites. It introduces a new metaphor of the regular icon with the 3D interactive pebble. A pebble is a dynamic tile in Windows 8, it displays an image that summarises its contents (eg. a favicon). By clicking on the pebble, one accesses the content in 2D. By reducing the content, one returns to the pebble. By reducing the pebble, one returns to the full mindscape. The idea is to create a C++ plugin which could be used within the Shiva editor to create our 3D scene.

1.1. Why Shiva 3D?

The choice of Shiva 3D comes after all Open Source solutions have been exhausted. The two best Open Source game engines available for Chréage being the Blender Game Engine and Panda 3D, both much too limited in terms of platform inter-operability and end-user base. Shiva 3D is the world’s most cross-platform game engine, its front end and back end are extremely versatile, and it enjoys full plugin-free HTML5 compatibility to display 3D scenes within a regular web browser. Of all the non-free solutions for fully compliant, versatile and accessible 3D integrations for Chréage it is the best option.

For example, the interest of Shiva 3D over Unity 3D for Chréage is the greater access it allows for manipulating its source code and for achieving full interactivity within a 3D scene, unlike the Awesomium plugin for example. Shiva 3D also developed full, plugin-free HTML5 compatibility before Unity 3D. Shiva 3D is the only engine able to embed the CEF as a core plugin. Also, in terms of portability and efficiency for further developments, the Shiva 3D compatibility for HTML5 is 2Mo as of today, against 80Mo in Unity 3D…

1.2. Why Chromium Embedded Framework (CEF) ?

The Chromium Embedded Framework (CEF) is an open source project based on the Google Chromium project. Unlike the Chromium project itself, which focuses mainly on Google Chrome applications development, CEF focuses on facilitating embedded browser use cases in third-party applications. Unlike Awesomium, it is fully Open Source, and unlike Berkelium, which is Open Source, it is still maintained and supported.

CEF insulates the user from the underlying Chromium and Blink code complexity by offering production-quality stable APIs, release branches tracking specific Chromium releases, and binary distributions. Most features in CEF have default implementations that provide rich functionality while requiring little or no integration work from the user.

CEF3 is the next generation of CEF based on the multi-process Chromium Content API.

- Improved performance and stability (JavaScript and plugins run in a separate process).
- Support for Retina displays.
- GPU acceleration for WebGL and 3D CSS.
- A range of new features like WebRTC (webcam support) and speech input.
- Better automated UI testing via the DevTools remote debugging protocol and ChromeDriver2.
- Faster access to current and future Web features and standards.

2. Using a Binary Distribution

Binary distributions of CEF3 are available from the project Downloads page. They contain all files necessary to build a particular version of CEF3 on a particular platform

(Windows, Mac OS X or Linux). Regardless of the platform, they all share the same general structure:

- **cefclient** contains the cefclient sample application configured to build using the files in the binary distribution. This application demonstrates a wide range of CEF functionalities.
- **Debug** contains a debug build of the CEF shared library (libcef) and any other libraries required to run on the platform. This application demonstrates the minimal functionality required to create a browser window.
- **include** contains all required CEF header files.
- **libcef_dll** contains the source code for the libcef_dll_wrapper static library that all applications using the CEF C++ API must link against. See the "C++ Wrapper" section for more information.
- **Release** contains a release build the CEF shared library (libcef) and any other libraries required to run on the platform.
- **Resources** contains resources required by applications using CEF. This includes .pak files (binary files with globbed resources) and potentially other files such as images and cursors depending on the platform.
- **tools** contains scripts for post-processing the build depending on the platform.

2.1. Important Concepts

There are some important underlying concepts to developing CEF3-based applications that should be understood before proceeding.

C++ Wrapper

The libcef shared library exports a C API that isolates the user from the CEF runtime and code base. The libcef_dll_wrapper project, which is distributed in source code form as part of the binary release, wraps this exported C API in a C++ API that is then linked into the client application. The code for this C/C++ API translation layer is automatically generated by the translator tool. Direct usage of the C API is described on theUsingTheCAPI page.

Processes

CEF3 runs using multiple processes. The main process which handles window creation, painting and network access is called the "browser" process. This is generally the same process as the host application and the majority of the application logic will run in the browser process. Blink rendering and JavaScript execution occur in a separate "render" process. Some application logic, such as JavaScript bindings and DOM access, will also run in the render process. The default process model will spawn a new render process for each unique origin (scheme + domain). Other processes will be spawned as needed, such as "plugin" processes to handle plugins like Flash and "gpu" processes to handle accelerated compositing.

By default, the main executable application will be spawned multiple times to represent separate processes. This is handled *via* command-line flags that are passed into the CefExecuteProcess function. If the main application executable is large, takes a long time to load, or is otherwise unsuitable for non-browser processes the host can use a separate executable for those other processes. This can be configured via the CefSettings.browser_subprocess_path variable.

The separate processes spawned by CEF3 communicate using Inter-Process Communication (IPC). Application logic implemented in the browser and render processes can communicate by sending asynchronous messages back and forth. JavaScriptIntegration in the render process can expose asynchronous APIs that are handled in the browser process. See the "Inter-Process Communication" section for more information.

Threads

Each process in CEF3 runs multiple threads. For a complete list of threads see the cef_thread_id_t enumeration. The browser process for example contains the following commonly-referenced threads:

- **TID_UI** thread is the main thread in the browser process. This will be the same as the main application thread if CefInitialize() is called with a CefSettings.multi_threaded_message_loop value of false.
- **TID_IO** thread is used in the browser process to process IPC and network messages.
- **TID_FILE** thread is used in the browser process to interact with the file system.
- **TID_RENDERER** thread is the main thread in the renderer process.

Due to the multi-threaded nature of CEF it is important to use locking or message passing to protect data members from access on multiple threads. The IMPLEMENT_LOCKING macro provides Lock() and Unlock() methods and an AutoLock scoped object for synchronizing access to blocks of code. The CefPostTask family of functions support easy asynchronous message passing between threads. The current thread can be verified using the CefCurrentlyOn() function. The cefclient application uses the following defines to verify that methods are executed on the expected thread. With trunk revision 1769 (on Google Code) and newer these defines are included in the include/wrapper/cef_helpers.h header file.

```
#define                                          CEF_REQUIRE_UI_THREAD()
DCHECK(CefCurrentlyOn(TID_UI));
#define                                          CEF_REQUIRE_IO_THREAD()
```

```
DCHECK(CefCurrentlyOn(TID_IO));
#define                                     CEF_REQUIRE_FILE_THREAD()
 DCHECK(CefCurrentlyOn(TID_FILE));
#define                                 CEF_REQUIRE_RENDERER_THREAD()
DCHECK(CefCurrentlyOn(TID_RENDERER));
```

Starting with trunk revision 1769 (on Google Code) the IMPLEMENT_LOCKING macro has been deprecated in favor of Chromium's base::Lock and base::AutoLock types. These types are now exposed in CEF via the include/base folder. For example:

```
// Include the necessary header.
#include "include/base/cef_lock.h"

// Class declaration.
class MyClass : public CefBase {
 public:
  MyClass() : value_(0) {}
  // Method that may be called on multiple threads.
  void IncrementValue();
 private:
  // Value that may be accessed on multiple theads.
  int value_;
  // Lock used to protect access to |value_|.
  base::Lock lock_;
  IMPLEMENT_REFCOUNTING(MyClass);
};

// Class implementation.
void MyClass::IncrementValue() {
  // Acquire the lock for the scope of this method.
  base::AutoLock lock_scope(lock_);
  // |value_| can now be modified safely.
  value_++;
}
```

2.2 Reference Counting

All framework classes implement the CefBase interface and all instance pointers are handled using the CefRefPtr smart pointer implementation that automatically handles reference counting via calls to AddRef() and Release().The easiest way to implement these classes is as follows:

```
class MyClass : public CefBase {
 public:
  // Various class methods here...

 private:
```

```
  // Various class members here...

  IMPLEMENT_REFCOUNTING(MyClass);  // Provides atomic refcounting im-
plementation.
};

// References a MyClass instance
CefRefPtr<MyClass> my_class = new MyClass();
```

2.3 Strings

CEF defines its own data structure for representing strings, and this, for a few different reasons:

- The libcef library and the host application may use different runtimes for managing heap memory. All objects, including strings, need to be freed using the same runtime that allocated the memory.
- The libcef library can be compiled to support different underlying string types (UTF8, UTF16 or wide). The default is UTF16 but it can be changed by modifying the defines in cef_string.h and recompiling CEF. When choosing the wide string type keep in mind that the size will vary depending on the platform.

For UTF16 the string structure will typically look like this:

```
typedef struct _cef_string_utf16_t {
  char16* str;  // Pointer to the string
  size_t length;  // String length
  void (*dtor)(char16* str);  // Destructor for freeing the string on
the correct heap
} cef_string_utf16_t;
```

The selected string type is then typedef'd to the generic type:

```
typedef char16 cef_char_t;
typedef cef_string_utf16_t cef_string_t;
```

CEF provides a number of C API functions for operating on the CEF string types (mapped via #defines to the type-specific functions). For example:

- **cef_string_set** will assign a string value to the structure with or without copying the value.
- **cef_string_clear** will clear the string value.
- **cef_string_cmp** will compare two string values.

CEF also provides functions for converting between all supported string types (ASCII, UTF8, UTF16 and wide). See the cef_string.h and cef_string_types.h headers for the complete list of functions.

Usage of CEF strings in C++ is simplified by the CefString class. CefString provides automatic conversion to and from std::string (UTF8) and std::wstring (wide) types. It can also be used to wrap an existing cef_string_t structure for assignment purposes.

Assignment to and from std::string:

```
std::string str = “Some UTF8 string”;

// Equivalent ways of assigning |str| to |cef_str|. Conversion from
UTF8 will occur if necessary.
CefString cef_str(str);
cef_str = str;
cef_str.FromString(str);

// Equivalent ways of assigning |cef_str| to |str|. Conversion to UTF8
will occur if necessary.
str = cef_str;
str = cef_str.ToString();
```

Assignment to and from std::wstring:

```
std::wstring str = “Some wide string”;

// Equivalent ways of assigning |str| to |cef_str|. Conversion from
wide will occur if necessary.
CefString cef_str(str);
cef_str = str;
cef_str.FromWString(str);

// Equivalent ways of assigning |cef_str| to |str|. Conversion to wide
will occur if necessary.
str = cef_str;
str = cef_str.ToWString();
```

Using the FromASCII() method assuming you know the format is ASCII:

```
const char* cstr = “Some ASCII string”;
CefString cef_str;
cef_str.FromASCII(cstr);
```

Some structures like CefSettings have cef_string_t members. CefString can be used to simplify the assignment to those members:

```
CefSettings settings;
const char* path = “/path/to/log.txt”;

// Equivalent assignments.
CefString(&settings.log_file).FromASCII(path);
cef_string_from_ascii(path, strlen(path), &settings.log_file);
```

2.4 Command Line Arguments

Many features in CEF3 and Chromium can be configured using command line arguments. These arguments take the form "--some-argument[=optional-param]" and are passed into CEF via CefExecuteProcess() and the CefMainArgs structure (see the “Application Structure” section below).

- To disable the processing of arguments from the command line set CefSettings.command_line_args_disabled to true before passing the CefSettings structure into CefInitialize().
- To specify CEF/Chromium command line arguments inside the host application implement the CefApp::OnBeforeCommandLineProcessing() method.
- To pass application-specific (non-CEF/Chromium) command line arguments to sub-processes implement the CefBrowserProcessHandler::OnBeforeChildProcessLaunch() method.

See comments in client_switches.cpp for more information on supported CEF/Chromium command line switches.

3. Application Structure

Every CEF3 application has the same general structure.

- Provide an entry-point function that initializes CEF and runs either sub-process executable logic or the CEF message loop.
- Provide an implementation of CefApp to handle process-specific callbacks.
- Provide an implementation of CefClient to handle browser-instance-specific callbacks.
- Call CefBrowserHost::CreateBrowser() to create a browser instance and manage the browser life span using CefLifeSpanHandler.

3.1 Entry-Point Function

As described in the “Processes” section a CEF3 application will run multiple processes. The processes can all use the same executable or a separate executable can be specified for the sub-processes. Execution of the process begins in the entry-point function. Complete platform-specific examples for Windows, Linux and Mac OS-X are available in cefclient_win.cc, cefclient_gtk.cc and cefclient_mac.mm respectively.

When launching sub-processes CEF will specify configuration information using the command-line that must be passed into the CefExecuteProcess function via the CefMainArgs structure. The definition of CefMainArgs is platform-specific. On Linux and Mac OS X the command accepts the argc and argv values which are passed into the main() function.

```
CefMainArgs main_args(argc, argv);
```

On Windows the command accepts the instance handle (HINSTANCE) which is passed into the wWinMain() function. The instance handle is also retrievable via GetModuleHandle(NULL).

```
CefMainArgs main_args(hInstance);
```

3.2 Single Executable

When running as a single executable the entry-point function is required to differentiate between the different process types. The single executable structure is supported on Windows and Linux but not on Mac OS X.

```
// Program entry-point function.
int main(int argc, char* argv[]) {
  // Structure for passing command-line arguments.
  // The definition of this structure is platform-specific.
  CefMainArgs main_args(argc, argv);

  // Optional implementation of the CefApp interface.
  CefRefPtr<MyApp> app(new MyApp);

  // Execute the sub-process logic, if any. This will either return
immediately for the browser
  // process or block until the sub-process should exit.
  int exit_code = CefExecuteProcess(main_args, app.get());
```

```
  if (exit_code >= 0) {
    // The sub-process terminated, exit now.
    return exit_code;
  }

  // Populate this structure to customize CEF behavior.
  CefSettings settings;

  // Initialize CEF in the main process.
  CefInitialize(main_args, settings, app.get());

  // Run the CEF message loop. This will block until CefQuitMes-
sageLoop() is called.
  CefRunMessageLoop();

  // Shut down CEF.
  CefShutdown();

  return 0;
}
```

3.3 Separate Sub-Process Executable

When using a separate sub-process executable one needs two separate executable projects and two separate entry-point functions.

