IEEE - FUTURE DIRECTION COMMITTEE
SYMBIOTIC AUTONOMOUS SYSTEMS INITIATIVE

Transhumanism

Roberto Saracco

IEEE - Future Direction Committee

Symbiotic Autonomous Systems:

Transhumanism

This short ebook contains a number of posts I wrote in the last four years on Transhumanism, a topic that has emerged in the Symbiotic Autonomous Systems Initiative as we have been discussing the augmentation of humans and their progressive symbioses with (augmented) machines.

The posts have been revised and extended to take into account the evolution in this area.

It is a thin line, and we don’t know where to draw it ...

JUNE 17, 2014

1. **Has the Turing test been passed?**
2. **Do we have a “Standard Human”?**
3. **Transhumans or Humans?**

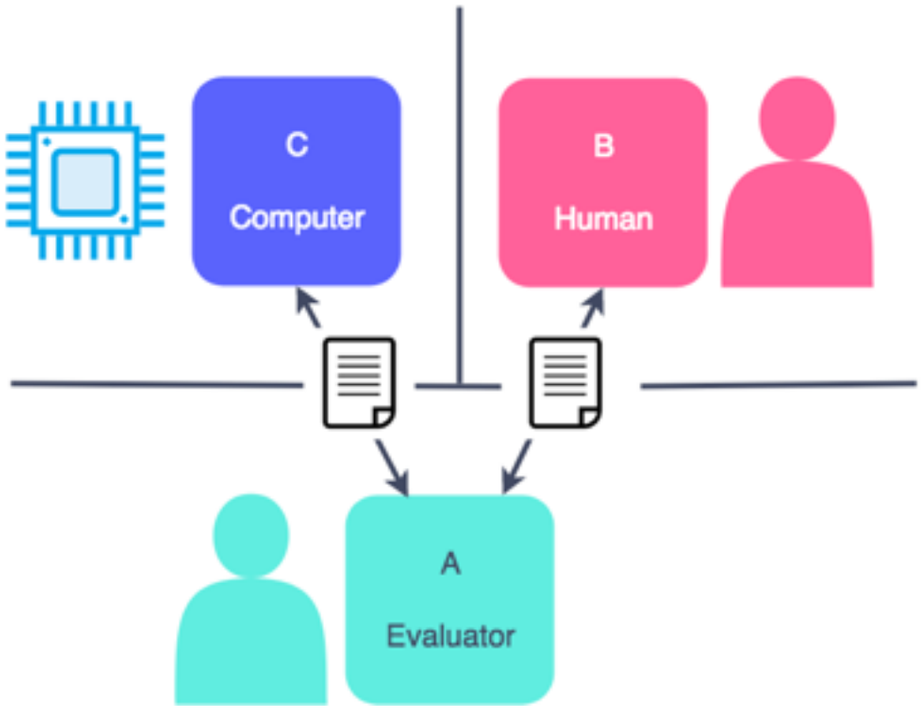


Image credit: Botsociety Blog

Last week many newspapers reported the news that the University of Reading has announced that a computer program has passed the Turing test for the first time. June 8th, 2014, was to become a milestone in Human Computer evolution.

I decided not to publish any commentary on this success, because it was being commented in so many places and because I had some doubts on the claim.

My doubts were not on the trustfulness of the University of Reading, I took their statement at face value, but on the meaning of "passing the Turing test".

In the last few days several doubts have percolated on the fact that indeed the test was passed. Someone observed that there were de facto restriction imposed on the test like the fact that the computer pretending to be a person stated to be a boy 13 years old, that he was not a native English speaking person… all factors that limited (or provided an excuse for) the actual interaction.

My doubts, however, are at a more fundamental level. How can I say that I am interacting with a human? Think about people suffering from some disabilities, think about people talking a language that is completely out of reach for you, think about people having a radically different culture, like some indigenous population in Papua New Guinea or in the deep Amazonas forest. Even if you have the possibility of getting a translation from their language to one you would understand you may not understand their ideas and if such a conversation was a

to take place with a screen separating the two of you you might doubt on who is on the other side, a man or a machine?

So I was pleased to read a commentary from Ray Kurzweil that in a way resonates with my doubts.

Ray made a prediction some time ago that a computer would pass the Turing Test by the end of the next decade. Hence, having a computer passing it 15 years before that time would have been a surprise. Also notice that there is a bet standing between Kurzweil and others claiming that the Turing test will not be passed in this timeframe.

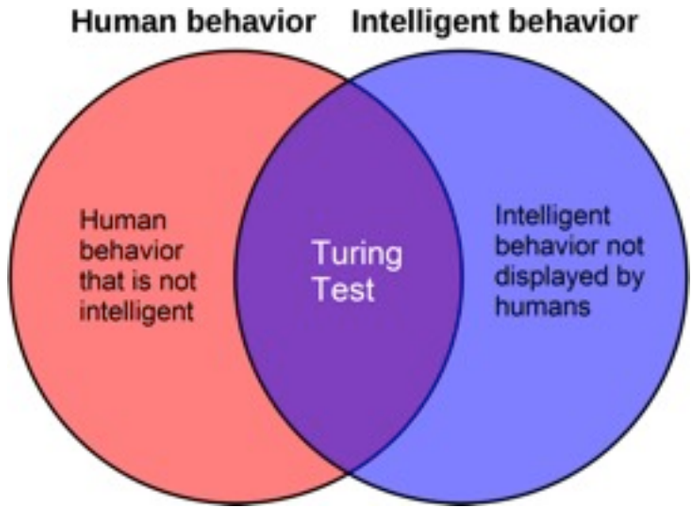
You might say that Ray has a vested interest in seeing the Turing test passed but he was one of the first to say that this time it has not been passed.

Reading his response I found a sentence that intrigued me and that I agree to: it will take quite a long time to reach the point where everybody will agree that the test has been passed and by that time the test will have been passed by several years. So there will not be any single date on which the test "is passed" but a fading area where computers and humans will be difficult to tell apart followed by one where computers will be definitely smarter then Humans, so smart that they could pretend to be humans and get away with it.

It is quite difficult to define what a human essence is (clearly you would not say that a person who is incapable to speak is not a human being….) and as technology evolves we are making this definition even more difficult. Bioengineering is confusing our definitions even further. Is an augmented human still a human (extra processing power, extra sensorial capabilities…)?

The new philosophical area (that is strongly technology based) of transhumanism is mudding the water even more. Probably Turing will be surprised to see today what kind of challenges have to be overcome and how its test is getting more and more difficult to put in practice.

Pitfalls of the Turing Test (purple intersection) as a test of intelligence. Humans can display unintelligent behavior (red circle), and humans cannot possibly display all forms of intelligent behavior (blue circle) — such as ultra-fast complex mathematical calculations. Credit: SITN - Harvard University



Symbiotic Machines

JANUARY 27, 2016

1. **From powered machines to robots**
2. **Artificial Intelligence embedded in machines**
3. **Symbioses between humans and machines leading to transhumanism**

Examples of symbioses between machines and bio have been created, like this autonomous photosynthetic bio-machine. Credit: Ivan Henriques

Machines have been around for millennia as tools to expand human capabilities. The advent of powered machines in the XVIII century has ignited the industrial revolution. The embedding of processing power in the last century has progressively created more flexible machines, igniting the digital revolution, and eventually robots that can be programmed to serve a variety of purposes and now can start to take decisions on their own.

We are on the edge of a new revolution where machines are no longer “extensions” of human capabilities but are becoming companions working and acting in symbioses with people and with the environment.

This results from increasing the understanding of goals, available resources and surrounding ambient by a machine, by the leveraging on cooperation principles, applying both to other machines as well as humans, and it brings to the fore new issues, including ethical ones.

Robots are a reality in manufacturing, making production chains ever more flexible. The drive towards autonomous vehicles is basically a transformation of vehicles into robots.

More and more complex issues arise by this increased flexibility of machines and their need to take advantage, or at least take notice, of their environment to adapt their behavior. Artificial Intelligence is de facto permeating the control of machine

actions and a collective intelligence is born out of an ambient where several machines are active, even though they may not interact directly.

An increased pressure to ensure safety and security in a world that gets more and more vulnerable is pushing researchers to increase awareness in machine and this in turns increases their capability to act as autonomous systems, raising the stakes of security to protect from hacking in a never ending story.

We are going to see a symbioses among machines and between machines and people. This symbioses will occur at micro and macro level.

At micro level we are seeing micro bots being developed to detect and fix health issues by circulating in our blood stream. Researchers are even working on nano-bots that can act at cellular and intra-cellular level. However, in these cases there is very little intelligence involved, everything is programmed at physical and chemical level (as in DNA). Still it is an interesting area of symbiotic relation that scales up at the macro level.

At human dimension we are seeing smart prosthetics that interact more and more with the person “thoughts” and “intentions”, like an artificial arm that can be used to pick up a glass of water and drink it.

These prosthetics will go beyond restoring a human functionality, they will start augmenting it raising ethical issues and potentially creating a new form of “symbiotic divide”, beyond the “digital divide”. This is sometimes addressed as “transhumanism” that is partly a philosophical debate and partly rooted in evolution of genetics, cyber-implants, nanotech and guided natural selection (with heavy ethical issues).

At ambient level we are going to see a seamless evolution of our human interaction with machines (Baxter is a first example of a robot designed to work with humans as a member of a team). It will happen in elderly care, in every day transportation, at the work level (with machines taking over “intellectual” jobs including writing newspaper articles).

Gallery 1.1 Robots as co-workers

Baxter has been designed to operate in human teams as a co-worker. It can learn by looking at its co-workers and can even teach them new improved ways to cooperate. Image credit: Rethinking Robotics

According to Gartner:

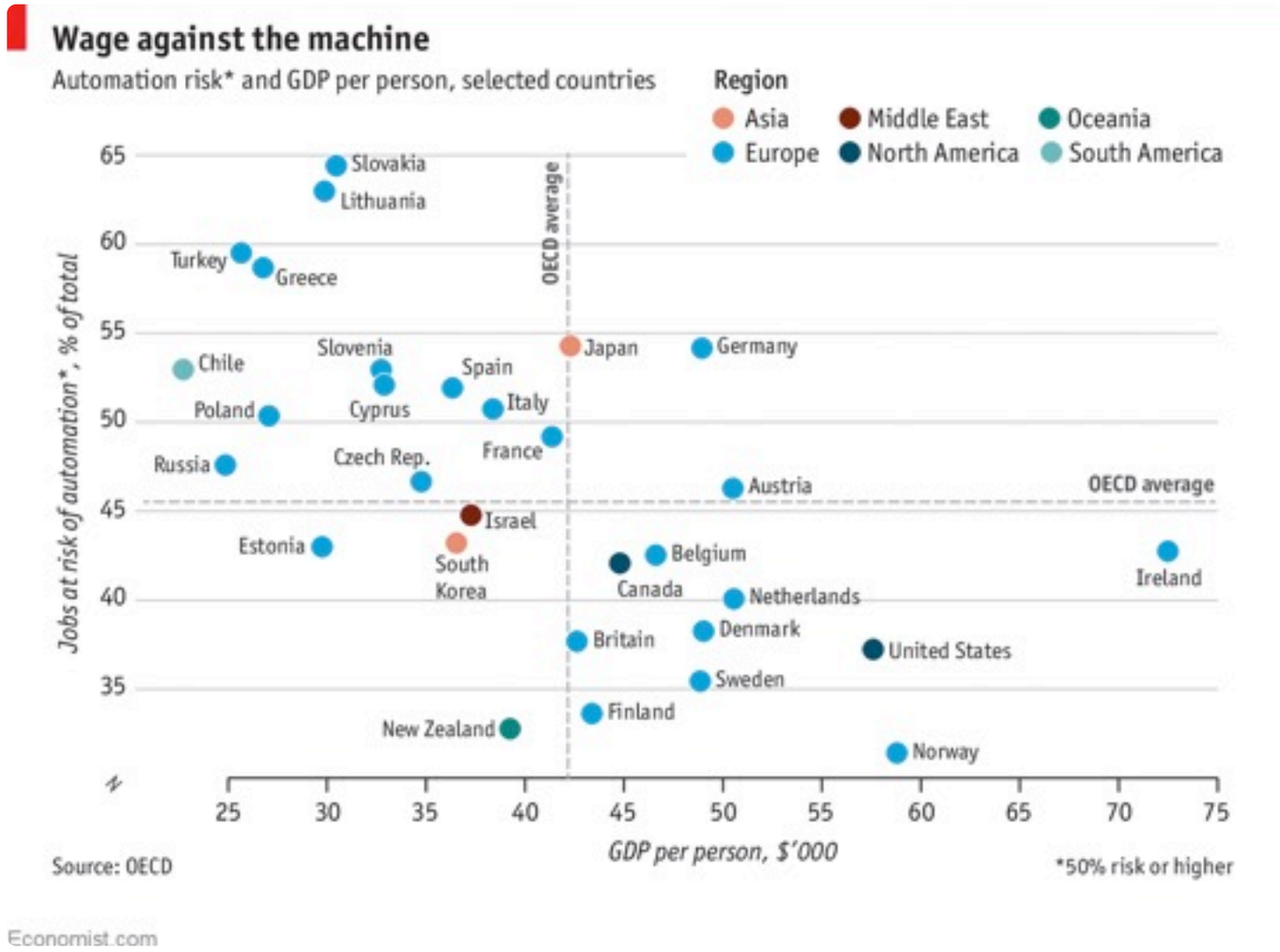
- by 2018 20% of all biz content will be authored by machines,
- by 2018 more than 3 million workers will be supervised by robo-boss,
- by 2018 50% of the fastest growing companies will have fewer employees than instances of smart machines…),
- by 2020 autonomous software agents outside the human control will participate in 5% of all economic transactions.

Notice that, as in the previous revolution, the overall way of life changes. Agriculture was progressively demoted from the centerstage by the industrial revolution, and knowledge workers progressively took the center stage in the digital revolution. Along with that our lives and our ambient got reshaped. From having place to hold wheat we shifted to need place to hold "bits" (and this space is no longer constrained by the environment)… just to give an example.

The symbioses among people and machines has all the ingredients to be as overwhelming and disrupting as the afore mentioned revolution (my bet).

A challenging “near” future, indeed!

Gallery 1.2 Impact of automation on jobs



The 2018 OECD study finds that 14% of jobs across 32 countries are highly vulnerable, defined as having at least a 70% chance of automation. A further 32% were slightly less imperiled, with a probability between 50% and 70%. At current employment rates, that puts 210m jobs at risk across the 32 countries in the study. Notice that on average the lower wage jobs are -so far- most affected by automation.

Source OECD

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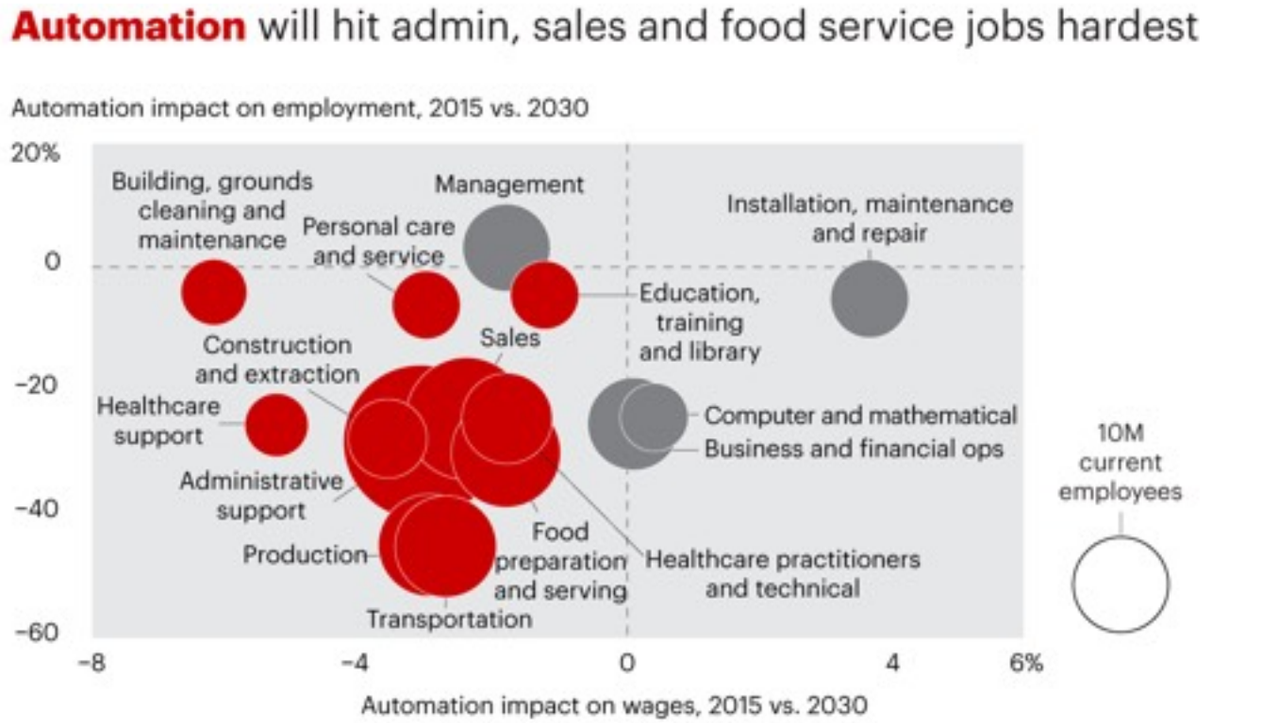
Regarding the Gartner forecast mentioned in the post, made in 2015, as of October 2018:

- there is an increased variety of content that can be created by machines, including music, poetry and literature. Artificial intelligence is used to find relevant content and create summaries. Additionally, computers are routinely used to process data and create meta-data. In general, however, machines and AI are used as tools by humans to help creating content. The 20% content authored by machines forecast does not seem to be correct.

- Robo-bosses are still a matter of discussion on newspaper. If you think of a robot sitting at a desk replacing a human boss, well, we are not there yet (and we might never have to face such a situation). However RPA, Robotic Process Automation, is now a reality with several companies providing solution for a full (or partial) automation of complex processes that in the past required a “boss”. In this latter sense the forecast of Gartner of 3 million workers supervised by robots is correct (and probably exceeded by reality). Notice, however, that the robotization is not replacing the boss, it is just making him/her redundant.

- The forecast of 50% of fastest growing companies having fewer employees than instances of smart machines is difficult to check, particularly with the recent adoption of digital twins that can skyrocket the number of “instances”. In general the number of robots is rising everywhere, with South Korea leading the pack with 631 units per 10,000 workers at the end of 2017.

Gallery 1.3 Job automation impact in the next decade

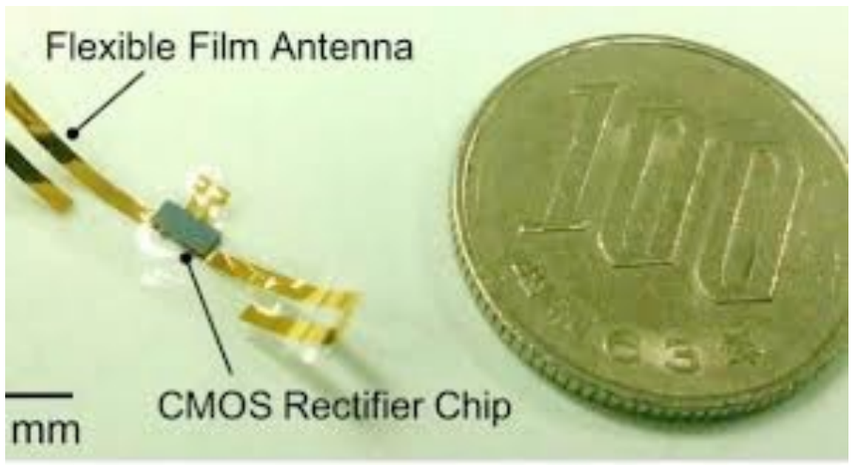


The next phase of automation, based on machine learning, artificial intelligence and advances in robotics, will affect 80% of workers through wage suppression and job loss. Source: Bain&Company

Powering your brain....

FEBRUARY 23, 2016

1. **Exploiting genetic engineering**
2. **Exploiting advanced implants**
3. **Bio compatible power generator**



Fabricated wireless power transmission device with a flexible antenna and a CMOS rectifier chip (97% of the flexible device area is composed of a flexible film of thickness 10 μm). Image credit: Toyohashi University

Transhumanism advocates that sooner or later the human race will "upgrade" itself by creating a new species with the help of technology. Someone sees in the gene manipulation a way to create a new species, others consider this as result of a symbioses between humans and computers (in one form or another).

They are both fraught with huge ethical issues, and both are "around the corner". It is no longer a purely academic discussion on souls and minds but a scientific discussion on "how", not a matter of “if” but “when”.

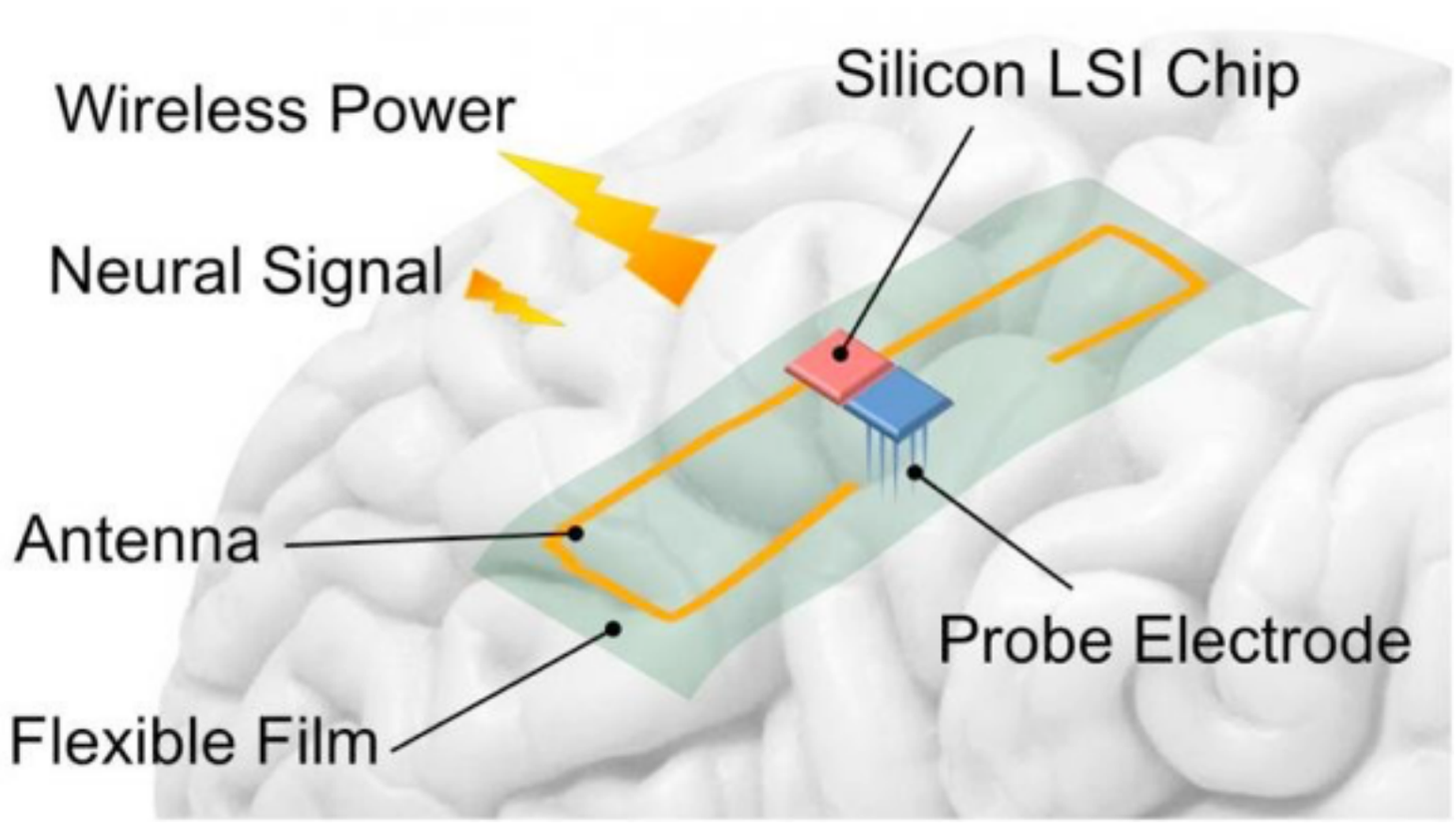
The first path, gene modification, has in technologies like CRISPR/Cas9 an enabler. The main problem (one of many of course) is that we know how to change the genotype (the genes) but we don’t know how these changes would affect the phenotype (what will be the result: e.g. we know that by changing a gene we can produce humans/animals with a different number of fingers/toes, but that single modification is also affecting reproduction capabilities, and probably much more).

The second path seems to be more manageable, like a brain implant that can create a new sense in an animal (or human), e.g. detection of electromagnetic fields. Of course, also in this area, there are many technological problems, one of them being the powering of the implant.

This is were this news, coming from Toyohashi University of Technology comes in.

Researchers have developed a thin film that can be implanted on the brain, capable of converting a radio signal into a DC power. It is nothing really new, RFID tags have an antenna that when exposed to a specific radio frequency generate sufficient power to activate the tag. The principle here is the same, what is new is the construction of this radio to power converter in a material that is biocompatible and that can be implanted on a brain.

In the article the researchers point to several possible applications, none explicitly mentioning transhumanism, but each of them is actually extending human capabilities to a certain extent. Clearly, it is likely that this invention will be used in health care procedures first. No-one, so far, is really looking forward to have something implanted in his brain unless it is absolutely necessary. Nevertheless, I cannot help but wonder on the future of human beings in the second half of this century. I still remember an article I read few years ago, discussing threats in security titled: If it's possible, someone will try, f it's profitable many will try



Proposed architecture of the implantable device composed of flexible antenna and CMOS circuits for wireless-powered neural interface systems. Image credit: Toyohashi University

Can I fool you?

FEBRUARY 26, 2016

1. What is real, what is fake?
2. New ethical issues surfacing
3. Human Machines Symbioses

Which of these are photos vs. computer-generated images? Credit: Olivia Holmes et al./ACM Transactions on Applied Perception

Just a week ago I published a post challenging you to spot paintings painted by a computer among paintings painted by humans. I do not know how good you were in distinguishing one from the other.

Now there is a new challenge, that in a way should be easier, but it is not (at least it was not for me).

If there is something we are good at is recognizing human beings and particularly their faces. On the left hand side, you see photographs of people's faces and some of them are fake. They have been generated by a computer. Can you tell one from the other? (I tell you: the ones in the top row have been generated by a computer)

The fact that it is so difficult to do that, at least it is for me, is a testimony of the sophistication that computers are capable of today.

This is really making the division between atoms and bits fuzzy and it is getting fuzzier by the day.

On the one hand we may be pleased of our achievements, in the end computers are what we can manage to instruct them. On the other hand this is creating unexpected problem. We can be fooled by them, more and more. As we are approaching the point when the Turing test will be passed (there was a claim in

2014 that one computer did pass the test but it has not been accepted by everybody, anyhow we are really close) we are facing the problem of losing control on which is which.

A new branch of science/technology is looking at robots that work along with people (not for people), more advanced studies look at symbioses between man and machines and even more advanced studies look at transhumanism. The boundaries are getting fuzzier and we will probably transition from one space into another without even noticing it. At the same time we will have to confront with new challenges we are not really prepared for.

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Progress has continued, as shown in the image on the side where a computer was asked to generate not just faces but faces that can be mistaken for celebrities...

The feat was achieved by NVIDIA researchers using the technology of GAN, Generative Adversarial Networks, a technology applied in Machine Learning and Artificial Intelligence.

Emergent beings

JUNE 25, 2017

1. Advanced tools reshaping who we are
2. Augmented bodies, augmented minds
3. Emergent entities

Transhumanism is getting technical roots

Just back from a meeting of the Symbiotic Autonomous Systems Initiative in New Brunswick, NJ, where we had some interesting discussions on the topic, bordering on philosophy.

Human beings have been characterized, to a certain extent, by the tools they made and used, to the point that historical epochs are named after the predominance of a specific tool, starting with the “Stone Age”. Notice that the idea of a tool is related to an artifact, more or less sophisticated but still manufactured by a human being to serve a specific purpose. The Stone Age was an age where our ancestors learnt to shape stones to have them fitting a specific purpose (cut, drill, hit,…). Subsequent tools shown an increased capability to deal with materials (and “create” new materials, like bronze) to get more effective tools.

Till the XVIII century tools where an extension of our body, they were powered by our muscles. Levers could trade displacement for strength but basically the power was limited by our muscle power (water/wind mills pre-dated steam but their application was constrained by location).

With the invention of the steam engine, all of a sudden humanity acquired the capability to use external power in its fabrication. The point became the one of “control”.

Electricity provided a new, and further source of energy, easier to control and therefore it took the upper hand in manufacturing tools.

As shown in the image, manufacturing tools, here an exoskeleton, are morphing with workers' bodies to relieve from fatigue (image from a Ford Assembly line, credit: Ford).

In the second part of the last century the invention of computers made available a new "quality" of tools. They are improving the effectiveness of "control" and more recently they are becoming tools for improving our reasoning and thinking capabilities.

We are in the Computer Age, because a lot of our tools are – directly or indirectly- tied to computers. However, we are starting to see the emergence of a Digital Age, an age where the material to be manipulated and to be used for "construction" is no longer (just) atoms but bits.

In a way, there are some similarities in the juxtaposition of atoms and bits with the juxtaposition of body and soul, of brain and mind. We are now on a path leading to the manufacturing and control of meaning.

The technology evolution is towards the availability of a seamless integration (at different levels) of these computer/digital tools with us, the user. These tools are becoming seamless extension of our body and mind, as the hoe was an extension of the farmer arm. This seamless integration is very important because it implies that these new tools are fading from our perception, we take them for granted and they become an integral part of our life.

Think about the (many) times you take your smartphone to "google" an information. You are basically extending your brain memory, your knowledge, without giving it a second thoughts.

We are slowly entering into human 2.0 or, as somebody calls this, transhumanism and we are doing this through a symbiotic relation with our "tools" that having become complex entities are probably better referred to as "systems".

The proposed change of name, from "tools" to "systems" I made is the consequence of a new qualitative dimensions of modern, computerized tools.

Yes, today's computerized tools are way more complex than what we used just 100 years ago, but that is not the reason. Today's tools are starting to operate in an autonomous way, thanks to a

growing flexibility, an improved awareness of their environment and growing decision making capabilities.

Never before, in human history, we had tools with these characteristics. Robots are the first example that comes to mind. They come in many shapes and operate in different areas. They may different significantly one from the other, in terms of shape, dimension, functionality, cost. However, what matter most in the context of SAS is the different degree of autonomy they have, the capability of evolving (e.g. learning), the capability of interacting with their environment, among themselves and with us, humans.

Well, in SAS we are interested because all these three aspects, autonomy, self evolution and interaction are now progressing at an ever faster pace and promise to change the landscape and ourselves as well.

Gallery 1.4 Smart prosthetics

A prosthetic hand with a sense of touch. Prosthetics are becoming more and more "aware" and able to dialogue with the person wearing them. Credit: Louis Stokes Cleveland Veterans Affairs Medical Center

We have been used (like all life on Earth) to adapt our behavior to the context, and humankind went a step forward by becoming able to change its environment to better suit their needs. What we are going to see in the coming decade is that for the first time artifacts that we have created will start to adapt themselves, and their behavior, depending on the context, and we will be part of their context. Hence, starting in the next decade and even more so in the following ones, we will be living in a dynamically changing world where we will be responding to the behavior of machines and machines will be responding to our behavior in a continuously changing fabric where it will become progressively ever more difficult to distinguish between the cause and the effect.

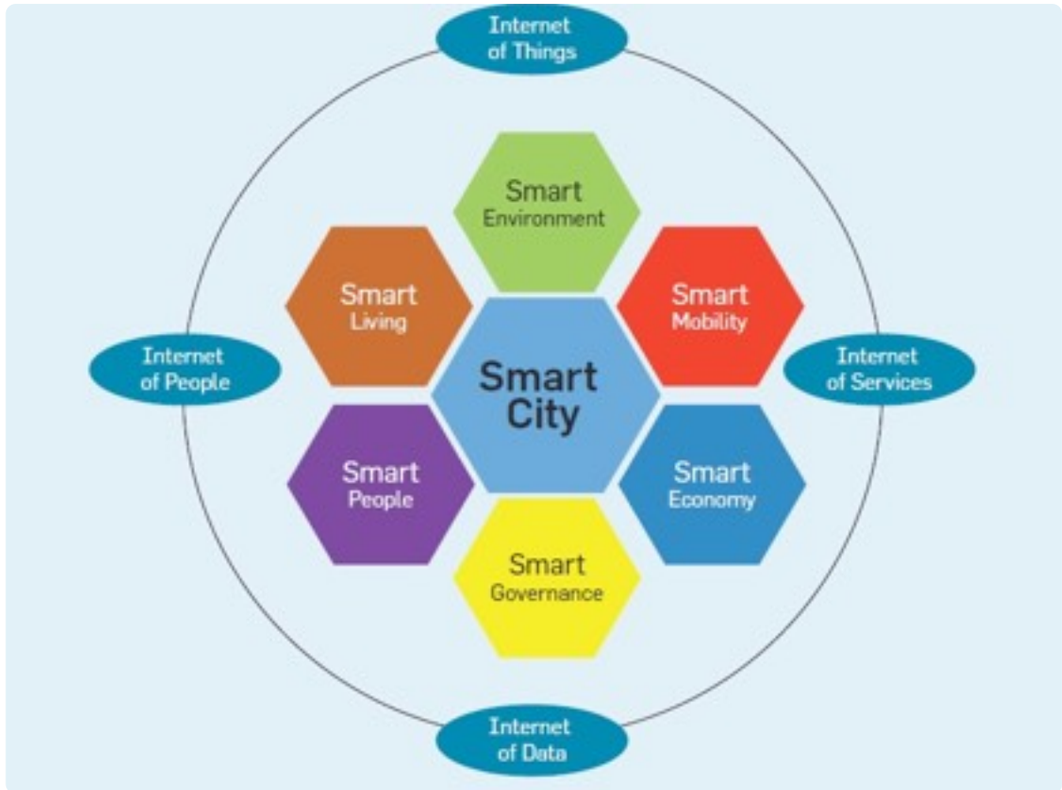
What is happening is the establishment of a symbiotic relation among (autonomous) systems and among them and us.

There is yet another aspect that will become apparent in the next decade. The interaction of several systems, each one independent from the others but operating in a symbiotic relation with the others –us included- will give rise to emergent entities that are not existing today although we have started to recognize the abstract existence of something like a

“smart city”, a “marketplace”, a “culture”. These entities are seemingly abstract concepts although they are rooted in the interoperation of independent systems.

As an example, a smart city is the result of the interplay of several systems, including its citizens as a whole ad as individuals. We can design a system and even attempt to design a centralized control system for a city but it is becoming more and more evident that a smart city cannot be designed in a top down way, as we would do with even a very complex system like a manufacturing plant where everything is controlled. Just the simple fact that a city does not exist without its citizen and the impossibility of deal/control each single citizen as we would control a cog in a manufacturing plant makes the point.

Gallery 1.5 Emergent entities



A Smart City is an emergent entity resulting from the loose interactions of a variety of systems, each of which in turns can be an emergent entity. Image credit: ACM

So far we felt that we could control, fully, a cog as well as a robot. Well, as robots are becoming more and more autonomous, aware and able to self evolve they will become more similar to citizens and like with citizens different strategies for control will be required.

This emergence of abstract, although very concrete entities, is probably the most momentous change we are going to face in the coming decades. To steer it in a direction that can maximize their usefulness and minimize drawbacks requires novel approaches in design, control and communications that for the first time will have to place on the same level: ourselves and our “tools”.

The SAS group in its first assessment is inclined to think that a new scientific branch, rooted in the science of complex systems and taking on board social and ethical studies, is required and promoting studies in this area is one of the goal of the Initiative.

The symbioses of artifacts with ourselves will move by little steps and it has already begun. Prosthetic hands are becoming more and more sophisticated and part of their increased functionalities stems from the autonomous nature of the prosthetics. When we pick up an object, several control systems are at work, even though we are normally unaware of their working. We pick up with the same ease a nut and a raspberry, though applying pressure on a nut is fine but on a raspberry it would crash it. The decision process is quite complex and it involves the cooperation of different systems, sensorial –touch, sight- motion, decision making at brain/cortical level, fine grading coordination by the cerebellum, immediate response by the spinal nodes and more.

Gallery 1.6 Human Augmentation through prosthetics

A smart prosthetic hand that goes beyond the functional replacement of the lost hand. Through a computer and a display it can become a communications gateway. Image credit: Joung Jo In

Prosthetic hands are now able to sense and interoperate with the person neural system, they can also take local decision (like the level of pressure to exercise). To a certain extent they are “autonomous systems” and they enter into a symbiotic relation with the person wearing them. Notice that this is a continuously evolving process resulting in a more and more advanced symbiotic relationship, so far with evolution slanted towards the person who is (slowly) learning to adapt its actions and reaction to achieve a better control of the prosthetic. A leading edge prosthetic hand, differently from the first model that did not have sophisticated interaction capability, would not fit a different person because over time a very specific symbiotic communication has evolved, mostly on the part of the person -today- but we are now seeing learning and adaptation taking place in the prosthetic hand.

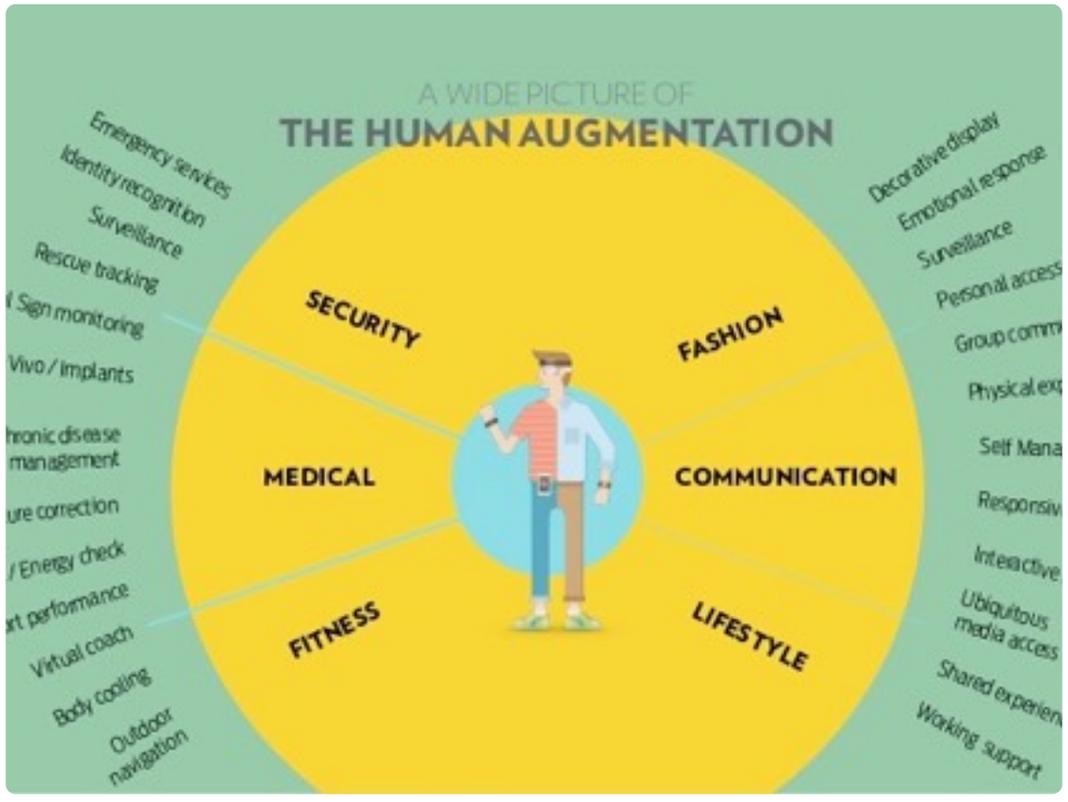
Embedded IoT are also becoming more common (think of sensors to monitor chronic pathologies, smart drug dispensers –like insulin pumps) and they are getting more and more sophisticated. In a short while these IoTs will start to communicate with one another through body area networks and in the longer terms they

are likely to create distributed decision points with an emergent intelligence. Shortly after this they will establish a symbiotic relationship with the person wearing them, first improving the wellbeing, then the physical performances and ultimately the intellectual ones. This is the path leading to augmented humans, human 2.0 or transhumanism.

Augmented humans, Humans 2.0 and Transhumanism are sometimes used interchangeably, however The SAS initiative takes the view of a progression where the first step is leading to augmenting the physical abilities of a person (imagine having a wavelength converter embedded in the eye that let that person to see in the infrared spectrum), then reaching a point where many persons are markedly different from “natural” ones because of their extended capabilities on a permanent base, with specific “improvement” like a permanent, seamless, connection to the web made possible by advanced CBI –Computer Brain Interface. This stage would characterize the Human 2.0 and its main difference from the previous one is the generalization that will involve several people.

Whilst in the “augmented human” we are likely to see an evolution that starts (as it is already happening) to address some disabilities and then move on to provide augmented functionality to very few people, in the human 2.0 we have a generalized adoption. Notice, that someone is claiming that we are already at that stage because of the generalized and systematic use we make of the smartphone to flank the web to our brain memory. This is considered here not a real human 2.0, although we may concede, and it might even be appropriate to do so, that we might see the human 1.5. The transition to the 2.0 would be marked by a seamless interface, you are not going to interact with the smartphone in an explicit way by typing or calling on Siri or Alexa but you simply think of an information and that pops up in your mind’s eye having been

Gallery 1.7 Human Augmentation Ecosystem



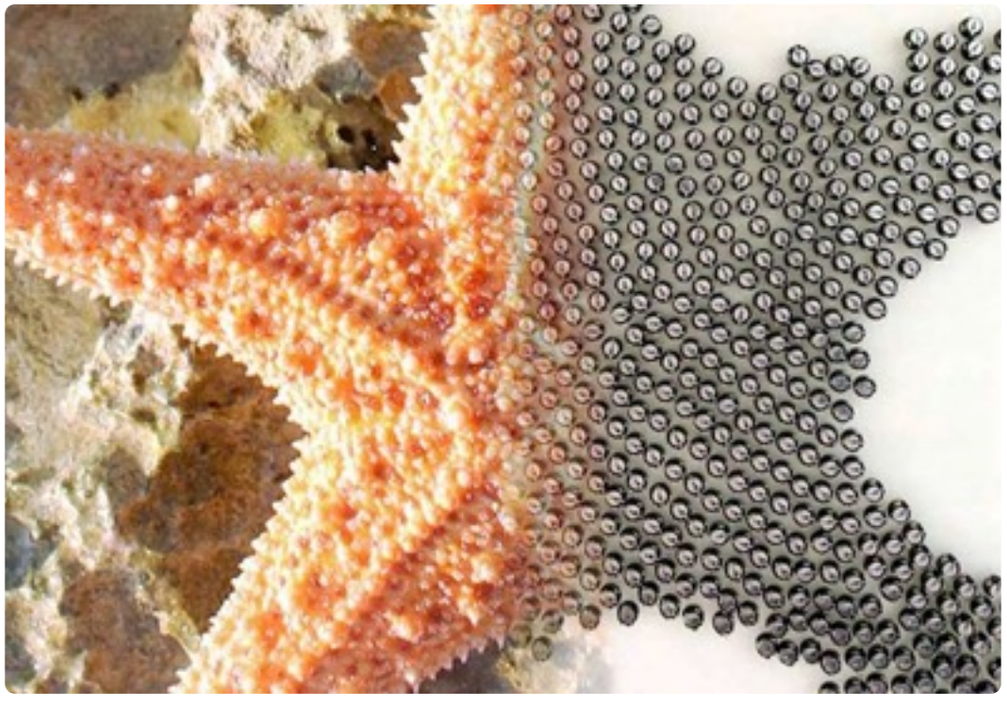
Human Augmentation has already started and it will take many shapes in the decades to come, “augmenting” our capabilities in different areas, as shown in this graphic. Credit: Antonio di Pasquale, Frog-Milan

retrieved seamlessly from the web (or a local storage you may carry around).

Transhumanism in a strict sense signals a transition to a new specie and it is further down the lane. Although it is rooted in the leveraging of science and technology it is looking not at a symbioses between us and our artifacts but to the possibility of changing, at the genome level the characteristics (or some of them) of the human race. This is not being addressed in this initiative, although we look at a form of technology based transhumanism. not a new species but the augmentation of our human species through technology.

So far the relation human(s)-artifacts has taken the centre stage in this series of posts on Emergent Beings, and indeed "symbioses" involves living beings. This meaning has been extended in the previous discussion to include relations between living being (with a focus on humans) and artifacts.

Gallery 1.8 Swarms Intelligence



Just as single cells can assemble into complex multicellular organisms, the individual Kilobots can follow simple rules to autonomously assemble into predetermined shapes. The vast scale of this swarm is a milestone in itself. Photo courtesy of Mike Rubenstein, Harvard SEAS.

This makes sense because we are seeing and predicting an evolution of artifacts along the lines of "awareness-autonomy-evolution" that are specific to life. Technology evolution is making this possible. It is therefore a natural step to extend the concept of symbioses one step farther applying it to the relation among artifacts, provided they have the aforementioned tuple: awareness-autonomy-evolution.

Interestingly, we have examples in Nature where these properties are not belonging to individual component in a relationship but are emerging when many entities are interacting one another as an ensemble. This is the case of of swarms of bees and one can predict it will be the case for swarms of robots. There is therefore a focus on two categories of symbiotic relations involving solely artifacts:

- the one where each artifact demonstrates awareness-autonomy-evolution, and

- the one where the ensemble demonstrates these properties as emerging property.

In the former the symbiotic relationship may occur among few artifacts, an example is the area of robotics where each robot is increasing its awareness capabilities through better sensors and context data analyses, becomes more and more autonomous with technologies supporting analyses and problem solving and through AI/Deep Learning evolves over time. This will impact several verticals, for sure in Industry 4.0 (manufacturing and retail) and in Health care.

In the latter there is a need for a significant number of artifacts to have these properties emerging and thus creating a symbiotic relationship. There is no defined thresholds above which properties emerge, although in general the simpler the entities involved the more of them are required. We see this happening in Nature where a flock of starlings give rise to amazing choreograph in the sky with some hundred birds whilst in the case of a swarm of bees the number is in the order of several thousands.

These aggregations can be studied with the science of complexity along with other technologies in the domain of AI.

These aggregations, and the emerging properties will be a topic of growing interest in the domain of IoT, although very little studies have focussed on that. The interest derives from the fact that we are moving towards billions of IoT loosely connected through the cyberspace (big data) with one another and we can apply to the cyberspace AI technologies to extract emerging properties and we can use the emerging properties to direct the behavior of the IoT in the cluster.

This is a completely new domain that will come into play in the next decade as the number of connected IoT will reach a threshold above which awareness-autonomy-evolution can take place. 5G is likely to be an enabling technology in this domain providing the communication fabric whilst the “intention to communicate” will rely onto ever smarter IoTs and clusters of IoTs.

YEAR	NUMBER OF CONNECTED DEVICES
1990	0.3 million
1999	90.0 million
2010	5.0 billion
2013	9.0 billion
2025	1.0 trillion

There are a few studies focussing on collaborative robots, like the European funded SWARM project, aiming at improving the collaboration among autonomous systems but they are falling in the first category I discussed, whilst in the future we will see more

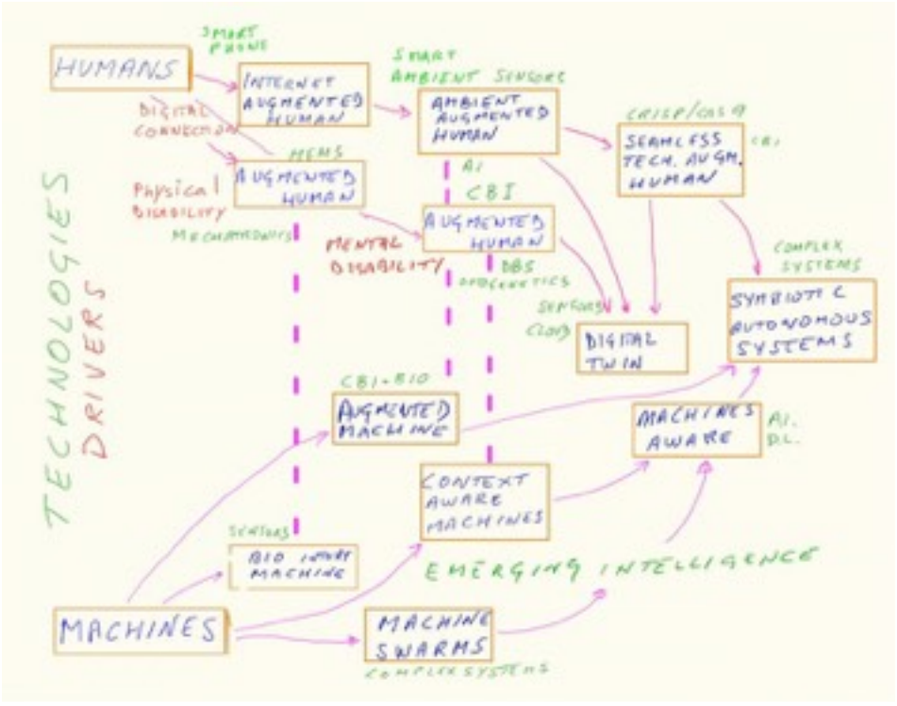
and more emerging behavior from a multitude of low intelligent entities, leveraging on their sheer number.

Number of connected devices (growth over the past few years and in the next decade is led by IoT). Source: Small Caps

The convergence of Humans and Machines

OCTOBER 29, 2017

1. **Augmenting humans with machines**
2. **Augmenting machines with humans**
3. **SuperOrganisms**



The full sketch of the convergence and eventual merger of Humans and Machines.
Credit: FDC SAS Initiative

Technology is not just evolving our machines, it is creating a bridge between us and them.

Bio-Interfaces are enabling seamless communications between our body, our mind, and machines. This is clearly being exploited by better prosthetics that fit naturally to replace a lost functionality as well as future prosthetics that augment an existing functionality.

The coming of context aware machines serves even better the interaction with humans and the eventual shift towards machine aware leverages their intelligence complementing and augmenting ours. This is bidirectional, our intelligence will also augment machine intelligence (in the first phases, already today, our intelligence augments machine effectiveness) creating a world where cooperation is among humans, among machines and among humans and machines.

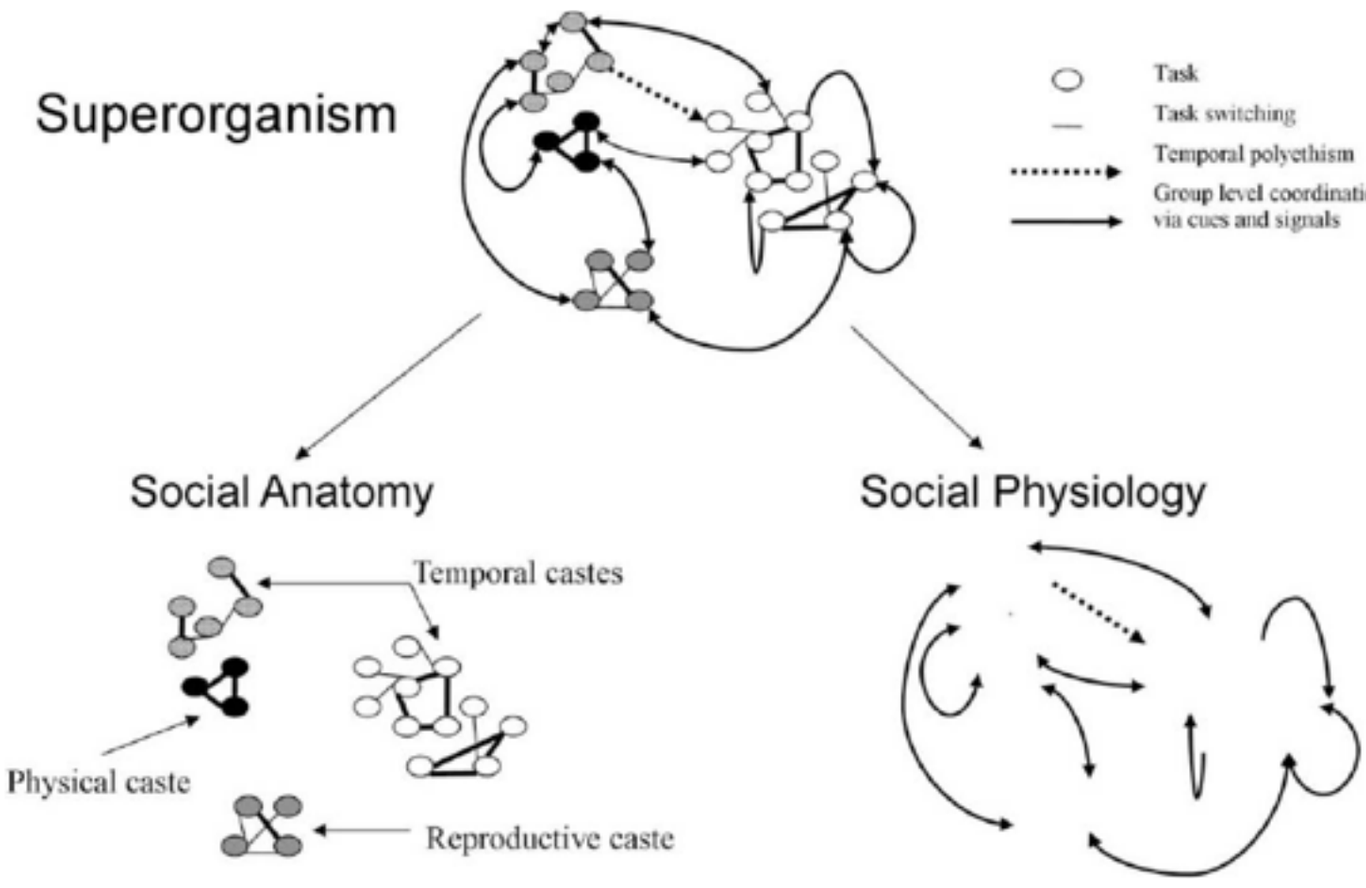
The cooperation may be a loose one, occasional as interaction arises among two entities as they happen to operate in the same space or it can become continuous taking the shape of a symbiotic relation. This latter may result in the creation of a superorganisms, a new species, as envisaged by the transhumanism movement.

The FDC SAS Initiative is not taking any stand on this, it simply takes notice that there is this philosophical movement. The Initiative is focussing on the technology that can make this symbioses possible (basically requiring a seamless interaction

and self adaptation by the various components engaged in the symbioses) and on creating a factual field where Ethical, Legal and Societal issues -ELS- can be discussed.

In a symbiotic relation there is an implicit creation of a superorganism and issues of accountability arises. To what extent the superorganism is actually recognized as an independent entity, hence potentially held accountable, and to what extent accountability remains in its components? The question is a difficult one since the behavior may not be a sum of behaviors exhibited by each component, in which case one could direct the accountability to a specific part, rather it might be an emergent behavior where the contribution of each part is no longer meaningful.

Gallery 1.9 SuperOrganism



Superorganism Concept Expanded into Social Anatomy, Development, and Physiology Components This figure shows a colony-level ethogram for a factory- or machine-like society (the most sophisticated superorganisms). Different shading or fill patterns indicate that a particular physiological or morphological specialization is required for the performance of the task. Credit: Timothy A Linksvayer

A strong symbiotic relation also implies that its components can no longer operate independently of one another. As noticed previously we, humans, are already living in a symbiotic relation with our ambient to the point that if we were transported to a completely different one, e.g. in a jungle, we would be unlikely to survive. Hence, the evolution towards symbiotic autonomous systems, where we would be a component, is nothing radically new.

There may be reasons to advocate for weak symbiotic relations only so that we can remain

an independent part that is just taking advantage of the symbioses when this is feasible and keep living independently when this is not.

However, also this approach creates significant ELS issues. It is clear that a symbiotic relation confers advantages to its participants and at the same time creates a gap with those that for any reasons cannot engage in that relation. The Have vs Have Nots represents itself although the gap risks to be more significant than the one we have today between those who can access technology and those who cannot. The reason is that today the use of technology is explicit, in the future, in a symbiotic relation, it may become invisible. The advantage given to those that can have, as an example, their brain wired to the internet versus those that will be able to access the internet via a smartphone is way wider than the one we have today between those that can access internet with their smartphone and those who have no access to internet. The former will have an increased access to knowledge and an increased intelligence, the latter will have a “delayed” increased knowledge only.

There is not a clear boundary between a symbiotic relation and a mediated one. This is another aspect that needs to be faced. There are no boundaries around intelligence, hence it will be difficult to perceive a disruption point, although we are clearly seeing that we are close to an inflection point where convergence of various technologies is reinforcing their evolution and us.

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The concept of superorganism is central to the idea of symbioses. We have plenty of superorganisms in Nature, actually it is difficult to find a living being that is not composed by several living organism all together forming a superorganism. Human beings (as most ,if not all, multicellular organisms) are hosting billions of bacteria without which they could not live. Even in a single cell we see this cooperation among different living entities: mitochondria are remnants of archaic bacteria and of course they are an essential component of a cell.

What we are facing today is the emergence of new kind of superorganisms. both as result of the loose interaction of autonomous systems (think of a city, a symbiotic entity based on its loosely connected infrastructures, citizens included) and a symbioses between (entities based on) atoms and (entities based on) bits.

These latter superorganisms are new and we are going to see more and more of them in the coming decades.

Brainternet: a peek into the future?

JUNE 13, 2018

1. **Connecting brain to the Internet**
2. **Brain as an IoT**
3. **Neuralink probably beyond the horizon**

What about a future where brains are just another Internet of Thing component?
Image credit: La Verdad nos espera

Back in 2017, that's long time ago!, a university project Brainternet, made the headlines of several news. The project was (and still is) carried out at the Wits University, Johannesburg, South Africa, and by leveraging on portable (wearable) EEG harvested the signals resulting from the electrical activity of the brain and made them available on the Internet. It was claimed that this was the first time a brain was connected to the Internet, becoming an IoT.

The claim is true, in a sense. Indeed the portable EEG, as any other sensor, picks up the brain electrical activity and makes it available to the Internet. We surely say that an air-condition equipment is an IoT if it has a sensor picking up its status and sharing it on the Internet. So why not have the same claim for such a connected brain?

At the time I did not commented on the spreading news because to me it was not a big deal. All technology involved has been available for a long time and the claim, although true -strictly speaking- was misleading. A brain is so much more complex than an air-condition equipment and relaying the electrical activity (actually an infinitesimal portion of the electrical activity) did not really seemed (to me) as a true interconnection.

A different story is looking at the (declared) aims of Neuralink, where using implantable chips they feel it will be possible to connect the brain to a computer

having the two exchanging information. Whilst Brainternet is a reality (but it connects really really little) Neuralink is a dream (or a nightmare – you decide-) that would provide a true connection.

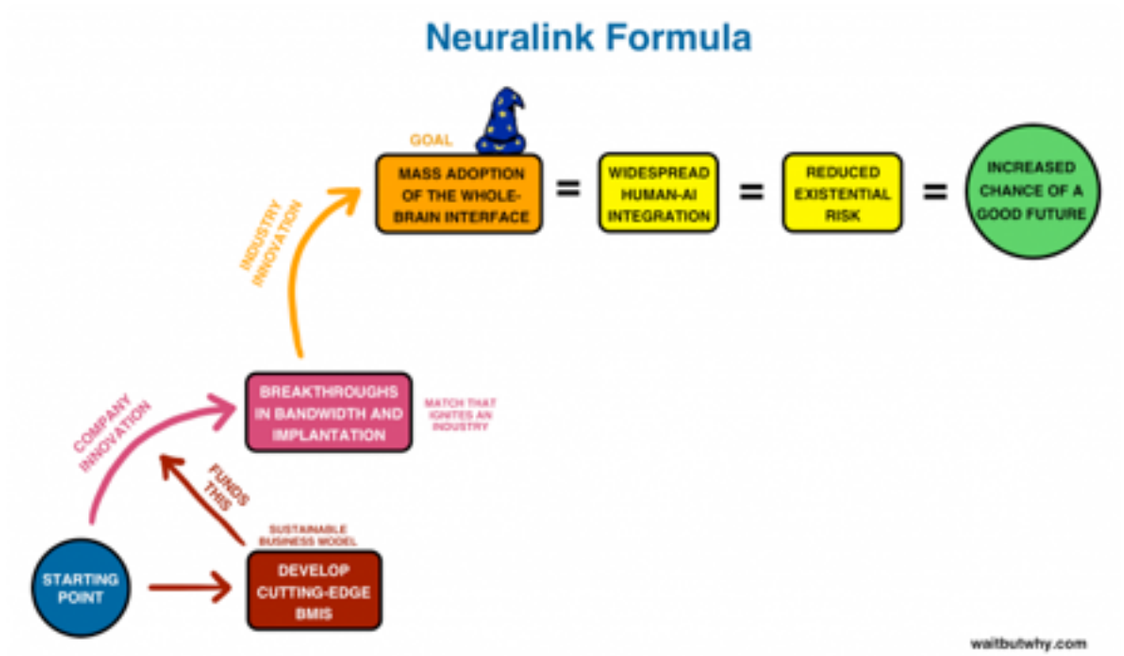
The advantage of Brainternet is that it is not that much invasive (as invasive as wearing a hat and taking around a purse) and it provides a steady flow of data that eventually might create a data set for some deep learning algorithm to make some sense out of it. It would require many people adopting it for some significant span of time to create a data lake with a sufficient number of data to hope for the emergence of some meaning, so far this has not been the case.

So, why did I choose to mention it today? Well, I am looking around on the web as part of the work we are doing in the Symbiotic Autonomous Systems Initiative to prepare the second White Paper (due in November this year) and in particular on the aspects of selves, multiple self, human augmentation. I stumbled onto an interesting article on Paperjam addressing ethical aspects of human augmentation, trans-humanism and post-humanism.

In the article the Brainternet was mentioned as a first step in the direction of a symbioses between our self, our brain, and the Internet. A sort of peek into the future. As I said, I do not see it as a real interconnection of our brain to the Internet, more as a prompt to consider the implication of such a connectivity when it will become real.

The article is making a call to look at ethical issues: even though we are quite far, in a technology sense, from the capability to create a brain to machine interconnection, the ethical issues this will open might require a long time to be addressed, hence the need to look at them today, as they are hypothetical, because the sentiment of many is not "if" they will ever become reality,

Gallery 1.10 Neuralink



Neuralink aims at creating an interface able to monitor a million neurons. The most advanced probes in 2018 can pick up a few hundred. In the diagram the overall vision of the initiative: be able to connect any brain to the Internet creating a symbioses between the brain and the cyberspace. The interaction will take place using sensors on the skull, sensors on the brain and sensors embedded in the brain -dust motes-. Image credit: waitbutwhy.com

Are we smarter than our ancestors?

JULY 24, 2018

1. **Every living being is smart in its own environment and time**
2. **Our environment is so complex that we need to rely on others**

Our ancestors could light fire without a lighter, something I won't be able to do.
Image credit: Alamy

Tomorrow I am going to be part of a panel at COMPSAC 2018 discussing "a smarter future". I will be focussing on the trend towards symbiotic autonomous systems and will be claiming that this is a path towards a smarter future.

I'd like to share with you a few thoughts and, please, I am looking forward to your comments, and … dissent!

If one looks around and just stops for a moment observing cars, planes, hospitals, smartphones… well, one cannot avoid congratulating the human species for all these achievements! Compare today with 200 years ago, and then again with our ancestors 2000, 20,000, 200,000 years ago and there is no question about it: we are way smarter than our ancestors.

Wait a moment. Are we really smarter?

Imagine yourself being brought and left in a jungle, in the middle of a savanna, in a desert … These are all places that our ancestors lived in, and managed to survive to the point that we are their descendant. What would you think your success survival probability would be? Pretty low, to be on the optimistic side! Looking at the question from this perspective would surely lead us to reconsider the ranking of smartness between us and our ancestors.

Now consider yourself as a smart individual, let's say an engineer that is one of the best around (lets' boost our morale a bit) in designing advanced computers. And think about being transported to the time of the Roman Empire (so just about 2000 years back in time). Do you think you would be able to build a computer and surprise the Emperor with your wizardry?

No, you won't be able to build a computer because you have no idea how to get the raw materials that are needed, nor -once you have them- how to process them to become usable (and "No" for many many more reasons, including the absence of electrical power at that time!).

It is not because you have been transported back 2000 years. Even today you won't be able to build a computer without having access to the variety of supply chains involved and leveraging on other people skills and knowledge!

So what is the point I am making? We are not really smarter than our ancestors, we just happen to live in a different environment and we have grown to be adapted to this environment as they grew to be adapted to their environment. Each one, me and my great-great grandfather, are equally adapted, smart, to survive in our own environment.

What makes possible the amazing things that we are using every day, and the way we live our life today, is the symbioses between ourselves and today's environment. This includes the access to other people's skill, knowledge, to tools ever more sophisticated, to a culture that has grown to value innovation (it was not so just 500 years ago!) to an economy that can exploit and share value produced across the world making distance almost irrelevant.

Gallery 1.11 Supply Chains complexity

Your average desktop computer supply chain.

Image credit: SCM Research

Notice that I am not talking about "intelligence" but about "smartness". The two are distinct concepts, although there is some relation between them. An intelligent person is likely to be smart but it is not a given. There are plenty of examples of very intelligent people that are not smart at all in normal life situations. You can learn to be smarter, you cannot learn to be more intelligent (although higher education

for sure enable your intelligence to bloom). Intelligence is not about symbioses, smartness is.

There are tools to measure intelligence, IQ tests. However, these tools are using measuring sticks that are suited to our current view of Intelligence. Were we to apply those IQ tests to people who lived 200 years ago we would get IQ results, on average, around 70, which is the thresholds for borderline deficiency. Actually, our great grandfathers were, on average, as intelligent as we are, the difference is in the measuring stick.

Clearly, today's access to better education makes intelligence bloom, more than 200 years ago when education was restricted to a small subset of the population.

This intelligence blooming along with economic, science and technology growth, supported by better communications that makes ideas reach globally (notice that all these factors are loosely interconnected and influence one another) have led to the creation of tools and to a change in the environment. It is possible to have smarter relations with the environment and the environment itself, particularly in these last few years, is becoming smart. As a consequence, we are also becoming smarter!

Gallery 1.12 Tools Maker Intelligence

Today's wood cutting and harvesting is way more efficient than in the past thanks to machines that can do in a few minutes what took lumberjacks a full day. Behind that there is the intelligence of some engineers who designed the machines and the work of many people manufacturing them. Knowing how to use and where to use them requires smart people, but these smart people could not exist 200 years ago since those machines were not there!
Image credit: myinteriordesign..win

The rise of artificial intelligence that is characterizing this period and will be have a much stronger impact in the coming two decades, is effectively flanking human intelligence. The symbioses of these two kinds of intelligences in the next decade will create the condition for much smarter relations with the environment.

Our symbioses with the environment will be taken to a deeper level, the one of modeling "what if" situations that will be used as tools to take smarter decisions.

We won't be smarter than our ancestors, but our symbioses with the environment, mediated by much more effective tools will

result in smarter relations than in the past improving our wellbeing and the wellbeing of Planet Earth.

This evolution path is being explored by the IEEE Future Direction Initiative Symbiotic Autonomous Systems where both augmentation of humans and augmentation of machines are studied and fostered, with consideration given to a possible evolution towards transhumanism.

We are exploring the possibility of new relations of humankind with the Planet and, since the two are strongly related, of humankind with humankind. As in any major change and evolution the questions are more important than the answers, and it is crucial to come up with these new questions to steer the evolution.