Main application entry-point function:

```
// Program entry-point function.
int main(int argc, char* argv[]) {
  // Structure for passing command-line arguments.
  // The definition of this structure is platform-specific.
  CefMainArgs main_args(argc, argv);

  // Optional implementation of the CefApp interface.
  CefRefPtr<MyApp> app(new MyApp);

  // Populate this structure to customize CEF behavior.
  CefSettings settings;

  // Specify the path for the sub-process executable.
  CefString(&settings.browser_subprocess_path).Fro-
mASCII("/path/to/subprocess");

  // Initialize CEF in the main process.
  CefInitialize(main_args, settings, app.get());
```

```
  // Run the CEF message loop. This will block until CefQuitMes-
sageLoop() is called.
  CefRunMessageLoop();

  // Shut down CEF.
  CefShutdown();

  return 0;
}
```

Sub-process application entry-point function:

```
// Program entry-point function.
int main(int argc, char* argv[]) {
  // Structure for passing command-line arguments.
  // The definition of this structure is platform-specific.
  CefMainArgs main_args(argc, argv);

  // Optional implementation of the CefApp interface.
  CefRefPtr<MyApp> app(new MyApp);

  // Execute the sub-process logic. This will block until the sub-
process should exit.
  return CefExecuteProcess(main_args, app.get());
}
```

3.4 Message Loop Integration

CEF can also integrate with an existing application message loop instead of running its own message loop. There are two ways to do this.

1. Call CefDoMessageLoopWork() on a regular basis instead of calling CefRunMessageLoop(). Each call to CefDoMessageLoopWork() will perform a single iteration of the CEF message loop. Caution should be used with this approach. Calling the method too infrequently will starve the CEF message loop and negatively impact browser performance. Calling the method too frequently will negatively impact CPU usage.
2. Set CefSettings.multi_threaded_message_loop = true (Windows only). This will cause CEF to run the browser UI thread on a separate thread from the main application thread. With this approach neither CefDoMessageLoopWork() nor CefRunMessageLoop() need to be called. CefInitialize() and CefShutdown() should still be called on the main application thread. You will need to provide your own mechanism for communicating with the main application thread (see for example the

message window usage in cefclient_win.cpp). You can test this mode in cefclient on Windows by running with the “--multi-threaded-message-loop” command-line flag.

3.5 CefSettings

The CefSettings structure allows configuration of application-wide CEF settings. Some commonly configured members include:

- **single_process** Set to true to use a single process for the browser and renderer. Also configurable using the "single-process" command-line switch. See the “Processes” section for more information.
- **browser_subprocess_path** The path to a separate executable that will be launched for sub-processes. See the “Separate Sub-Process Executable” section for more information.
- **multi_threaded_message_loop** Set to true to have the browser process message loop run in a separate thread. See the “Message Loop Integration” section for more information.
- **command_line_args_disabled** Set to true to disable configuration of browser process features using standard CEF and Chromium command-line arguments. See the “Command Line Arguments” section for more information.
- **cache_path** The location where cache data will be stored on disk. If empty an in-memory cache will be used for some features and a temporary disk cache will be used for others. HTML5 databases such as localStorage will only persist across sessions if a cache path is specified.
- **locale** The locale string that will be passed to Blink. If empty the default locale of "en-US" will be used. This value is ignored on Linux where locale is determined using environment variable parsing with the precedence order: LANGUAGE, LC_ALL, LC_MESSAGES and LANG. Also configurable using the "lang" command-line switch.
- **log_file** The directory and file name to use for the debug log. If empty, the default name of "debug.log" will be used and the file will be written to the application directory. Also configurable using the "log-file" command-line switch.
- **log_severity** The log severity. Only messages of this severity level or higher will be logged. Also configurable using the "log-severity" command-line switch with a value of "verbose", "info", "warning", "error", "error-report" or "disable".
- **resources_dir_path** The fully qualified path for the resources directory. If this value is empty the cef.pak and/or devtools_resources.pak files must be located in

the module directory on Windows/Linux or the app bundle Resources directory on Mac OS X. Also configurable using the "resources-dir-path" command-line switch.

- **locales_dir_path** The fully qualified path for the locales directory. If this value is empty the locales directory must be located in the module directory. This value is ignored on Mac OS X where pack files are always loaded from the app bundle Resources directory. Also configurable using the "locales-dir-path" command-line switch.
- **remote_debugging_port** Set to a value between 1024 and 65535 to enable remote debugging on the specified port. For example, if 8080 is specified the remote debugging URL will be http://localhost:8080. CEF can be remotely debugged from any CEF or Chrome browser window. Also configurable using the "remote-debugging-port" command-line switch.

3.6 CefBrowser and CefFrame

The CefBrowser and CefFrame objects are used for sending commands to the browser and for retrieving state information in callback methods. Each CefBrowser object will have a single main CefFrame object representing the top-level frame and zero or more CefFrame objects representing sub-frames. For example, a browser that loads two iframes will have three CefFrame objects (the top-level frame and the two iframes).

To load a URL in the browser main frame:

```
browser->GetMainFrame()->LoadURL(some_url);
```

To navigate the browser backwards:

```
browser->GoBack();
```

To retrieve the main frame HTML contents:

```
// Implementation of the CefStringVisitor interface.
class Visitor : public CefStringVisitor {
 public:
```

```
  Visitor() {}

  // Called asynchronously when the HTML contents are available.
  virtual void Visit(const CefString& string) OVERRIDE {
    // Do something with |string|...
  }

  IMPLEMENT_REFCOUNTING(Visitor);
};

browser->GetMainFrame()->GetSource(new Visitor());
```

CefBrowser and CefFrame objects exist in both the browser process and the render process. Host behavior can be controlled in the browser process via the CefBrowser::GetHost() method. For example, the native handle for a windowed browser can be retrieved as follows:

```
// CefWindowHandle is defined as HWND on Windows, NSView* on Mac OS X
// and GtkWidget* on Linux.
CefWindowHandle window_handle = browser->GetHost()->GetWindowHan-
dle();
```

Other methods are available for history navigation, loading of strings and requests, sending edit commands, retrieving text/html contents, and more. See the CEF documentation for the complete list of supported methods.

3.7 CefApp

The CefApp interface provides access to process-specific callbacks. Important callbacks include:

- **OnBeforeCommandLineProcessing** which provides the opportunity to programmatically set command-line arguments. See the “Command Line Arguments” section for more information.
- **OnRegisterCustomSchemes** which provides an opportunity to register custom schemes. See the “”Request Handling” section for more information.
- **GetBrowserProcessHandler** which returns the handler for functionality specific to the browser process including the OnContextInitialized() method.

- **GetRenderProcessHandler** which returns the handler for functionality specific to the render process. This includes JavaScript-related callbacks and process messages. See JavaScriptIntegration and the “Inter-Process Communication” section for more information.

Here is an example of a CefApp implementation:

```
// MyApp implements CefApp and the process-specific interfaces.
class MyApp : public CefApp,
              public CefBrowserProcessHandler,
              public CefRenderProcessHandler {
 public:
  MyApp() {}

  // CefApp methods. Important to return |this| for the handler
callbacks.
  virtual void OnBeforeCommandLineProcessing(
      const CefString& process_type,
      CefRefPtr<CefCommandLine> command_line) {
    // Programmatically configure command-line arguments...
  }
  virtual void OnRegisterCustomSchemes(
      CefRefPtr<CefSchemeRegistrar> registrar) OVERRIDE {
    // Register custom schemes...
  }
  virtual CefRefPtr<CefBrowserProcessHandler> GetBrowserProcessHan-
dler()
      OVERRIDE { return this; }
  virtual CefRefPtr<CefRenderProcessHandler> GetRenderProcessHan-
dler()
      OVERRIDE { return this; }

  // CefBrowserProcessHandler methods.
  virtual void OnContextInitialized() OVERRIDE {
    // The browser process UI thread has been initialized...
  }
  virtual void OnRenderProcessThreadCreated(CefRefPtr<CefListValue>
extra_info)
                                            OVERRIDE {
    // Send startup information to a new render process...
  }

  // CefRenderProcessHandler methods.
  virtual void OnRenderThreadCreated(CefRefPtr<CefListValue> ex-
tra_info)
                                     OVERRIDE {
    // The render process main thread has been initialized...
    // Receive startup information in the new render process...
  }
```

```
  virtual void OnWebKitInitialized(CefRefPtr<ClientApp> app) OVERRIDE
{
    // WebKit has been initialized, register V8 extensions...
  }
  virtual void OnBrowserCreated(CefRefPtr<CefBrowser> browser) OVER-
RIDE {
    // Browser created in this render process...
  }
  virtual void OnBrowserDestroyed(CefRefPtr<CefBrowser> browser)
OVERRIDE {
    // Browser destroyed in this render process...
  }
  virtual bool OnBeforeNavigation(CefRefPtr<CefBrowser> browser,
                                  CefRefPtr<CefFrame> frame,
                                  CefRefPtr<CefRequest> request,
                                  NavigationType navigation_type,
                                  bool is_redirect) OVERRIDE {
    // Allow or block different types of navigation...
  }
  virtual void OnContextCreated(CefRefPtr<CefBrowser> browser,
                                CefRefPtr<CefFrame> frame,
                                CefRefPtr<CefV8Context>
context) OVERRIDE {
    // JavaScript context created, add V8 bindings here...
  }
  virtual void OnContextReleased(CefRefPtr<CefBrowser> browser,
                                 CefRefPtr<CefFrame> frame,
                                 CefRefPtr<CefV8Context> context)
OVERRIDE {
    // JavaScript context released, release V8 references here...
  }
  virtual bool OnProcessMessageReceived(
      CefRefPtr<CefBrowser> browser,
      CefProcessId source_process,
      CefRefPtr<CefProcessMessage> message) OVERRIDE {
    // Handle IPC messages from the browser process...
  }

  IMPLEMENT_REFCOUNTING(MyApp);
};
```

3.8 CefClient

The CefClient interface provides access to browser-instance-specific callbacks. A single CefClient instance can be shared among any number of browsers. Important callbacks include:

- Handlers for elements like browser life span, context menus, dialogs, display notifications, drag events, focus events, keyboard events and more. The majority of handlers are optional. See the documentation in cef_client.h for the side effects, if any, of not implementing a specific handler.

- **OnProcessMessageReceived** which is called when an IPC message is received from the render process. See the “Inter-Process Communication” section for more information.

Example CefClient implementation:

```
// MyHandler implements CefClient and a number of other interfaces.
class MyHandler : public CefClient,
                  public CefContextMenuHandler,
                  public CefDisplayHandler,
                  public CefDownloadHandler,
                  public CefDragHandler,
                  public CefGeolocationHandler,
                  public CefKeyboardHandler,
                  public CefLifeSpanHandler,
                  public CefLoadHandler,
                  public CefRequestHandler {
 public:
  MyHandler();

  // CefClient methods. Important to return |this| for the handler
callbacks.
  virtual CefRefPtr<CefContextMenuHandler> GetContextMenuHandler()
OVERRIDE {
    return this;
  }
  virtual CefRefPtr<CefDisplayHandler> GetDisplayHandler() OVERRIDE {
    return this;
  }
  virtual CefRefPtr<CefDownloadHandler> GetDownloadHandler() OVERRIDE
{
    return this;
  }
  virtual CefRefPtr<CefDragHandler> GetDragHandler() OVERRIDE {
    return this;
  }
  virtual CefRefPtr<CefGeolocationHandler> GetGeolocationHandler()
OVERRIDE {
    return this;
  }
  virtual CefRefPtr<CefKeyboardHandler> GetKeyboardHandler() OVERRIDE
{
    return this;
  }
  virtual CefRefPtr<CefLifeSpanHandler> GetLifeSpanHandler() OVERRIDE
{
```

```
    return this;
  }
  virtual CefRefPtr<CefLoadHandler> GetLoadHandler() OVERRIDE {
    return this;
  }
  virtual CefRefPtr<CefRequestHandler> GetRequestHandler() OVERRIDE {
    return this;
  }
  virtual bool OnProcessMessageReceived(CefRefPtr<CefBrowser>
browser,
                                        CefProcessId source_process,
                                        CefRefPtr<CefProcess-
Message> message)
                                        OVERRIDE {
    // Handle IPC messages from the render process...
  }

  // CefContextMenuHandler methods
  virtual void OnBeforeContextMenu(CefRefPtr<CefBrowser> browser,
                                   CefRefPtr<CefFrame> frame,
                                   CefRefPtr<CefContextMenuParams>
params,
                                   CefRefPtr<CefMenuModel> model)
OVERRIDE {
    // Customize the context menu...
  }
  virtual bool OnContextMenuCommand(CefRefPtr<CefBrowser> browser,
                                    CefRefPtr<CefFrame> frame,
                                    CefRefPtr<CefContextMenuParams>
params,
                                    int command_id,
                                    EventFlags event_flags) OVERRIDE
{
    // Handle a context menu command...
  }

  // CefDisplayHandler methods
  virtual void OnLoadingStateChange(CefRefPtr<CefBrowser> browser,
                                    bool isLoading,
                                    bool canGoBack,
                                    bool canGoForward) OVERRIDE {
    // Update UI for browser state...
  }
  virtual void OnAddressChange(CefRefPtr<CefBrowser> browser,
                               CefRefPtr<CefFrame> frame,
                               const CefString& url) OVERRIDE {
    // Update the URL in the address bar...
  }
  virtual void OnTitleChange(CefRefPtr<CefBrowser> browser,
                             const CefString& title) OVERRIDE {
    // Update the browser window title...
```

```
  }
  virtual bool OnConsoleMessage(CefRefPtr<CefBrowser> browser,
                                const CefString& message,
                                const CefString& source,
                                int line) OVERRIDE {
    // Log a console message...
  }

  // CefDownloadHandler methods
  virtual void OnBeforeDownload(
      CefRefPtr<CefBrowser> browser,
      CefRefPtr<CefDownloadItem> download_item,
      const CefString& suggested_name,
      CefRefPtr<CefBeforeDownloadCallback> callback) OVERRIDE {
    // Specify a file path or cancel the download...
  }
  virtual void OnDownloadUpdated(
      CefRefPtr<CefBrowser> browser,
      CefRefPtr<CefDownloadItem> download_item,
      CefRefPtr<CefDownloadItemCallback> callback) OVERRIDE {
    // Update the download status...
  }

  // CefDragHandler methods
  virtual bool OnDragEnter(CefRefPtr<CefBrowser> browser,
                           CefRefPtr<CefDragData> dragData,
                           DragOperationsMask mask) OVERRIDE {
    // Allow or deny drag events...
  }

  // CefGeolocationHandler methods
  virtual void OnRequestGeolocationPermission(
      CefRefPtr<CefBrowser> browser,
      const CefString& requesting_url,
      int request_id,
      CefRefPtr<CefGeolocationCallback> callback) OVERRIDE {
    // Allow or deny geolocation API access...
  }

  // CefKeyboardHandler methods
  virtual bool OnPreKeyEvent(CefRefPtr<CefBrowser> browser,
                             const CefKeyEvent& event,
                             CefEventHandle os_event,
                             bool* is_keyboard_shortcut) OVERRIDE {
    // Perform custom handling of key events...
  }

  // CefLifeSpanHandler methods
  virtual bool OnBeforePopup(CefRefPtr<CefBrowser> browser,
                             CefRefPtr<CefFrame> frame,
                             const CefString& target_url,
```

```
                             const CefString& target_frame_-
name,
                             const CefPopupFeatures& popupFeatures,
                             CefWindowInfo& windowInfo,
                             CefRefPtr<CefClient>& client,
                             CefBrowserSettings& settings,
                             bool* no_javascript_access) OVERRIDE {
    // Allow or block popup windows, customize popup window crea-
tion...
  }
  virtual void OnAfterCreated(CefRefPtr<CefBrowser> browser) OVERRIDE
{
    // Browser window created successfully...
  }
  virtual bool DoClose(CefRefPtr<CefBrowser> browser) OVERRIDE {
    // Allow or block browser window close...
  }
  virtual void OnBeforeClose(CefRefPtr<CefBrowser> browser) OVERRIDE
{
    // Browser window is closed, perform cleanup...
  }

  // CefLoadHandler methods
  virtual void OnLoadStart(CefRefPtr<CefBrowser> browser,
                           CefRefPtr<CefFrame> frame) OVERRIDE {
    // A frame has started loading content...
  }
  virtual void OnLoadEnd(CefRefPtr<CefBrowser> browser,
                         CefRefPtr<CefFrame> frame,
                         int httpStatusCode) OVERRIDE {
    // A frame has finished loading content...
  }
  virtual void OnLoadError(CefRefPtr<CefBrowser> browser,
                           CefRefPtr<CefFrame> frame,
                           ErrorCode errorCode,
                           const CefString& errorText,
                           const CefString& failedUrl) OVERRIDE {
    // A frame has failed to load content...
  }
  virtual void OnRenderProcessTerminated(CefRefPtr<CefBrowser>
browser,
                                         TerminationStatus status)
OVERRIDE {
    // A render process has crashed...
  }

  // CefRequestHandler methods
  virtual CefRefPtr<CefResourceHandler> GetResourceHandler(
      CefRefPtr<CefBrowser> browser,
      CefRefPtr<CefFrame> frame,
      CefRefPtr<CefRequest> request) OVERRIDE {
```

```
    // Optionally intercept resource requests...
  }
  virtual bool OnQuotaRequest(CefRefPtr<CefBrowser> browser,
                              const CefString& origin_url,
                              int64 new_size,
                              CefRefPtr<CefQuotaCallback> callback)
OVERRIDE {
    // Allow or block quota requests...
  }
  virtual void OnProtocolExecution(CefRefPtr<CefBrowser> browser,
                                   const CefString& url,
                                   bool& allow_os_execution) OVERRIDE
{
    // Handle execution of external protocols...
  }

  IMPLEMENT_REFCOUNTING(MyHandler);
};
```

3.9 Browser Life Span

Browser life span begins with a call to CefBrowserHost::CreateBrowser() or CefBrowserHost::CreateBrowserSync(). Convenient places to execute this logic include the CefBrowserProcessHandler::OnContextInitialized() callback or platform-specific message handlers like WM_CREATE on Windows.

```
// Information about the window that will be created including par-
enting, size, etc.
// The definition of this structure is platform-specific.
CefWindowInfo info;
// On Windows for example...
info.SetAsChild(parent_hwnd, client_rect);

// Customizes this structure to control browser behavior.
CefBrowserSettings settings;

// CefClient implementation.
CefRefPtr<MyClient> client(new MyClient);

// Creates the browser asynchronously. Initially loads the Google
URL.
CefBrowserHost::CreateBrowser(info, client.get(),
"http://www.google.com", settings);
```

The CefLifeSpanHandler class provides the callbacks necessary for managing browser life span. Below is an extract of the relevant methods and members.

```
class MyClient : public CefClient,
                 public CefLifeSpanHandler,
                 ... {
  // CefClient methods.
  virtual CefRefPtr<CefLifeSpanHandler> GetLifeSpanHandler() OVERRIDE
{
    return this;
  }

  // CefLifeSpanHandler methods.
  void OnAfterCreated(CefRefPtr<CefBrowser> browser) OVERRIDE;
  bool DoClose(CefRefPtr<CefBrowser> browser) OVERRIDE;
  void OnBeforeClose(CefRefPtr<CefBrowser> browser) OVERRIDE;

  // Member accessors.
  CefRefPtr<CefBrowser> GetBrower() { return m_Browser; }
  bool IsClosing() { return m_bIsClosing; }

 private:
  CefRefPtr<CefBrowser> m_Browser;
  int m_BrowserId;
  int m_BrowserCount;
  bool m_bIsClosing;

  IMPLEMENT_REFCOUNTING(MyClient);
  IMPLEMENT_LOCKING(MyClient);  // Deprecated -- see the “Threads”
section.
};
```

The OnAfterCreated() method will be called immediately after the browser object is created. The host application can use this method to keep a reference to the main browser object.

```
void MyClient::OnAfterCreated(CefRefPtr<CefBrowser> browser) {
  // Must be executed on the UI thread.
  REQUIRE_UI_THREAD();
  // Protect data members from access on multiple threads.
  AutoLock lock_scope(this);  // Deprecated -- see the “Threads” sec-
tion.

  if (!m_Browser.get())   {
    // Keep a reference to the main browser.
    m_Browser = browser;
    m_BrowserId = browser->GetIdentifier();
  }
```

```
  // Keep track of how many browsers currently exist.
  m_BrowserCount++;
}
```

To destroy the browser call CefBrowserHost::CloseBrowser().

```
// Notify the browser window that we would like to close it. This
will result in a call to
// MyHandler::DoClose() if the JavaScript 'onbeforeunload' event han-
dler allows it.
browser->GetHost()->CloseBrowser(false);
```

If the browser is parented to another window then the close event may originate in the OS function for that parent window (for example, by clicking the X on the parent window). The parent window then needs to call CloseBrowser(false) and wait for a second OS close event to indicate that the browser has allowed the close. The second OS close event will not be sent if the close is canceled by a JavaScript ‘onbeforeunload’ event handler or by the DoClose() callback. Notice the IsClosing() check in the below examples -- it will return false for the first OS close event and true for the second (after DoClose is called).

Handling in the parent window WndProc on Windows:

```
case WM_CLOSE:
  if (g_handler.get() && !g_handler->IsClosing()) {
    CefRefPtr<CefBrowser> browser = g_handler->GetBrowser();
    if (browser.get()) {
      // Notify the browser window that we would like to close it.
This will result in a call to
      // MyHandler::DoClose() if the JavaScript 'onbeforeunload'
event handler allows it.
      browser->GetHost()->CloseBrowser(false);

      // Cancel the close.
      return 0;
    }
  }

  // Allow the close.
  break;

case WM_DESTROY:
```

```
  // Quitting CEF is handled in MyHandler::OnBeforeClose().
  return 0;
}
```

Handling the “delete_event” signal on Linux:

```
gboolean delete_event(GtkWidget* widget, GdkEvent* event,
                      GtkWindow* window) {
  if (g_handler.get() && !g_handler->IsClosing()) {
    CefRefPtr<CefBrowser> browser = g_handler->GetBrowser();
    if (browser.get()) {
      // Notify the browser window that we would like to close it.
This will result in a call to
      // MyHandler::DoClose() if the JavaScript 'onbeforeunload'
event handler allows it.
      browser->GetHost()->CloseBrowser(false);

      // Cancel the close.
      return TRUE;
    }
  }

  // Allow the close.
  return FALSE;
}
```

Handling the windowShouldClose: selector on Mac OS X:

```
// Called when the window is about to close. Performs the self-de-
struction
// sequence by getting rid of the window. By returning YES, we allow
the window
// to be removed from the screen.
- (BOOL)windowShouldClose:(id)window {
  if (g_handler.get() && !g_handler->IsClosing()) {
    CefRefPtr<CefBrowser> browser = g_handler->GetBrowser();
    if (browser.get()) {
      // Notify the browser window that we would like to close it.
This will result in a call to
      // MyHandler::DoClose() if the JavaScript 'onbeforeunload'
event handler allows it.
      browser->GetHost()->CloseBrowser(false);
```

```
      // Cancel the close.
      return NO;
    }
  }

  // Try to make the window go away.
  [window autorelease];

  // Clean ourselves up after clearing the stack of anything that
might have the
  // window on it.
  [self performSelectorOnMainThread:@selector(cleanup:)
                         withObject:window
                      waitUntilDone:NO];

  // Allow the close.
  return YES;
}
```

The DoClose() method sets the m_bIsClosing flag and returns false to send the second OS close event.

```
bool MyClient::DoClose(CefRefPtr<CefBrowser> browser) {
  // Must be executed on the UI thread.
  REQUIRE_UI_THREAD();
  // Protects data members from access on multiple threads.
  AutoLock lock_scope(this);

  // Closing the main window requires special handling. See the Do-
Close()
  // documentation in the CEF header for a detailed description of
this
  // process.
  if (m_BrowserId == browser->GetIdentifier()) {
    // Notify the browser that the parent window is about to close.
    browser->GetHost()->ParentWindowWillClose();

    // Set a flag to indicate that the window close should be al-
lowed.
    m_bIsClosing = true;
  }

  // Allow the close. For windowed browsers this will result in the
OS close
  // event being sent.
  return false;
}
```

When the OS function receives the second OS close event it allows the parent window to actually close. This then results in a call to OnBeforeClose(). Make sure to release any references to the browser object in the OnBeforeClose() callback.

```
void MyHandler::OnBeforeClose(CefRefPtr<CefBrowser> browser) {
  // Must be executed on the UI thread.
  REQUIRE_UI_THREAD();
  // Protect data members from access on multiple threads.
  AutoLock lock_scope(this);

  if (m_BrowserId == browser->GetIdentifier()) {
    // Free the browser pointer so that the browser can be destroyed.
    m_Browser = NULL;
  }

  if (--m_BrowserCount == 0) {
    // All browser windows have closed. Quit the application message
loop.
    CefQuitMessageLoop();
  }
}
```

See the cefclient application for complete working examples on each platform.

3.10 Off-Screen Rendering

With off-screen rendering CEF does not create a native browser window. Instead, CEF provides the host application with invalidated regions and a pixel buffer and the host application notifies CEF of mouse, keyboard and focus events. Off-screen rendering does not currently support accelerated compositing so performance may suffer as compared to a windowed browser. Off-screen browsers will receive the same notifications as windowed browsers including the life span notifications described in the previous section. To use off-screen rendering:

1. Implement the CefRenderHandler interface. All methods are required unless otherwise indicated.
2. Call CefWindowInfo::SetAsOffScreen() and optionally CefWindowInfo::SetTransparentPainting() before passing the CefWindowInfo structure to CefBrowserHost::CreateBrowser(). If no parent window is passed to SetAsOffScreen some functionality like context menus may not be available.

3. The CefRenderHandler::GetViewRect() method will be called to retrieve the desired view rectangle.
4. The CefRenderHandler::OnPaint() method will be called to provide invalid regions and the updated pixel buffer. The cefclient application draws the buffer using OpenGL but your application can use whatever technique you prefer.
5. To resize the browser call CefBrowserHost::WasResized(). This will result in a call to GetViewRect() to retrieve the new size followed by a call to OnPaint().
6. Call the CefBrowserHost::SendXXX() methods to notify the browser of mouse, keyboard and focus events.
7. Call CefBrowserHost::CloseBrowser() to destroy browser.

Run cefclient with the "--off-screen-rendering-enabled" command-line flag for a working example.

4. Posting Tasks

Tasks can be posted between the various threads in a single process using the CefPostTask family of methods (see the cef_task.h header file for the complete list). The task will execute asynchronously on the message loop of the target thread. For example, to execute the MyObject::MyMethod method on the UI thread and pass it two parameters:

```
CefPostTask(TID_UI, NewCefRunnableMethod(object, &MyObject::MyMethod,
param1, param2));
```

To execute the MyFunction function on the IO thread and pass it two parameters:

```
CefPostTask(TID_IO, NewCefRunnableFunction(MyFunction, param1,
param2));
```

See the cef_runnable.h header file for more information on the NewCefRunnable templates (deprecated -- see below).

If the host application needs to keep a reference to a run loop it can use the CefTaskRunner class. For example, to get the task runner for the UI thread:

```
CefRefPtr<CefTaskRunner> task_runner = CefTaskRunner::Get-
ForThread(TID_UI);
```

Starting with trunk revision 1769 (on Google Code) cef_runnable.h has been deprecated in favor of Chromium's base::Bind and base::Callback types. These types are now exposed in CEF via the include/base folder. For example:

```
// Includes the necessary headers.
#include "include/base/cef_bind.h"
#include "include/wrapper/cef_closure_task.h"

// To execute a bound function:

// Defines a function.
void MyFunc(int arg) { /* do something with |arg| on the UI thread */
}

// Posts a task that will execute MyFunc on the UI thread and pass an
|arg|
// value of 5.
CefPostTask(TID_UI, base::Bind(&MyFunc, 5));

// To execute a bound method:

// Defines a class.
class MyClass : public CefBase {
 public:
  MyClass() {}
  void MyMethod(int arg) { /* do something with |arg| on the UI
thread */ }
 private:
  IMPLEMENT_REFCOUNTING(MyClass);
};

// Creates an instance of MyClass.
CefRefPtr<MyClass> instance = new MyClass();

// Posts a task that will execute MyClass::MyMethod on the UI thread
and pass
// an |arg| value of 5. |instance| will be kept alive until after the
task
// completes.
CefPostTask(TID_UI, base::Bind(&MyClass::MyMethod, instance, 5));
```

The cef_closure_task.h header provides helpers for converting a base::Closure to a CefTask. For complete base::Bind and base::Callback usage information see comments in the cef_callback.h header.

5. Inter-Process Communication (IPC)

Since CEF3 runs in multiple processes it is necessary to provide mechanisms for communicating between those processes. CefBrowser and CefFrame objects exist in both the browser and render processes which helps to facilitate this process. Each CefBrowser and CefFrame object also has a unique ID value associated with it that will match on both sides of the process boundary.

5.1 Process Startup Messages

To provide all render processes with the same information on startup implement CefBrowserProcessHandler::OnRenderProcessThreadCreated() in the browser process. This will pass information to CefRenderProcessHandler::OnRenderThreadCreated() in the render process.