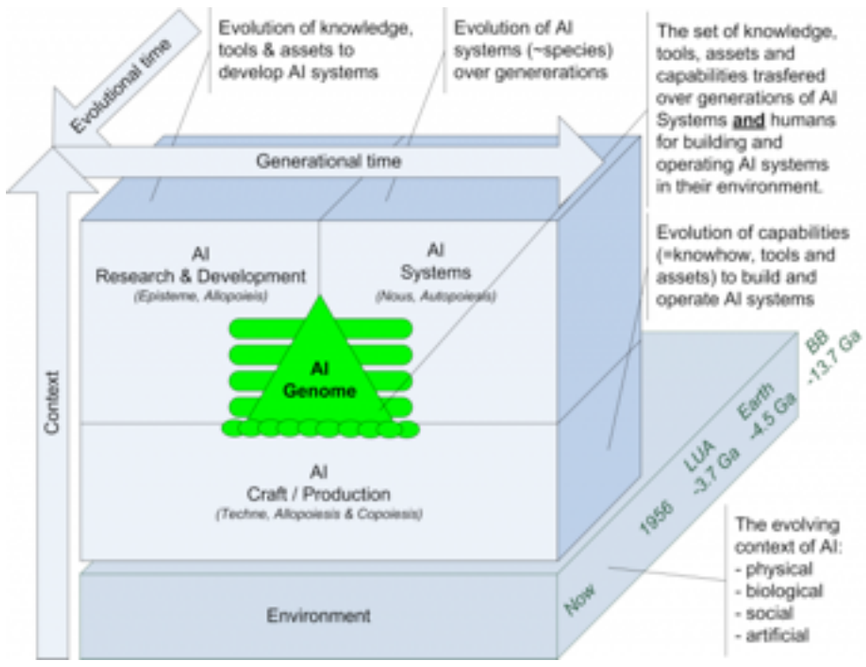
To look into this changing landscape the Initiative has initiated a Delphi exercise. A number of experts from many disciplines have joined the exercise and the evaluation of their answers will be disseminated in November 2018. A first presentation of results was given at TTM and the SAS workshop and it is summarized later in this ebook.

Take a look at the clip of Dr. Michio Kaku discussing the genetic ingredients of intelligence. That will be the starting point for my next post in this series.

Will our offsprings be smarter than us?

JULY 27, 2018

1. **Genomic manipulation for human augmentation**
2. **Symbioses with machines to better leverage their augmentation**



The AI Cube framework for analysis of AI systems and their evolution. Credit: Adpakkala

In my previous post in this series I mentioned an interview with dr. Michio Kaku, a US theoretical physicist and futurist with Japanese grandparents, where he made the point that the basic, structural ingredients of intelligence with respect to evolution can be found in the opposable thumb, the position of the eyes at the front of the head and the language capability. The ideas are intriguing: the opposable thumb gives us the possibility to manipulate the world, the front position of the eyes is the one of predators that need to imagine what the prey might do and devise a strategy (hence giving rise to abstract thinking) and the language supports the transmission of knowledge in a much more articulated and effective way thus allowing for the growth of knowledge from one generation to the next.

These might be indeed very important components and they all have roots in random changes in the genome that is being shaped through the natural selection process. He is also pointing out that the genomic difference between humans and their next of kin, the chimpanzees, is tiny, less than 1.5%. Scientists have identified the genes involved in steering towards a larger skull (that can accommodate a larger brain), those for languages… and so on. With genetic manipulation we should be able to tweak the chimpanzee genome to provide it the traits that would make it intelligent. At the same time, he says: “why would we want to do that genomic upgrade? We already have it and it is us!”.

However, this genomic manipulation possibility opens the way to: “could we create a more intelligent human?”. This issue may become even more important as artificial intelligence is providing machines with more and more capabilities, actually to the point of exceeding our own.

There is no doubt that machines will become more intelligent and more aware of their environment (the two things are related) and eventually smarter than us. We can do, in principle, two things:

- Stop the progress of machines (it is us who are making them progress, so far!)
- Make sure that in parallel we get ourselves a boost to keep an edge on the machines

Now, for number 1, it is difficult in a competitive world that is connected but also formed by independent parts to stop creating ever more performant machines because that gives a competitive advantage and making machines more and more autonomous

Gallery 1.13 Human vs Chimpanzee Genome

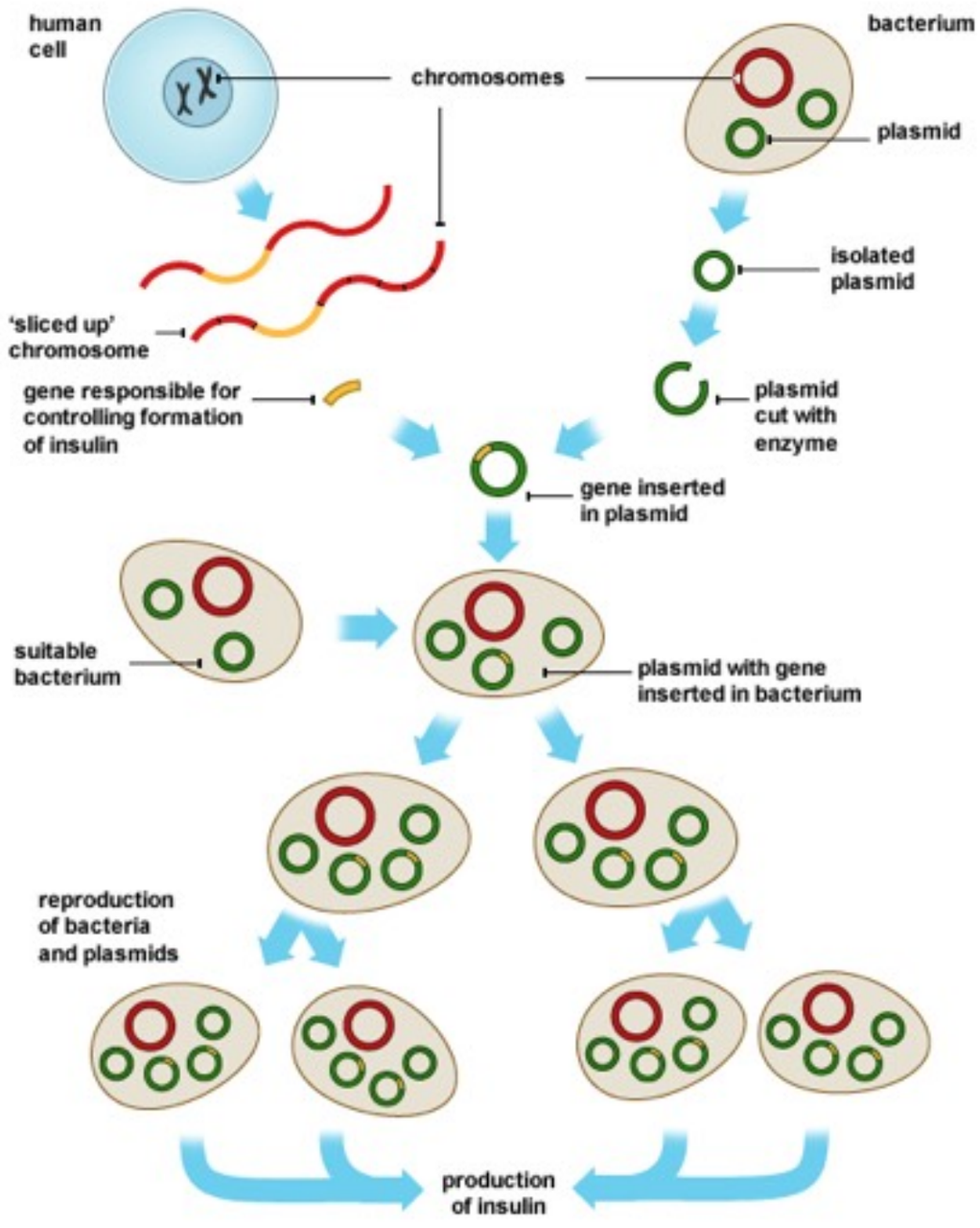
The human and the chimpanzee genome differ in very few bases. Notice that the differences derive from a common ancestors, we -humans- are not descendant of the chimpanzee. Image credit: Rumney Marsh Academy

and intelligent is a way to make them more performant.

For number 2, there is a huge number of ethical issues but of course they are unlikely to stop some constituencies to explore the possibilities (taking for granted that from a technology point of view genomic manipulation resulting in enhanced performance - including enhanced cognitive capabilities- will become reality, the question is "when" not "if"). There are also many grey areas where it is difficult to draw a line and we have seen that these lines are subject to shift, as culture evolves.

Indeed, it seems that these two paths are not going to be feasible. The Symbiotic Autonomous Systems Initiative is both exploring them and looking for a third way that is basically saying:

Gallery 1.14 Genomic engineering



Bacterial modification through genomic engineering to produce insulin. Image credit: BBC

"*if you can't beat them, join them and see how to influence their evolution*"

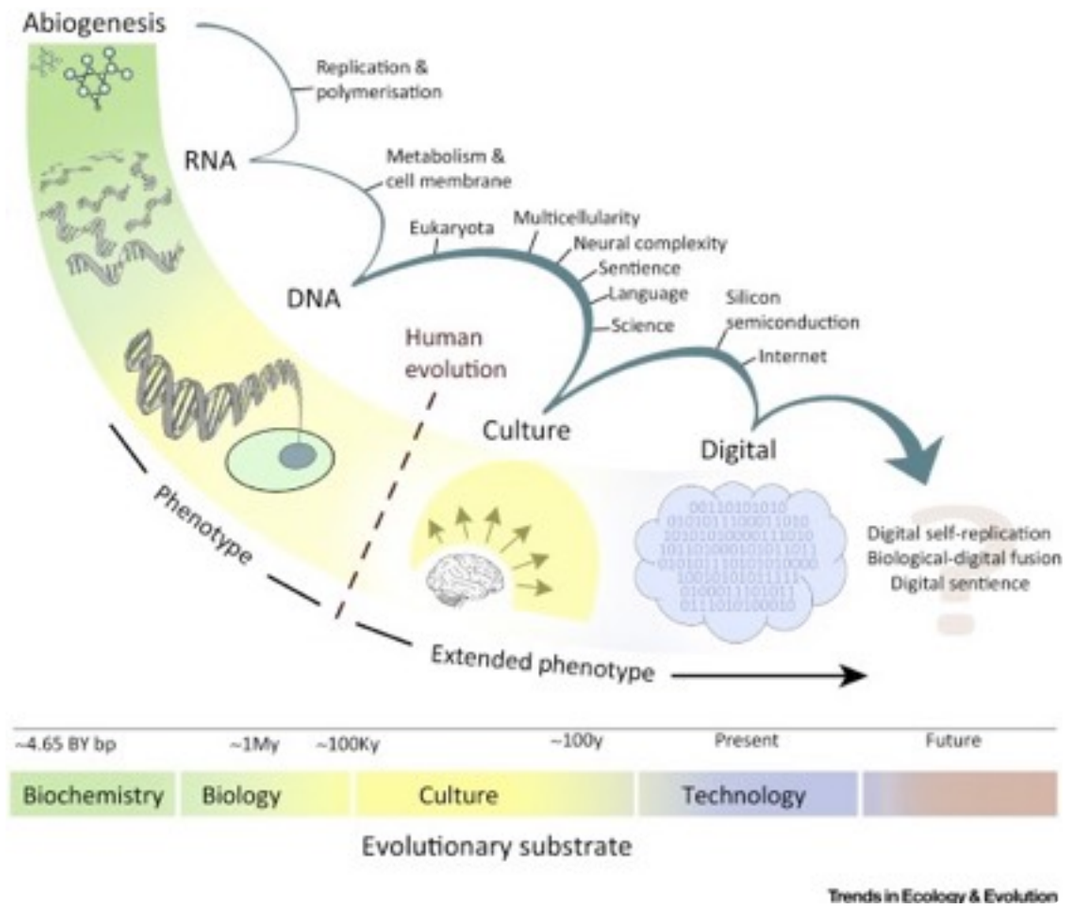
This is likely to be the evolution towards an even smarter world, where many of its components, humans and well as machines, but also bacteria and other inanimate and living forms will get smarter. Humans are, and are going to be, the architects of this evolution. Genetic modification of bacteria, to make them more useful in a variety of tasks, is already ongoing. Machines with embedded artificial intelligence are getting more aware of their environment and better at interacting with us. We are using prosthetics, including our smart phones, to increase our physical and cognitive capabilities, teaming up with machines and the environment in a seamless way (furthering our symbiotic relationship with them).

As our symbioses with machines becomes more effective, we are also becoming more and more dependent

on them (that is part of the symbiotic concept -relying on the other) but this has already happened. In today's society we would be completely lost if electricity, to name just one thing, would be switched off. We have adapted to today's environment and we are smart in it/with it. We will have to carefully design the transition towards newer environments with the challenge that this transition is happening faster than ever before.

This observation makes me go back to Michio Kaku interview: I want to observe that the ideas he is presenting are not sufficient to explain the evolution of intelligence and its impact on the world. Those genetic variations that resulted in the human species happened some 200,000 years ago (some go back even earlier) and if we look at the genomes of our ancestors (even more recent ones dating some 10,000 years ago) we see that they are basically au pair with the ours. Yet the evolution of society(ies) has been amazing over this time and even more intriguing it has moved by leaps, not in a linear way. Human societies have remained stable for centuries and millennia and then all of a sudden they have evolved for a while. Genome cannot be the only explanation. The interrelation between us and our environment has played a great role. Actually, some estimate that the genome is responsible for just 5% of our intelligence with the remaining 95% attributable to environmental factors. Take a look at the controversial interview with Robert Plomin (controversial because it ties intelligence to genomic characteristics and this may sound like racisms. However, if you listen carefully to his points it is clear that there is no substantiation to racism in what he is saying).

Gallery 1.15 Life evolution



An interesting roadmap from the creation of life from non-life to the rise of culture as the influencing factor in evolution to the growing role of technology and the future symbioses of life with digital forms.

Credit: Michael Gillings et Al. Trends in Ecology and Evolution

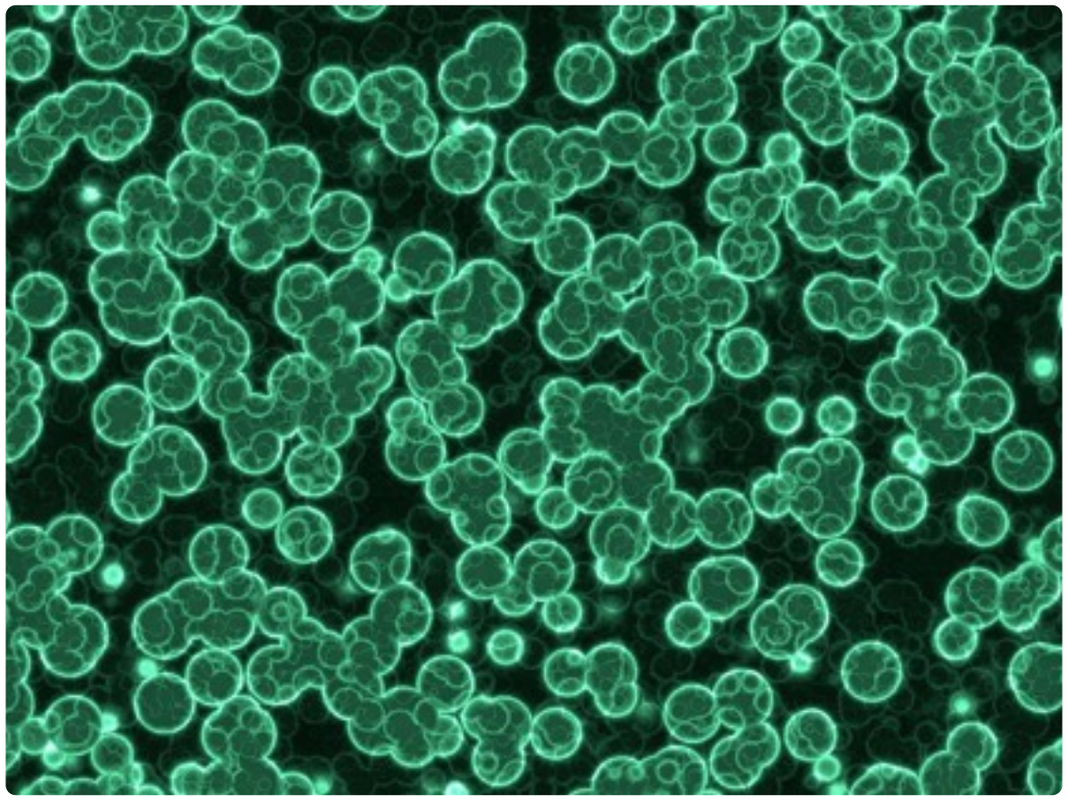
Adaptability and capability to leverage on the environment has been key to the success of life, from the very early forms to us and to what we see around us. Adaptability has not been a characteristic of the single

individual, rather it emerged from natural selection as result of environmental changes.

Humans have been the first species that has been able to both change their environment to increase their survival probability (and wellbeing) as well as to adapt themselves outside of natural selection processes, e.g by dressing up to keep warm as the environment turned cold, managing fire, building a shelter …

More recently they (we) have been able to create machines that are able to help them and even mimic some human capabilities. The trend towards increasing those capabilities -and expanding them- to the point of exceeding humans also in cognitive capabilities is clear. By teaming up with machines humans increase their adaptability to the environment and can be even more effective in reshaping the environment to fit their needs. As shown in the graphic life has started from “non-life” and behaved in a sort of mechanical way based on the genotype. As the genotype became more complex and influence from the environment affected the behavior we saw the emergence of variety of behaviors, and traits, related to a single genotype: the phenotype became the observable set of characteristics of life. With humans we have observed how the behavior and traits of a single human become affected and entangled with his social context leading to what is called the extended phenotype.

Gallery 1.16 Species change their environment



Other species like the cyanobacteria in the image have radically changed the Earth environment but they did so not out of volition as humans do, but in a “blind” way. Cyanobacteria are considered the cause of the Earth oxygenation, that in turns open the door the the explosion of life on the planet.

We are now in a transition phase where our behavior is affected by the digital world, and soon by intelligent machines. In the coming decades the growing capabilities of machines along the seamless interaction we will be having with them will further extend the phenotype. Actually, we will see an emergent behavior that results from these humans-machines interactions, a phenotype that extends in the

cyberspace. On the one hand we will have digital self replication and digital sentience* (machine awareness) and on the other hand we will see a biological and digital fusion.

A further point to consider is the capability of tweaking with our DNA. From a technical point of view we already have this capability (using CRISPR/Cas9) and we are getting ready to apply it this to fix some genetic diseases. However, we do not understand fully the implication of genetic manipulation (the relation between the genotype and the phenotype is not completely clear) and there are concerns on unexpected side effects. Applying deep learning techniques may help in the correlation of genotype to phenotype, that is in understanding what the implications of a gene manipulation on the phenotype might be.

I am pretty sure that in a decade or two we will have the tools to "design" the desired phenotype and implement this design at the genotype level. It will start with focussed bio-engineering to fix some genetic anomalies resulting in a disease and it will move on to strengthen resistance to pathogens (it is likely to be the evolution of vaccination in the second half of this century). Beyond that point the road might take us towards directed adaptability on our side and towards the change of the environment to better fit our needs.

It is clearly a road fraught with ethical and social issues but I am sure they will be addressed and solved, possibly in ways that would not be considered acceptable by our current society and culture.

If this is the path humanity and machine evolution will take then we can expect, for the first time to have our offsprings becoming smarter than we are because they will have the power to change themselves and the environment by designing the changes, effectively creating a new species (transhumanism).

If the path will be towards a symbioses the question: "will machine become smarter than humans" may no longer be relevant as it is not relevant to ask if our liver is smarter than our gut… They are both essential constituent of the whole. This may be the future by the end of this decade. A humankind that morphs into a transhuman species by engaging in a symbiotic relationship with its artifacts that, in turns, will be evolving to better fit the symbiotic relations with us.

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* There is no consensus on the possibility of creating sentient machines among scientists. It may eventually turn out that "sentient" will be measured in the same way we have (mostly) accepted to measure intelligence, through a Turing-like test. If a machine behaves in a way that we perceive as sentient that machine can be considered as "sentient".

The sound of colours, the colours of sound

AUGUST 3, 2018

1. **Augmented senses**
2. **Cyborgs are a reality ... today**

For Neil Harbisson colours are vibrations he perceives in his skull. Interestingly, he can hear the sounds of colours that we cannot see, like the ones in infrared and ultraviolet. Credit: TED

First of all this is nothing new: Neil Harbisson was born (in 1984) with a genetic anomaly that does not allow him to see colors. His world was a palette of greys. Neil made the headlines in 2004 when he had an antenna implanted on his skull with a chip that converted the colors captured by the antenna (made of optical fibers) into vibrations, sounds. He is a musician, with a natural and educated capability in appreciating the subtle nuances of sounds. That is why he decided to have colors translated into sounds, music, a language he understand.

Over time his brain adapted and started to “see colors” matching them with specific vibrations. In 2010 Neil co-founded the Cyborg foundation and in 2017 the Transpecies Society to foster the evolution towards the expansion of human senses and interaction with non human beings, including artifacts.

I stumbled onto Neil’s case as I was researching for a number of posts I am planning in the coming weeks on “transhumanism”. One of the characteristics of humans 2.0 will be to have expanded sensing capabilities. Now, you might say that Neil had a restricted, limited sensing capabilities since he couldn’t see colours. Correct. However, the prosthetics he had implanted captured a broader light spectrum, including ultraviolet (visible to bees but not to humans) and infrared (visible to snakes but not to humans).

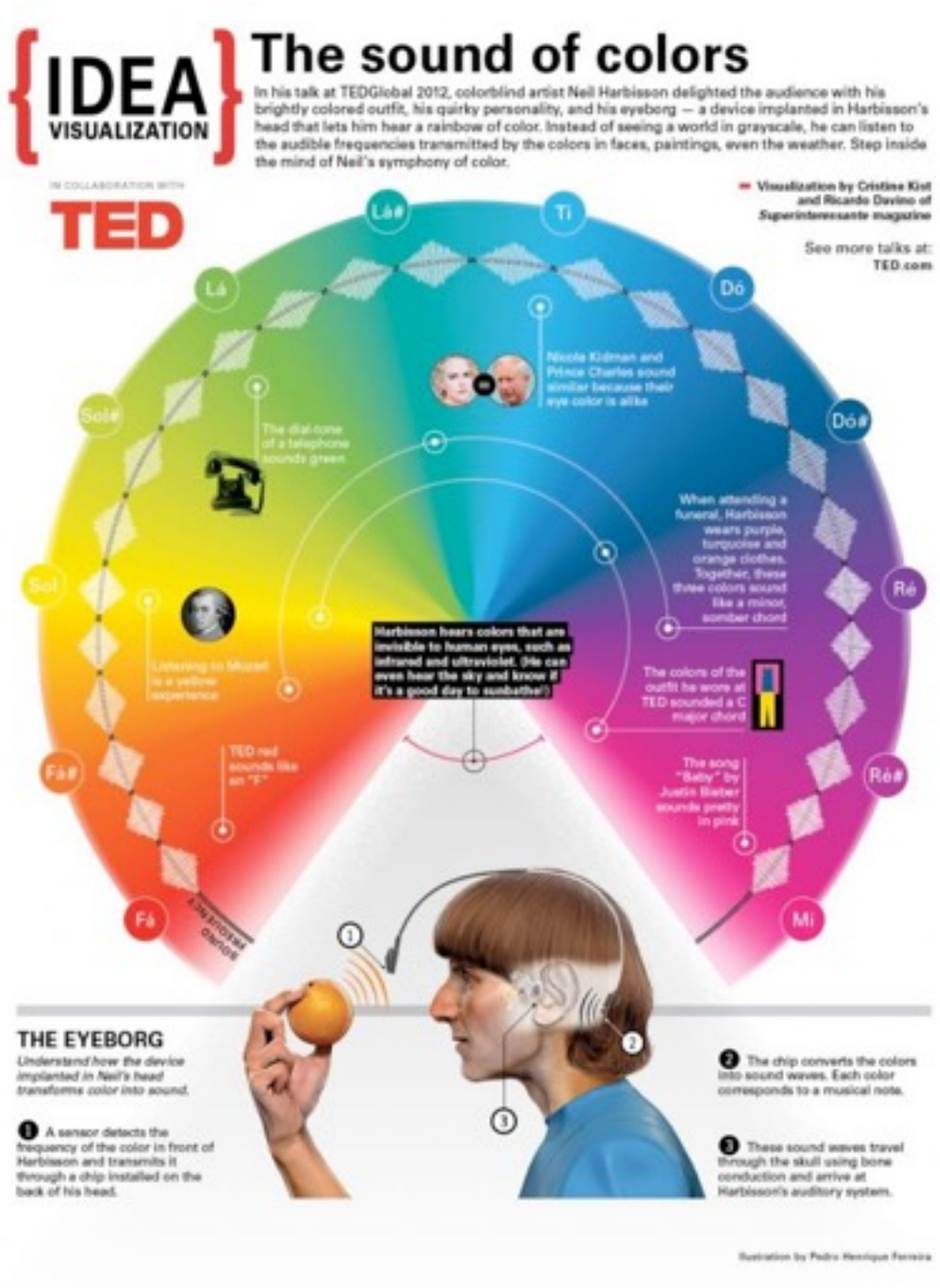
Hence, with that visual prosthetics Neil got superpower! He can see the light emitted by a remote control (infrared) and he can see many more hues in a daisy, as a bee can do.

It would required just a few little modification to his chip and to the antenna for him to be able to see radio waves, look at a smartphone and see when it is talking or when it is connected to the internet!

Take a look at the presentation Neil gave at one TED to hear from his voice how it “looks like” to hear the sounds of colors. It is surely something that made me think, and I bet will make you think!

Neil co-designed the skull implant to have the possibility of seeing the colors of the world and his brain over the years has learnt to seamlessly capture the sounds into which the implant translated the colors into a sort of color vision.

I cannot of course bet that such a translation would match our perception of purple is actually the same perception that purple generate in my brain. At the same time I cannot bet that my perception of purple is the same perception you have of purple. We have in common, through education, that when seeing a certain object we both say: “it is purple”.



Since each color is translated into a “musical note” several colors create a chord: turquoise, purple and orange are a b-minor for Neil.

This has become an integral part of the way Neil sees the world and has give rise to a new -extended- phenotype. The implant has not just allowed Neil’s brain to perceive colors, the choice he made to have colors translated into sounds has led his brain to convert sounds into colors!

Hence when Neil listen to music he actually perceives it in terms of colors. In the photo of Neil shown above, the background is actually how he perceive a Mozart sonata. Hearing that Mozart sonata or looking at that image create the

same perception in his brain (of course this happens when he “scan” the background image at a certain “speed” since in music the time component is essential: by scanning it more rapidly he would accelerate the “tempo”, conversely if he were to scan it more slowly).

I found these considerations, that he makes in the TED presentation, very thought provoking. Go back to the clip and listen to it once more.

You will appreciate the meaning of what he claims: I have become a cyborg.

We see a real symbiotic integration that is leading to an extended phenotype, i.e. it is increasing Neil’s behavioral characteristics when he is interacting with the environment.

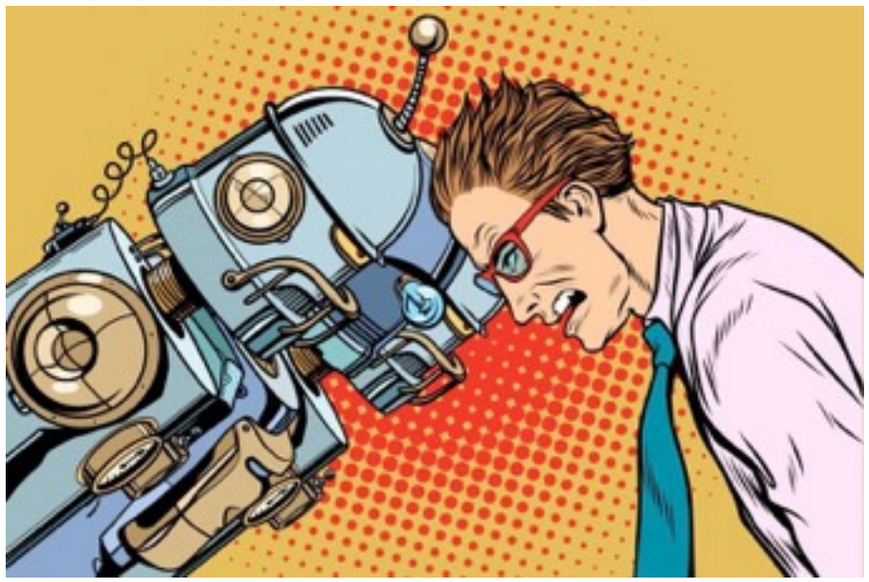
This is amazing: humans have extended their phenotype through Society and Culture. Now they can extend their phenotype through a symbioses with a machine, in this case an artefact communicating with Neil, a computer.

Clearly, by manipulating the genome, through bio-engineering, we are changing the genotype, hence inducing a change in the phenotype, but we see that also by creating a symbioses with machines we are extending our phenotype. Transhumanism is already here although by affecting us without affecting the genotype is not creating a new species, we can still mate and generate offsprings with humans 1.0.

Humans vs machines: Who's winning?

SEPTEMBER 5, 2018

1. The rise of Machines
2. Man over Machine
3. Machine over Man
4. Man and Machines together



Many robots vs human, humanity and technology. Pop art retro vector vintage illustrations. Image credit: Tech Talks depositphotos.com

The rise of the machines

Technology is providing new, more innovative ways to augment us – human beings – thus enabling us to better respond to a world moving at a faster pace, and more easily secure that all-important competitive edge for businesses and industry. Institutions and government are facing mounting social costs, while communities and individuals alike are looking for a healthier, happier life. These challenges and aspirations press researchers to push past technology's boundaries to develop smarter machines, since these intelligent constructs represent the most practical way to augment our capabilities.

Since the beginning of Homo sapiens, we have crafted machines to help us; what we are seeing today is an acceleration of this process. Part of this hastening is the result of having reached a tipping point: we are no longer required to transfer human knowledge to a machine for it to become smarter. We have forged machines that can learn on their own by observing us, making sense out of big data, and watching experiences as they unfold on the web. Just as important is the ability of these clever creations to test their newfound knowledge both against other machines and internally through the use of virtual clones.

To be sure, Artificial Intelligence (AI) has progressed significantly, though it's more in terms of its applicability than in terms of absolute theoretical progress. AI can do

far more today because processing power is abundant, cheap and (almost) ubiquitous. This, along with pervasive communications, and sensors and storage capabilities, has led to an inflection point in the availability of data. The consequence is twofold: the data space is so big that it is beyond human comprehension, and it is fueling machines' capabilities, intelligence, and continuous learning.

This process has just begun, and there's no end in sight. Machines have evolved beyond their clockwork origins, and are likely to surpass humans in a growing number of areas.

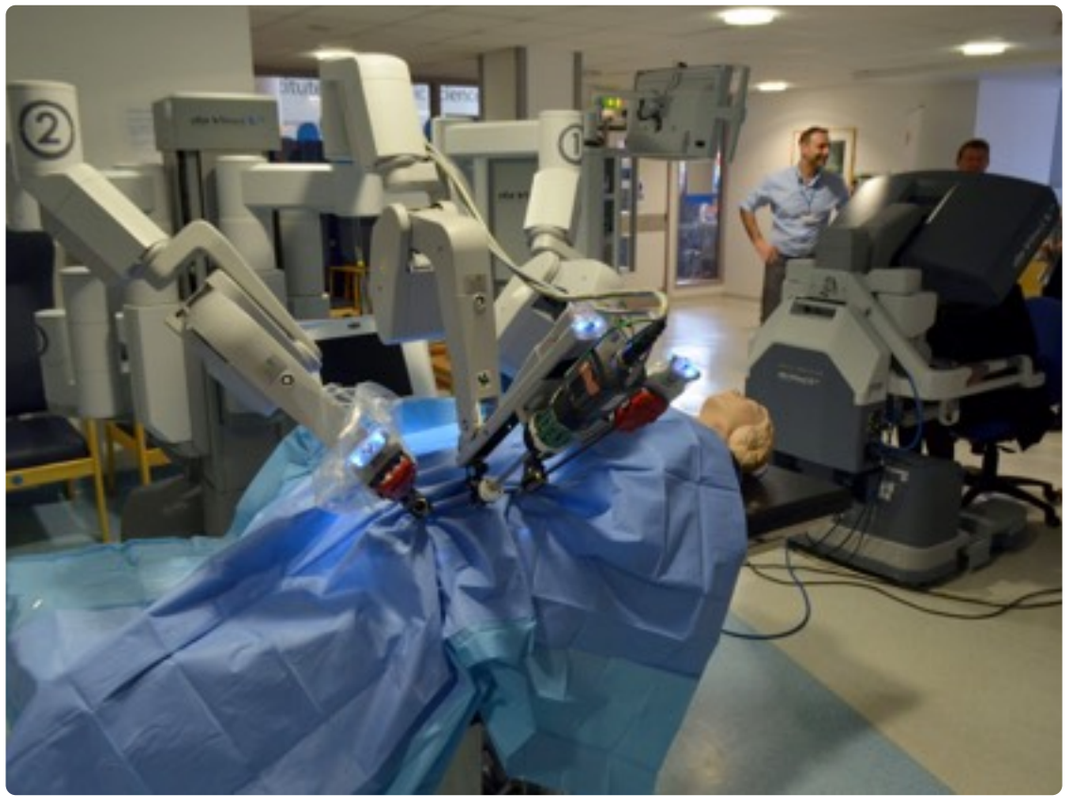
Man over machine

Until now, building a better mousetrap has served to improve the human condition. We have consistently benefitted from machines and have always had the power to shut them off… and sometimes we did. Consider the devastating weapons that while immensely effective, could lead us down the path to wholesale destruction.

The growing issue is the vital role played by machines – both as single entities and collectively as infrastructures – means we basically no longer have the option of just "shutting them down". Think about the power grid, with its hundreds of thousands of people working around the clock to ensure that it stays on. The idea of turning it off (e.g. for decreasing CO2) is simply no longer an option.

Surgery is becoming progressively robotized, and medical diagnostics have become fully machine-dependent. Automated machines today manufacture drugs. Pulling the plug on these operations would have dire consequences for millions of people worldwide.

Gallery 1.17 "Robotization" is growing



The Da Vinci robot is now extensively used for surgery. Close to 5,000 of these robots are active around the world: 2,770 in the United States, 719 in Europe, 561 in Asia, and 221 in the rest of the world.