5.2 Process Runtime Messages

To pass information at any time during the process lifespan use process messages via the CefProcessMessage class. These messages are associated with a specific CefBrowser instance and are sent using the CefBrowser::SendProcessMessage() method. The process message should contain whatever state information is required via CefProcessMessage::GetArgumentList().

```
// Create the message object.
CefRefPtr<CefProcessMessage> msg= CefProcessMessage::Create(“my_mes-
sage”);

// Retrieve the argument list object.
CefRefPtr<CefListValue> args = msg>GetArgumentList();

// Populate the argument values.
args->SetString(0, “my string”);
args->SetInt(0, 10);

// Send the process message to the render process.
// Use PID_BROWSER instead when sending a message to the browser pro-
cess.
browser->SendProcessMessage(PID_RENDERER, msg);
```

A message sent from the browser process to the render process will arrive in CefRenderProcessHandler::OnProcessMessageReceived(). A message sent from the render process to the browser process will arrive in CefClient::OnProcessMessageReceived().

```
bool MyHandler::OnProcessMessageReceived(
    CefRefPtr<CefBrowser> browser,
    CefProcessId source_process,
    CefRefPtr<CefProcessMessage> message) {
  // Check the message name.
  const std::string& message_name = message->GetName();
  if (message_name == “my_message”) {
    // Handle the message here...
    return true;
  }
  return false;
}
```

To associate the message with a particular CefFrame pass the frame ID (retrievable via CefFrame::GetIdentifier()) as an argument and retrieve the associated CefFrame in the receiving process via the CefBrowser::GetFrame() method.

```
// Helper macros for splitting and combining the int64 frame ID
value.
#define MAKE_INT64(int_low, int_high) \
    ((int64) (((int) (int_low)) | ((int64) ((int) (int_high))) <<
32))
#define LOW_INT(int64_val) ((int) (int64_val))
#define HIGH_INT(int64_val) ((int) (((int64) (int64_val) >> 32) &
0xFFFFFFFFL))

// Sending the frame ID.
const int64 frame_id = frame->GetIdentifier();
args->SetInt(0, LOW_INT(frame_id));
args->SetInt(1, HIGH_INT(frame_id));

// Receiving the frame ID.
const int64 frame_id = MAKE_INT64(args->GetInt(0), args->GetInt(1));
CefRefPtr<CefFrame> frame = browser->GetFrame(frame_id);
```

5.3 Asynchronous JavaScript Bindings

JavaScriptIntegration is implemented in the render process but frequently need to communicate with the browser process. The JavaScript APIs themselves should be designed to work asynchronously using closures andpromises.

5.4 Generic Message Router

Starting with trunk revision 1574 (on Google Code) CEF provides a generic implementation for routing asynchronous messages between JavaScript running in the renderer process and C++ running in the browser process. An application interacts with the router by passing it data from standard CEF C++ callbacks (OnBeforeBrowse, OnProcessMessageRecieved, OnContextCreated, etc). The renderer-side router supports generic JavaScript callback registration and execution while the browser-side router supports application-specific logic via one or more application-provided Handler instances.

The JavaScript bindings look like this:

```
// Create and send a new query.
var request_id = window.cefQuery({
    request: 'my_request',
    persistent: false,
    onSuccess: function(response) {},
    onFailure: function(error_code, error_message) {}
});

// Optionally cancel the query.
window.cefQueryCancel(request_id);
```

The C++ handler looks like this:

```
class Callback : public CefBase {
 public:
  ///
  // Notify the associated JavaScript onSuccess callback that the
query has
  // completed successfully with the specified |response|.
  ///
  virtual void Success(const CefString& response) =0;

  ///
  // Notify the associated JavaScript onFailure callback that the
query has
```

```
  // failed with the specified |error_code| and |error_message|.
  ///
  virtual void Failure(int error_code, const CefString& error_mes-
sage) =0;
};

class Handler {
 public:
  ///
  // Executed when a new query is received. |query_id| uniquely iden-
tifies the
  // query for the life span of the router. Return true to handle the
query
  // or false to propagate the query to other registered handlers, if
any. If
  // no handlers return true from this method then the query will be
  // automatically canceled with an error code of -1 delivered to the
  // JavaScript onFailure callback. If this method returns true then
a
  // Callback method must be executed either in this method or asyn-
chronously
  // to complete the query.
  ///
  virtual bool OnQuery(CefRefPtr<CefBrowser> browser,
                       CefRefPtr<CefFrame> frame,
                       int64 query_id,
                       const CefString& request,
                       bool persistent,
                       CefRefPtr<Callback> callback) {
    return false;
  }

  ///
  // Executed when a query has been canceled either explicitly using
the
  // JavaScript cancel function or implicitly due to browser destruc-
tion,
  // navigation or renderer process termination. It will only be
called for
  // the single handler that returned true from OnQuery for the same
  // |query_id|. No references to the associated Callback object
should be
  // kept after this method is called, nor should any Callback meth-
ods be
  // executed.
  ///
  virtual void OnQueryCanceled(CefRefPtr<CefBrowser> browser,
                               CefRefPtr<CefFrame> frame,
                               int64 query_id) {}
};
```

See wrapper/cef_message_router.h for complete usage documentation.

5.5 Custom Implementation

A CEF-based application can also provide its own custom implementation of asynchronous JavaScript bindings. A simplistic implementation could work as follows:

1. The JavaScript binding in the render process is passed a callback function.

```
// In JavaScript register the callback function.
app.setMessageCallback('binding_test', function(name, args) {
  document.getElementById('result').value = "Response: "+args[0];
});
```

2. The render process keeps a reference to the callback function.

```
// Map of message callbacks.
typedef std::map<std::pair<std::string, int>,
                 std::pair<CefRefPtr<CefV8Context>, Ce-
fRefPtr<CefV8Value> > >
                 CallbackMap;
CallbackMap callback_map_;

// In the CefV8Handler::Execute implementation for "setMessage-
Callback".
if (arguments.size() == 2 && arguments[0]->IsString() &&
    arguments[1]->IsFunction()) {
  std::string message_name = arguments[0]->GetStringValue();
  CefRefPtr<CefV8Context> context = CefV8Context::GetCurrent-
Context();
  int browser_id = context->GetBrowser()->GetIdentifier();
  callback_map_.insert(
      std::make_pair(std::make_pair(message_name, browser_id),
                     std::make_pair(context, arguments[1])));
}
```

3. The render process sends an asynchronous IPC message to the browser process requesting that work be performed.

4. The browser process receives the IPC message and performs the work.

5. Upon completion of the work the browser process sends an asynchronous IPC message back to the render process with the result.

6. The render process receives the IPC message and executes the callback function with the result.

```
// Execute the registered JavaScript callback if any.
if (!callback_map_.empty()) {
  const CefString& message_name = message->GetName();
  CallbackMap::const_iterator it = callback_map_.find(
      std::make_pair(message_name.ToString(),
                     browser->GetIdentifier()));
  if (it != callback_map_.end()) {
    // Keep a local reference to the objects. The callback may remove
itself
    // from the callback map.
    CefRefPtr<CefV8Context> context = it->second.first;
    CefRefPtr<CefV8Value> callback = it->second.second;

    // Enter the context.
    context->Enter();

    CefV8ValueList arguments;

    // First argument is the message name.
    arguments.push_back(CefV8Value::CreateString(message_name));

    // Second argument is the list of message arguments.
    CefRefPtr<CefListValue> list = message->GetArgumentList();
    CefRefPtr<CefV8Value> args = CefV8Value::CreateArray(list->Get-
Size());
    SetList(list, args);  // Helper function to convert CefListValue
to CefV8Value.
    arguments.push_back(args);

    // Execute the callback.
    CefRefPtr<CefV8Value> retval = callback->ExecuteFunction(NULL,
arguments);
    if (retval.get()) {
      if (retval->IsBool())
        handled = retval->GetBoolValue();
    }

    // Exit the context.
    context->Exit();
  }
}
```

7. Release any V8 references associated with the context in CefRenderProcessHandler::OnContextReleased().

```
void MyHandler::OnContextReleased(CefRefPtr<CefBrowser> browser,
                                  CefRefPtr<CefFrame> frame,
                                  CefRefPtr<CefV8Context> context) {
  // Remove any JavaScript callbacks registered for the context that
has been released.
  if (!callback_map_.empty()) {
    CallbackMap::iterator it = callback_map_.begin();
    for (; it != callback_map_.end();) {
      if (it->second.first->IsSame(context))
        callback_map_.erase(it++);
      else
        ++it;
    }
  }
}
```

5.5 Synchronous Requests

In rare cases it may be necessary to implement synchronous communication between the browser and render processes. This should be avoided whenever possible because it will negatively impact performance in the render process. However, if you must have synchronous communication consider using synchronous XMLHttpRequests which will block the render process while awaiting handling in the browser process network layer. The browser process can handle the requests using a custom scheme handler or network interception. See the “Network Layer” section for more information.

6. Network Layer

By default network requests in CEF3 will be handled in a manner transparent to the host application. For applications wishing for a closer relationship with the network layer CEF3 exposes a range of network-related functionalities.

Network-related callbacks can occur on different threads so make sure to pay attention to the documentation and properly protect your data members.

6.1 Custom Requests

The simplest way to load a URL in a browser frame is via the CefFrame::LoadURL() method.

```
browser->GetMainFrame()->LoadURL(some_url);
```

Applications wishing to send more complex requests containing custom request headers or upload data can use the CefFrame::LoadRequest() method. This method accepts a CefRequest object as the single argument.

```
// Create a CefRequest object.
CefRefPtr<CefRequest> request = CefRequest::Create();

// Set the request URL.
request->SetURL(some_url);

// Set the request method. Supported methods include GET, POST, HEAD,
DELETE and PUT.
request->SetMethod("POST");

// Optionally specify custom headers.
CefRequest::HeaderMap headerMap;
headerMap.insert(
    std::make_pair("X-My-Header", "My Header Value"));
request->SetHeaderMap(headerMap);

// Optionally specify upload content.
// The default "Content-Type" header value is "application/x-www-
form-urlencoded".
// Set "Content-Type" via the HeaderMap if a different value is de-
sired.
const std::string& upload_data = "arg1=val1&arg2=val2";
CefRefPtr<CefPostData> postData = CefPostData::Create();
CefRefPtr<CefPostDataElement> element = CefPostDataElement::Create();
element->SetToBytes(upload_data.size(), upload_data.c_str());
postData->AddElement(element);
request->SetPostData(postData);
```

6.2 Browser-Independent Requests

Applications can send network requests not associated with a particular browser via the CefURLRequest class. Implement the CefURLRequestClient interface to handle the resulting response. CefURLRequest can be used in both the browser and render processes.

```
class MyRequestClient : public CefURLRequestClient {
```

```
 public:
  MyRequestClient()
    : upload_total_(0),
      download_total_(0) {}

  virtual void OnRequestComplete(CefRefPtr<CefURLRequest> request)
OVERRIDE {
    CefURLRequest::Status status = request->GetRequestStatus();
    CefURLRequest::ErrorCode error_code = request->GetRequest-
Error();
    CefRefPtr<CefResponse> response = request->GetResponse();

    // Do something with the response...
  }

  virtual void OnUploadProgress(CefRefPtr<CefURLRequest> request,
                                uint64 current,
                                uint64 total) OVERRIDE {
    upload_total_ = total;
  }

  virtual void OnDownloadProgress(CefRefPtr<CefURLRequest> request,
                                  uint64 current,
                                  uint64 total) OVERRIDE {
    download_total_ = total;
  }

  virtual void OnDownloadData(CefRefPtr<CefURLRequest> request,
                              const void* data,
                              size_t data_length) OVERRIDE {
    download_data_ += std::string(static_cast<const char*>(data),
data_length);
  }

 private:
  uint64 upload_total_;
  uint64 download_total_;
  std::string download_data_;

 private:
  IMPLEMENT_REFCOUNTING(MyRequestClient);
};
```

To send the request:

```
// Set up the CefRequest object.
CefRefPtr<CefRequest> request = CefRequest::Create();
```

```
// Populate |request| as shown above...

// Create the client instance.
CefRefPtr<MyRequestClient> client = new MyRequestClient();

// Start the request. MyRequestClient callbacks will be executed
asynchronously.
CefRefPtr<CefURLRequest> url_request = CefURLRequest::Create(request,
client.get());
// To cancel the request: url_request->Cancel();
```

Requests made with **CefURLRequest** can also specify custom behaviors via the **CefRequest::SetFlags()** method. Supported bit flags include:

- **UR_FLAG_SKIP_CACHE** If set the cache will be skipped when handling the request.
- **UR_FLAG_ALLOW_CACHED_CREDENTIALS** If set cookies may be sent with the request and saved from the response. **UR_FLAG_ALLOW_CACHED_CREDENTIALS** must also be set.
- **UR_FLAG_REPORT_UPLOAD_PROGRESS** If set upload progress events will be generated when a request has a body.
- **UR_FLAG_REPORT_LOAD_TIMING** If set load timing info will be collected for the request.
- **UR_FLAG_REPORT_RAW_HEADERS** If set the headers sent and received for the request will be recorded.
- **UR_FLAG_NO_DOWNLOAD_DATA** If set the **CefURLRequestClient::OnDownloadData** method will not be called.
- **UR_FLAG_NO_RETRY_ON_5XX** If set 5XX redirect errors will be propagated to the observer instead of automatically re-tried. This currently only applies for requests originated in the browser process.

For example, to skip the cache and not report download data:

```
request->SetFlags(UR_FLAG_SKIP_CACHE | UR_FLAG_NO_DOWNLOAD_DATA);
```

6.3 Request Handling

CEF3 supports two approaches for handling network requests inside of an application. The scheme handler approach allows registration of a handler for requests targeting a particular origin (scheme + domain). The request interception approach allows handling of arbitrary requests at the application's discretion.

Use the HTTP scheme instead of a custom scheme to avoid a range of potential issues.

If you choose to use a custom scheme (anything other than "HTTP", "HTTPS", etc) you must register it with CEF so that it will behave as expected. If you would like your custom scheme to behave similar to HTTP (support POST requests and enforce HTTP access control (CORS) restrictions) then it should be registered as a "standard" scheme. If you are planning to perform cross-origin requests to other schemes or send POST requests via XMLHttpRequest to your scheme handler then you should use the HTTP scheme instead of a custom scheme to avoid potential issues. If you wish to use custom schemes the attributes are registered via the CefApp::OnRegisterCustomSchemes() callback which must be implemented in all processes.

```
void MyApp::OnRegisterCustomSchemes(CefRefPtr<CefSchemeRegistrar>
registrar) {
  // Register "client" as a standard scheme.
  registrar->AddCustomScheme("client", true, false, false);
}
```

6.4 Scheme Handler

A scheme handler is registered via the CefRegisterSchemeHandlerFactory() function. A good place to call this function is from CefBrowserProcessHandler::OnContextInitialized(). For example, you can register a handler for "client://myapp/" requests:

```
CefRegisterSchemeHandlerFactory("client", "myapp", new MyScheme-
HandlerFactory());
```

Handlers can be used with both built-in schemes (HTTP, HTTPS, etc) and custom schemes. When using a built-in scheme choose a domain name unique to your application (like "myapp" or "internal"). Implement theCefSchemeHandlerFactory and CefResourceHandler classes to handle the request and provide response data. If using custom schemes don't forget to implement the CefApp::OnRegisterCustomSchemes method as described above. See the “Scheme Handler” test in cefclient (implemented in scheme_test.[cpp|h]) for a working example.

```
// Implementation of the factory for creating client request han-
dlers.
class MySchemeHandlerFactory : public CefSchemeHandlerFactory {
 public:
  virtual CefRefPtr<CefResourceHandler> Create(CefRefPtr<CefBrowser>
browser,
                                               CefRefPtr<CefFrame>
frame,
                                               const CefString&
scheme_name,
                                               CefRefPtr<CefRequest>
request)
                                               OVERRIDE {
    // Return a new resource handler instance to handle the request.
    return new MyResourceHandler();
  }

  IMPLEMENT_REFCOUNTING(MySchemeHandlerFactory);
};

// Implementation of the resource handler for client requests.
class MyResourceHandler : public CefResourceHandler {
 public:
  MyResourceHandler() {}

  virtual bool ProcessRequest(CefRefPtr<CefRequest> request,
                              CefRefPtr<CefCallback> callback)
                              OVERRIDE {
    // Evaluate |request| to determine proper handling...
    // Execute |callback| once header information is available.
    // Return true to handle the request.
    return true;
  }

  virtual void GetResponseHeaders(CefRefPtr<CefResponse> response,
                                  int64& response_length,
                                  CefString& redirectUrl) OVERRIDE {
    // Populate the response headers.
    response->SetMimeType("text/html");
    response->SetStatus(200);

    // Specify the resulting response length.
    response_length = ...;
  }
```

```
  virtual void Cancel() OVERRIDE {
    // Cancel the response...
  }

  virtual bool ReadResponse(void* data_out,
                            int bytes_to_read,
                            int& bytes_read,
                            CefRefPtr<CefCallback> callback)
                            OVERRIDE {
    // Read up to |bytes_to_read| data into |data_out| and set
|bytes_read|.
    // If data isn't immediately available set bytes_read=0 and exe-
cute
    // |callback| asynchronously.
    // Return true to continue the request or false to complete the
request.
    return …;
  }

 private:
  IMPLEMENT_REFCOUNTING(MyResourceHandler);
};
```

If the response data is known at request time the CefStreamResourceHandler class provides a convenient default implementation of CefResourceHandler.

```
// CefStreamResourceHandler is part of the libcef_dll_wrapper pro-
ject.
#include “include/wrapper/cef_stream_resource_handler.h”

const std::string& html_content = “<html><body>Hello!</body></html>”;

// Create a stream reader for |html_content|.
CefRefPtr<CefStreamReader> stream =
    CefStreamReader::CreateForData(
        static_cast<void*>(const_cast<char*>(html_content.c_str())),
        html_content.size());

// Constructor for HTTP status code 200 and no custom response head-
ers.
// There’s also a version of the constructor for custom status code
and response headers.
return new CefStreamResourceHandler("text/html", stream);
```

6.5 Request Interception

The CefRequestHandler::GetResourceHandler() method supports the interception of arbitrary requests. It uses the same CefResourceHandler class as the scheme handler approach. If using custom schemes don't forget to implement the CefApp::OnR egisterCustomSchemes method as described above. See ClientHandler::GetResourceHandler (implemented in client_handler.cpp) for a working example.

```
CefRefPtr<CefResourceHandler> MyHandler::GetResourceHandler(
      CefRefPtr<CefBrowser> browser,
      CefRefPtr<CefFrame> frame,
      CefRefPtr<CefRequest> request) {
  // Evaluate |request| to determine proper handling...
  if (...)
    return new MyResourceHandler();

  // Return NULL for default handling of the request.
  return NULL;
}
```

6.6 Other Callbacks

The CefRequestHandler interface provides callbacks for various network-related events incuding authentication, cookie handling, external protocol handling, certificate errors and so on.

6.7 Proxy Resolution

Proxy settings are configured in CEF3 using the same command-line flags as Google Chrome.

```
--proxy-server=host:port
      Specify the HTTP/SOCKS4/SOCKS5 proxy server to use for re-
quests. An individual proxy
      server is specified using the format:

        [<proxy-scheme>://]<proxy-host>[:<proxy-port>]

      Where <proxy-scheme> is the protocol of the proxy server, and
is one of:

        "http", "socks", "socks4", "socks5".
```

```
      If the <proxy-scheme> is omitted, it defaults to "http". Also
note that "socks" is equivalent to
      "socks5".

      Examples:

        --proxy-server="foopy:99"
            Use the HTTP proxy "foopy:99" to load all URLs.

        --proxy-server="socks://foobar:1080"
            Use the SOCKS v5 proxy "foobar:1080" to load all URLs.

        --proxy-server="sock4://foobar:1080"
            Use the SOCKS v4 proxy "foobar:1080" to load all URLs.

        --proxy-server="socks5://foobar:66"
            Use the SOCKS v5 proxy "foobar:66" to load all URLs.

      It is also possible to specify a separate proxy server for dif-
ferent URL types, by prefixing
      the proxy server specifier with a URL specifier:

      Example:

        --proxy-server="https=proxy1:80;http=socks4://baz:1080"
            Load https://* URLs using the HTTP proxy "proxy1:80". And
load http://*
            URLs using the SOCKS v4 proxy "baz:1080".

--no-proxy-server
      Disables the proxy server.

--proxy-auto-detect
      Autodetect  proxy  configuration.

--proxy-pac-url=URL
      Specify proxy autoconfiguration URL.
```

If the proxy requires authentication the CefRequestHandler::GetAuthCredentials() callback will be executed with an |isProxy| value of true to retrieve the username and password.

```
bool MyHandler::GetAuthCredentials(
    CefRefPtr<CefBrowser> browser,
    CefRefPtr<CefFrame> frame,
    bool isProxy,
    const CefString& host,
```

```
    int port,
    const CefString& realm,
    const CefString& scheme,
    CefRefPtr<CefAuthCallback> callback) {
  if (isProxy) {
    // Provide credentials for the proxy server connection.
    callback->Continue("myuser", "mypass");
    return true;
  }
  return false;
}
```

Web content loading during application startup can be delayed due to network proxy resolution (for example, if "Automatically detect proxy settings" is checked on Windows). For best user experience consider designing your application to first show a static splash page and then redirect to the actual website using [meta refresh]() -- the redirect will be blocked until proxy resolution completes. For testing purposes proxy resolution can be disabled using the "--no-proxy-server" command-line flag. Proxy resolution delays can also be duplicated in Google Chrome by running "chrome --url=..." from the command line

7. Shiva Plugin Presentation

```
//----------------------           API Functions       -----------
-----------------

inline S3DX::AIVariable     createInstance       (
              )

inline S3DX::AIVariable     destroyInstance      ( const S3DX::AIVar-
iable& sInstanceID)

inline S3DX::AIVariable     loadURL              ( const S3DX::AIVar-
iable& sInstanceID, const S3DX::AIVariable& sURL
                                    )

inline S3DX::AIVariable     setWindowSize        ( const S3DX::AIVar-
iable& sInstanceID, const S3DX::AIVariable& nWindowWidth, const
S3DX::AIVariable& nWindowHeight                )

inline S3DX::AIVariable     render               ( const S3DX::AIVar-
iable& sInstanceID, const S3DX::AIVariable& hPixelMap
)
```

```
inline S3DX::AIVariable     setVisible          ( const S3DX::AIVar-
iable& sInstanceID, const S3DX::AIVariable& bVisible
)

inline S3DX::AIVariable     getFocusElementType  ( const S3DX::AIVar-
iable& sInstanceID )

inline S3DX::AIVariable     triggerAction        ( const S3DX::AIVar-
iable& sInstanceID, const S3DX::AIVariable& kAction
)

inline S3DX::AIVariable     onMouseButtonUp      ( const S3DX::AIVar-
iable& sInstanceID, const S3DX::AIVariable& nButton, const S3DX::AI-
Variable& nPointX, const S3DX::AIVariable& nPointY
                                                           )

inline S3DX::AIVariable     onMouseButtonDown    ( const S3DX::AIVar-
iable& sInstanceID, const S3DX::AIVariable& nButton, const S3DX::AI-
Variable& nPointX, const S3DX::AIVariable& nPointY
                                                           )

inline S3DX::AIVariable     onMouseMove          ( const S3DX::AIVar-
iable& sInstanceID, const S3DX::AIVariable& nPointX, const S3DX::AI-
Variable& nPointY                          )

inline S3DX::AIVariable     onMouseWheel         ( const S3DX::AIVar-
iable& sInstanceID, const S3DX::AIVariable& nPointX, const S3DX::AI-
Variable& nPointY, const S3DX::AIVariable& nDeltaY
                                                           )

inline S3DX::AIVariable     onKeyboardKeyUp      ( const S3DX::AIVar-
iable& sInstanceID, const S3DX::AIVariable& kKeyCode
)

inline S3DX::AIVariable     onKeyboardKeyDown    ( const S3DX::AIVar-
iable& sInstanceID, const S3DX::AIVariable& kKeyCode
)
```

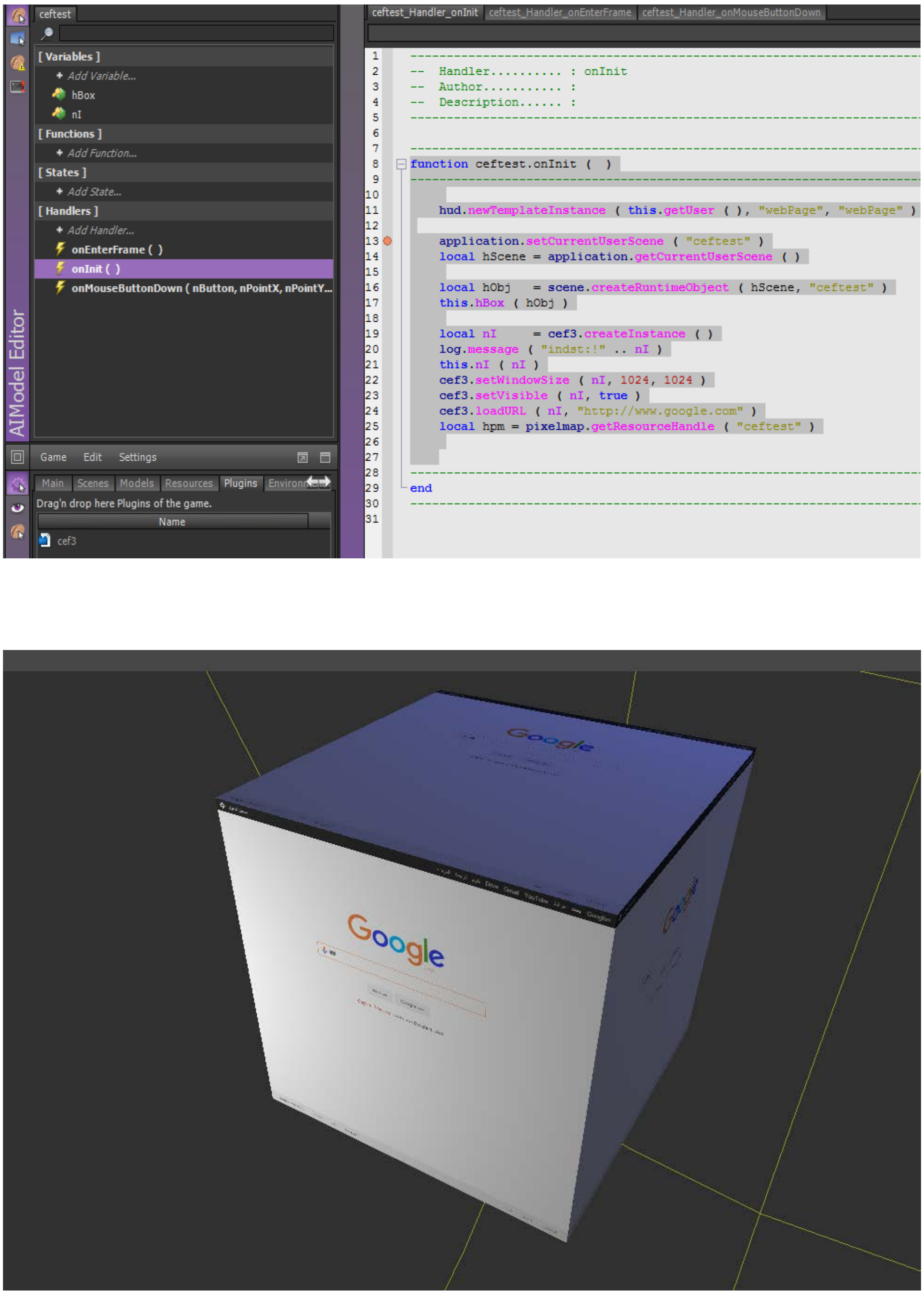
8. Conclusion

It is now possible to fully embed a working Chromium browser within Shiva 3D, with all the functionalities and Application Programming Interfaces (APIs) of the Chromium Embedded Framework, and without the use of either the Berkelium or Awesomium software . This scheme is versatile, flexible, customisable, and above all, fully interactive from the back-end to the front-end, unlike the Awesomium plugin. It constitutes a critical node of the Chreage software, in particular in its back-end/front-end synergy and relative seamlessness. The very purpose of Chréage, that of being a middleware between users and contents (and neuroergonomic softwares are typically middleware, since they, by design, plug themselves between users and contents) could not be achieved without this integration.

The next step will be to attempt a reverse integration, embedding Shiva within the CEF itself, to achieve a full HTML5 output by taking advantage of this functionality in Shiva, which has the advantage of being lean, robust and portable. This will be left to another technical prototype.