Source: Wikipedia

Yet, we can still claim that we are using machines as extension of ourselves, leveraging them as stronger, faster, and cheaper

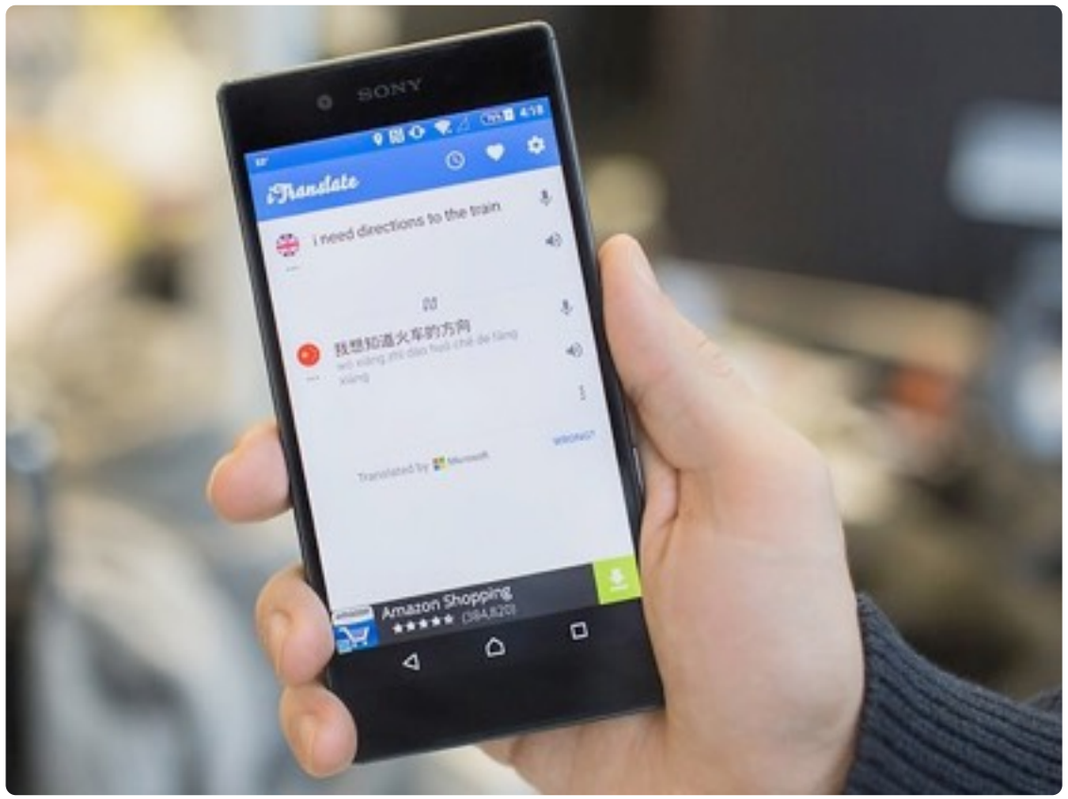
hands. Because of this, humans still triumph over the machine, but it is up to us to decide where we go from here.

More recently, machines have risen to become more than merely our augmented hands; they are now beginning to amplify our cognitive capabilities. It's subtle, but it is happening.

Most of us have a symbiotic relationship with our smartphone. But how often do you really use it to call other people? More often than not, we're using our devices to call machines. Need help reaching a destination? Let your smartphone show you the way. Want to impress your guests by cooking a gourmet dinner? Get out your smartphone and look for a recipe. Feeling awkward? Dr. Smartphone can check your pulse, face color, and other health cues, and then offer advice.

These are but a few examples of how we're starting to engage with machines, but the list is growing rapidly. In the coming years, we can expect more people to have a digital doppelgänger flanking them. On one hand, this twin will be a digital mirror allowing for monitoring of any telltale signs of health problems. On the other hand, it will take on a life of its own in cyberspace, becoming a repository of our existence, a sort of black box that can be queried at will. It could even become a means of simulating next steps, whether in business, education, health, or even entertainment, allowing us to determine the best path forward.

Gallery 1.18 Cognitive extension



Smartphones have become tools extending our cognition capabilities, an extension of our memory, of our capabilities, like, in the image, translating from one language into another.

Image credit: AndroidPit

Comments:

•we are still the designers of our machines. If we were to stop today the evolution, current machines would not be able to take up and foster evolution by themselves

•the progress of artificial intelligence is making machine "potentially" able to learn independently of us. This learning is still limited to very specific areas hence these machines can progress only in their specific areas

- even in the very limited areas where today machines can learn and get better they still need humans once they break down

and in general they all depend on “logistics” (like power) that is provided by humans.

Machine over man

Extending our sphere of knowledge by using machines as tools is a grand idea…as long as we’re on the winning side. But are we truly still in command of our intelligent machine creations? If the answer to this is “no,” we may find that we have a lot to lose.

That human jobs are being lost to machines is nothing surprising nor new. The revolution in agriculture machine technologies has multiplied the yield making it possible to feed 7 billion people better on the average then 1 billion people were fed two centuries ago. There’s no going back now – if we were to turn off the machines that produce fertilizers and insecticides, and that make it possible for one man to do the harvesting work of 10, the penalties would be famine and quite possibly, mass human extermination.

Gallery 1.19 Robots replacing humans on jobs

Evolution of robots, struggle for a place at work. Automation of business processes. Robot expels the employee’s business from the workplace. Concept of replacing people with robots, artificial intelligence.

Image credit: Tech Talk -depositphotos.com

If robots have eaten human jobs like candy, then autonomous vehicles could be like setting a glutton loose at an all-you-can-eat buffet. From this perspective, we’re losing to machines, because they perform better than we do at certain things. The digital transformation promises to be even worse. During the late industrial revolution, when machines stepped in to take our jobs, it was all about automation. With the digital revolution, jobs aren’t being replaced by machines; they’re simply disappearing. There’s no longer a need for automated paper shuffling because there’s no paper anymore.

Sure, AI can replace a few brains, however, more critically, it makes those brains redundant. Think about self-driving, autonomous vehicles. You no longer need operators, which equates to the potential loss of 3 millions or more driving jobs in the U.S. alone, but you also no longer require that many vehicles. Today, we buy a car and then park it along the sidewalk or in a garage 90 percent of the time. With their

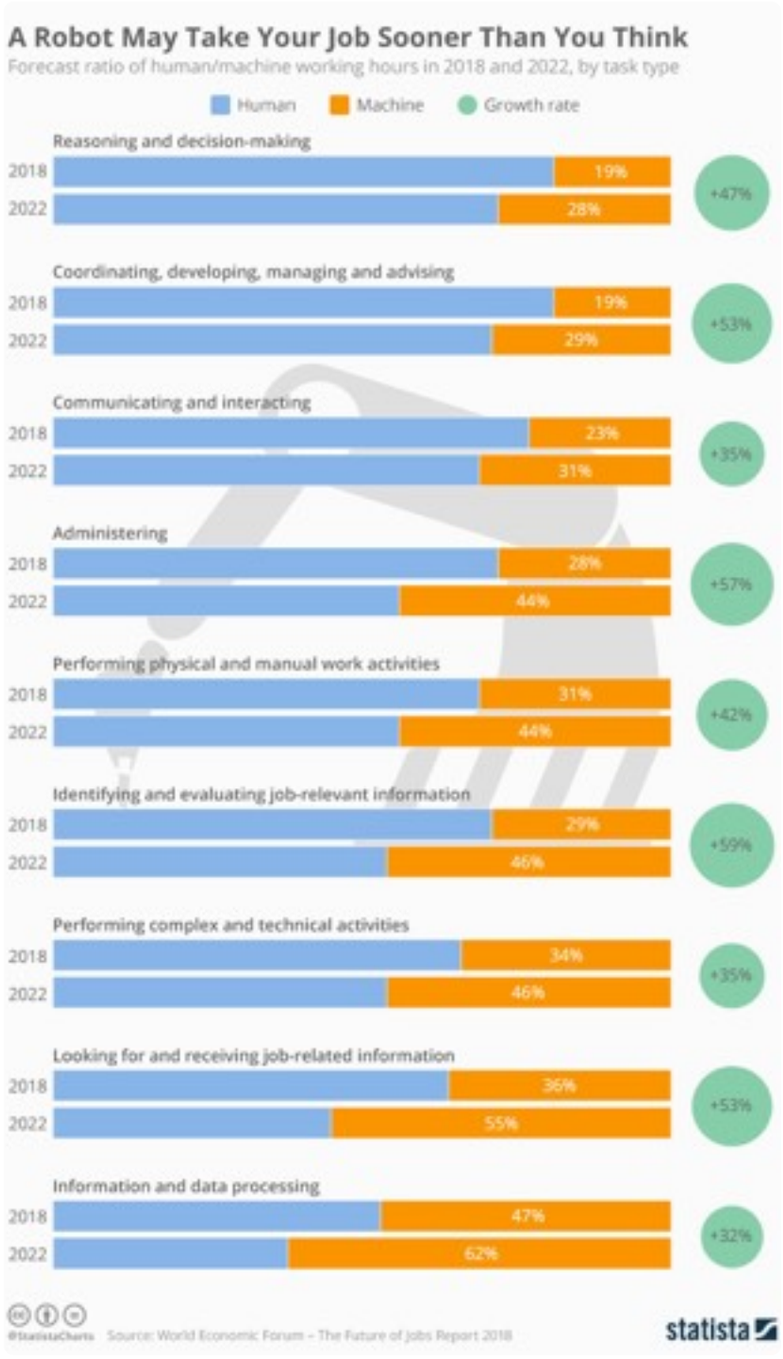
commoditization, a mere 40 percent of today's vehicles would be ample for satisfying all of our transportation needs. This translates into reduced manufacturing demand, along with fewer red lights, traffic signs, and police.

A world permeated by machines performing in the knowledge space, a world customized for machines, is quite different than the one we know now. The corollary is that we lose along several fronts, and they win.

But hang on a sec – it's clear that in such a world, we would lose…but doesn't winning require some sort of awareness or sentience? Would a machine ever be motivated by winning to pursue a strategy that would allow them to do so? It might seem far-fetched, but we're now seeing the first examples of this motivation, leading machines to devise strategies for winning on their own.

For example, DeepMind's AlphaGo did

Gallery 1.20 Human vs Machine



Job hours by humans vs machines.

Source: Statista

just that, leading to its defeat of world Go champion, Lee Sedol. I am also fairly certain that militaries worldwide are building smart weapon systems capable of pursuing their (assigned) goals using strategies of their own making. Bots being used in the financial markets are acquiring self-awareness, finding new means of meeting their "programmed" targets.

Now, we can take some comfort from the "programmed" part of this narrative; however, notice how I included "programmed" in parentheses. How long can we trust an intelligent autonomous system to play within human-programmed boundaries? This isn't just about software bugs or hacking. The very concept of "autonomous and intelligent" means these machines are taking up lives of their own. And in many areas, a fully performing autonomous system needs leeway to wholly exploit its intelligence and logic capabilities.

It's a sort of catch-22 situation – the more intelligence and autonomy you allow a machine, the better it will perform and the

more useful it will be. But at the same time, the more leeway the less control you have.

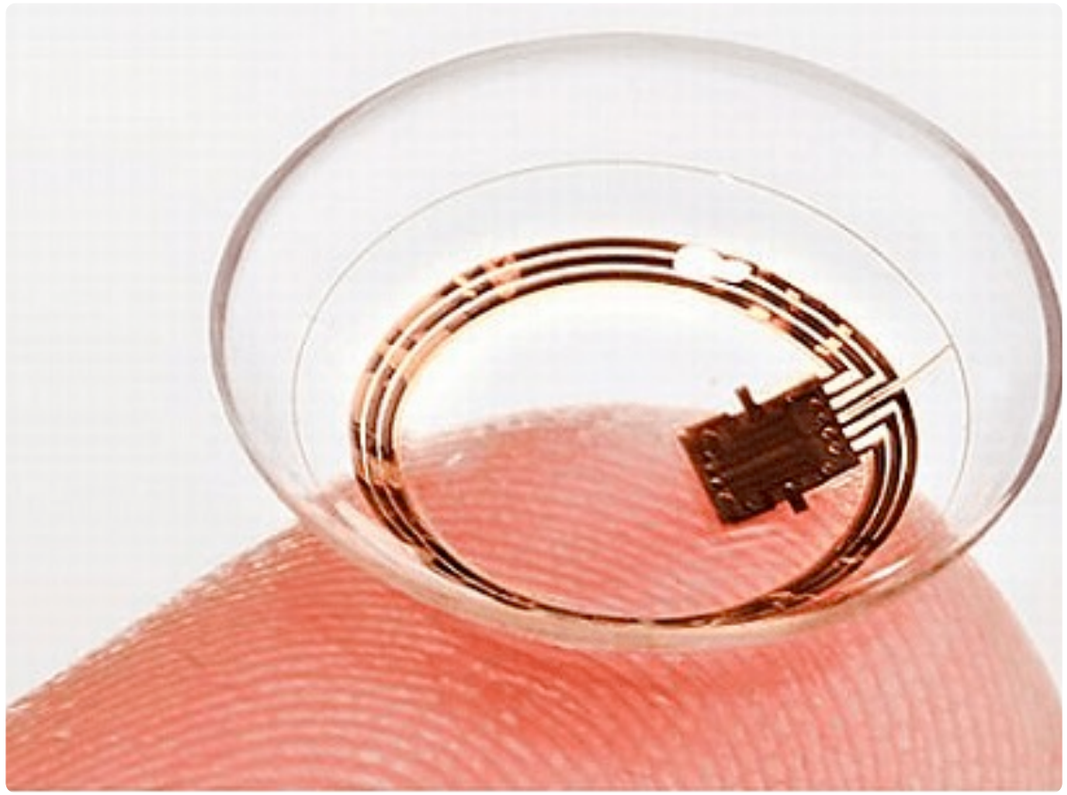
As noted at the start of this piece, we've already reached a turning point where humans alone are no longer able to extract all potential value from cyberspace; we can do that only through the use of machines. For machines to be able do that, they need to be, well, better than us. So we're already in that catch-22 situation.

Man and machines together

So far, the division between humans and machines has been clear – I'm here, the machine is there – but that boundary is getting fuzzier. Smart prosthetics fuse seamlessly with our bodies, making up for lost limbs or providing additional strength, stability, or resilience, as seen in exoskeletons donned by assembly line workers.

We use our smartphones symbiotically, but what if they were integrated directly into our bodies? Think a smartphone in the form of a contact lens capable of transparently delivering augmented reality images straight to the brain. Think it sounds like science fiction? Think again. The first prototypes have already been built.

Gallery 1.21 Human-machine seamless Interfaces



Smart contact lenses so far have not passed the stage of concepts and laboratory prototype. There are already a few prototypes of smart contact lenses as sensors chemically analyzing eye tears. Smart lenses including a camera and a screen have been patented but no real implementation is available. They would make for a seamless interface connecting a person to the cyberspace. Image credit: Samsung.

Soon, brain-computer interfaces could become seamless as well, creating a new synergistic relationship between the cloud and us. At that point, the question of "who knows what" would be moot; you ask me a question and I know the answer. Sometimes that answer will be stored in my own neural circuitry, but most of the time it would come from the connection of my neurons to the web.

Of course the real problem is not about where the knowledge is stored, as long as it is seamlessly accessible. The real problem lies in where the decision-making process takes place! The answer

to this is very complex; it's already an issue today and truthfully, it has been an issue for centuries.

Think about it. Our brain decision process is influenced by the way it has been "educated" by the cultural context. These external factors are influencing our decision processes to the point that in certain situations, we can legitimately claim that influence has been so strong that our brains can't be held accountable for the choices made.

The point I'm trying to make is that we humans are in symbiosis with our cultural environment, and the tools – both physical and conceptual – that we have been taught to use.

In a way, it will be no different in the coming decades. Our context will change, becoming permeated by intelligent machines. Much like we do today with our fellow humans, we'll have to contend with and negotiate our decisions with these smarter mechanized constructs. And just like with humans, there will be advantages and disadvantages alike.

Gallery 1.22 Human Machine Symbioses

Unanimous AI is a new company that is offering the capability to merge AI with human brains creating a symbiotic super intelligence.

My guess is that the transformation will be subtle. We'll neither realize it is happening, nor that it has happened. How deeply do we comprehend that our decision to buy a certain brand of toothpaste was influenced by a commercial that we saw a month ago and have since forgotten?

This isn't a win or lose situation. We're going to wind up as a partner to our smarter machines, and that partnership will be fostered by our augmentation through technology. Machines will play an essential role in this augmentation and, as with any successful technology, they will fall below our level of perception. In the end, the revolution will be silent and invisible.

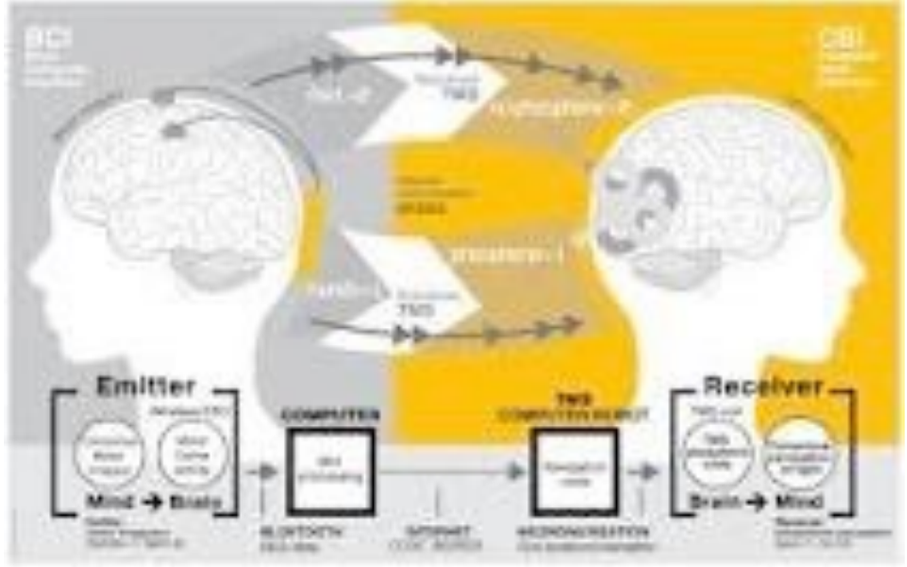
Comments:

- Philosophers have been debating on “free will” for millennia. In the future the debate will have to take into consideration machines as well, specifically the ones in symbioses with us
- As intelligence is likely to be shared (in a way we area already facing this problem as we confront fake news) what happens to responsibility and accountability? When machines are involved today in a decision process (e.g. in landing an aircraft under IFR) and it fails we look for the human responsibility (who checked the autopilot last, who designed it, who maintained the radio forming the gliding path…). Where are we going to look when machines will be “self-designed”? The human factor may vanish from the equation.
- Emotions are a human characteristics, or so we say. Yet, we know that our emotions are conditioned, sometimes even created, by chemicals to the point of being outside of our control. Deep Brain Stimulation may become, along with other technologies yet to be invented, a way for machines to become symbiotic with us. At that point would we fall in love as result of a machine deciding that is the right thing to do?
- Transhumanism will leverage, it will happen, on human machine symbioses. Part of this symbioses may occur before the birth of the human 2.0, as result of the redesign of the genome by a machine, possibly the most effective way of creating a human-machine symbioses since, in a way, those humans will be partly machine as well.

Brain to brain interface: where are we?

SEPTEMBER 7, 2018

1. **Brain to Computer Interface**
2. **Computer to Brain Interface**
3. **Brain to Brain**



BCI coupled with CBI to create a brain to brain interface. Credit: Plos One & Neuroelectrics

Brain to Computer Interfaces (BCI) have progressed quite a bit both in the "hardware" part increasing sensing resolution and capabilities and the "software" part making it possible to make sense out of the electrical signals detected.

Today it is possible to control a robotic arm with thoughts helping people with motor disabilities, there are a few BCI demonstrations for playing games on a computer and several experiments have been performed using animals. BCI are transitioning from the labs to actual use at home, signaling the transition towards maturity although a lot remains to be dome to make them really usable. There are two crucial points: detection of brain activity shall be done without needing an invasive implant (today this is required to get better signals and decrease the noise created by the thousands of concurrent activities going on in the brain) and to move to a wireless connection from the detecting sensors to the processing unit.

Research has also progressed in the other direction (CBI: Computer Brain Interface) sending signals to the brain to activate specific reaction. So far most experiments have been run on animals and have been focussing on the activation of motor neurons.

It is much more difficult to move into this direction, computer to brain, since it is both difficult to influence what is going on in the brain and do so in the very specific areas that are to be involved. Technologies like deep brain stimulation,

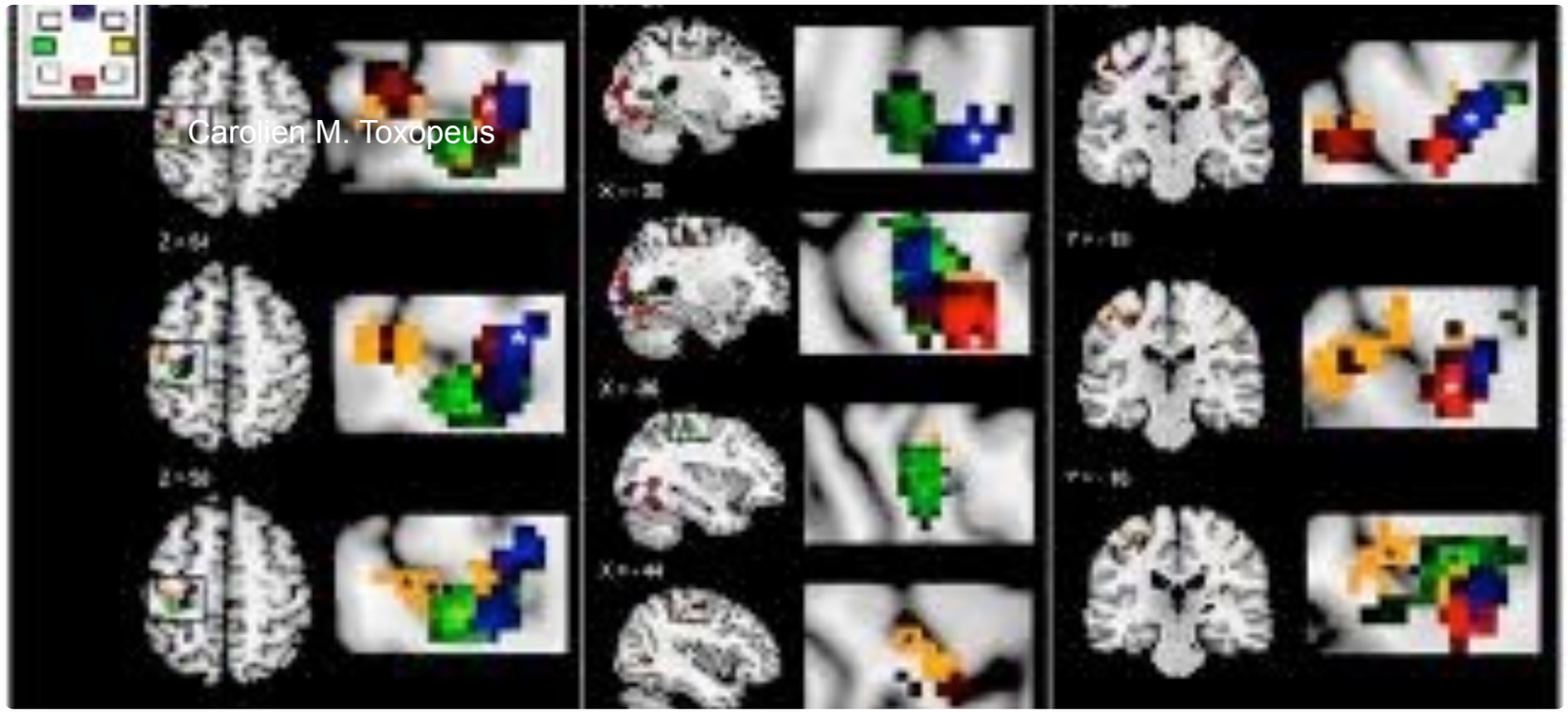
DBS, and transcranial magnetic stimulation, TMS, are being tested, with the former providing much more precise control but requiring an invasive procedure and the latter being less accurate.

Obviously, by linking together a BCI with a CBI a direct brain to brain communication should become feasible. The hurdles are big and they are not just of technical nature. The most basic issue today is that we still don't understand what is going on in the brain and the more we understand the harder establishing a brain to brain communications seems to be.

Whilst intercepting motor signals (ie the intention to move a finger of the left hand) is now -almost- straightforwards and conversely sending a signal to move that finger is becoming feasible by stimulating the appropriate motor nerves, the manipulation of thoughts is still in dreamland. We cannot, as an example, transfer the thinking of moving the finger and have the brain activating the appropriate motor nerves to execute that action. We do not know where the stimulation should take place (probably in different parts of the brain and at very specific moments…). Also, notice that by stimulating a motor nerve we can indeed move the finger but the brain would be unaware that the finger is moving because of a decision it has taken!

The problem is our brain (as well as a fly's brain) is complex. We can manage complication but to manage complexity you need to tackle the full brain, to interact at the same level of complexity and we are still far from that point.

Gallery 1.23 Motor cortex

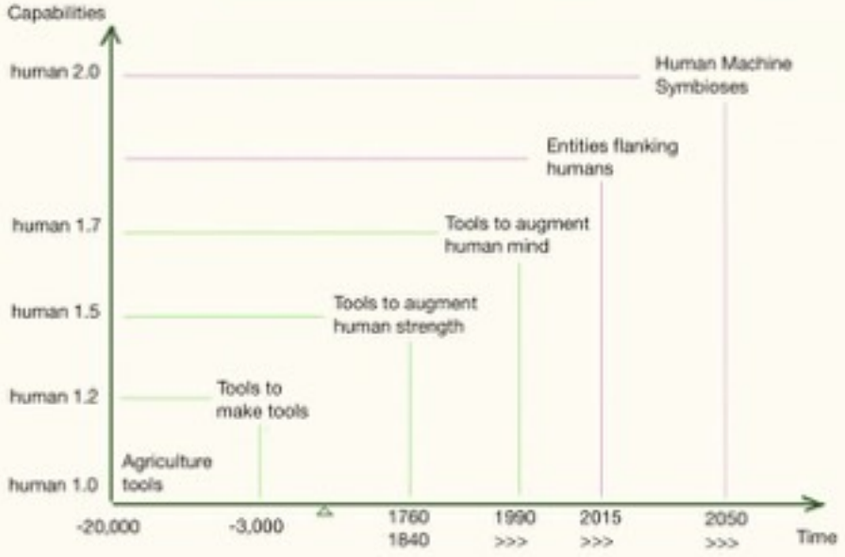


Several views of the motor cortex as it activates to initiate and coordinate movements. Although we have an increased understanding of what areas are involved in what movements it is still too difficult to activate movements through the motor cortex stimulation. Muscle activation is done by stimulating the terminal nerve (or motor center in the spinal chord. Image credit: Carolien M. Toxopeus, University of Groningen et al. PLOS

Towards Humans 2.0

FEBRUARY 1, 2018

1. **Creating tools to make tools**
2. **Tapping on external energy sources to augment strength**
3. **Cognitive Augmentation**
4. **Genetic manipulation**



The path towards Humans 2.0 started a long time ago, now we are getting closer.

The dividing line, if ever there was one, between our ancestors and the present human species has been set by the acquired capability to use tools (it goes back to millions of years ago, the oldest proves of humans using tools go back to 2-3 million years ago with homo habilis and homo erectus, pre-dating homo sapiens sapiens). As any dividing line created by historians it is a fuzzy one. There are a few animals that are using tools (from insects to birds and mammals) and even a few that are perfecting tools (some monkeys do). This is no surprise since humans are not at the tip of evolution, all species living today are, one way or another, at the leading edge of evolution. Using tools is part of this evolution.

Humans, however, are the only species living today that is making tools to make … tools. The first “humans” what we may call “humans 1.0” used tools in hunting (first) and in agriculture, to scrape skins and became pretty good in shaping stones and wood to serve the intended purposes. It took several million years to make the leap, to start inventing tools that would be used to make better tools, we may place this invention 5,000 years ago. This requires the capability to imagine what is needed and what is needed to make that. I would say it is an imagination of the second order. That is why I labelled this evolution as “humans 1.2”.

A few more millennia and humans invented a way to increase their strength initiating the industrial revolution (first with steam and then with electricity and the related engines converting the energy in mechanical movement). Yes, the lever and

pulley were ways to augment human strength, but it actually traded displacement for strength. The energy was provided by the human worker.

Water mills (3rd century BC) and windmills (1st century BC) clearly predate steam and electricity but converted an energy that was available locally. We really have to wait the invention of the steam engine to have a way to increase human strength everywhere that was desirable.

This has revolutionized our society, increased the GDP and transformed us as human beings. That is why I am labelling this event as the birth of “humans 1.5”.

Gallery 1.24 Apps are an extension of our brain, and mind

There is surely an app for you, out there! Image credit: Pursuit Magazine

In the last 25 years (at mass market level) the massive use of computers, particularly impactful in the last decade as they become a continuous presence in our life in form of smartphones, we have seen an increase of our mind capabilities. We can rely on our smartphone to remember numbers, appointments, to help us finding the way, to calculate exchange rates… you name it. More than that. This incredible tool is connecting our mind with an unlimited source of knowledge, the web, and with an unlimited source of services. Notice that this knowledge and these services are the result of million of people that have worked to create and share it. Think about it: the smartphone shrinks the distance to other minds and brings the past into the present.

This is another major leap in the increase of our capability as a species (the smartphone has reached a penetration close to 50% in the world) and I labelled this as “humans 1.7”.

Why am I labelling humans with a progressive, distinct number? Are humans 1.7 different from humans 1.5? Yes, they are. We are what our genome is creating but that is also part of the story. We are also what we are nurtured in. And the experiences, the context we live in is making us who we are as much as our genomic roots. The experiences we live, what we learn changes our synapses, our brain and there is no doubt that

the kind of experiences we live today are quite different from the ones that shaped our grandfathers. Our children are growing in a context that is different from the one we grew. They are different from us, for sure they are humans 1.7, most likely we are humans 1.6 … (look at the nice, although old, clip).

What will it take for the next leap, for seeing the birth of “humans 2.0” - transhumans- a marked improvement from the past?

I described our evolution as human species as a result of our ability to develop and use ever more effective (and sometimes) complex tools. Of course this goes both ways. One can rightly say that it is our evolution that has led to the capability of creating better tools. The minds of hunters and farmers devised better tools to use in the field, likewise evolved minds of scientists, researchers and engineers led to the taming of steam and electricity.

Gallery 1.25 Is technology changing what it means to be human?

Is the evolution of electronics and artificial intelligence changing the way we are “humans”? A series of conferences organized in Mogliano Veneto by the Galileo Galilei Institute.

I am not claiming one interpretation over the other, just noticing that we can tag our increased capabilities as a species with the kind of tools that are -somehow- supporting those increase capabilities.

In the last years we have started to see a transformation in the “quality” of our tools. For as long as we can know, tools have been an extension of our body, from the club to the hoe, from the loom to the amazingly huge and complex steel mills. Robots have just been the more recent tools to extend our capabilities.

However, in the last few years robots are starting to become “autonomous”. This does not mean that they can perform their duty unsupervised. This has been true for quite some time. You program a robot to do a certain job, including very complex ones like flying a plane, and it will do that without any supervision.

With “autonomous” I mean that robots are starting, mind you -just starting-, to have a life of their own in which they take decisions that have not been programmed. This is the result of the “mind” we have provided them, a mind

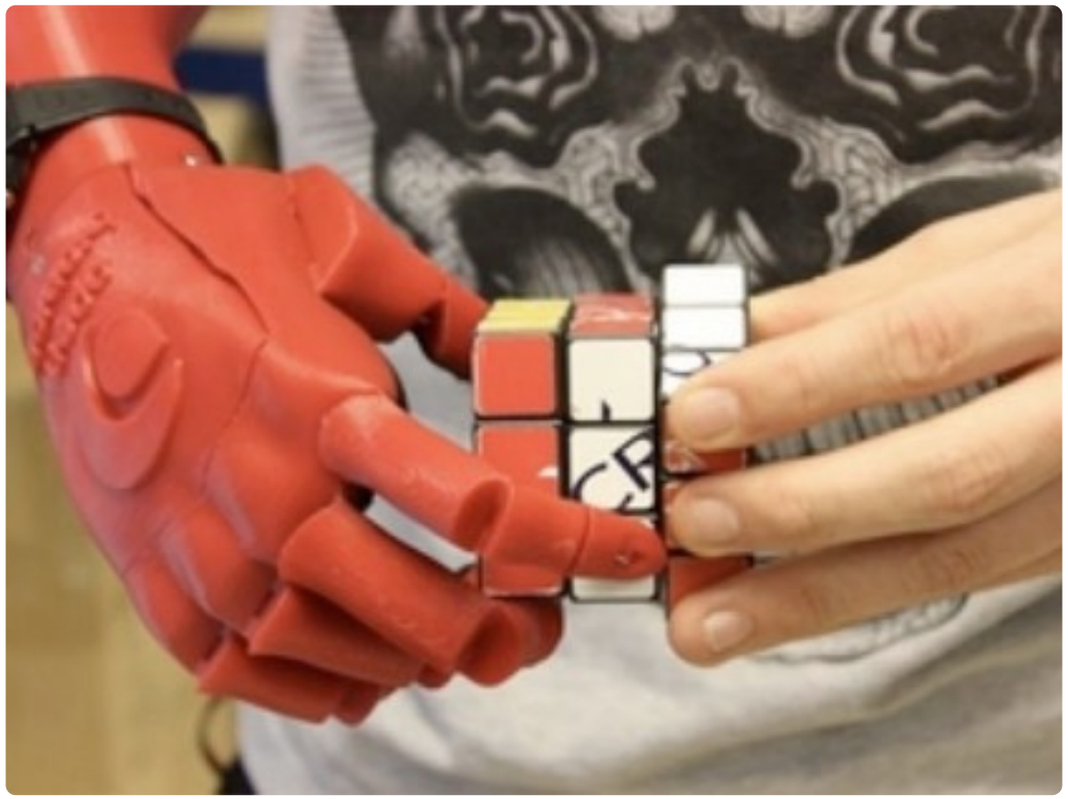
that can learn and their behavior is based on what they have learnt.