Mind ergonomy for the Knowledge Economy

Fig.1 Sample Command (up) and sample result (down)



Conclusion

William James defined psychology as the "Science of mental life". The entire subject of this work has been the question of leveraging mental life. I have outlined a modest attempt at doing with the various spans of our mental life what Vitruve has codified with the span of our bodily life. This has proved a fascinatingly rich endeavour, opening a world of possibility this work has just very barely explored. I have wanted to answer three questions : Why should we leverage mental life ? How should we leverage it ? What could be a practical result of such a leverage ?

To the question Why, I have answered with the simple, improvable and refutable paradigm of the knowledge economy in which I have particularly focused on flows, that proved rather simple to theorise, although their interferences could be quite complex to model. The constructive or destructive interference between old and novel knowledge remain a fascinating phenomenon, which we could model in a predictive manner in the future. I have expanded the importance of knowledge flows in Blue Economy, and argued its fundamental equation was "knowledge + waste = asset" and developed the idea that genetic algorithms could be "bred" to create value almost *ex nihilo,* which I have called a "silicocracy", an evolution of physiocracy.

To the question How, I have answered with a lot of neuroergonomics and some biomimetics. Neuroergonomics could help us define the various spans of our working mind, and route contents to the most adapted of each of them. I have developed a prototype manifestation of this principle with Hyperwriting : if any media is but the externalisation of a mental function, writing would consist of externalising working memory, and Hyperwriting, at least, of externalising episodic memory. Ultimately, Hyperwriting is a glyphic writing with the method of loci. The prototype I have presented here I have called "curvy A" in honour or "Linear A", the still undeciphered minoan script. I have also posed two problems in the neuroergonomics of user interface : the Mindscape and Serendipity problems. The first asks whether there is a better way to achieve an overview on the elements of a list for a user than just randomly throwing them before oneself, the second asks whether it is systematically possible to self-organise the contents of a list so as to maximise their serendipity, either for an individual user or for a group. Regarding bio-inspiration, among others I have found essential to define a "Noome", that is, the set of all the mental objects of a human being from birth to death, the noosphere equivalent of the physiome, or of the kinesphere.

To the question What, I have answered by prototype applications of gamification, which have led to a wargame for enterprises, kFlow, and to an ergonomic Mindscape based on a procedural architecture, which I have called Chréage. Chréage uses and simplifies technologies from the video game industry to generate mindscapes on the fly, and facilitate their making, their editing, their forking and hence, their evolution. Its primary purpose is to expand the exploration of the World Wide Web not only to single URLs but to entire collections of curated URLs, hence going from WWW to $\mathfrak{P}$(WWW) namely the powerset of the WWW, which is probably one of the ultimate goals of "discovery engines". I have conceived Chréage as a tool to help researchers or any knowledge-intensive profession (which may end up being any profession) and increase the global knowledge flows.

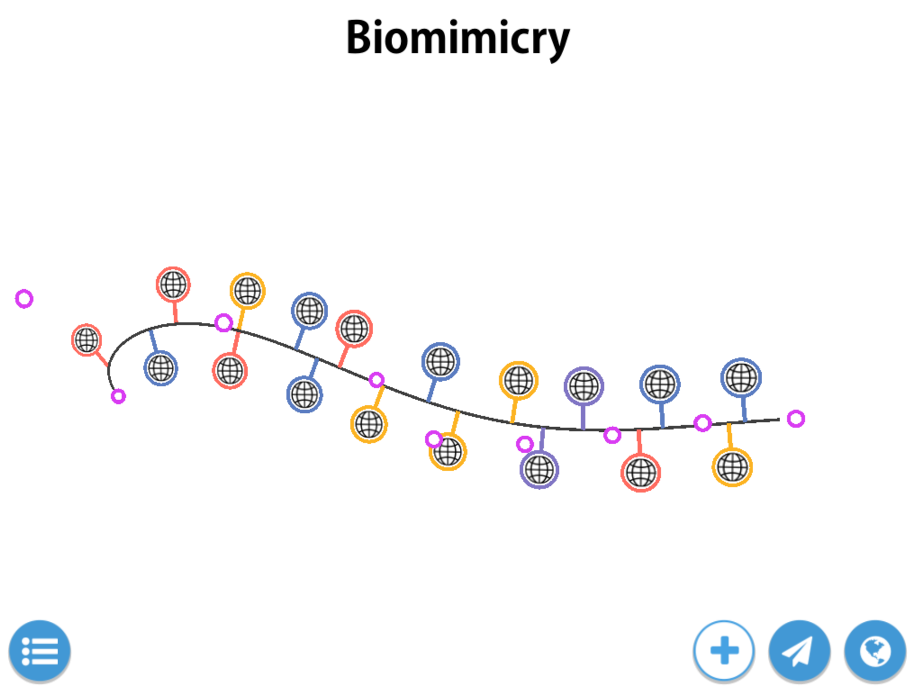
This work is just a beginning, and opens many more questions than it posed in the first place. I believe good research should lead to such a result : ending up with more questions to answer than those that were posed in the first place. To this extent, no doubt, this research has been successful.

Appendix

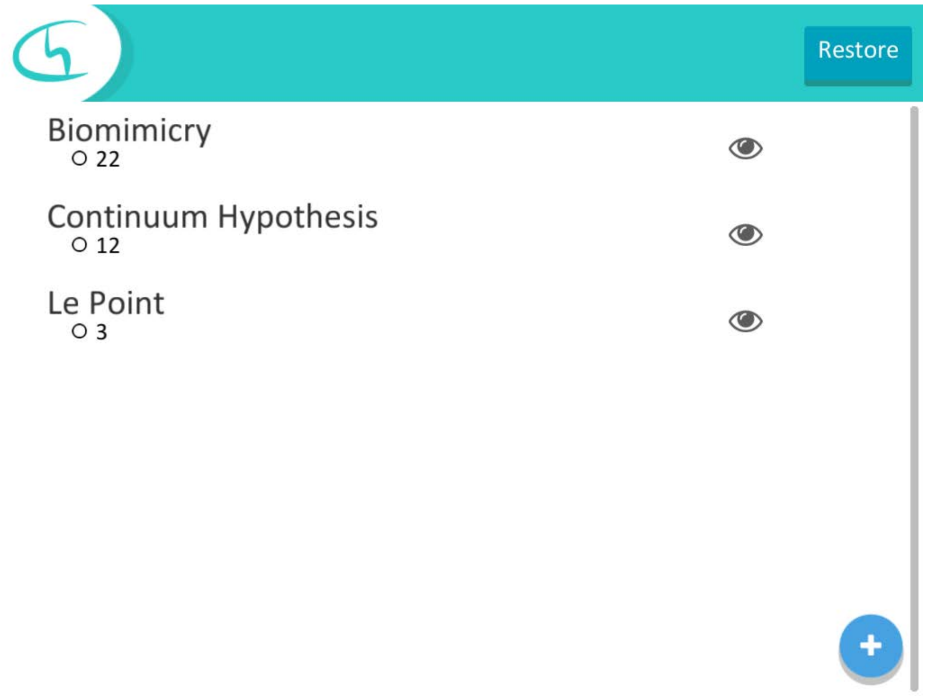
Screenshots from the Chréage WebGL proof of concept

Coded by Xavier Bourry. in WebGL. Islands are generated procedurally,. Their heightmap is generated from the L-System mapping individual URLs, each represented by their favicon

Screenshots from the Chréage Mini proof of concept (iOS 7)



This strand is used to map single urls, and to facilitate their exchange and sharing through social networks. It is “cute” but not so “powerful”. Its interest however, is the ability to share URLs not as single entities but as collections, in the way of a DNA strand. It is a software representation of what I called “CNA” or “Complex Noocleic Acid”. Its purpose was to provide affordances for groups of URLs.

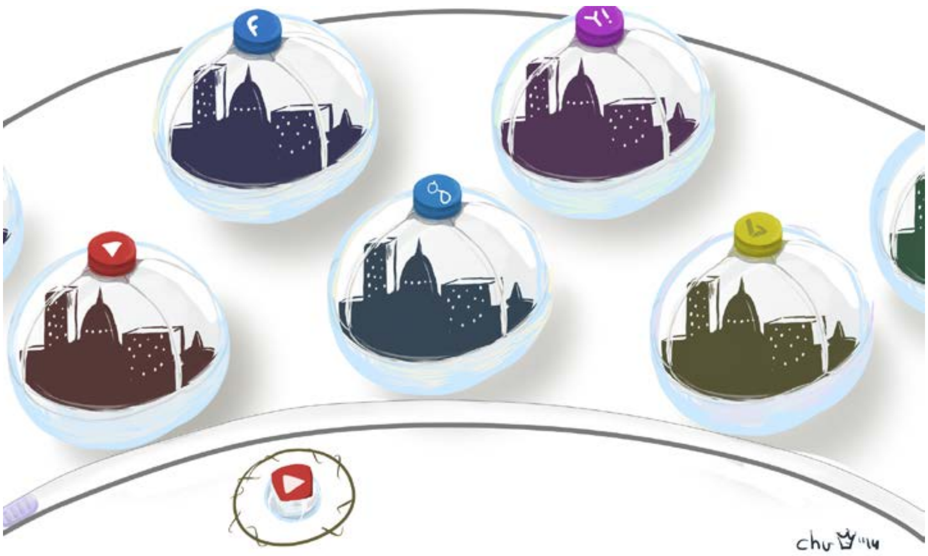


This is the Menu of the Chréage Mini PoC, where single strands are like individual folders.

Coded by Vastpark, Melbourne (2014) in Unity 3D.

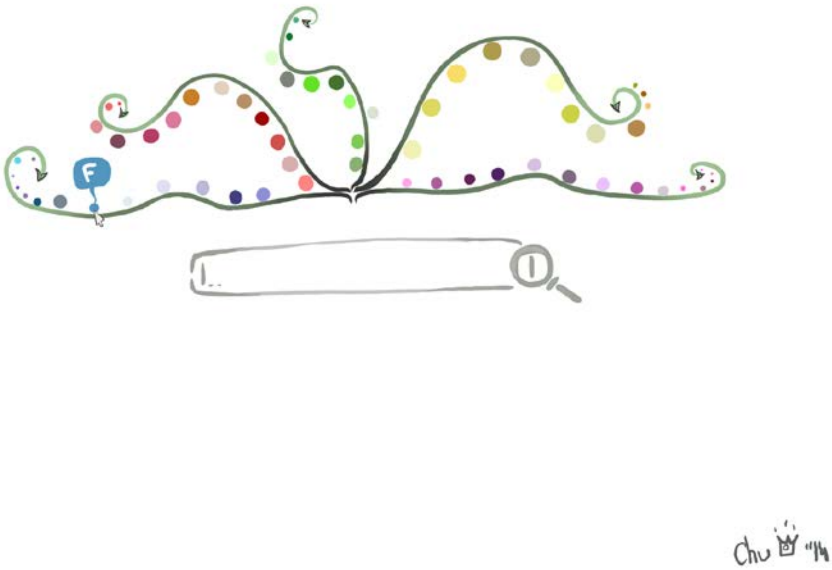
Designs from The Parthenay 2013-2014 Masterclass

A newspaper article describes the concept of the masterclass at the end of the section

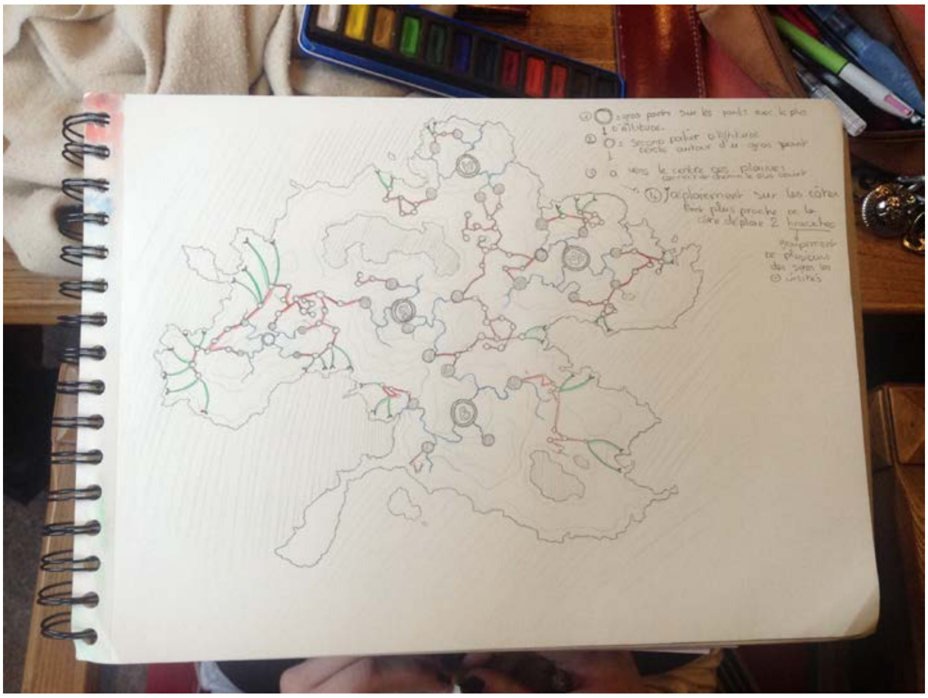


design by Marion Rodriguez

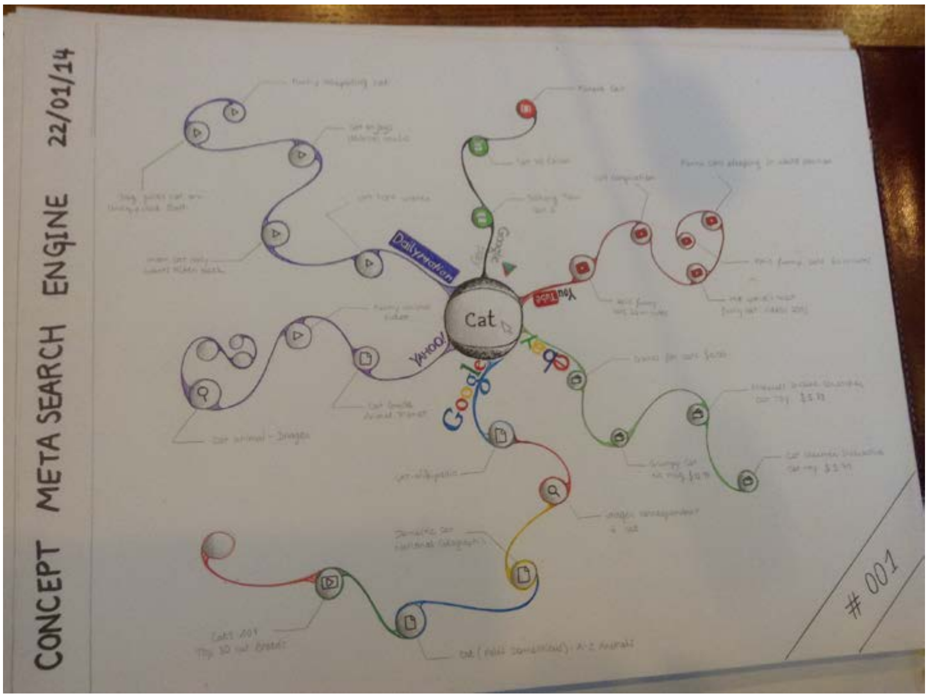
Mind ergonomy for the Knowledge Economy



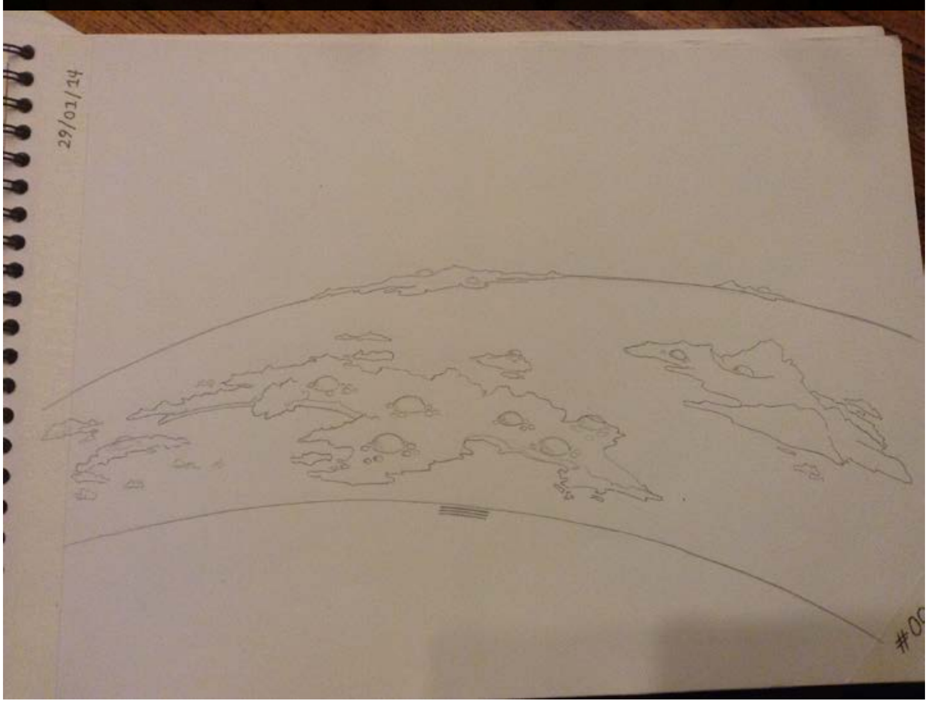
design by Marion Rodriguez

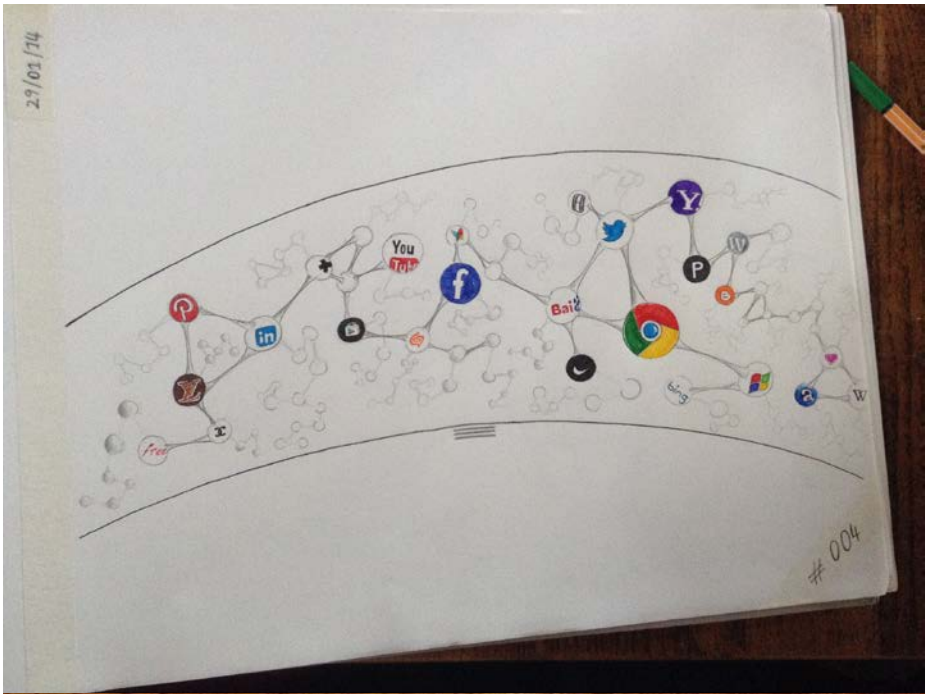


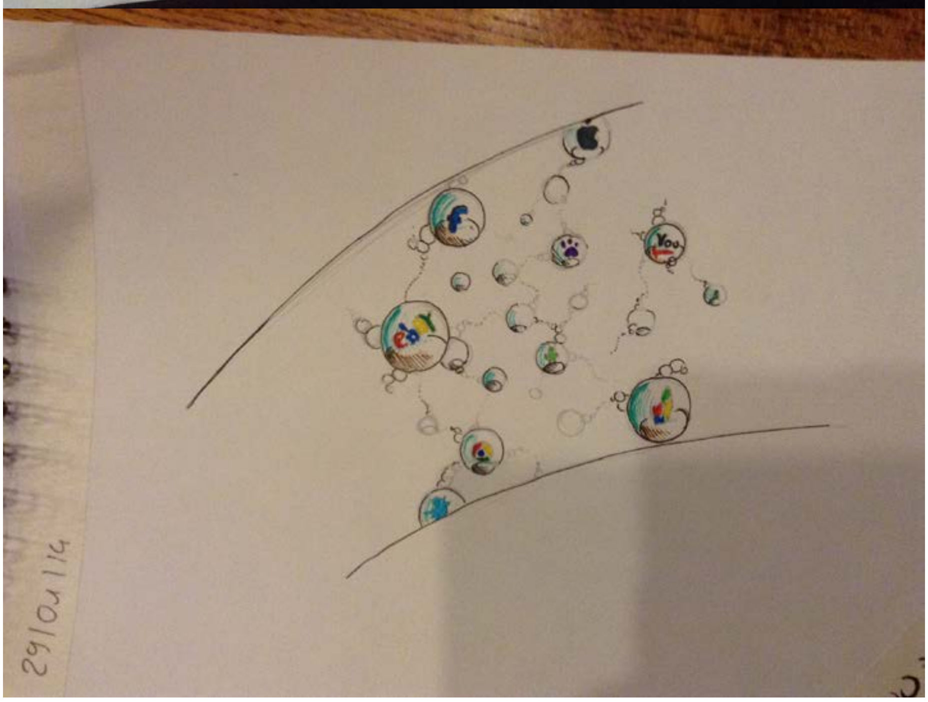
design by Nicolas Bouyssou

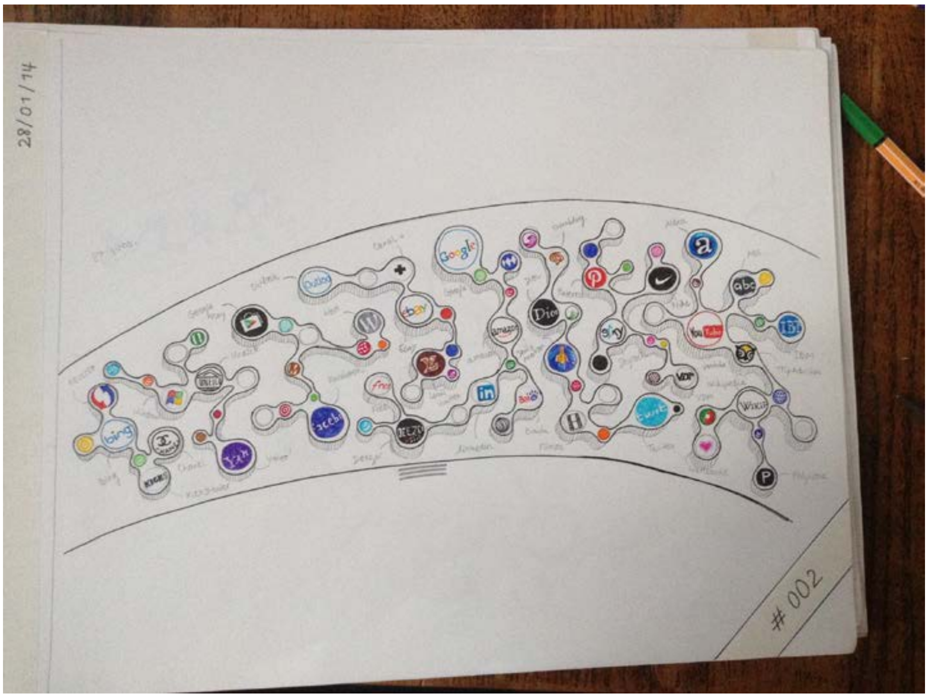


Design by Sarah Neveu


29/01/14


29/01/14
004


29/01/14



All designs above by Sarah Neveu. Note how close some are to the Apple Watch application launcher, although they were designed almost one year before its initial presentation.

rencontre

Idriss Aberkane, l'accoucheur des " geeks " de Gâtine

Ce neurotechnicien chercheur à Polytechnique accompagne toutes les semaines une quarantaine de lycéens dans le cadre du projet Chréage.

Il a 27 ans et – ce n'est rien de le dire – une tête bien faite ainsi que particulièrement bien pleine. Idriss Aberkane commence à être connu des Parthenaisiens. Il faut dire que ce génie de la biologie théorique, chercheur en neurotechnologie à Polytechnique, mais aussi féru de littérature, accompagne une quarantaine d'apprentis designers du lycée Ernest-Pérochon de Parthenay dans le cadre du projet baptisé « Chréage » pour les perspectives du web de troisième génération (3.0). Il est, par ailleurs, aussi intervenant du projet Vision qui continue de développer une application de jeu pédagogique autour de la naissance de l'univers destiné aux tablettes et téléphones portables.
Aujourd'hui, la NR a voulu faire plus ample connaissance avec ce jeune homme atypique.

Idriss Aberkane : itinéraire d'un jeune musulman de banlieue parisienne devenu chercheur à Stanford et Polytechnique, débusqué par François Gilbert pour « coacher » des lycéens de Parthenay.

Normale Sup, Cambridge, " X " et Silicon Valley

Né en 1986 dans le Val de Marne, en banlieue parisienne, au sein d'une zone d'éducation prioritaire (ZEP), Idriss Aberkane, véritable « perle de banlieue », est tombé tout petit, dès son école primaire qui était expérimentale, dans les jeux vidéo. Ensuite, ce musulman d'origine rejoint un lycée catholique puis l'université d'Orsay (Paris XI), sorte de Stanford à la française. Il a alors 17 ans et se découvre une passion dévorante pour la biologie théorique. A 19 ans, il est admis à l'École normale supérieure, où il ne se sent pas très à l'aise : « *Trop cadré, un peu castrateur, ce n'était peut-être pas une bonne idée de viser une sorte de titre de noblesse* », estime-t-il.
Le voilà parti pour Cambridge, en Angleterre puis, en 2006, l'année de ses 20 ans à Stanford, au cœur de la Silicon Valley, en Californie où il donne déjà quelques conférences. Devenu chercheur associé dans un laboratoire travaillant dans l'économie de la connaissance et du développement durable, il revient en France et pas n'importe où : à l'École polytechnique (« X ») pour un doctorat de neurothechnologie (il est aussi titulaire d'un autre doctorat en littérature à l'université de Strasbourg). Aujourd'hui neurotechnicien, il travaille dans le domaine de la neuro-ergonomie destinée à mieux répartir la charge cérébrale sur les différentes aires du cerveau, ce qui permet notamment d'optimiser les capacités mémorielles.

Il coache des " web-natifs " de Parthenay

C'est une rencontre avec François Gilbert, en charge de l'économie numérique à la communauté de communes de Parthenay, à travers des formations liées à l'enseignement privé, qu'Idriss Aberkane a découvert Parthenay, ville à cinq arobases, capitale du jeu (festival international Flip) et dotée d'un espace public numérique (EPN Armand-Jubien). Le courant passe et François Gilbert comprend le rôle que ce véritable disque dur externe vivant et plein d'idées novatrices peut apporter à Parthenay. Il participera donc au projet d'incubateur de jeux numériques et « Chréage » auquel sont inscrits une quarantaine de lycéens de la section STD2A (design et arts appliqués) du lycée Pérochon. « *C'est passionnant de travailler avec cette première génération de " web-natifs ", ces adolescents nés avec Internet car c'est avec eux que se développe le web 3.0 qui sera plus ergonomique, naturel et qui va probablement voir disparaître les claviers au profit des interfaces tactiles* », affirme-t-il. Chaque semaine, donc, Idriss Aberkane « coache » ces jeunes Gâtinais parmi lesquels figurent peut-être des développeurs de l'Internet et du design du futur. Un sacré parrainage !