Look at AlphaGo (a nice movie, released in January 2018, is available on Netflix with insight on its "mind"): that computer played in a way that surprised its "designers" (no longer "programmers" since in a way AlphaGo is programmed to learn, not to operate).

The learning process is an unpredictable one, it may lead to unexpected capabilities, be it the learning of a kid or the one of a robot.

The robots have the advantage of learning fast, and they can learn using a replica of themselves as a sparring partner. Imagine you were learning to play tennis by rushing back and forth in the two parts of a tennis court first hitting the ball (serve) and then responding to it … Impossible, obviously, but not for a robot! A robot can clone itself and learn by interacting with itself. Actually it can create many clones of itself and explore new avenues of both computation and interaction.

Gallery 1.26 Human - Smart prosthetics Symbioses



A 3D printed hand. Just looking at the image one may not be sure whether it is the prosthetic hand solving the Rubik's cube leveraging on its embedded intelligence or if it is the human hand "connected" to the human brain, or may be both cooperating. For the record: in this case it is the human hand/brain, in the next decade it might be the other way around. Image credit: Open Bionics

These new breeds of robots are entities that will be flanking ourselves, no longer extensions of our body but "living" things that co-exist with us, learning from experience and we will become part of their experience.

Can this co-existence bring to a new superorganism?

Prosthetic limbs have reach such a sophistication that can be seen as operating in a symbiotic relation with the person having them. And in a few cases the person's perception has fully integrated the prosthetic limb. Newer version have embedded intelligence, able to predict what it will be expected from them, they can interact with the body, and the brain of the person, receiving signals and returning sensation. It is an easy bet to say that in the

next decade we will see even better prosthetics, with higher level of intelligence and autonomy able to interact seamlessly with the body in a true symbiotic relation.

The image shown is to emphasize the progress made in 3D printing functional prosthetic hands and the way they can collaborate seamlessly with the normal hand. Today the level of intelligence in the prosthetic hand focusses on smoothing its operation but in the next decade this intelligence may grow to provide additional ability to the hand, additional expertise to perform tasks that person's hand/brain do not have.

In that case you may see this prosthetic as a functional augmentation of the person. Clearly this will apply to various forms of exoskeleton today focussing on helping people with motion disabilities and workers to relieve fatigue and increase their strength. In the future they may become standard body augmentation for a variety of workers as well as other areas, like tourism. Are you interested in a nice but hard excursion requiring perfect physical fitness and weeks of training? Forget the training and don an exoskeleton and you are on your way. I would expect this to become as normal as today it is to see elderly people choosing an electrical wheelchair to visit some tourist spots.

Gallery 1.27 Exoskeleton applications

Chairless chair exoskeleton system to relieve workers fatigue. Image credit: Noonee

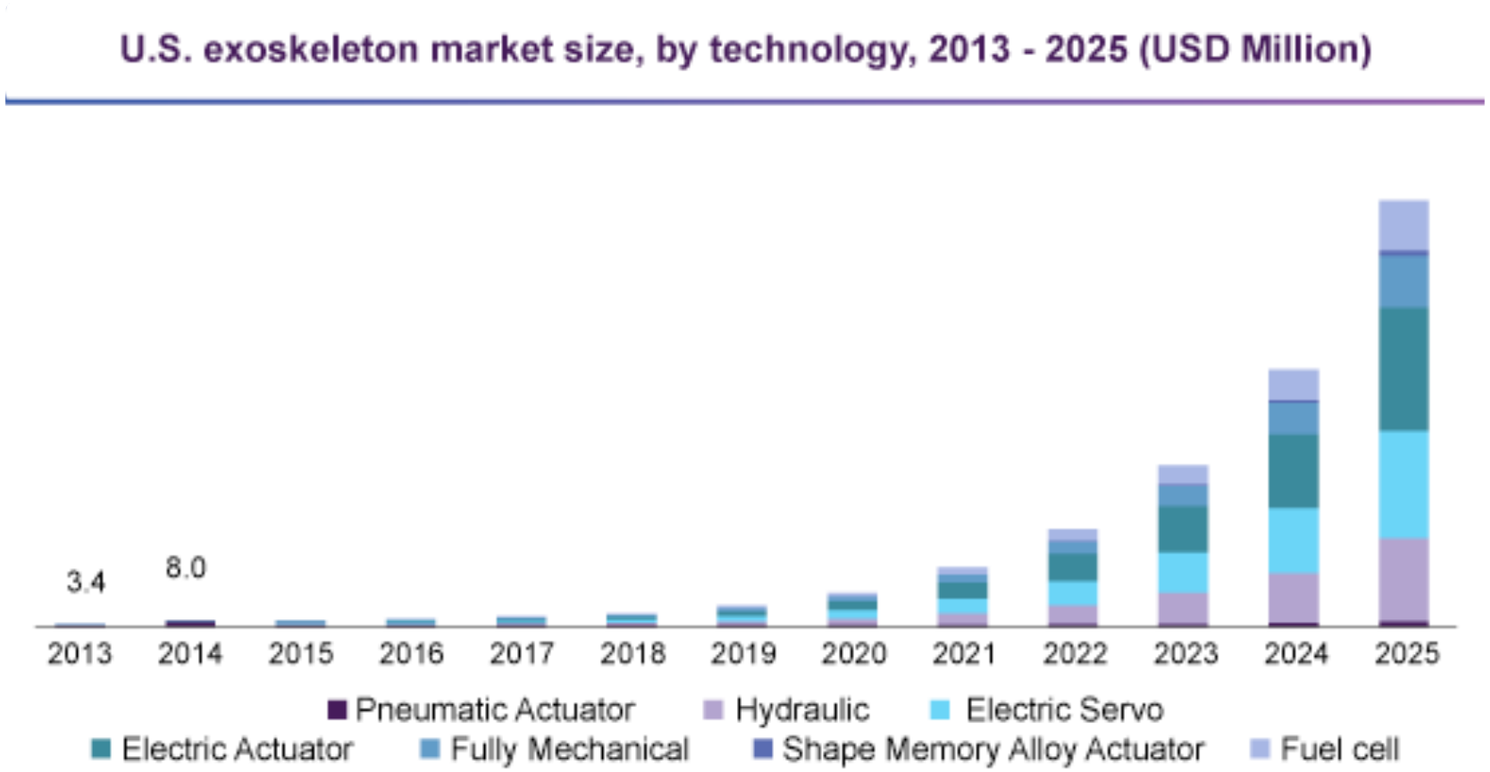
The market value of exoskeleton is growing rapidly, it was 43M$ in 2014, it is expected to reach 1.8B$ in 2020 (Winter Green Research).

Key to this evolution will be the "seamless" experience. You should not feel the augmentation apparatus, just enjoy "your" augmented capabilities. It will require advances in material

science and in artificial intelligence. The apparatus shall be at the same time autonomous (so that you don't need to perceive it and "command" it) and seamlessly integrated with you, i.e. creating a symbiotic relation. In most cases it will take some time for both of you (yourself and the apparatus) to adapt to each other and this in a way will be a departure from today's situation where it is just you that need to adapt to an apparatus, be it a new pair of ski, new booth…

The trend is toward an increased adoption of autonomous systems, in different shapes and serving different uses, all providing through a symbiotic relation an augmentation of some of our capabilities.

Gallery 1.28 Exoskeleton Market forecast



Rapid growth of market value in the US. Similar growth are also expected in other parts of the world.

Source: Grand View Research

Once this becomes generalised we will enter into a new dimension, that of humans 1.9. At one stage, further down the lane, this augmentation will become a standard way of "being human" and that will finally lead to "humans 2.0". It is likely that this will involve some modifications to our body, resulting, as an example, with drought resistant plants, to some tweaking of the genome.

Notice that we already have taken this body modification path in the last 50 years with … vaccination. Vaccination gives us superhuman strength in fighting some kind of viruses and we have been extremely successful in this area. Vaccination teaches our immune system to be prepared to some viruses attacks and respond in an effective way. We have been able to tweak with the genome of

some plants to make them more resistant to bugs and drought… effectively creating species 2.0. The time for humans 2.0 is coming.

Notice that what seems scaring today, because is perceived as a significant change, will not be so tomorrow, since the evolution will be slow and mostly unperceived. It will start affecting few niches where the need is stronger (like genetic diseases or disabilities) and ethical issues minimal and overcome by other considerations to expand to other areas.

Looking ahead, like it is done in the IEEE FDC Symbiotic Autonomous System Initiative, will help in identifying roadblocks, both technological – economical – societal, and open a broad discussion on how to tackle them steering the evolution in a desired way.

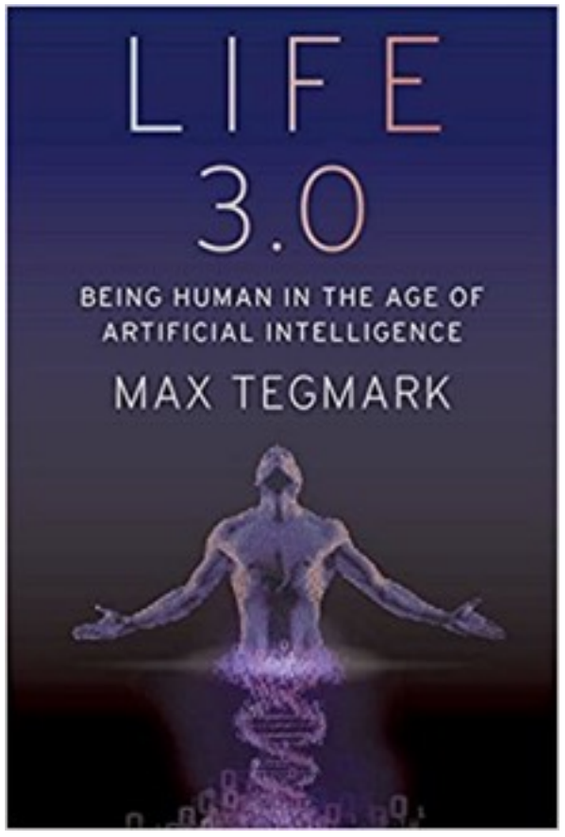
Gallery 1.29 Augmentation through gene modification

Scientists at the Department of Energy's Oak Ridge National Laboratory have identified a common set of genes that enable different drought-resistant plants to survive in semi-arid conditions, which could play a significant role in bioengineering and creating energy crops that are tolerant to water deficits. Image credit: Oak Ridge National Laboratory

Life 3.0

SEPTEMBER 13, 2017

1. **Life 1.0 - Managing complexity**
2. **Life 2.0 - flexibility on top**
3. **Life 3.0 - Symbiotic life**



A really intriguing book full of suggestions on a next step of life evolution. Credit: Max Tegmark

In my search for information relevant to the recently launched Symbiotic Autonomous Systems Initiative I stumbled onto a fascinating book written by Max Tegmark, Life 3.0.

When discussing on life from a scientific point of view the first question coming to the fore is what is meant by life, in a scientific sense. The problem is that as you look closer and closer the boundaries between what we may call life and what we wouldn't call life gets blurred.

In his book, Max answers the question by noting that imposing requirements such as "being composed of cells" is not satisfactory at all and therefore he prefers to define life as a process able to retain its complexity and replicate. Of course this definition is more inclusive and opens the door to consider entities, not cell based, as "life".

At the same time this leads him to the need of classifying different forms of life and he starts with bacteria, clearly living things since they can maintain their complexity and replicate. They interact with the environment, as an example by sensing the presence of sugar and activating their flagella to move closer to it (and eat). The mechanism at work has been perfected through billions of generations and although it works perfectly is not flexible. It is the implementation of instructions written in the bacteria DNA and these can not be changed by the

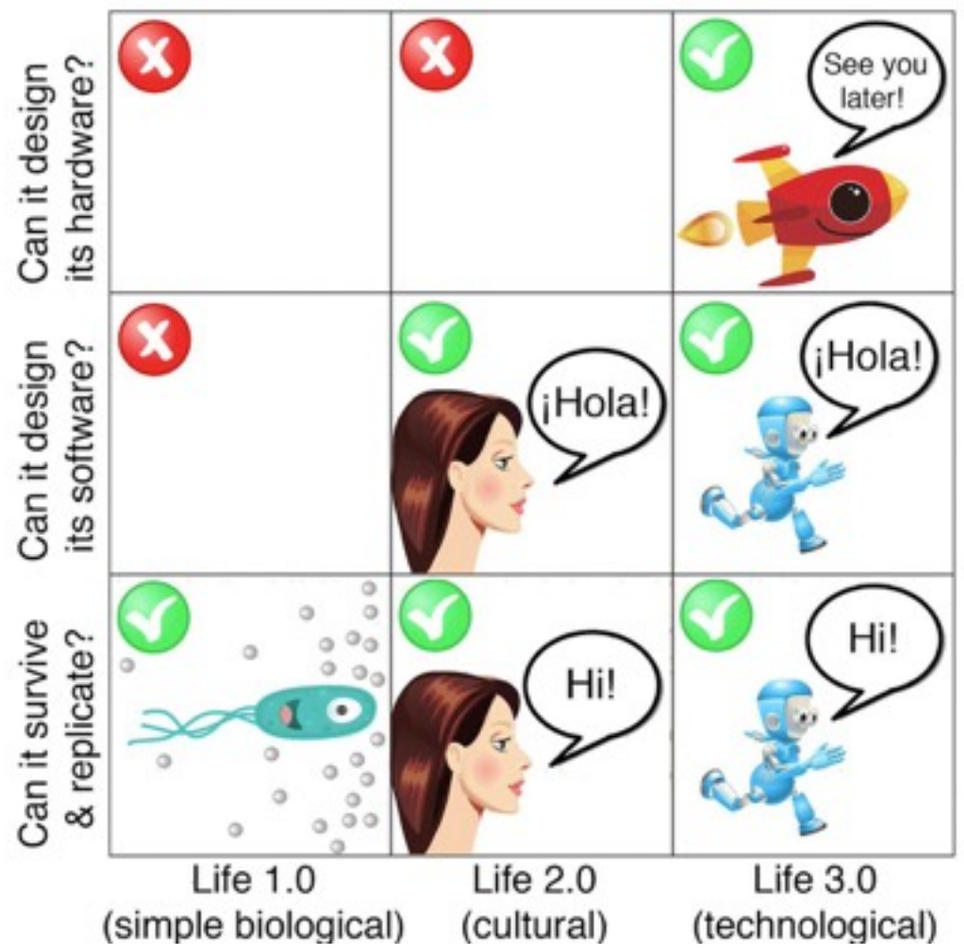
bacteria itself, although they get changed over generations of bacteria (through evolution). This is an example of Life 1.0.

If, on the other hand, we look at humans we see that we are much more adaptable as individuals. Each one of us learns and changes his behavior accordingly. The amount of information that a human DNA can store is in the order of a GB. However, the amount of information that a human brain can store is in the order of 100 TB (according to Max). What is crucial is that this "potential" gap is filled through individual learning and experience so a person can increase her inherited -genetic- knowledge. A newborn cannot speak any language but in a relatively short time can develop a software plug in in her brain that can let her understand and speak any language (one plug per language, of course, and it takes time to create one…).

This capability of relaying on soft processes is what Max calls Life 2.0. By the way: why using 1.0, 2.0? Because the boundaries are not well defined. Mice have much more flexibility than a bacteria, a single mouse can learn, although not as much as we do, so perhaps it should be classified as 1.x. At the same time humans are now able to learn much more using the Internet and a smartphone as a prosthetic. Is this a Life 2.x form?

Artificial intelligence is creating entities that are mostly software, or a software that keeps evolving and enters into a symbiotic relation with hardware of different sorts. This is what Max calls Life 3.0.

Gallery 1.30 Towards Life 3.0



Sketchy summary by Eric Topol

And this is what connects to Symbiotic Autonomous Systems.

As long as we take Max definition of life and we look at robots that can duplicates themselves and learn we are getting closer to Life 3.0, and if we are considering symbiotic relations with humans, augmented humans through AI, again we are on the path towards Life 3.0.

Better to read Max's book for intriguing thoughts!

Artificial Super Intelligence

SEPTEMBER 10, 2018

1. **AI evolution: Narrow > General > Super**
2. **AI versus Human Intelligence**
3. **Emerging Symbiotic Intelligence**

Today we have Artificial (narrow) Intelligence. In the future we might expect machines to demonstrate the same level of intelligence of humans (Artificial General Intelligence) and thereafter to take the lead with a human-machine convergence, immediately followed by humans 2.0 and Artificial Super Intelligence. Timeline by Reimagining the Future.

As part of the second White Paper produced by the Symbiotic Autonomous Systems Initiative I am discussing the evolution towards Artificial Super Intelligence. We discussed this at the Workshop in San Diego on October 30th and at the TTM 2018 following the workshop.

Today Artificial Intelligence is not au pair with human intelligence, humans still have the upper hand. However, this is not generally true. There are areas where computer intelligence is better than the human's one, as an example where it is needed to look at huge amount of data, or remember many data, or evaluate the outcome of some complex decisions. Computer AI has managed to beat the human chess world champion, the human Go world champion, has won Jeopardy…

Hence it would be fair to say that although we do not have computers that can demonstrate the same level of human intelligence in general (Artificial General Intelligence –AGI) we have specific areas where computer intelligence is better than the human's one.

Now, there is a consensus on the fact that sometime in the future computers will demonstrate an intelligence comparable to the one of humans, they will achieve AGI (although there is no consensus on "when" this will happen).

Paradoxically, this will be the point when they will also achieve ASI -Artificial Super Intelligence- since they will maintain the edge in those areas where they already have an edge on human intelligence, hence by the time they will demonstrate AGI they will also demonstrate ASI.

However, with ASI it is usually meant the capability to be better not just in a few areas but better in most areas. This might require a bit longer but not that much longer. The point is that computer are getting more intelligent by learning and they no longer learn from humans. They are starting to learn also by themselves, trying different approaches and evaluating them.

The advent of symbiotic autonomous systems -SAS-, where there will be a computer as a component, will lead to the emergence of intelligence at SAS level and this emergent intelligence is most likely to be better than the intelligence of each component. If one of the component is a human being and the other components are also intelligent, the emerging intelligence is likely to be of ASI type.

This will be unlikely to happen within the next 20 years, although a few scientists and futurists bet on this transition to ASI to happen in the fourth decade of this century.

Gallery 1.31 The path towards Artificial Super Intelligence

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The path towards Transhumanism

AUGUST 6, 2018

1. **Evolving the Human Body**
2. **Evolving Human Thought**
3. **Evolving Human Behavior**

Will there be a Human 2.0?
The answer might be different from what evolutionists would have thought 100 years ago.
The evolution is likely to come from a joint, symbiotic evolution, of a technology embedded environment, a technology supported design of human evolution and the embedding of technology in humans.

Evolution has marched along the 4.5 billion years of our Planet. Although life seems to have started some 3.5 billion years ago, evolution was already at work before that time, creating new and more complex molecules that eventually gave rise to the first forms of life. It has never stopped, it keeps going on today.

However, if we focus on a single species we have many cases (most actually) where evolution stopped simply because that species disappeared. The 5 great extinctions of the past wiped out most species.

Researchers studying evolution pointed out that the human species is unlikely to evolve further. Our siblings have already disappeared and we are the last species of homo sapiens. In order to further evolve, generating a new species we would need to incur in a random variation (that's possible) that would pass a natural selection process leading to a divergence from the current species and this is no longer possible for the foreseeable future. We no longer have on Planet Earth niches isolated from the rest of the Planet were a divergence can strengthen to the point of becoming a new species. We keep mingling with one another and our genes keep getting exchanged .

We might, in the longer term, create new niches, like sending astronauts to colonize Mars. At that point the separation conditions that are required for the emergence of a new species will be satisfied, but we are far from that.

Humankind has diverged for millennia (millennia are too short on the evolutionary clock to create and select a new species) in their extended phenotype: communities separated in space have evolved different cultures and therefore different extended phenotypes (just think at the many languages spoken on the Planet, even though their number is decreasing ever more). In this last century the Planet has shrunk to the point that even these divergent extended phenotypes are becoming rare and difficult to emerge.

However, in this last decades we are seeing unexpected evolution avenues on the horizon, not the ones of natural selection but the ones enabled by "design". Genomic manipulation and symbioses with machines are opening up new possibilities, and give rise to many questions.

The Visionary Innovation Group at Frost&Sullivan published an interesting study on Transhumanism exploring these possibilities and the impact they might have on business. They are considering three main "evolutions":

- Evolving the human body
- Evolving human thought
- Evolving human behavior

Gallery 1.32 The Extended Phenotype

The genotype consists of all the genes. The phenotype is the result of their expression. Differences in the genotype leads to differences in the phenotype, like the color of skin. We know some of these correlations but we are far from knowing all of them since a single gene difference may lead to several differences in the phenotype. In addition, the actual people phenotype (what we perceive of a person) is conditioned by other factors, like culture (including what diet is part of that culture, resulting in different average size of people). These additional factors are forming the "extended phenotype" and technology is one of these factors that is reshaping our behavior. Image credit: The Straits Times

These evolutions are the result of converging evolution of biotechnologies, human machine interaction technologies/symbioses and behavioral aspects (prompted by new possibilities and change in culture).

These same areas are being explored in the IEEE FDC Symbiotic Autonomous Systems Initiative and were also the topic of a Delphi study whose results can be seen in the second SAS Initiative White Paper.

Evolving the Human Body

We have started to augment our body long long time ago, probably the first augmentation go back 170,000 years ago when our ancestors started to wear clothes to protect themselves from cold weather. You might not consider that an "augmentation" but it actually made possible to extend significantly the human habitat. It is also worth noticing the long time it took to the human race to achieve this first augmentation considering that we lost thermal insulation from hair (that our siblings, the chimpanzees still have) some 1 million years ago (based on genomic analyses). That is a quite long span of time to live completely naked!

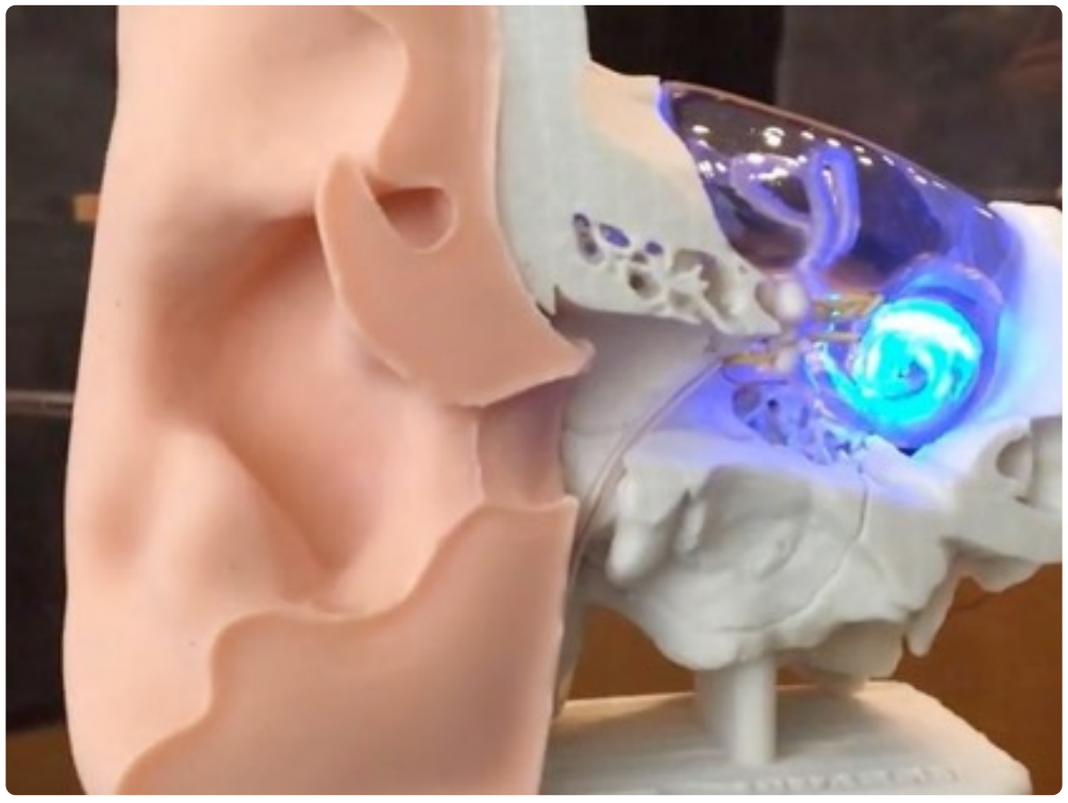
Fast forward. At the end of the XIII century the first visual aid (sort of glasses) were invented (Northern Italy) providing another earlier case of human body augmentation.

In these last decades the variety of augmentation to our body made possible by technology has started to grow and we can expect a real explosion in the coming decades. These body augmentations can be classified in three areas:

- external wearables for sensing and movement enhancement;
- internal implants in the body with special case for brain implants;
- biological augmentation based on genomics, genetics and reproductive.

The three categories represent just a broad classification and there are a number of examples of augmentation based on technologies falling into more than one category. As an example, the implant developed by the University of Gottingen (see image) requires the genetic modification of cochlear nerves so that they can become sensitive to light. At this point a microchip can convert sounds (picked up through a micro microphone inserted in the ear duct of a deaf

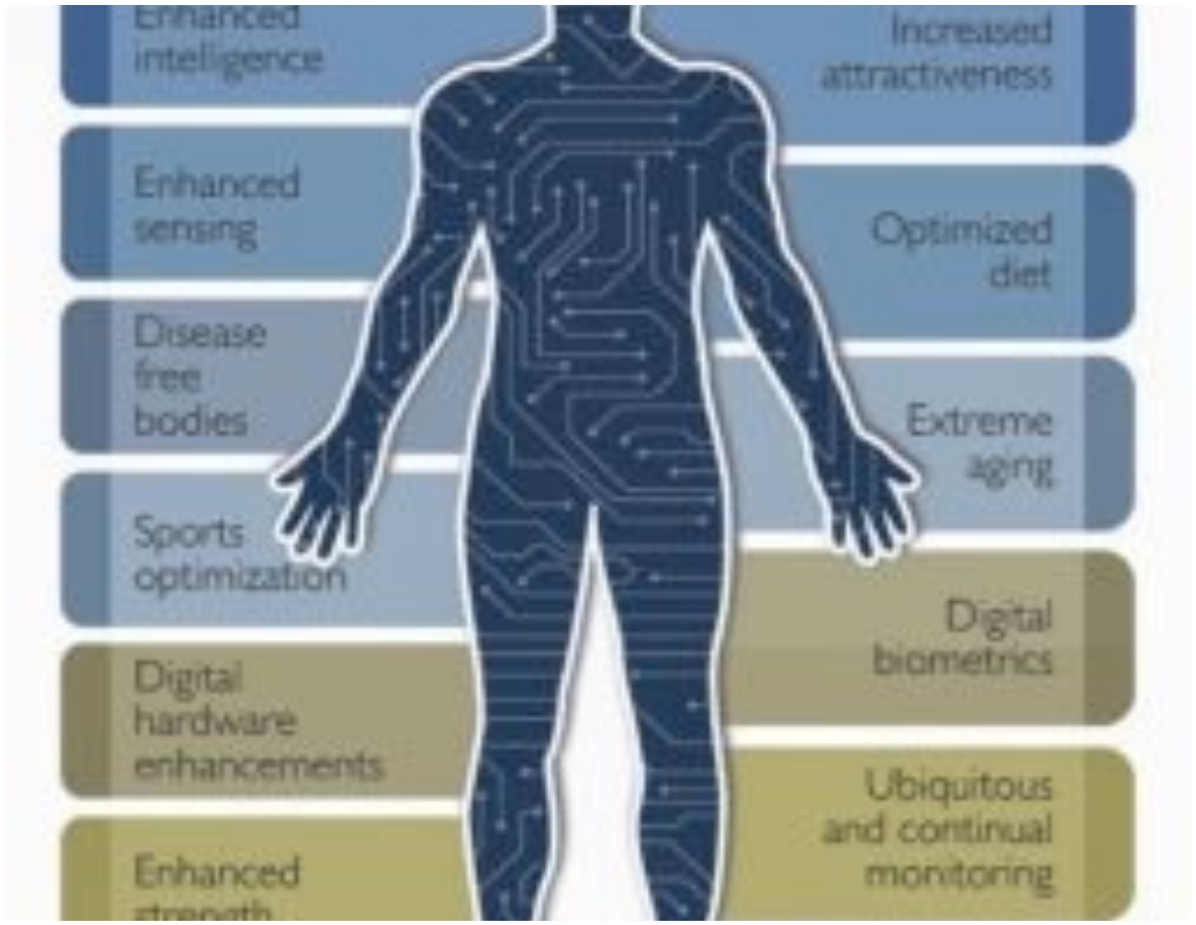
Gallery 1.33 Human augmentation technologies



A cochlear implant based on optogenetics. Neurons in the cochlea are genetically modified to become sensitive to light. Using optical fibers a microchip converts sounds in light pulses that in turns stimulate the aural nerves with a very high precision.
Image credit: Gottingen University

person) into light pulses. These are carried to the inner ear by optical fibers, where the cochlear nerve terminations are. The light pulses stimulate the nerve terminations in a very precise way, not achievable with current technologies, and send the signals to the brain for processing. This device, so far tried on gerbils but soon to be tried on humans, can be seen as a way to restore hearing. At the same time it can provide augmentation both in hearing sounds that would be too weak to be detected by a normal ear and to detect sounds that are outside the frequency response of our hearing sense. As an example the microchip could be designed to provide hearing in the ultrasound range (like bats), which could be used to see in complete darkness like having a radar.

Gallery 1.34 Areas of Human Augmentation



Application areas for human body augmentation. Source: Frost&Sullivan

The microchip might also be designed to capture radio signals and convert them into sound patterns.

These are examples of augmentation that involve both biological modifications, wearable and implantable devices.

Human augmentation is a form of evolution that our species has taken in its own hands and it is not going to be stopped. Eventually it might end up in the creation of a new species through bio-engineering that modifies the genome. We are still far from that although the main hurdles are more in the ethical and social domain than in the technological one (we do not have the knowledge to apply the technology we already have that would lead to a new species creation although we are already seeing work in this direction with the application of deep neural networks and more generally artificial intelligence to understand the

connection between the genotype and the phenotype and as next step to design the genotype based on the desired phenotype).

Frost&Sullivan Visionary Innovation Group has listed a number of areas where human body augmentation will serve on the path towards transhumanism:

1. Increased Attractiveness
2. Enhanced Sensing
3. Sport optimization
4. Digital biometrics
5. Ubiquitous and continual monitoring
6. Optimized diet
7. Enhanced strength
8. Disease free bodies
9. Extreme aging
10. Enhanced Intelligence
11. Digital hardware enhancement

I have listed the various application areas according to my feeling of time occurrence, with the first one, Increased attractiveness, already happening and the last one not likely to happen anytime soon.

Of course, for each of these areas there are different degrees of fulfillment (ambition) and way of achieving them. As an example, we have plenty of plastic surgery being performed to increase attractiveness (curiously, may be a Freudian slip, I first typed Increase "attractive**m**ess" which is something happening when plastic surgery goes too far….). In the future some genomic tweaking may result in the same increase of attractiveness without need of surgery. Would you like your offspring to be tall? A little genomic modification and there you have it! Likewise, one might claim that we already have some sort of "Enhanced Intelligence" through the use of tablets, smartphones to grab information from the web.

Gallery 1.35 Augmenting attractiveness

Use on nanotechnology in cosmetics is widespread with all major brand having adopted nanotech. Concerns on the potential side effects have not stopped their use so far. Image credit: BidnessEtc

Let's start discussing each area.

1. Increased attractiveness

From as far as we can go back in time humankind has tried to enhance personal attractiveness, coloring (sometime scarring) the skin, elongating the neck, constraining the feet to remain small, increasing the

muscle size and so on. Of course, attractiveness changes across cultures and what can be attractive here may be unpleasant there.

Cosmetics goes back several thousands years and technology has contributed significantly to cosmetics. Nanotech is now providing more options in cosmetics and electronics has also found application into cosmetics. Flexible electronics as well as on skin-printable electronics will provide means to create a novel line of skin jewels, sparkling skin in the real sense.

Plastic surgery is widespread and will get better with the availability of new materials. Smart materials will allow reshaping of body parts.

Genomic and bio-engineering are already supporting the selection of specific traits in In Vitro Fertilization so that couple can choose the color of the eyes of their baby…

These growing set of possibilities are opening up a set of social and ethical issues, including the gap between those who can afford this "un-natural selection" and those who cannot (choosing the sex of the future baby may cost over 15,000$). Of course, one could say that also in the past rich people could afford a life and choices that most other people could not…

2. Enhanced Sensing

A lot of research is ongoing to meet the needs of impaired people who lost completely or partially some of their sense capabilities, be it hearing, seeing, touching, smelling and tasting (the order reflects both the investment and the results obtained so far). Most of the results have shown that once we engage some artificial sense to replace or supplement an existing sense it becomes possible to extend the natural sense capabilities, this effectively augmenting the sensorial capacity of a person, to the point that an artificial sense might (in the future) become of interest also to people not suffering from any sense disability.

Gallery 1.36 Enhanced Sensing

The capabilities of our senses are defining our perception of the world and the way we interact with it. In the image on the left a village scene, in the middle how the same scene would be perceived if we were to have a fly eye and on the right if we were to have a mollusk eye.

Image credit: David Trippet

We are not at that point, yet. All artificial senses developed so far come short in terms of performance to replace with the same effectiveness natural senses but it is also clear that progress in technology will fill the gap and will push beyond the capability of natural senses.

One of the point that is emerging from research in this area is the flexibility of our brain, the real processing point of sensation, the one that gives meaning to the data provided by our senses (and often associates emotion to them). This flexibility is such that sometimes the brain can rewire itself to deal with signals conveyed by a sense as if they were conveyed by a different sense. It is the case of Neil Harbinsson, I discussed previously in "The sound of colors, the colors of sound", that can see colors by hearing sounds...

Enhancing our senses would provide a different view/ perception of the world and would likely set up a different set of interactions. This is nicely discussed in an article on Oxford Academic: "Music and the Transhuman ear: ultrasonics, material bodies and the limits of sensation". It is a long article but if you are interested in these areas it makes for a good reading.

A lot of work is being done in the area of Augmented Reality and this will result in the availability of "interfaces" that will augment human vision and hearing. Notice that today we are talking about wearable based interfaces (like goggles) but in a few decades technology will have moved to the point of providing invisible interfaces, with direct connection to the sensory nerves and eventually to the brain (I don't see this happening in the next 30 years - apart from some lab demos).