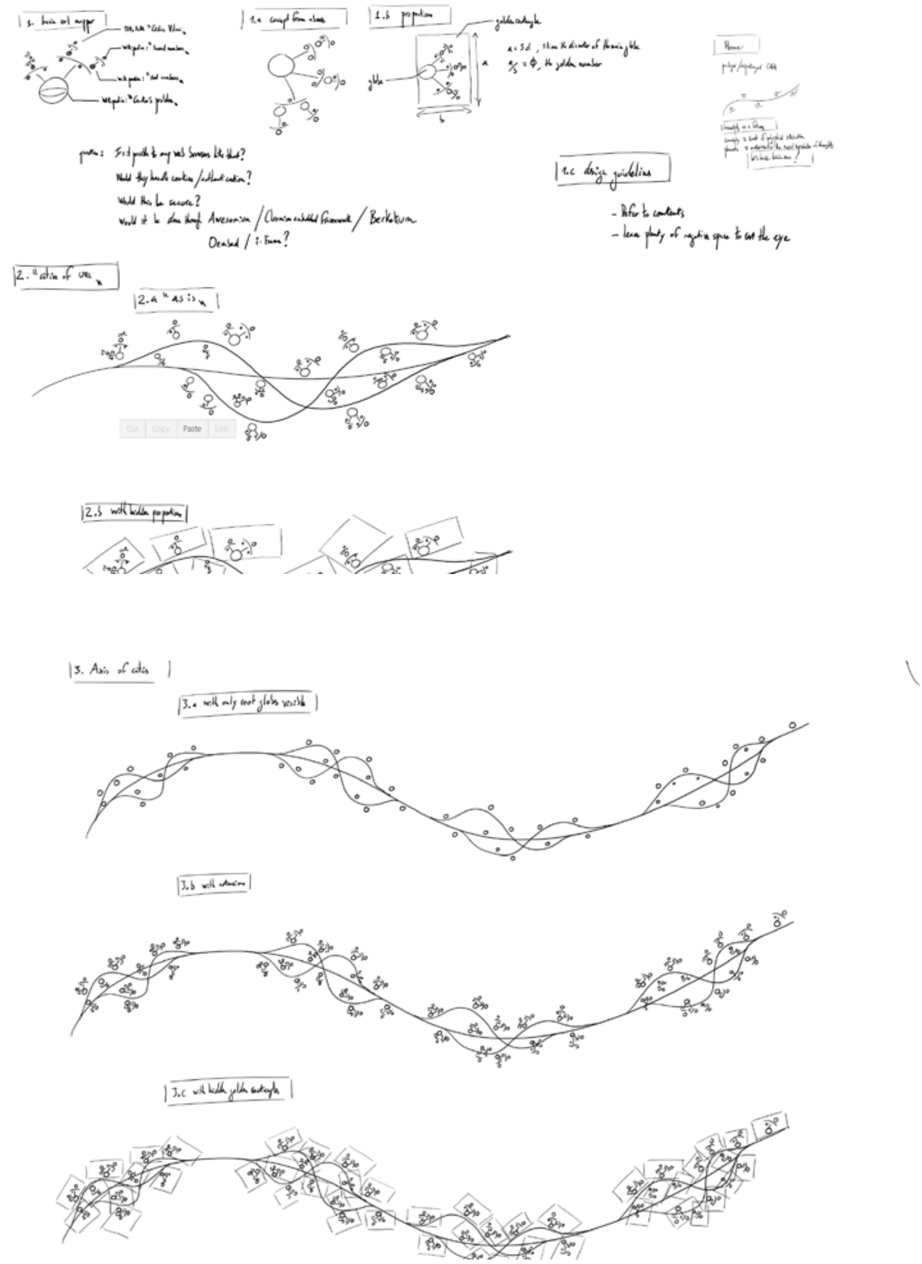
Gil Beucher
nr.parthenay@nrco.fr

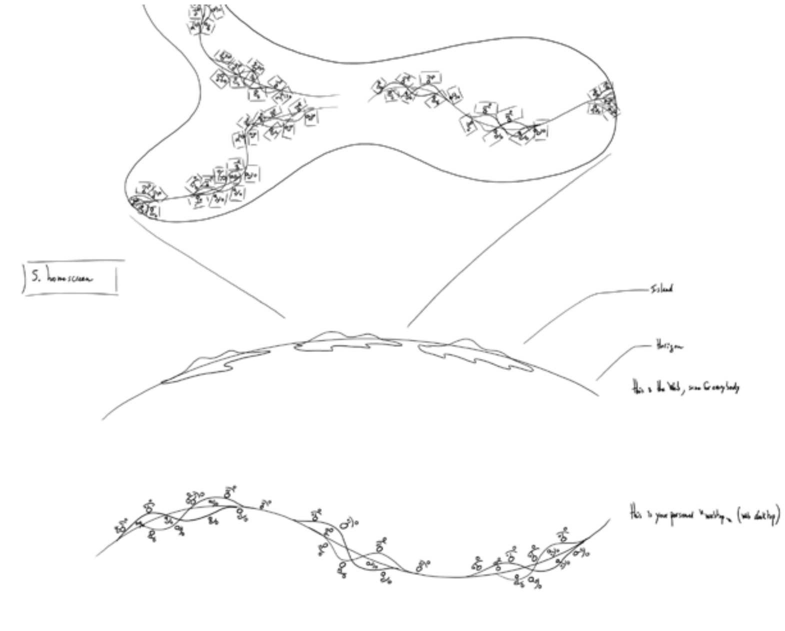
The students who completed the masterclass were

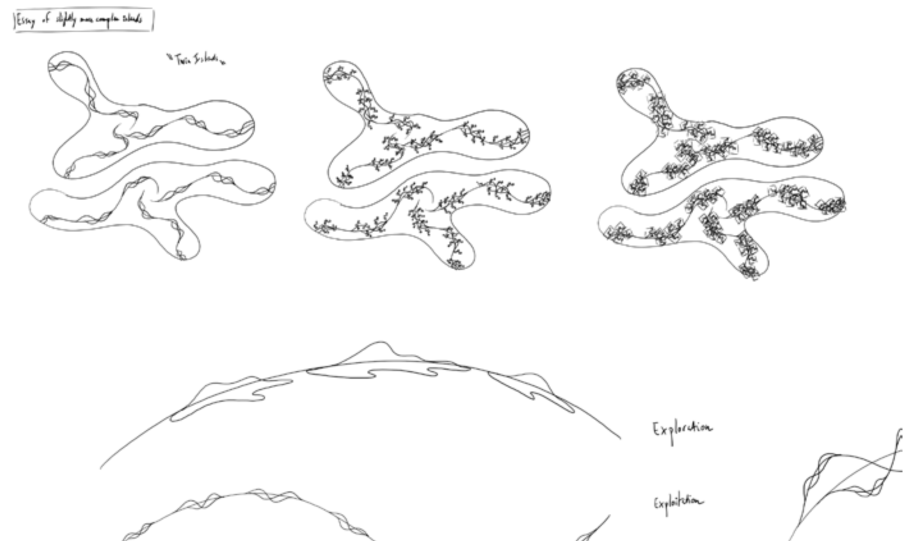
Corentin Mimeau	Caroline Gonçalves	Marion Rodriguez
Guido Grégoire	Thomas Lamiaud	Florian Charbonneau
Alexia Porcher	Louise Baudouin	Margot Jollit
Clémentine Ballanger	Mallory Jansé-Tobayas	Camille Berton
Kévin Maître	Julien retrain	Melissa Madier
Elissa Ferjani	Marion Peynet	Mathis Conan
Nicolas Bouyssou	Theo Maria	Hugo Husson

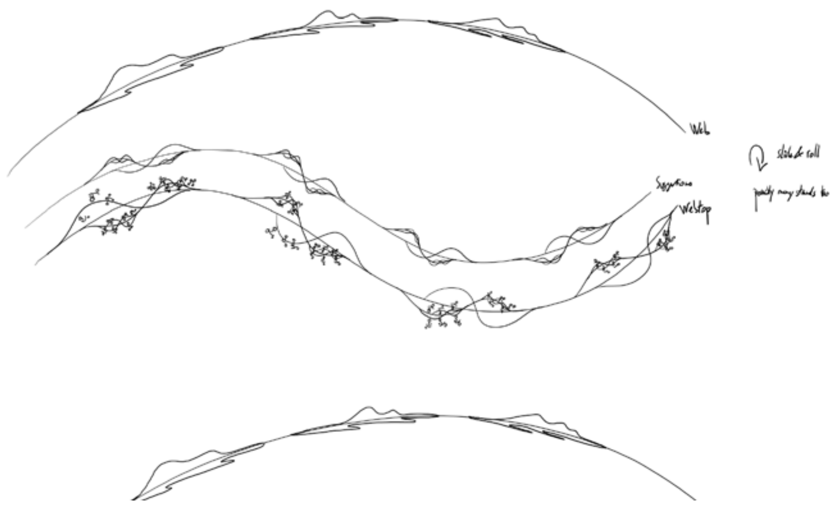
Renaud Lionnet
Fanny Baloge
Robert Harding
Ophélie Dubois
Rudra Kansara

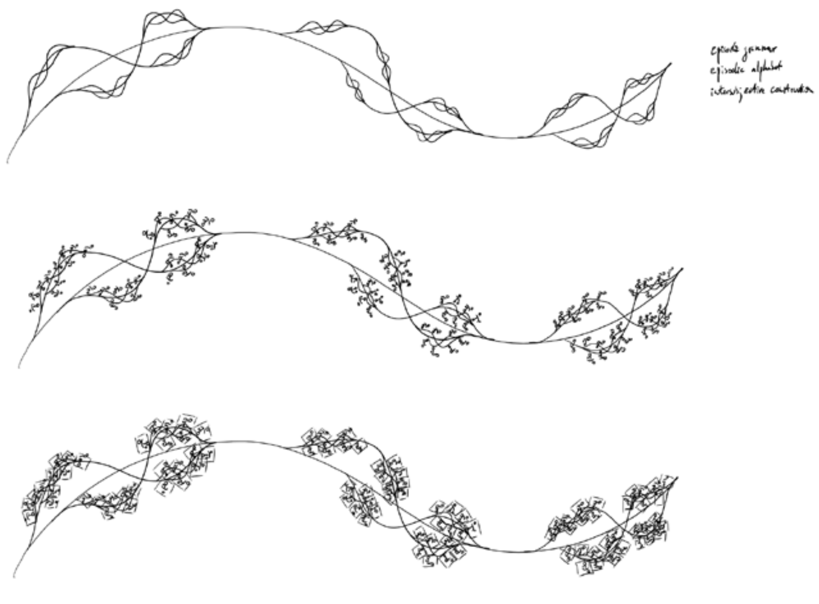
Early studies for Curvy A and Chréage

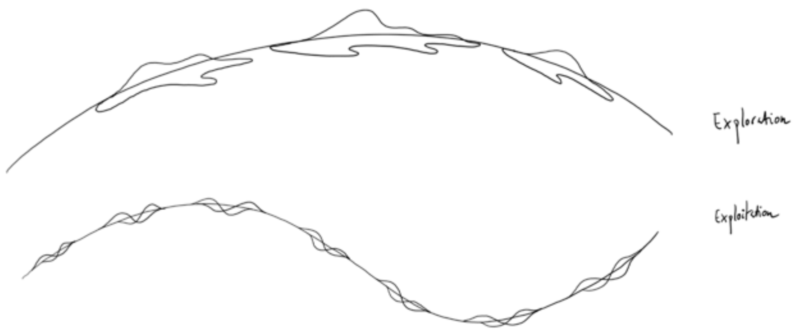


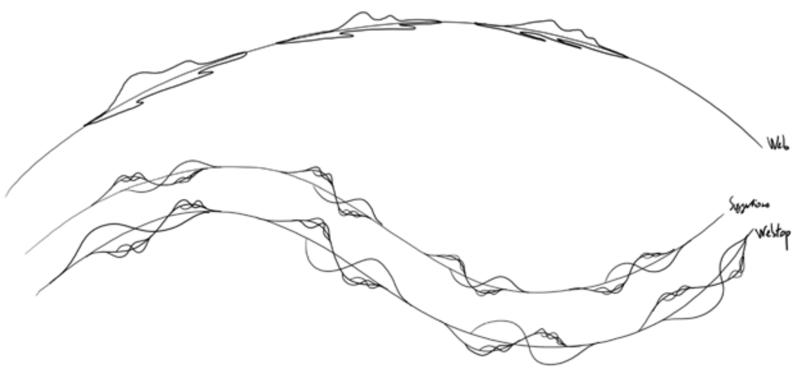

5. homescreen
Island
Horizon
This is the Web, seen from everybody
This is your personal "webtop" (web desktop)


Essay of slightly more complex islands
"Twin Islands"
Exploration
Exploitation


Web
Webtop


episodic grammar
episodic alphabet
intersubjective construction


Exploration
Exploitation


Web
Suggestions
Webtop

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ÉCOLE DOCTORALE
Sciences de l'homme et de la société (SHS)

Title : Mind Ergonomy for the Knowledge Economy : Software Neuroergonomics and Biomimetics for the Knowledge Economy. Why? How? What?

Keywords : software neuroergonomics - software biomimetics - user interface - knowledge economy - artificial writing - biomimicry – neurotechnologies

Abstract : Could we flow knowledge faster and better? Why is this a problem in the first place? How can we tackle it technologically? What could be a prototype solution? This work unifies these questions in the outline of a single, refutable and improvable paradigm of noodynamics - the study of knowledge flows - and nooconomics, the knowledge economy. This paradigm will answer the question "Why". Neuroergonomics ("brain ergonomics"), and biomimicry, will be summoned in answer to the question "How". Their contribution will follow from the knowledge flow equations proposed in this work. Two original optimisation problems are also posed in software neuroergonomics and biomimetics: the Mindscape and Serendipity Problem. A case of theoretical neuroergonomics, or neuroergonomics *ex ante* is proposed with the study of *Hyperwriting*, a written grapheme-loceme association, or a glyphic method for externalising spatial memory. Its application to the design of user interface will finally found neuroergonomic design, or *neuromimicry*, with the example of a collegial interface to augment multiscale knowledge flows: *Chréage*. The anatomy of this prototype mindscape will be the technological conclusion of this work, and its answer to the question "What"?

Titre : Neuroergonomie et Biomimétique logicielle pour l'économie de la connaissance: Pourquoi? Comment? Quoi?

Mots clés : neuroergonomie logicielle – biomimétique logicielle – interface homme-machine – économie de la connaissance – écriture artificielle – biomimétisme – neurotechnologies

Résumé : La connaissance mondiale déclarée double environ tous les 9 ans (Kozmetsky, Smilor 1999) Parallèlement, le langage écrit ou verbal demeure le mode de transmission privilégié de la connaissance dans les organisations et sur le Web où aucune *lingua franca* n'a émergé, et qui est dès lors fractionné en contenus sinophone, anglophone, hispanophone, arabophone, hindiphone etc. Nous utilisons les travaux de Pesenti *et al* (2001), sur la mémoire épisodique dans son détournement par les calculateurs prodiges pour théoriser et concevoir une nouvelle interface homme-machine spatialisée qui permette à l'utilisateur individuel et en groupe de visualiser, de manipuler mentalement et d'échanger plus de connaissances. La théorisation et la conception de cette gamme d'interfaces, basées sur des algorithmes de spatialisation de listes, et l'unique objet de notre thèse.

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