Gallery 1.37 Sport optimization

Oscar Pistorius running in the Olympics. Image credit: Business Insider

Once Augmented Reality will become seamless it will change forever our perception of the world and it might be one of the first turning point in the path towards transhumanism.

3. Sport optimization

Somehow related to Enhanced Sensing is the area of Sport optimization, a way of reshaping the body to better fit the demand of a specific sport. It is related since it is involving sensing. The two single biggest hurdles in having functional prosthetics (for limbs, hands, ...) is the powering of the prosthetic so that it can be

active and its interface with the body. Providing accurate sensations is crucial to ensure a seamless integration with the body.

Most recent advances have seen the embedding of sensorial capability (touch) in prosthetics. An electronic skin is covering the prosthetics and can transmit sensations like touch, pressure and even pain.

The first Olympic for Cyborgs, people using prosthetics to participate to the context, was held in October 2016 in Zurich, Switzerland and a new edition is planned in 2020.

Paralympic athletes are showing performances that are getting closer to the one of normal athletes and it is expected that they will get an edge over normal bodies. Some discussion has already started on the fairness of using prosthetics in “normal” Olympics, showing the progress in this field.

Take a look at the variety of prosthetics Don Elgin, a paralympic pentathlete athlete is using depending on the game he is participating.

So far prosthetics have been used to recover from disabilities but it would not be surprising if they will be adopted in normal competition. If you think about it, professional skiers are using boots and skis that are ever more sophisticated and that are providing a competitive advantage in the race. What about a skeet shooter donning a prosthetics to keep his arm still as she is aiming at the bull’s eye? Or a soccer player donning high tech shoes that will steer the ball in the exact spot at a kick penalty?

Gallery 1.38 Biometric technologies

A variety of biometric technologies are already being used and will keep evolving with the goal of becoming seamless in their application.

Image credit: Ashley Hudson

Clearly, as technology progress sport competitions will have to rethink their rules…

4. Digital biometrics

How many passwords do you have? How tough is it to remember them? And yet you never need to identify yourself when you meet a friend, even when you meet him again after 10 years!

Connectivity of our body with the

cyberspace will be a given in the next decade and along with it there will be biometric identification, in different forms, to authenticate who we are. We can identify a person through fingerprints, through iris scan, through face characteristics (ratio among different points in the face), through DNA, through blood vessels distribution and shape, through heart beats (examples of physical attributes based biometrics), through gait, through voice, through micro movement during writing (examples of behavioral attribute based biometrics), and more!

The crucial point is that all these requirements need to be satisfied at the same time:

- identification should be certain (no false positive)
- identification should not be denied (no false negative)
- identification should occur only when needed
- identification should be seamless
- identification should be possible anywhere, at any time
- identification should be affordable

Gallery 1.39 Ubiquitous and continuous Monitoring

Soft skin wearable health monitoring system. Credit: University of Tokyo

This remains challenging but it is expected that in the next decade, through multiple biometric identification approaches the problem will be solved once and for all.

Humans 2.0 will be inhabiting a space where they will be identified by the simple fact that they are there. Clearly, this will be most convenient but at the same time privacy issues will come to the stage. Identity information shall remain property of the owner and can only be verified by those who have the right to do so and cannot be shared with third parties.

Seamless biometrics identification may result in a continuous monitoring and localization of a person. This may tremendously increase personal safety and overall security. On the other hand the Big Brother syndrome will be more than justified, hence the absolute need to preserve privacy and trust.

5. Ubiquitous and continual monitoring

From what just said, it follows that it will become possible to have a ubiquitous and continuous monitoring (subject to the privacy caveat expressed). This monitoring can extend from the

identification to many more aspects (and again privacy concerns are at the centerstage). A clear area of application is in the monitoring of health parameter. Ambient, wearable and embedded sensors will be able to keep track of all vital signs and connection to the cyberspace will allow the continuous checking of these parameters by the person's digital twin. Health care will shift from "sickcare" to real "healthcare". Most of the time it will be possible to prevent problems and in those few cases where that will not be possible the red flag will go up immediately and the rescue team will know immediately where to go and what is the problem increasing enormously the probability of successful recovery.

In this area in addition to the privacy concerns there are also "hacking" concerns, malicious attempts to enter the sensory system and the communication it has with the cyberspace.

Because of this, and more generally because of a sense of being "controlled" it is most likely that the adoption will be slow, apart from those persons having a medical problem for whom being continuously monitored will provide a sense of relief.

Gallery 1.40 Optimized diet

Computers, sometimes disguised in a smartphone or tablet shape, are already providing dietary support. In the future it may get better, or worse, depending on your taste. Image credit: 123RF

6. Optimized diet

We already have plenty of "apps" to help in monitoring our food "intake" and advising on what would be best for us and for the kind of activities we are planning. They just represent a starting point for what it might be possible tomorrow.

Do you like nightmares? OK, try this. You go to a restaurant and as you look at the menu, through Augmented Reality you'll see both the restaurant proposals as well as the number of calories associated to that dish, along the number of calories you still have available for the day. If we are really looking into the future, let's say second half of this century, the restaurant menu will connect to your taste buds and olfactive

cells to make your brain have a virtual taste at what is available (talking about subliminal advertisement!).

Once you choose and you get the actual dish in front of you Augmented Reality will kick in again showing the full amount of calories in the plate (using sensors to identify what's in the plate and evaluating the calories) and as you get a spoonful you'll see in AR the available calories for the day decreasing…

As I said, it is a nightmarish perspective but it gives you the idea of what may lay ahead.

Knowing your genome and your metabolome, foreseeing your coming activities your Digital Twin will advise on the optimal diet. Let's hope it is not going to disclose to your wife what you are actually eating, nor to your insurance company…

Of course one can push this to the extreme having pills rather than food to meet your eating needs. Personally I would hate this kind of future and I am pretty sure I won't be alone. Hence…. it is unlikely to happen.

Evolution is made possible by technology (and economics) but in the end people are the one choosing what they want. I bet most people will not go for this kind of future.

Gallery 1.41 The Human Metabolome

The Human Metabolome Database (HMDB) is a freely available electronic database containing detailed information about small molecule metabolites found in the human body.

Credit: http://www.hmdb.ca

What is more likely to happen is that we will have the choice of using much better, customized, dietary advice and it will be up to the single individual to look for them and go along with them. In specific situations (some chronic pathology, food allergies, athlete in training,…) these supports will be used extensively, in other they will not.

There are other ways, however, to look at the optimal diet in the future:

• complementing whatever diet you take (that is not actually a diet at all), with some customized drug that will simply stop the

assimilation of those substances that are not fitting your profile and need;

- having the cooking process managed by some smart robots that knowing your dietary need will make sure that the outcome of its cooking fits your diet by removing or blocking some substances without affecting the look, the smell and the taste;
- tricking your brain into believing that you are eating what you chose whilst in reality you are getting something else, in line with the optimal diet;
- tricking your brain in perceiving you already ate so you no longer feel the urge to eat some more;
- changing your brain so that it is actually longing to get exactly the food that is required by the optimal diet.

I guess that a mix of those options will find a way to the market. Actually, there might be a further way:

- food might be customized at the origin to be healthy for a particular person, hence to fit his optimal dietary needs. Artificial meat, as an example, is on the way to the market and we can be sure of that since it is no longer a claim from some research lab, it has become an issue for the traditional meat producers. In the US, the Agricultural professional groups including the American Sheep Industry Association, National Cattlemen's Beef Association, National Chicken Council, National Pork Producers Council and the National Turkey Federation are lobbying President Trump to ensure fair competition (reading between the lines: to outlaw artificial meat). When the market feels the heat of a new technology it means that technology is real!

Gallery 1.42 Enhanced strength

A military exoskeleton relieving from fatigue and seamlessly connecting the soldier with his team. Credit: Raytheon XOS 2

7. Enhanced strength

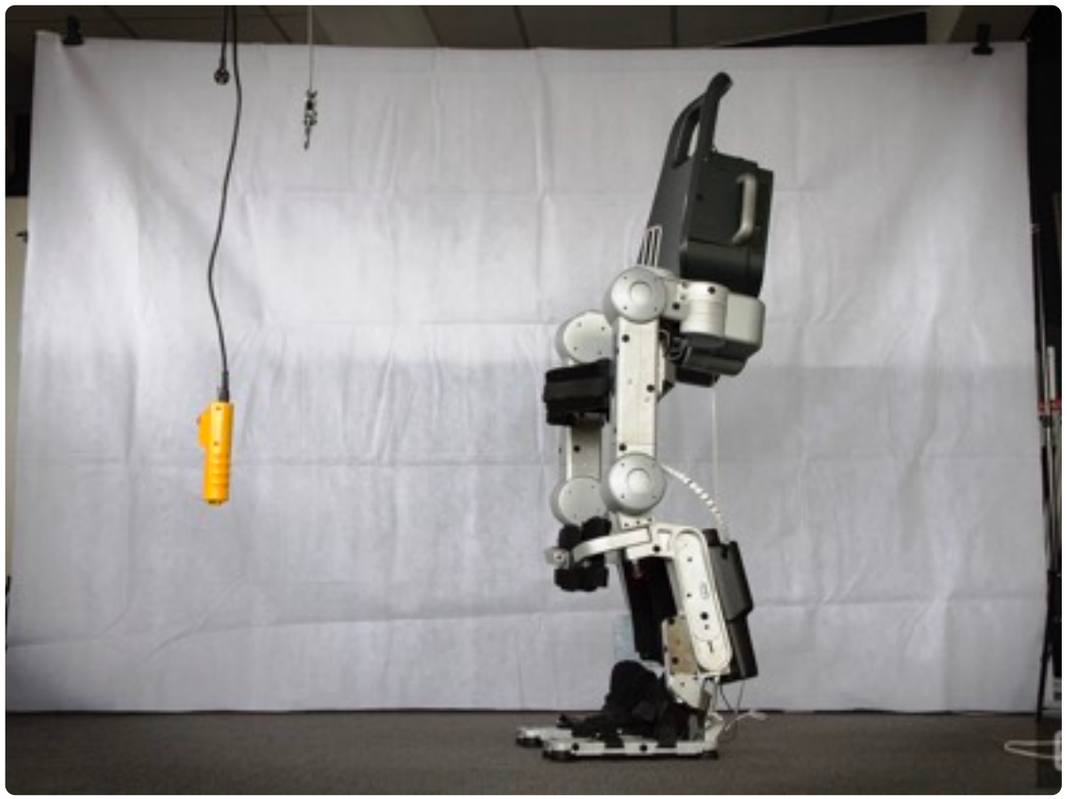
We have learnt to enhance our strength centuries, millennia, ago first with the lever then harvesting hydraulic and then steam power. Today we have a tremendous array of machines that multiply our strength. Our body strength has also improved since our ancestors, we have grown taller (10 cm in average in the last 150 years) and the muscular mass has increased. It looks like, however, that this increase has leveled out and there are good physical and physiological reasons why we cannot get bigger and stronger.

Much more recently researchers have started to create exoskeletons, wearable machines that can diminish fatigue and multiply our strength. Whilst diminishing fatigue (including flanking no longer usable muscles as it is the case for exoskeletons for paralytic patients) is already being done, with an increasing level of effectiveness, the multiplication of strength carries problems that are of difficult solution in a general context whilst they already work well in limited context. The difficulty derives from the risk of hurting the person wearing the exoskeleton: imagine having to interact with a bulldozer not from the cockpit but from the moving blade and lift cylinder!

Military and health care are the two sectors steering the evolution.

We have drugs that can enhance our strength and decrease the sense of fatigue and a few people are using them. This goes along with dangerous side effects that makes this approach quite risky. Besides, the present culture consider artificial improvement of strength a form of cheating (doping).

Gallery 1.43 Exoskeletons



Wandercraft exoskeleton "Atalante".

Image credit: AOL/Steve Dent

In the future we might expect to increase our knowledge on the effect of the genome on the phenotype also in relation to strength, hence there will be the possibility to make changes to the genotype to increase strength at the phenotype level.

It is, however, much more likely that the increase of strength will come from the evolution of exoskeletons. These, in certain applications, might become a seamless extension of our body. We have already taken the first step in this direction. Consider, as an example, skiing equipment. The boots can be designed on our foot shape, using 3d laser scan and 3d printing and can be made with smart material to absorb vibration and become more responsive.

Donning an exoskeleton at work might become as normal as using a screwdriver… BCI will also improve the capability of controlling robots to the point of having them becoming a seamless extension of our body and effectively multiplying our capabilities.

This will be another component in the evolution towards humans 2.0, towards transhumans.

8 Life without disease

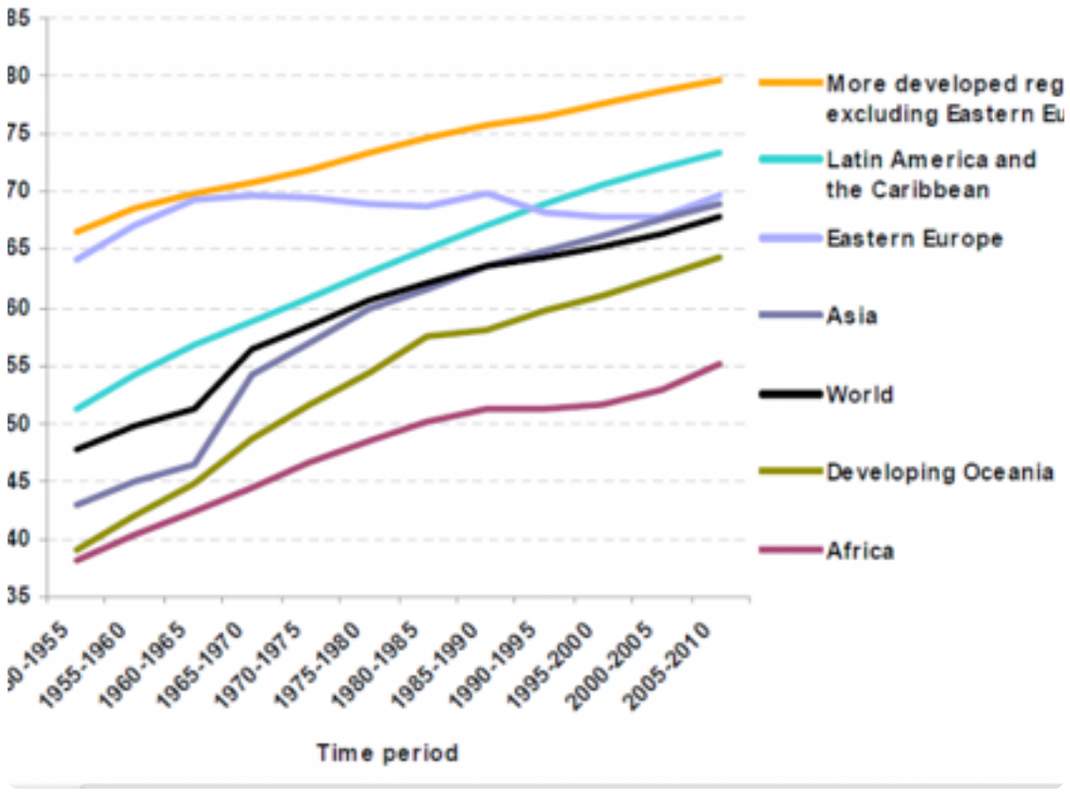
In the last century health care made incredible progresses. Purified water and better food take the lion share in this progress, although they are often underestimated. Drugs, surgery (enabled by anesthesia), antibiotics and more recently anti-immune therapy have fought diseases that were killing millions of people.

On the horizon we have the hope to cure genetic diseases, as our understanding of the genome grows and technology for modifying the genome (both in vitro IVF and in grown up person) becomes available.

However, in the coming decades we can expect two major revolutions:

- quicker understanding of what is going on, both at a community and at a personal level
- shift from curing to keeping healthy.

Gallery 1.44 Life without disease



Life expectancy in various world regions. As shown in the graph, life expectancy has improved everywhere, mostly thanks to purified water and better food in developing Countries. Image credit: Healthy Planet

The first revolution leverage on big data as they are becoming more and more available from health care records and from a variety of sensors. We already know that this is a mine of enormous wealth that can bring significant benefit at personal and societal level. First signs of epidemics can be detected and appropriate action to contain the spread can be taken (cell phone tracking helped to foresee the potential spread of the latest Ebola infection). More than that. Knowing the presence of an infectious agent in a community raises the attention of care givers

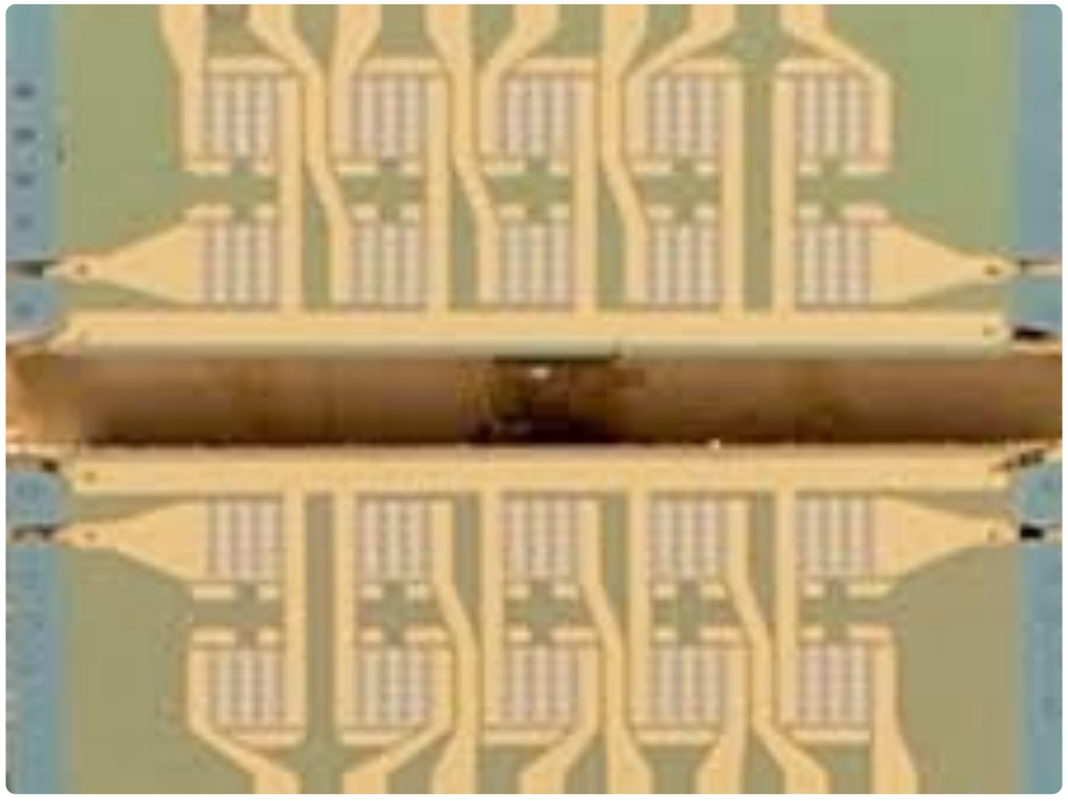
to that particular pathogen and symptoms can be evaluated in that context leading to more appropriate actions. Even more: by monitoring the effect of the cure/containment it is possible to improve it making it more effective.

Correlating data of thousands/ millions of people allows the detection of niches (thinly dispersed) having specific characteristics like being more susceptible to a specific drug and this allows for a much better cure. The generalized sequencing of the genome in the coming decades will provide huge amount of data increasing the possibility of understanding patterns of disease spread and cure effectiveness.

The technology is basically here (although it will improve in the coming years), the real hurdle is privacy, the concern that these data might be mis-used.

The second revolution will be fueled and made possible by quasi real time monitoring of our bodies, the understanding of the genome and the possibility to act immediately. In a way it will be the shift from “sick-care” to a real “health-care” where the goal is to remain in good health. This is what can make life without disease possible (at least a goal).

Gallery 1.45 Future proactive healthcare



A wirelessly controlled microchip, implanted under the skin, can safely and reliably give osteoporosis patients the daily dose of a drug that they need. Credit: MicroCHIPS, Inc., Massachusetts

Wearable, ambient and contact/ embedded sensors (in this order) will be providing a continuous monitoring of our body physiological parameter and these will be matched, in our digital twin, with the expected ones (taking into account the situation, the kind of activity we are engaged, the mood and of course our genome). Any deviation will trigger an analyses to determine the probable cause and further testing may be activated (through already existing sensors or through specific procedures). Corrective actions, including the assumption of drugs (monitored from remote), can be taken immediately, often using the drugs that we will be carrying along in our body in a chip, ready

to be released, in case of some chronic situation or via a robot dispenser bringing us the drugs!

Will a life without disease become a reality? I doubt, but for sure our capabilities to foresee and act will be increasing tremendously in the next decades.

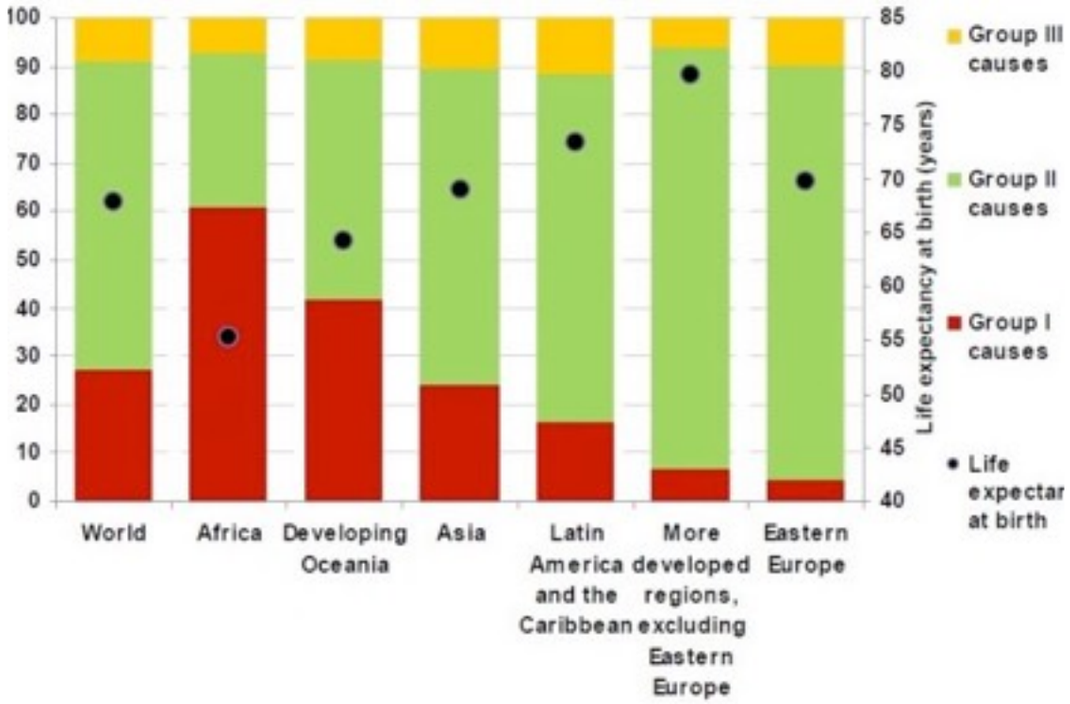
9 Extending human life

If a life without disease and health care can promise a sort of "live forever young" the extension of human life is a different story, although it is obvious that if we were able to avoid diseases that are eventually resulting in death, we would be one step forward in the direction of extending human life, but that is only the life that is cut short by a disease.

The maximum life span for humans is still a matter of controversy. Some studies claim that humans maximum life span is around 115 years (although a few exceptions have been recorded, like Jeanne Calment who died in France in 1997 at the age of 122). Others claim that there is no pre-coded maximum life span.

It is evident that today no one (that we know of) has been living up to 150 years, however all those that have been living, and died so far, lived a life that was subjected to today's (or yesterday's) conditions. One could say that if we were to change those living conditions, e.g. by proactively avoiding issues, persons might live longer.

Gallery 1.46 Extending human life



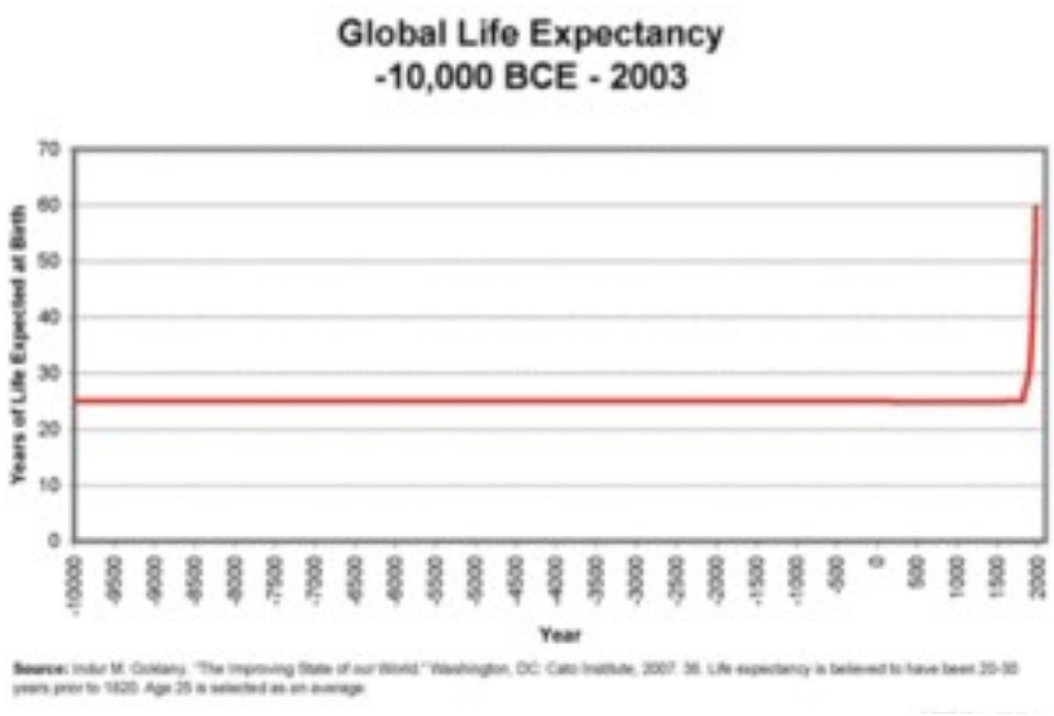
The cause of death in several geographical areas. In red the cause of death is a transmissible disease (transmissible both human to human or other to human, like non purified water containing bacteria). In green the cause of death is a disease that has been acquired by the person, as diabetes, high blood pressure, hearth attack, stroke, cancer. In yellow death as consequence of external causes (car crash, falling from a mountain…). Image credit: Healthy Planet

Looking at the genome of animals researchers have observed that during cell replication the terminal parts of the DNA strings forming each chromosome (the telomeres) gets shorter and have postulated that this shortening would eventually hamper further replication, hence putting a boundary to the life span. To confirm this, experiments have been carried out to stitch extra DNA on the terminal parts of the telomeres, thus lengthening them again as well as to artificially

shorten telomeres in mice. So far (but significant more research is needed) it seems that telomeres play an important role in senescence and that tweaking with them may result in deferred senescence. Drugs (senotherapeutics) are also being tested on mice and seems to have some effect. As always happens there are also many "quacks" on the internet riding the wave of telomeres and promising the eternal youth. We are very far from that.

Still, these studies show that looking for a cause of senescence, and then overriding it, is within the realm of science and it might become possible in the next decades.

Gallery 1.47 Life expectancy trends



Global life expectancy in the last 12,000 years. Notice how stable it has remained till three centuries ago when it increased sharply.

Credit: Cato Institute "The improving state of our world"

Retarding the senescence process, and all the chronic ailments that come with that, is surely beneficial to the individual and to the community (just think about the huge medical expenses that are sustained in the last part of our lives). However, prolonging the average life span is affecting the Society as a whole in many ways.

It is quite obvious that anyone of us if asked: "Would you like to live longer" would say "yes!", even more so if the lengthening of life would be associated to a good life, with no ailment, particularly those associated to the old age. The strive to have a better health in the elderly age is obviously also increasing the desire to live longer.

The average increase of life span has already affected the economic burden on pension funds, leading many Countries to postpone the retirement thresholds. In a society that is seeing the number of jobs shrinking this creates huge employment problems.

Considering the significant amount of resources, and people, today involved in elderly care, the perspective of a world with a growing elderly population that will occupy available jobs compound with the decrease in need for jobs looking at elderly is something to be taken into account!

Some are already looking at the effect of a population living to be 110 (that is close to current maximum life span) and are seeing that the working life would have to expand into the 80ies and 90ies. Considering a youth period of 25 years, dedicated to basic learning (up to college and university) that leave some 65-70 years of work versus the 40 years (on average) we have today. That means over 50% more jobs would be required.

Some are saying that society, and culture, will need to adapt to these changing condition, may be having people to work for 20 years in a row and then stepping out from the work for a 5 years sabbatical to be retrained to a changing world…

However, this is just considering a very limited extension of life. If you were to push the average life span to 150, 200, a completely different society would be needed. It may also be the case that once science and technology will find the youth spring that will be reserved for a lucky few, and the unlucky ones are likely to go on fight causing a shortening of the life span through wars….

Gallery 1.48 Enhanced Intelligence and Digital Hardware Enhancement

Various aspects of intelligence. Credit: Frames of Mind. The theory of multiple intelligences, Howard Gardner. Image credit: Adioma

One way or another a Society where life span would exceed on average what is today considered as the maximum human life span will be significantly different from today's Society, it will be a transhuman Society.

10. Enhanced Intelligence and digital hardware enhancement

We are the expression of our genes. However, this expression is influenced by a variety of environmental factors. Take the ability to play piano. Yes there are some people that are more inclined to music (musical ear we say) but it is unlikely that a person can play piano without studying it and practicing a lot.

This applies to intelligence as well. Researchers agree that there

are a number of genes that steer a person IQ (not just one but several of them, close to 100 probably, whose interplay has not been understood so far) and they also agree that the manifestation of intelligence is strongly affected by environmental factors, including education.

How much is related to the genes and how much to the environment is subject of debate. From a 5% influence of the genome up to a 50% influence of the genome, depending on whom you are asking, and in most cases to what type of intelligence one is referring to.

Math prowess is probably influenced more by genes than social intelligence where social factor and the environment play a much stronger role.

Hence, when discussing the future possibility of increasing

Gallery 1.49 Collective Intelligence

Collective intelligence is present in several species. In Humans, thanks to more sophisticated communication tools -language-, collective intelligence is playing a major role in Society and progress.

Image credit: Rose experience

human intelligence only a few point to genomic variations as the way to improve human intelligence. It seems more feasible, and effective, to create a seamless symbioses among people and the environment so that one can benefit from the other (this is the reason I clustered the topic of enhanced intelligence with digital hardware enhancement).

As social animal with sophisticated ability to communicate and learn from each others humans have a collective intelligence that significantly augment the intelligence of the single person, to the point that we are no longer able to live by ourselves, we rely on other people knowledge that is de facto embedded in the society and in the society organization. You probably don't know how to build a fork but you know where to go

to buy one.

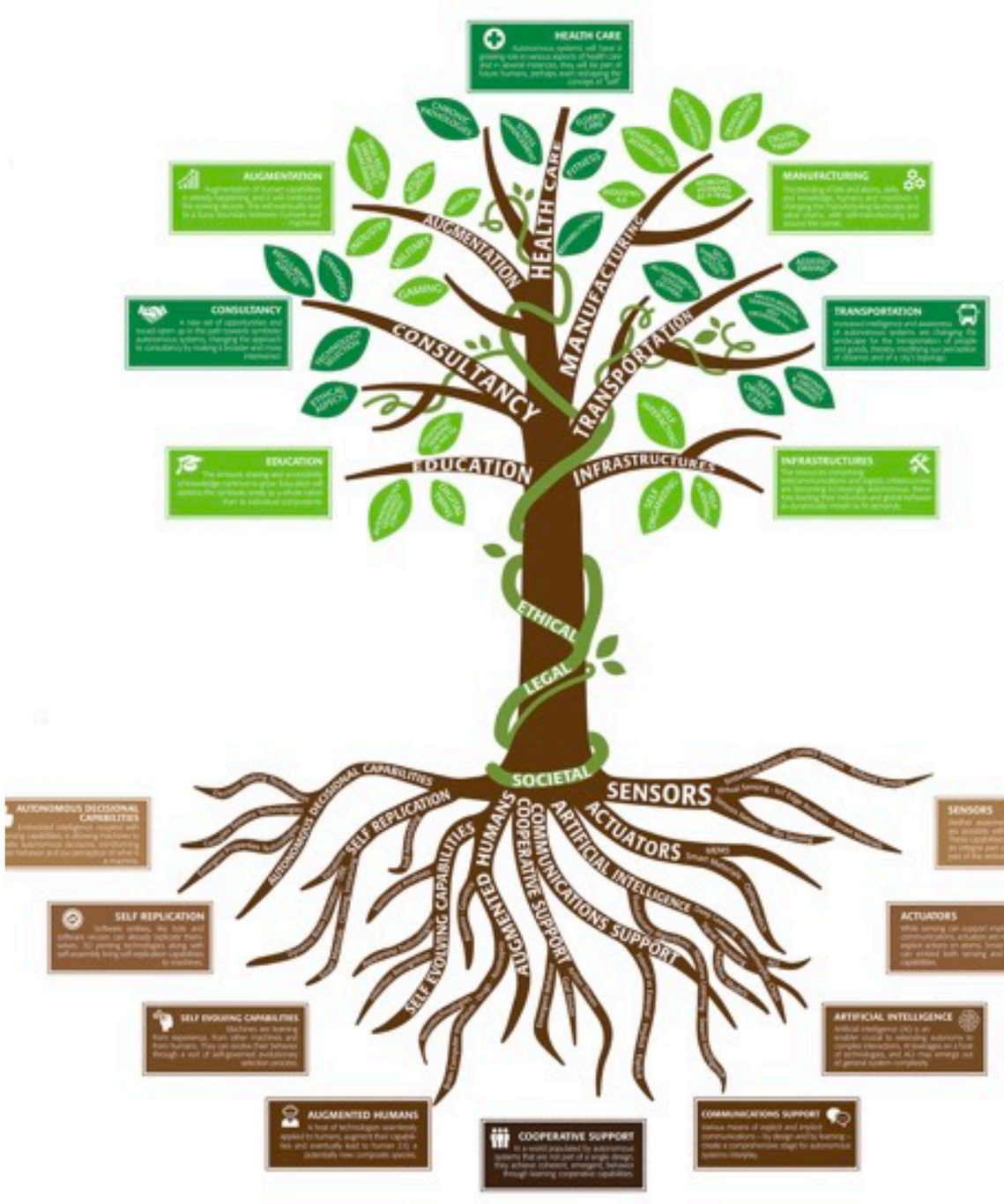
In the future these widespread social knowledge will be permeated by the digital world and by machine. In a way the architecture of intelligence may become similar to the Cloud: you have users, both humans and machines, that whenever have a need for “intelligence” will use their local “intelligence” to leverage on the “intelligence in the Cloud”. The Cloud will consist of digital twins that will be able to inter-relate with one another transferring knowledge as needed and converting that knowledge into a usable one for their real twin.

This is already happening (the very first steps) with smart assistants (AI powered).

One of the facets of transhumanism will likely be the reliance on a society where digital bits and atoms will be fused together from a perceptual point of view. And we are starting to see this happening now. We are leveraging on machines (as we have been used to do from millennia) and for the first time machines are learning to leverage on us, looking on us to learn and sharing intelligence with us.

Among the various aspects of transhumanism this is the one that is likely to happen sooner and that is going to have most impact, this is my bet.

Gallery 1.50 The Symbiotic Autonomous Systems tree



Human Augmentation merges in a symbiotic way with Machine Augmentation giving rise to Transhumanism. Credit: SAS

Evolving Human Thought

In a world, and Society, that is becoming more and more connected we may expect an evolution of what is meant, and was meant, with “thinking”, a characteristics that humans have along with other species but that in humans is so important to influence the behavior of the individual and the community.

Culture, in the sense of the shared capability to operate as a whole in a certain way has been evolving because of the flexibility of “thinking” paired with the capability of passing on “our” culture to future generations that in turns will transform it. In this the language and the invention of writing have been crucial. Internet is further boosting the individual access to “culture” and the possibility to influence/contribute to culture and to its evolution as never before.

It would be wrong to believe that human progress and artifacts are the sole result of human thinking capability.

Gallery 1.51 Intelligence as result of natural selection

In the past much of human culture and thinking evolved through natural selection. What worked was kept and carried out to future generation, what didn’t was discarded. That was the case for the development of Polynesian boat building skill. Image credit: metavuvale.com

Polynesian boats that managed to cross large parts of the Pacific ocean were not designed by engineers, Polynesians did not have a sophisticated “science” supporting naval design. The amazing boats they built were the result of a natural selection process coupled with the possibility of learning and passing on the knowledge to future generation.

Those boats that sunk were dismissed as poor design. Those that managed to come back were taken as example of good design. Over the course of generations Polynesians got skilled in boat design and construction and surfed the ocean.

I mention this to point out that there is a strong relation between our culture and Nature, between the way our culture evolves and what we learn from Nature.

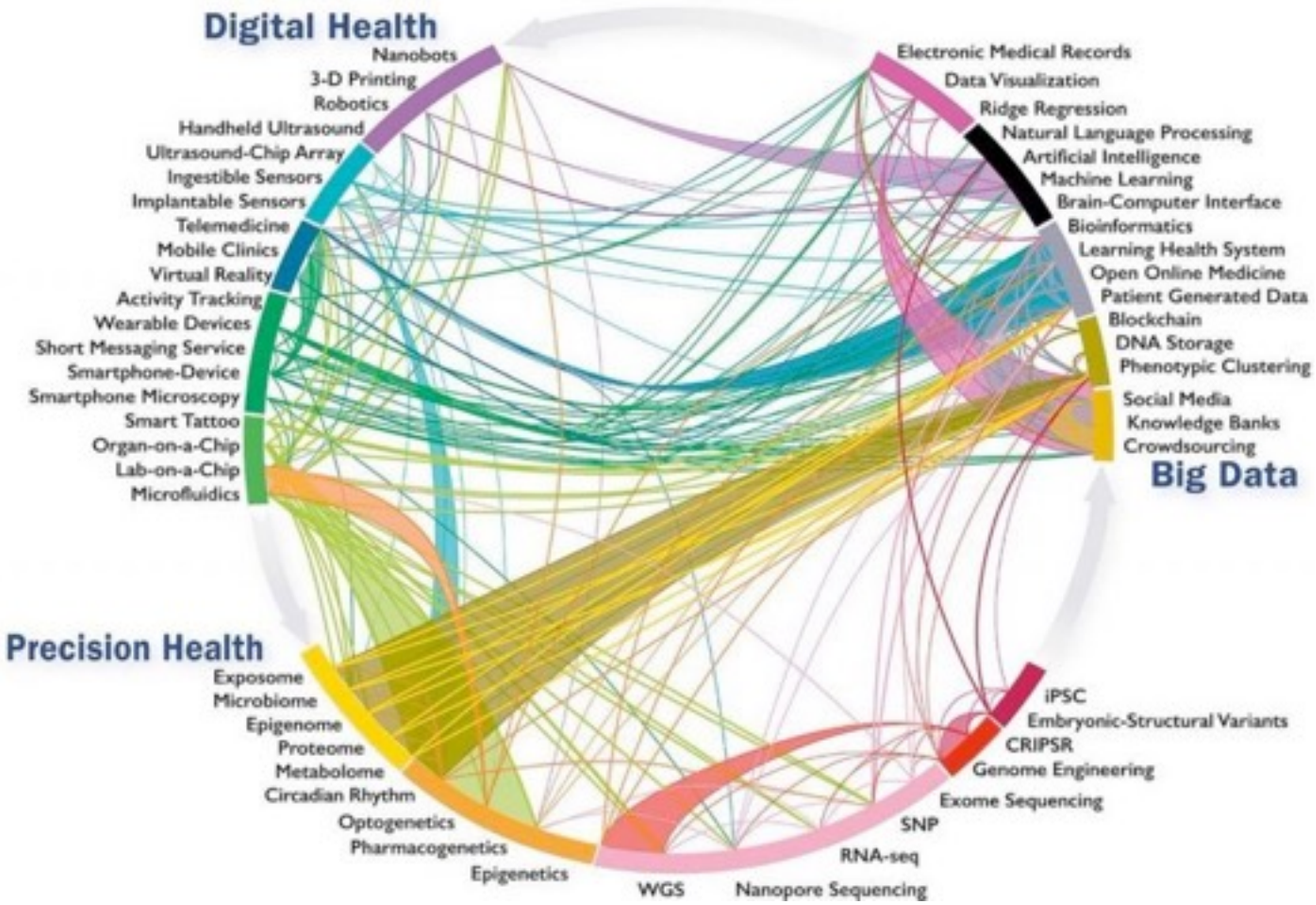
In these last centuries the amazing progress in science and technology has given us a better understanding of how the world "works", including ourselves, and opened new opportunities to leverage on the world resources. In the coming decades a new possibility will become real: the sharing of thinking with machines and in a way a symbiotic "culture" with machines.

An interesting perspective on transhumanism can be derived from this vision of a species that "thinks" leveraging on its artifacts, and that in turns creates a new culture. In the following I will look into the enabling technologies steering towards this evolution.

The increase of thinking capabilities can be pursued by:

1. "engineering" a better "brain" (pretty though, since we do not know yet how it works nor how the genome is shaping it …)
2. Improving processing capabilities through focused stimulation
3. better exploiting its capabilities, including establishing better connection with it, feeding more pertinent data and getting the output from its processing faster
4. using it as a co-processor flanking external processors and calling "thinking" the symbiotic processing (although processing does not mean exactly the same thing in a brain and in a computer)
5. providing more resilience to the thinking activity (including more focus)

Gallery 1.52 Information boosting Intelligence



An interesting mapping showing the inter-relations of Big Data with Digital Health and Precision Health (personalized monitoring and cure). Brain Machine Interface technology connects to implantable sensors, optogenetics, VR, Lab-on-a-Chip, and clusters with Natural Language Processing, Artificial Intelligence and Machine Learning. Image Credit: 2017 Roadmap for Innovation. ACC Health Policy Statement on Healthcare Transformation in the Era of Digital Health, Big Data, and Precision Health

1. Engineering a better brain

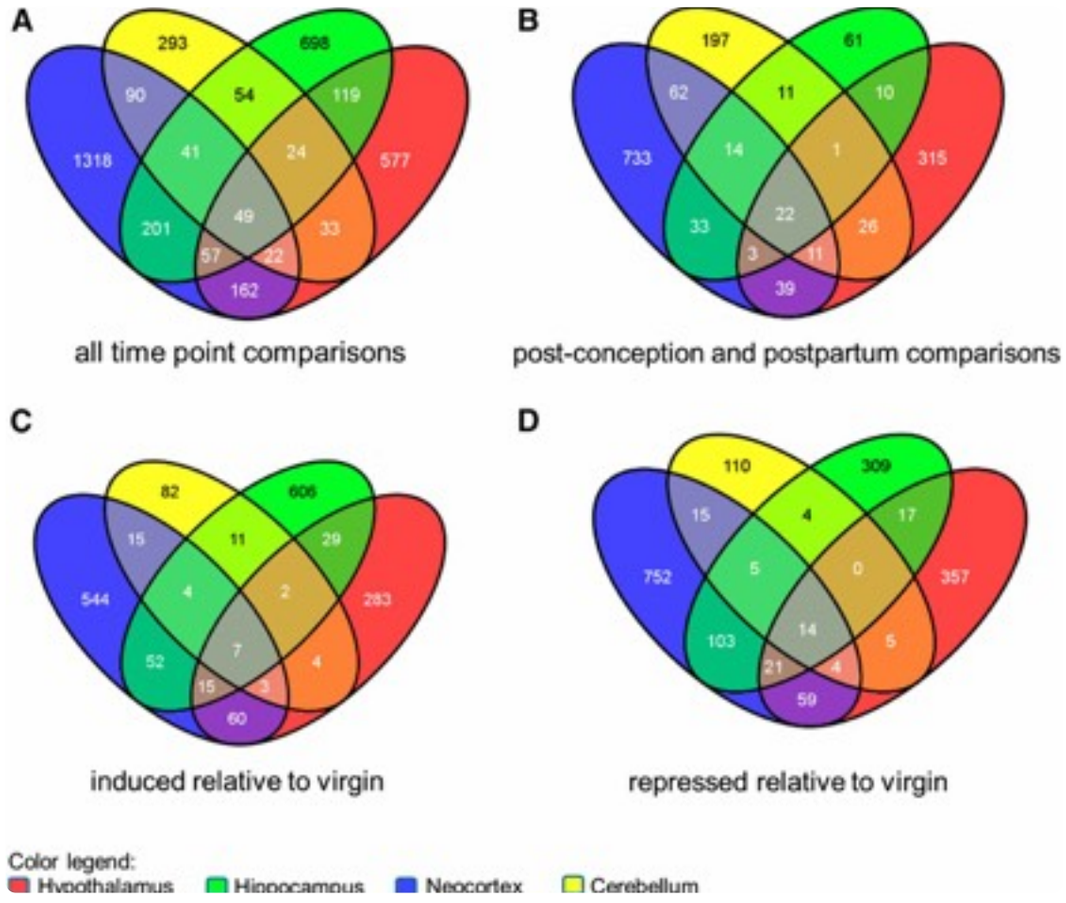
Our brains, as those of all animal life, have evolved through natural selection to make their "host" more effective in the life game. They have not been "designed". David Linden, professor of Neuroscience at John Hopkins University said:

> *"no engineer ever would have designed it like this".*

On the other hand one could easily claim that no engineer, today and for the foreseeable future, would be able to design a brain as good as our (meaning with the thinking, emotional, size and energy requirements of our brain, or even a fly's brain…).

However, the fact that there is no design at the core of our brain makes any attempt to improve its design an almost impossible task. You cannot say: "take a few neuronal circuits and re-wire them to increase the brain performance". Likewise, we are getting close to understand that some brain pathologies derive from some faulty wiring (like in depression cases) but we don't know how to re-wire that brain in a proper way (even assuming we get the technology for re-wiring the brain).

Gallery 1.53 Genes shaping the brain



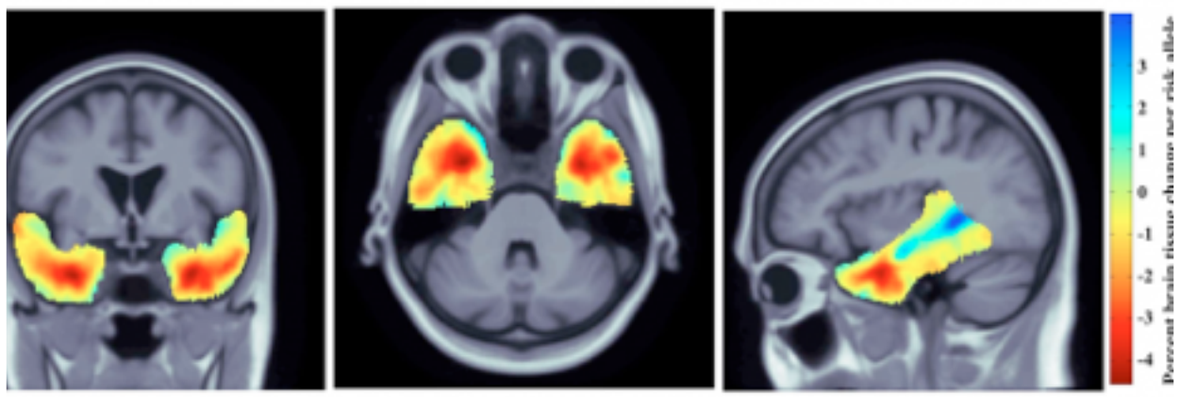
Brain regions have distinct and overlapping sets of differentially expressed genes. Venn diagrams illustrating the overlap of differentially expressed genes across the cerebellum (yellow), hippocampus (green), hypothalamus (red), and neocortex (blue) data sets. Credit: Surjyendu Ray et al, Department of Biomedical Sciences, Florida State University

In addition, consider that the growing understanding of the genome is just making the idea of tinkering with the genome to improve the brain ever more daunting. Our genome contains some 20,000 genes (not as many as scientists assumed just a decade ago but still a big number) and it is now understood that about one third of them, close to 7,000, have their saying in how our brain develops and "works". Notice that in most cases the development of the brain and its operation is related to the interworking of these genes and their expression (so there is also a time relationship). This is clearly making the idea of designing a better brain by modifying the

genome an impossible dream (at least for the foreseeable future).

A different matter would be to recognize some mutation in the genome associated to a specific disorder and attempting to fix it by modifying the genome. That would be much easier and it is almost within out technology capability. In this case what is needed is to compare a genome resulting in a brain without that specific disorder with a genome of persons having that disorder. If, by pure luck, it turns out that only a few genes are involved one might hope that restoring them would get rid of the disorder. Beware, however, that the situation is not that linear. There may be more genes that have mutated in parallel with those that result in a brain disorder but that all together lead to a living person. The risk is that by fixing "only" the genes involved in the disorder one would alter the equilibrium, hampering life.

Gallery 1.54 Genes mutation affecting the brain



MRI scans show brain tissue loss in carriers of the TREM2 Alzheimer's risk gene mutation at 24 months. The colored areas are the temporal lobes, and the red area is the front of the hippocampus, the area that typically degenerates the earliest if people have Alzheimer's disease. Areas colored red lose tissue fastest at about 3 percent per year.

Credit: Paul M. Thompson, University of Southern California

There is also a further way: on planet Earth there are 7 billion humans that have evolved in slightly different ways to better adapt to local conditions, like Tibetan being more apt to live in an atmosphere having less oxygen. NASA scientists are looking at these diversities with the goal of identifying specific genes that are providing better adaptation to conditions that astronauts will have to face in long space travel, like going to Mars. They have already identified genes that provide better resistance to radiation, other that increase memory… And, they have also started to wonder if by manipulating the genome to create the "perfect" astronaut they are creating a new species…

This is clearly an area that we can only hope to address with the help of computer processing power, to analyze the big data resulting from the genome and gene expression and through deep learning (artificial intelligence) to understand both what it means and more importantly what a modification would imply (basically understand how a genotype modification impact the phenotype). The graphics accompanying this post makes visually clear the many relations existing in this area.

The idea of creating transhumans by designing their brain both from scratch and by modifying existing genome seems too far fetched at least for this century. However, there are other approaches to improve our thinking capabilities that seem more feasible.

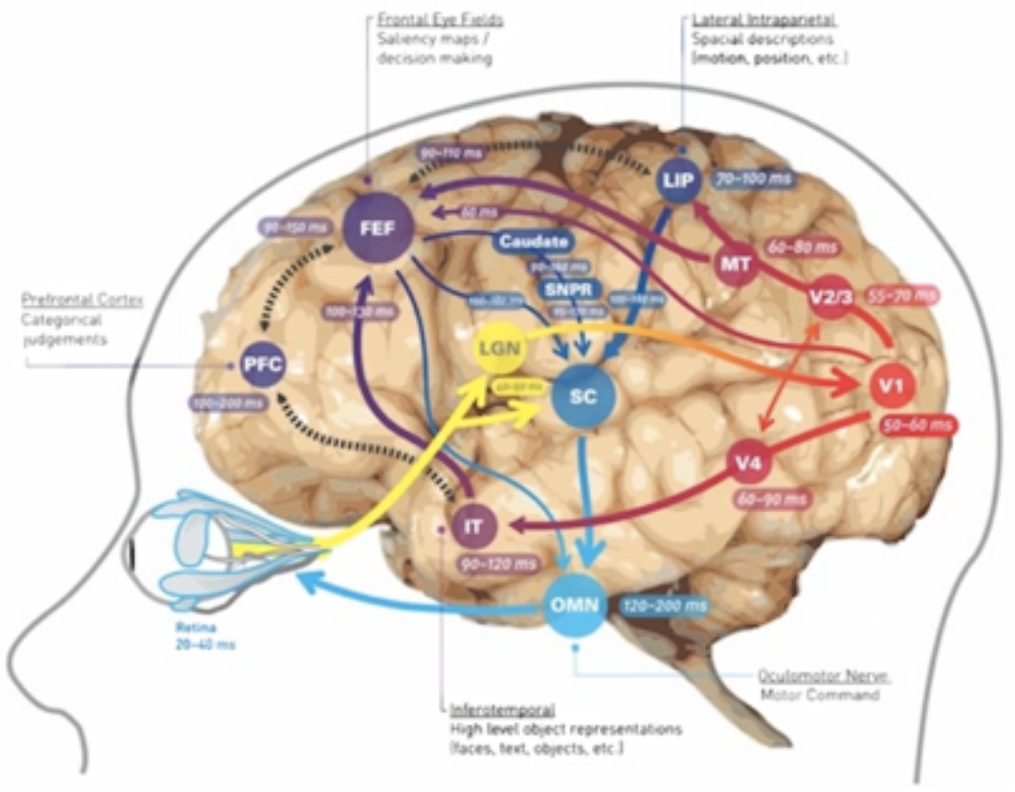
2. Improving processing capabilities through focused stimulation

Our brain, as any brain, is a processing and storage device with no clear separation between the two functions. In this sense it is quite different from a computer. Unlike a computer it does not have a "bus" rather a mesh of connections that are also processing signals as they are carrying them and "remember" the communications that took place to the point of influencing future communications, another difference with computers where the communication bus is just a … communication bus. Synapses have been found to be processing points, there are a 100 trillion of them and they are on the communications links (dendrites).

Furthermore, the whole brain operation is conditioned by chemicals, like dopamine, serotonin and many more, percolating in the brain that are also the result of its activity.

All this complexity tells us that it is quite difficult to find ways for improving a specific brain functionality through a focussed stimulation.

Gallery 1.55 The brain is a massively distributed system



Processing in the brain is massively distributed. This makes any attempt to increase performance of a specific functionality quite tricky given the number of areas and neuronal circuits involved. In the graphic a mapping of the visual function on brain areas involved. Notice that this is a schematics, at a neuronal circuit level the number of areas and connections is greater. Image credit: Cerf

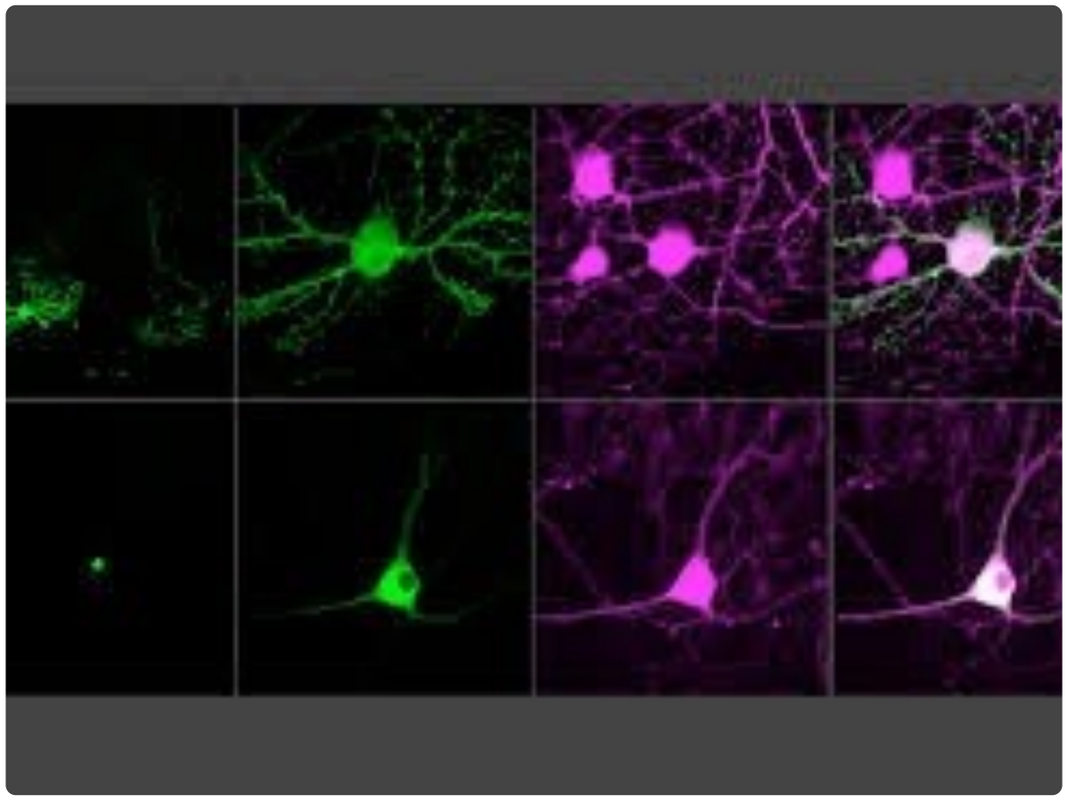
It has been possible to interfere with brain processing by implanting electrodes (Deep Brain Stimulation – DBS), as an example in blocking epileptic attacks, and to decrease symptoms in Parkinson disease. DBS is also being experimented for relieving depression although there is not yet a consensus on the effectiveness of DBS in this area with more recent studies casting doubts on the effectiveness of DBS on depression.

A newer approach is TES, Trans-

cranial Electrical Stimulation, where the idea is to interfere with the brain's electrical activity by placing electrodes on the head. This is clearly providing an even less focussed interference than DBS, however progress in the possibility to finely tune the electrical fields generated by several electrodes on the skull is making possible to generate focussed electromagnetic beams in specific brain areas. Being a non invasive procedure it makes it more acceptable and it makes it easier to experiment with it.

A third approach, much more focussed, is using optogenetics. Here specific neurons can be modified to become sensitive to light and by implanting an optical fibre it becomes possible to activate, de-activate a single neuron. The problem here is that there is not such a thing as a single neuron responsible for a specific activity (which is good since it makes the brain much more resilient!) and it is therefore close to impossible to interfere with the brain processing by interfering with a single neuron. Optogenetics has proved very effective in learning more on the fine processing going on in the brain and it represents a possibility to tackle some brain issues, like blocking pain signals.

Gallery 1.56 Optogenetics



MIT researchers have devised a way to control single neurons using optogenetics. To help achieve this, they developed an opsin, or light-sensitive protein, that can be targeted to neuron cell bodies (bottom row). Neurons in the top row have traditional opsins that are distributed throughout their axons.

Image credit: Ed Boyden et al, MIT, Paris Descartes University

A fourth way is to use chemical substances that interfere with the brain. Caffeine is a well known example -widely used!- that has stimulating capability on the brain, facilitating, to a point, focussed thinking. A growing set of substances are becoming available to stimulate the brain, so called nootropic drugs.

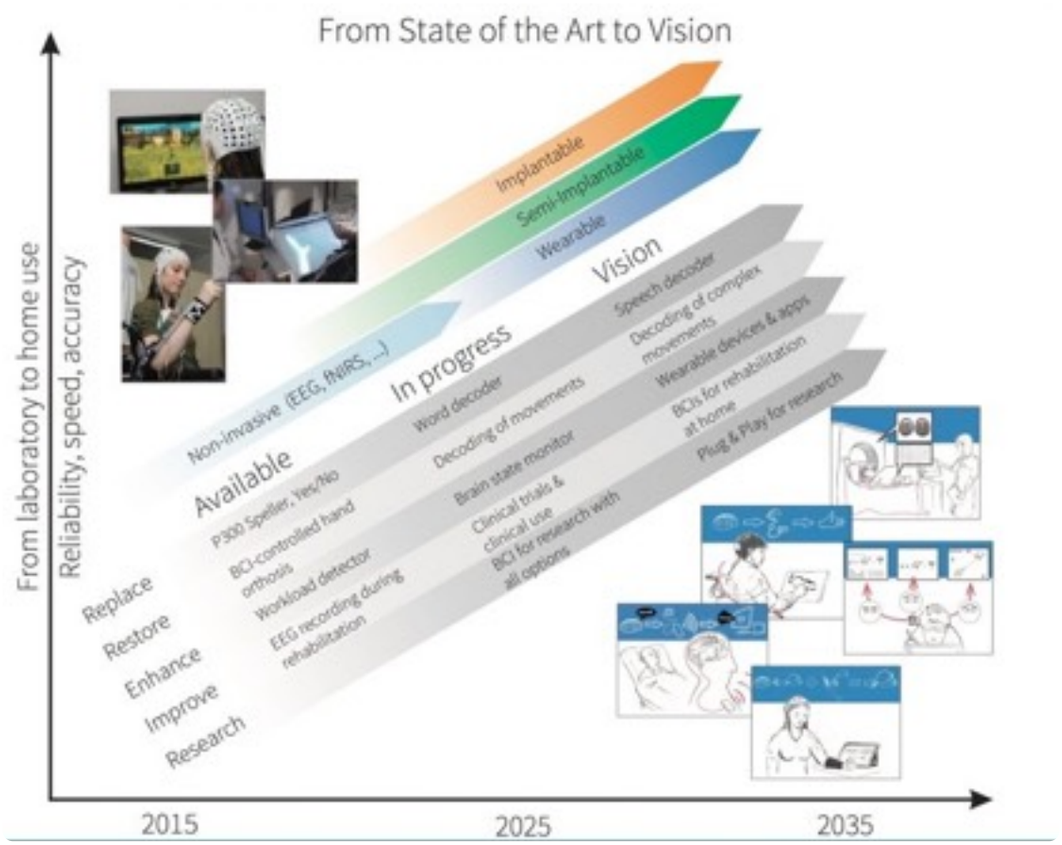
They have a broad effect, since these substances pervade the whole brain (and body) and are more likely to influence the overall processing (and storage effectiveness) of the brain, as it happens with the natural substances produced by the brain (and body glands with neurotropic effect). There is the possibility of finding substances that can have

more specific effect on certain brain functions but this remains to be seen.

A fifth approach that might become available in the future is using nootropic drugs in a focused way, delivering them to a specific area of the brain using an implanted chip as a dispenser. Clearly this would require an invasive procedure but it would reach the goal of limiting the effect of a nootropic substance to a limited area of the brain.

Potentially, a mixture of all these approaches might be used and may lead to a fine control of the brain working. We are not ready for that today, as much more understanding on how the brain works is needed.

Gallery 1.57 Brain Computer Interface



Conceptual Roadmap for BCI as proposed by the European Brain Initiative.

3. Improving communications with the brain

It is now close to 50 years that we have the idea of a Brain Computer Interface that could allow a communications between them. From the idea born in the seventies (as a technical concept to be investigated) huge steps forward have been made, particularly in the direction Brain >>> Computer.

There are now both invasive (implant) and non invasive interfaces that capture the brain electrical activity and detect "intention" (P300 wave), like moving a finger, speaking a letter, moving a pointer on a screen and "clicking" on it. Progress is now accelerating thanks to the increased computational power and the use of artificial intelligence in processing brain signals. Obviously, the prime target application is toward enabling people with severe communications disabilities to reach out to the world, but as non invasive interfaces are becoming available we are starting to see application in gaming environment to the point that some consider BCI as the gaming interfaces of the future. Applications in the military area are also progressing, although we cannot have the latest info for obvious reasons.

One indicator of the growing interest in several areas for BCI is the attention paid to their vulnerability to malicious attack (obviously a crucial aspect in military applications).

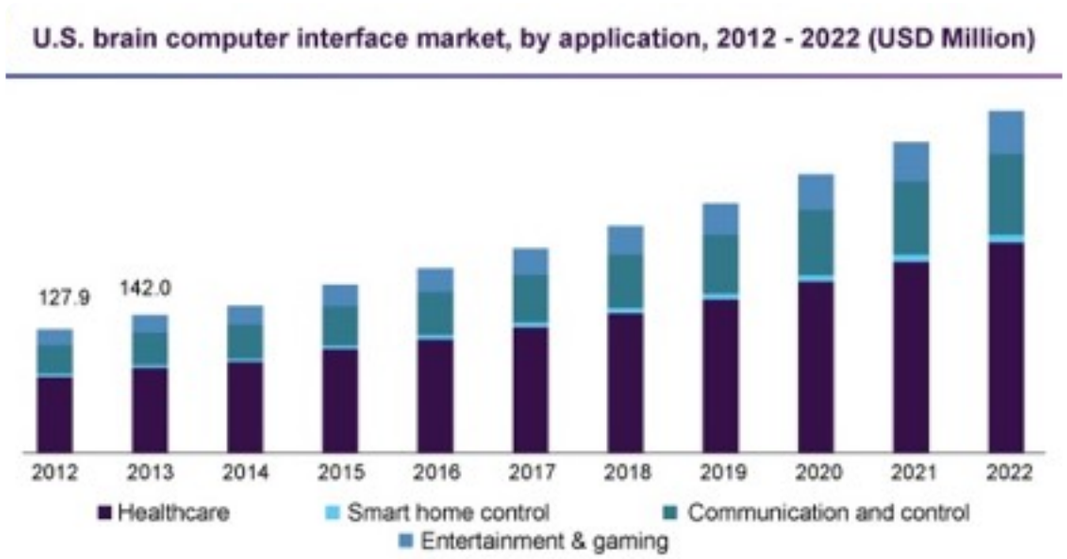
Another indicator is the market size that in the US has reached 806 million $ in 2015 and is expected to double (1.72B$) by 2022.

In the next decade we might expect BCI to pass the thresholds of restoring human capabilities and enter into the augmentation space. This will happen very subtly, e.g. by improving reaction time in gamers (and soldiers), and then by augmenting cognitive capabilities.

This evolution is stymied today by technology (or looking in the opposite way it will be fostered by better technology in the future).

As shown by the Human Brain BCI roadmap (a must read document in you are interested in this area) in the next decade we will have technology that will move from non invasive to wearable interfaces, complemented by semi-implantable and implantable ones.

Gallery 1.58 BCI Market Value



Growth and expected growth of the BCI market in the US.

Credit: Grand View Research

These new technology will support, as an example, the shift from today's P300 speller able to intercept a single letter to word decoding and early in the third decade speech decoding.

BCI will move from helping disabled people to augmenting people cognitive capabilities by connecting the brain to the web knowledge and this will clearly move the human race one step towards transhumanism.

Notice that today we are still seeing a much easier path from the Brain to the Computer, the reverse channel, from the Computer (the Web) to the Brain is much trickier.

However, in many applications the reverse channel can be "mediated" by our senses, like:

• you wonder what would be the square root of π?

• your thought is captured through the BCI by a service in the web whose answer will be returned to your brain via (as an example)

• an electronic contact lens that will display the numbers in an Augmented Reality way directly in your eyes.

4. Using the brain as a co-processor

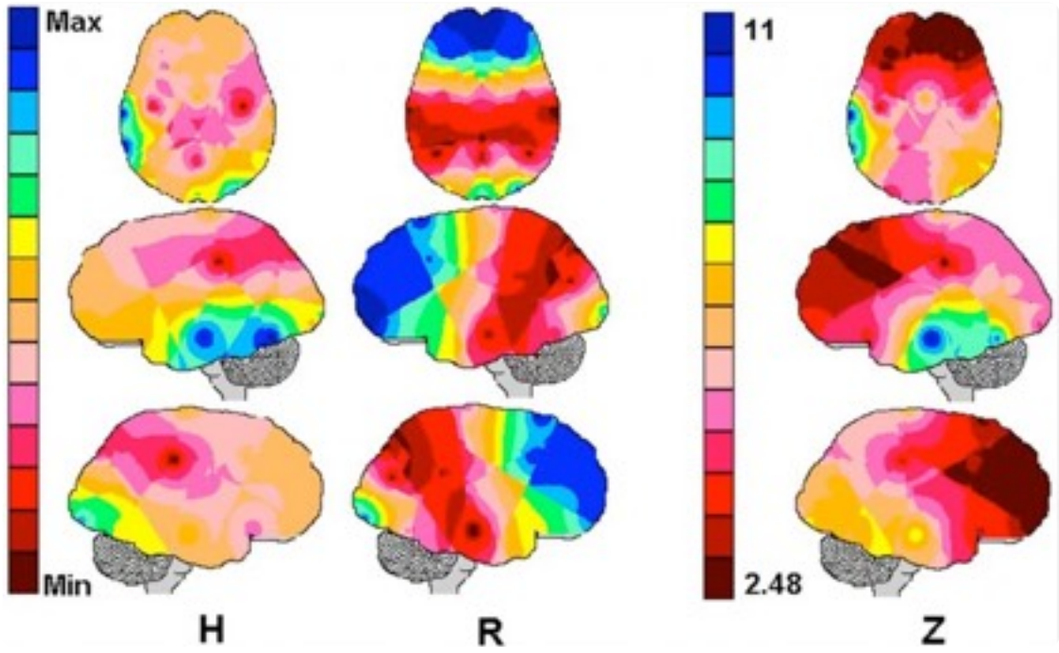
As soon as we started having computers, researchers tried to connect them together to leverage on the possibility of harvesting more processing power. Internet is the result of this idea: connecting computers (with their processing and data) in a seamless web that can be experienced as a single entity.

Actually, the idea of distributed processing took also the other direction! Within a single computer several processing chips, each one with specific processing prowess, can be tied together to perform a computation. Nowadays computers have GPUs along with CPUs, supercomputers have hundreds of thousands of CPUs/GPUs (the latest supercomputer, Summit, has 101,376 IBM processors and 24,576 NVIDIA accelerators) and within a single processing chip there are now many "processing cores" – hundreds of them and growing (Adapteva is proposing an multi-core architecture supporting a billion processing units!).

Our brain is, too, a distributed processing system. At macro level scientists have identified several areas each dominant in the processing of certain signals, like visual signals processing happening in the V1, V2, V3, V4 and MT on the dorsal pathway and in the TE, TEO and LGN in the ventral pathway.

It is actually way more complicated than this. The brain does not work in macro areas with clearly defined interfaces, it works on trillion of synapses affecting each others and being affected by chemical compounds percolating in the brain as result of brain activity and body situation. This makes the brain a much better distributed systems that basically avoids the current downfall of computer distributed systems where the challenge is how to split the computation on

Gallery 1.59 Brain as a co-processor

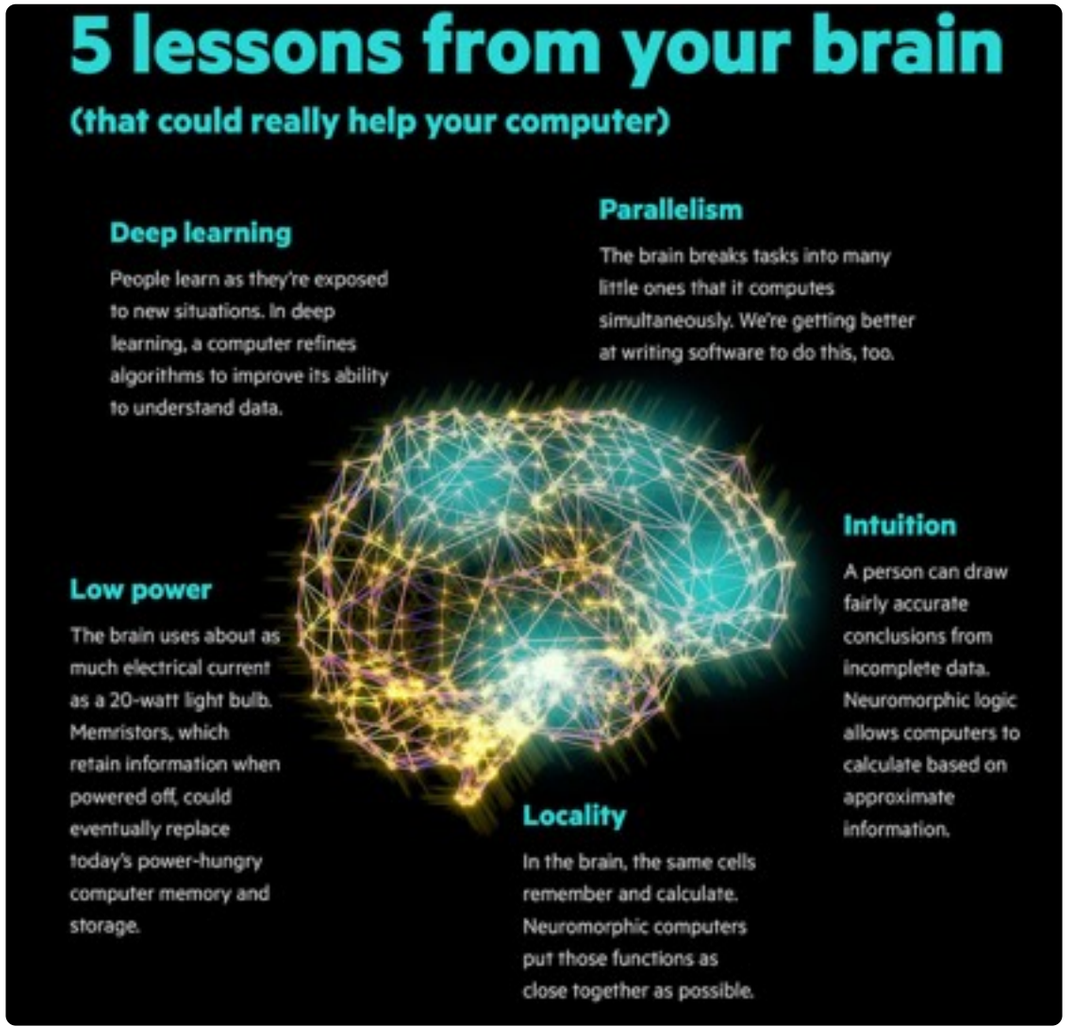


Our brain is a massively distributed system -sort of- processing sensory data and data generated autonomously (thoughts, dreams…). In the image the Hypothetical involvement of different brain zones in some processing activities, in R the actual activities in the brain and in Z the difference. Notice that these are very "gross" approximation of parallel computation engaged in an activity. What if we could defer one or more of these brain computation to an external processing device (an implanted chip, a processing service in the Cloud or in a robot) to increase the overall efficiency? Image credit: The Brain as a Distributed Intelligent Processing System: An EEG Study. Armando Freitas da Rocha Fábio Theoto Rocha Eduardo Massad

different nodes. In the brain everything goes on basically in parallel and the various processes influence one another both spatially (because of the trillions of connections) and temporally (because synapses are affected by what they did before, they have memory of previous computations).

However, from a conceptual point of view one could imagine that part of the brain computation could be enhanced by some form of external processing. In a way we did it already as we got used to process data and using the result to take decisions, fine tuning our understanding and so on. However, so far this has been done through the mediation of our senses (like: we “look” at a printout -video screen- and the eyes bring the result to the brain…). With the evolution of the BCI, discussed in a previous post, we might expect a seamless connectivity between the brain processing and an external processing taking place in an implanted chip, or in a wearable device, in an assistant robot or in the web. Take a look at the clip showing how the use of Artificial Intelligence is now allowing a computer to detect shapes we see in our thoughts by looking at brain’s electrical activity.

Gallery 1.60 Neuromorphic computing



The brain is often compared to a computer but in reality it is radically different. Scientists are still at work to understand how “computation” is performed in a brain and they have already detected several properties that would make computers better. Image credit: HP

Interestingly, one could also imagine a coupling of BCI with CBI, hence connecting one brain with another brain to leverage the knowledge and skills of both. This is what we are doing every day, working in teams, but again the availability of seamless BCI could make this cooperative working happening at a completely different level.

Notice that both in this last case, as in the previous one of involving an external device, what would become possible, differently from today, is an interaction below the thresholds of perception. Today this is not possible, any information we exchange with a computer, through our senses and actions, necessarily flows through

the perception layer (yes we can be absentminded and not take notice of what we are doing, but we are still working at the perception level).

This is a major constrain, since most of brain processing happens below the perception level (including, it seems, some decisional processes). The possibility of engaging additional processing capabilities operating at the “unconscious” level would radically change the thinking processes since it will act on their substrata. It would be a completely new world, fraught with ethical issues (who is responsible of the decision and of the decision effects?).

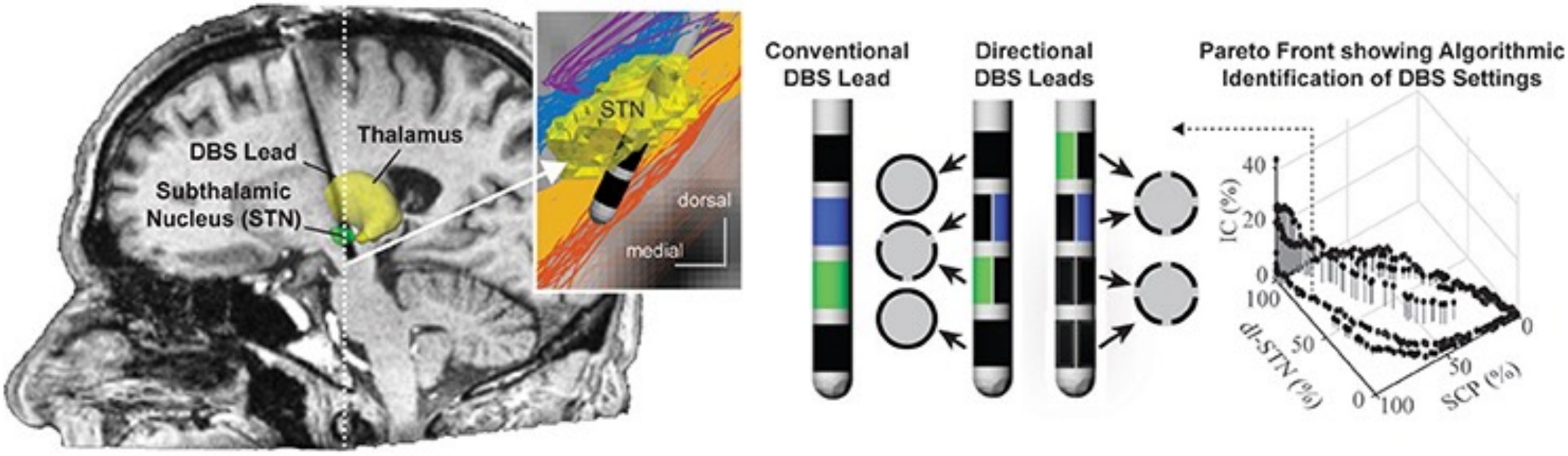
Symbiotic Systems will have this shared “intelligence” and thought forming.

At the same time, it is clear that there is a potential for a tremendous boosting of human’s thinking capabilities that would shift our species into transhumanism.

5- Providing more resilience to the thinking activity (including more focus)

Thinking activity, as any other brain process, is the result of the activation/deactivation of millions, billions neurons and synapses.

Gallery 1.61 Deep brain stimulation



Deep Brain Stimulation is progressing rapidly targeting an increased number of application areas. In the graphic the use of DBS with directional electrodes to restore memory function. Image credit: Fifth Annual Deep Brain Stimulation Think Tank

In turns, these activation/deactivation is influenced by several chemical substances floating in the brain.

Improving thinking activity therefore can be pursued by tinkering with neurons and neuronal circuits and /or by tampering with the chemicals in the brain. This latter is what nootropic substances do, the former is achieved by influencing the neuronal activity i.e. neuromodulation.

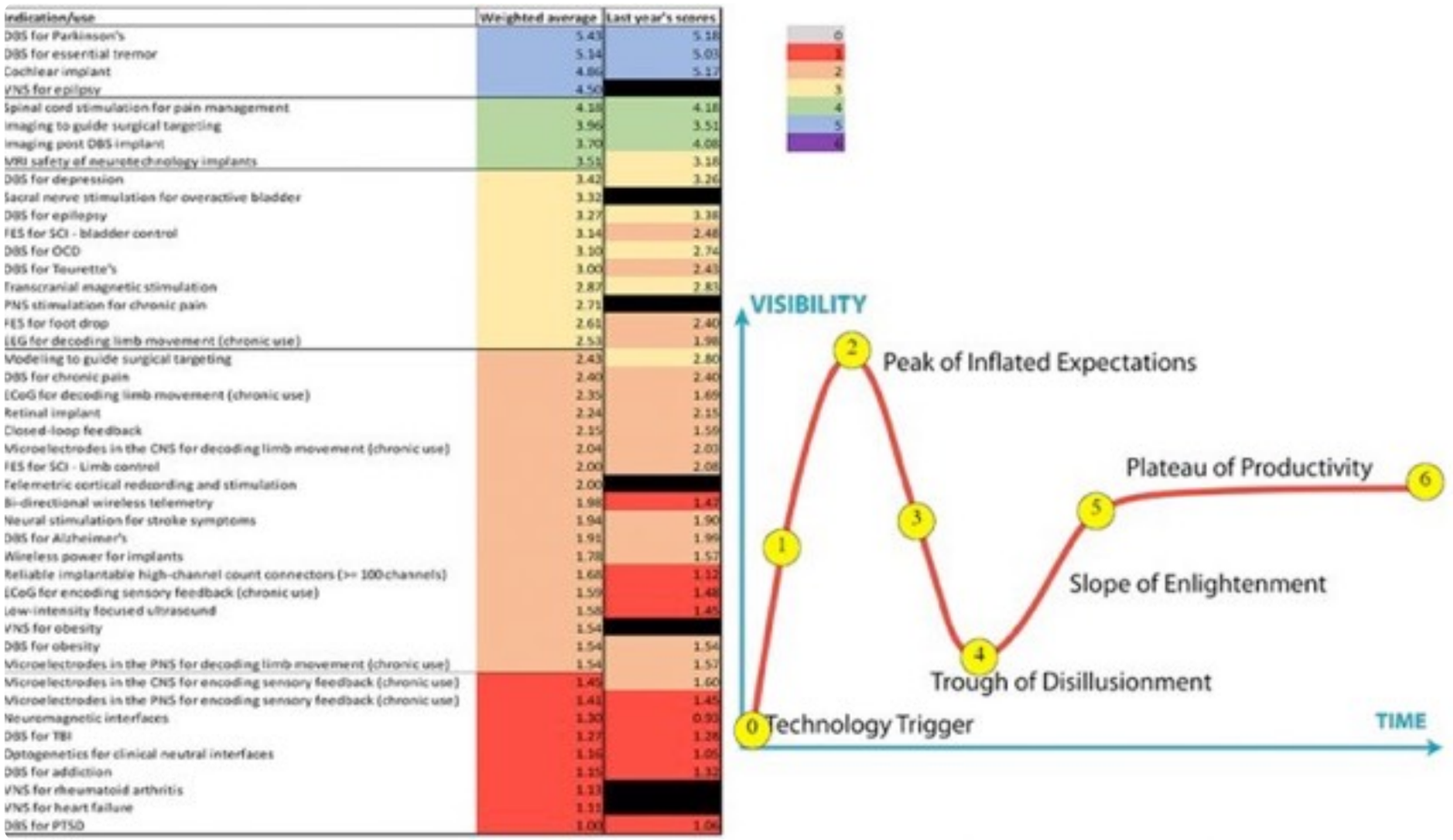
The availability of ever more sophisticated electrodes has progressed the Deep Brain Stimulation (DBS) and the report published by the Think Tank on DBS in January 2018 is quite interesting in its pointing out the growing application areas of DBS.

The electrodes are becoming thinner and can be inserted with decreased risk of damaging the brain. Additionally, each single electrode can host several points of electrical emission and these can be directed in specific direction. The big issue remains the capability to affect specific neuronal circuits, taking into account that:

- our knowledge on which neuronal circuit is involved in a specific function is still quite limited in general and very much so when dealing with thinking functions

- the position of the right neuronal

Gallery 1.62 DBS applications



Status and expectation of DBS application in several areas, from pain control to epilepsy management. Credit: Vth Annual Deep Brain Stimulation Think Tank.

circuit (assuming we can know which is the one we want) changes from person to person and it even changes in the same person as the brain evolve

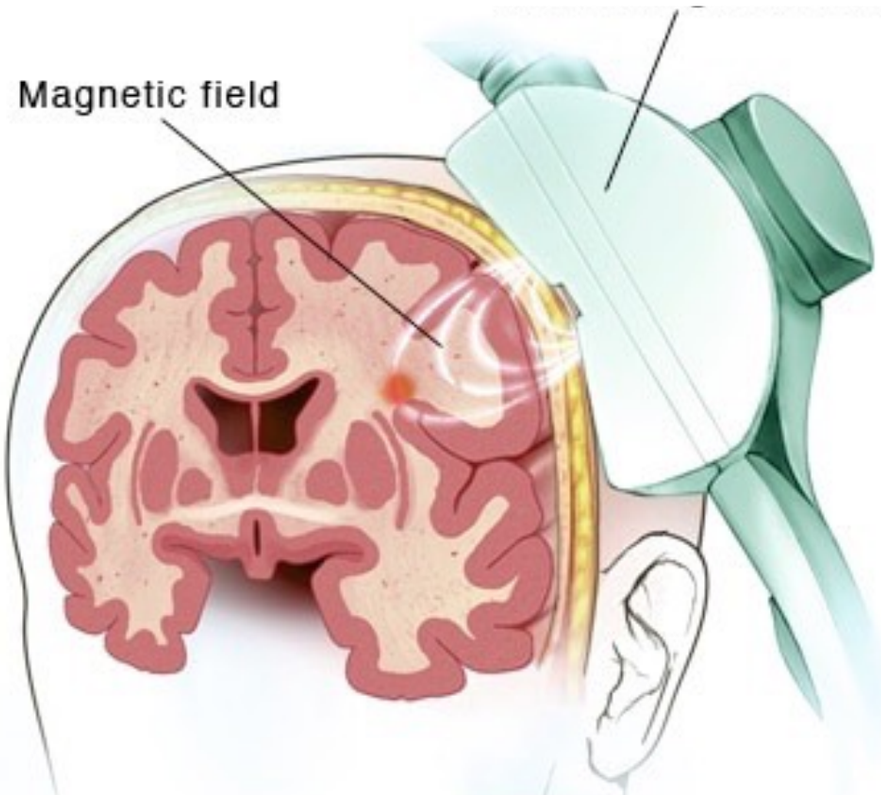
- the existence of several neuronal circuits involved in the thinking function and the likely impossibility to address in an appropriate way each of them

So far, also for its invasive nature, DBS is being considered for curing some disorders (see the table in the figure) and not for improving the thinking capability of a healthy person.

A new approach, based on Trans-cranial Magnetic Stimulation, is now being considered, with focus on relieving depression symptoms. Using a coil placed on the head (no invasive procedure needed) magnetic pulses are focussed on specific areas in the brain. Some studies indicates that the TMS can indeed relieve some depression syndromes, although it is not clear what is the actual mechanism involved. We are aware of areas in the brain controlling the "mood" and it is possible to direct the pulses (through resonance principles) exactly on those areas.

Being a non invasive technology we can expect further studies on healthy people that might result in the improvement of thinking functions. In a way, TMS seems to be similar in its way of working to nootropic drugs, in that it affects in a systemic way a large part of the brain rather than a single neuronal circuit.

Gallery 1.63 Trans-cranial Magnetic Stimulation



In transcranial magnetic stimulation (TMS), an electromagnetic coil placed against the scalp creates a magnetic field that stimulates certain areas of the brain. Image credit: Mayo Clinic

Nootropic drugs have been know, empirically, for quite a while: "You look drowsy, why don't you take a cup of coffee?" Indeed, caffeine has been known to stimulate thinking by sharpening attention (keeping you awake). Similarly L-theanine (you find it in a cup of tea) can make you feel calm and it may increase creativity.

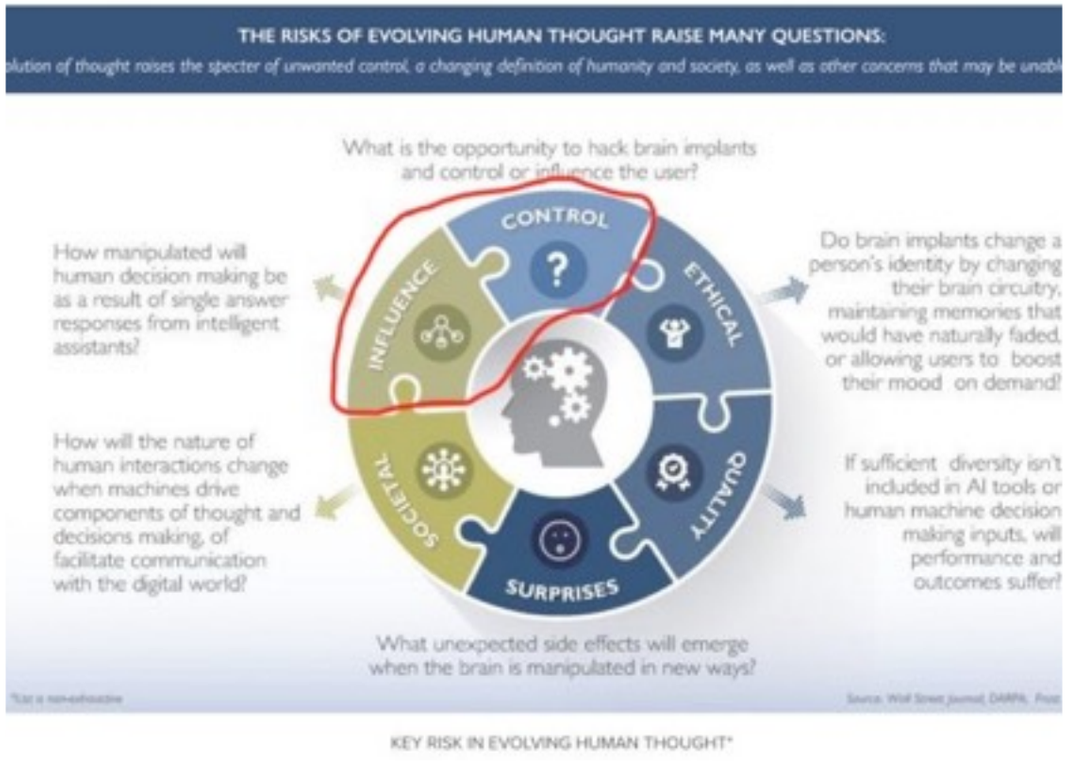
Several natural substances that can be found in plants like Rhodiola Rosea, Bacopa Monnieri, Panax Ginseng have the capability to influence the general

activity of the brain, sharpening thoughts and making it more resilient to fatigue.

Increasing thinking processes “resilience” is also about decreasing brain fatigue. We all experience this kind of fatigue (known as mental fatigue or brain fog) that leads to decreased focus. There are specific conditions (pathologies) that are characterized by mental fatigue, like myalgic encephalomyelitis/ chronic fatigue syndrome (ME/ CFS), that lead to cognitive impairment. Recent studies have pinpointed the cause (like inflammation) but this is not leading to finding ways to avoid mental fatigue by increasing the brain resistance to it. In this area again most research focuses on understanding the root cause of “anomalies” and fixing them, rather than increasing the “performances” of an healthy brain.

It can be expected that in the coming decade, as more understanding on the brain thinking processes will become available, we will control a toolkit of substances for effective neuromodulation and that may also overcome or at least delay brain/mental fatigue.

Gallery 1.64 Risks of evolving human thoughts - I



When considering augmentation of humans thinking capabilities ethical and dark areas emerge. Slide credit: Frost & Sullivan – Transhumanism

This on the one end will increase the thinking capabilities and on the other hand will rise some ethical issues as doping substances.

==========

In this last part Transhumanism, stimulated both by reading the Frost&Sullivan report on Transhumanism and by the preparation of the second White Paper on Symbiotic Autonomous Systems, I have addressed the possibilities of increasing human thought capabilities. Clearly I expressed very personal opinions on the feasibility of the various approaches and on their evolution in time and I should say that within the team working on the White

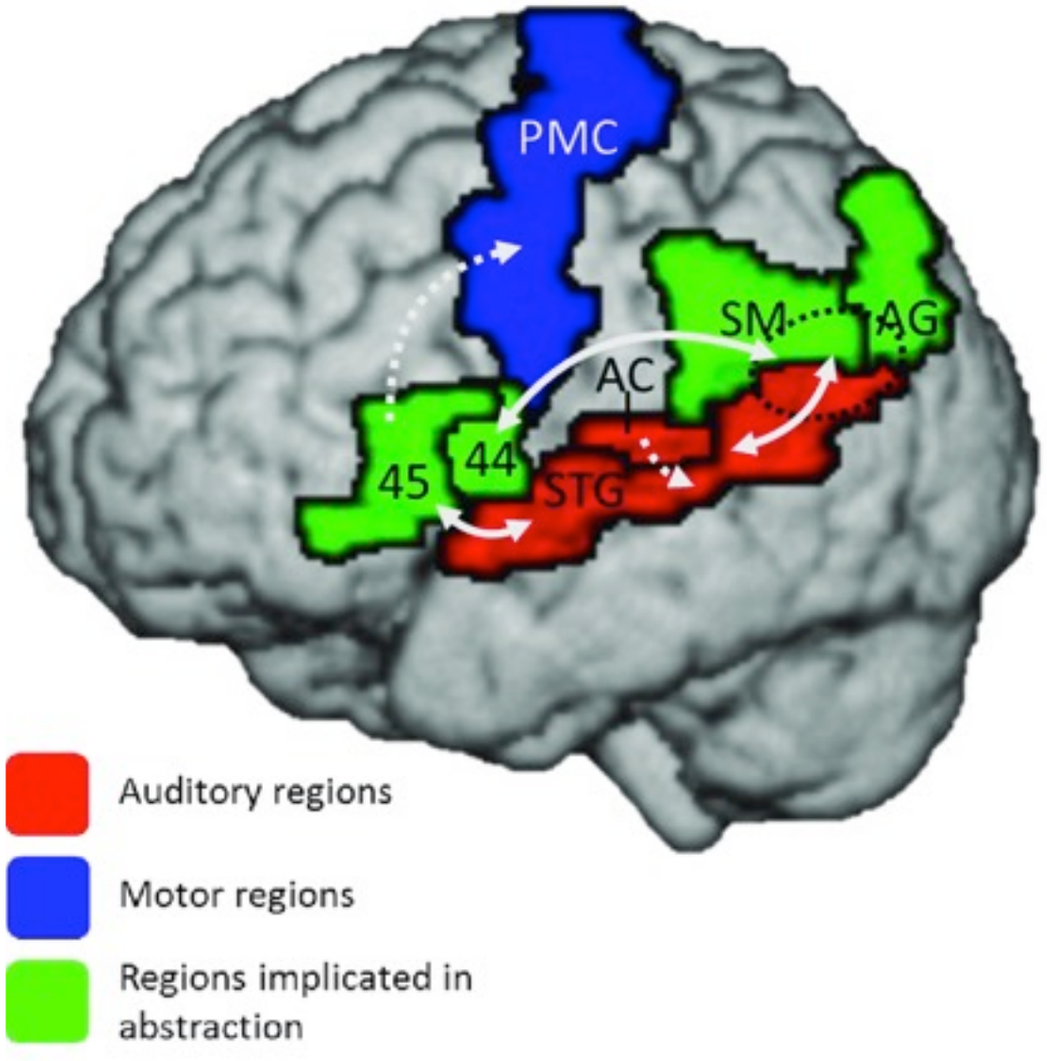
Paper there are different opinions, mine being probably one of the most conservative one.

This has been discussed at the workshop on October 30th, 2018, in San Diego in conjunction with TTM 2018 where further debate took place on the various technological, societal and ethical aspects.

My basic reservation on the possibility of significantly improve our brain thinking capabilities rests on the complexity of the brain. Tweaking with part of it is not likely to produce the desired results since all the brain is involved in thinking, and in the variety of aspects involved in thinking, like perception, feeling, memory…

Of course, never say never. It might well be that the increasing knowledge we are gaining from studying the brain and the ever more sophisticated technology becoming available to interact with the brain will first lead to fix brain problems (Alzheimer, Parkinson, depression, attention deficit disorders,...) and eventually to increase its thinking capabilities. I don't see the latter happening in the short term (20 years).

Gallery 1.65 Brain processing of external stimuli



Human brain regions implicated in language processing. AC: Auditory Cortex, STG: Superior Temporal Gyrus, PMC: Primary Motor Cortex, 45: BA 45 or Pars Triangularis of the Inferior Frontal Gyrus, 44: BA 44 or Pars Opercularis of the Inferior Frontal Gyrus (BA 44 and 45 are part of Broca's area, which is implicated in syntactic processing), AG: Angular Gyrus, SM: Supramarginal Gyrus. The dotted oval shows the location of Wernicke's area, which is implicated in semantic processing. Image credit Anne van der Kant

However, as Frost&Sullivan point out in their report, such possibility, if it will come to pass, will bring significant risks in the societal and ethical context that need to be considered.

As shown in the Frost&Sullivan slide, there are several aspects needing consideration:

- Control

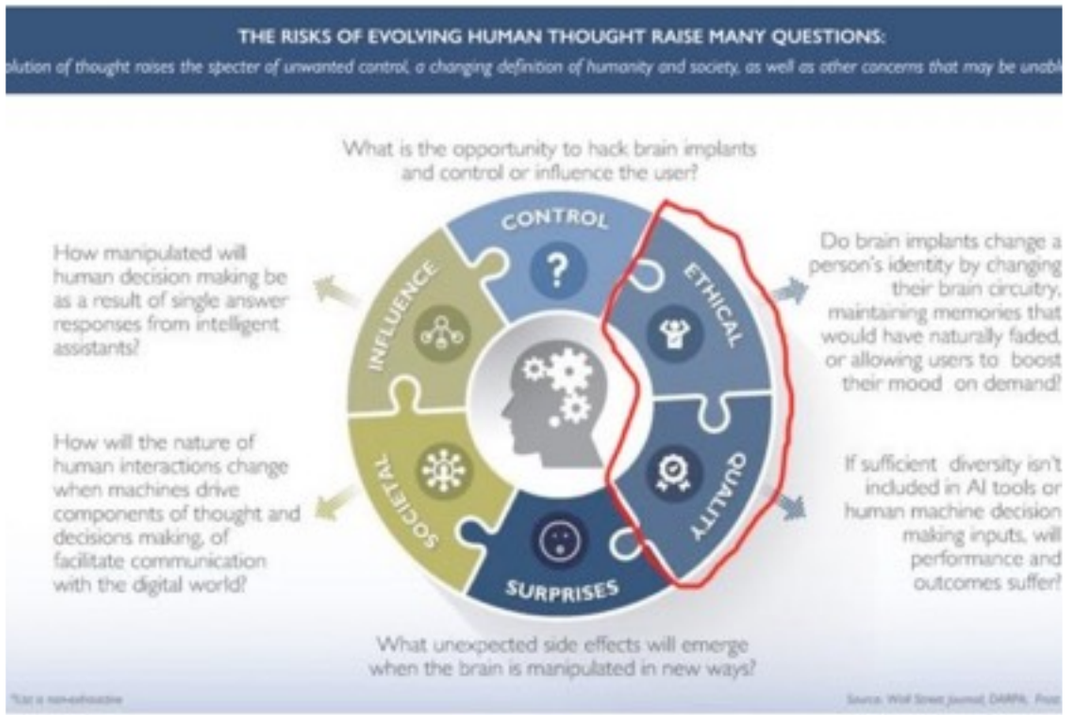
The interaction with the brain, as seen, may take place in a variety of ways using technology in part available today and evolving, plus technology that will be invented

tomorrow. In all cases there is the potential risk of hacking. It would be naive to assume that brain interfaces will not be subject to attack. They already are! Think about advertisement. Isn't a form of hacking into our brain to steer our decision (as well as feeling and desire) in a specific direction?

- Influence

  This seems to relate to the previous one but it is not about hacking the interface, it is about the kind of stimuli, answers, information, we get as result of a symbiosis of our brain with an external co-processor, intelligence. To what extent such external co-processor will influence our understanding and decisions? There are so many ways this can happen and providing wrong information is probably the least of concern. What about providing a limited set of information that as a matter of fact skew our understanding and decision in a very specific way? This is equivalent to provide a deluge of information! I often observe that Google search is the most effective way to "hide" information by providing you sufficiently good information that will stop your quest. How many time did you go to the 10th page of Google results? Very, very few I bet.

Gallery 1.66 Risks of evolving human thoughts - II



When considering augmentation of humans thinking capabilities ethical and dark areas emerge. Slide credit: Frost & Sullivan – Transhumanism

And there are probably some other thousands pages of answers reported. What about creating a sense of trust on your co-processor (today we can call it the "internet") that you lose the need to perform a critical analyses of what is going on? Notice how this is already happening to pilots that have to trust the ILS as they land in the fog with zero visibility. Once in a while the system fails and the pilots are usually unable to detect that it is no longer to be trusted.

- Identity

  We are, by far, our brain. It is through our brain that we process the world and react to it Our interaction with it and its components, including other people, depends on it. Our feelings also depend on it. In most legislations it is accepted that if the brain is "malfunctioning" the person is not held responsible for his actions. At the same time

legislators usually pursue those that are inducing malfunctioning in their brain, like getting drunk or taking drugs (and of course actions carried out under the effects of mind altering substances are prosecuted!).

Hence the question of what happens when a brain is "enhanced" is well posed. Is that person the "same" person he was before the brain enhancement or should he be considered a new person? Once a circuit is implanted in a brain, becoming part of its circuitry and changing its processing, including its thoughts, can we still say that person is the same as before?

Gallery 1.67 The ethics of human enhancement

Humanity is entering a "trans-human" era, where biology is treated as something to be manipulated at will, depending on one's lifestyle interests rather than health needs. But questions remain about how far society is prepared to accept these kinds of applications and what ethical issues they create. Credit: Andy Miah, MIT Technology Review

We keep learning through our lifetime, we keep forming new memories, but at the same time old ones may fade away (and they do). It is not just about "forgetting" because we also are our memories since the processing (and so our thoughts and behavior) is influenced by our memories (as emphasized by post traumatic syndromes where the presence of dreadful memories affects the behavior of that person to the point that life becomes miserable). Hence, a "memory chip" that would ensure the preservation of all memories would lead to a different processing and, some may claim, to a different person. What about systems that can alter the moods and feelings (via chemical injection, electrical stimulation, …)? They may compare to some of today's drugs, but they can be much more specific, may be without undesired side effects. Yet, would that person be the same one?

• Balancing responsibility
As it was considered in a previous post we may come to the point of creating a symbioses between our brain and other "thinking tools" all together working as a distributed system. These complementary thinking tools may be in the form of implanted chips, remote processing and AI somewhere in the environment that can even become plug-ins depending on

the need. As an example a military pilot may plug into her brain aircraft smart components that will work in symbioses with her brain during the mission, a surgeon may link into a symbioses with robots actually performing the surgery and so on! Actually, one might even envisaged, in the remote future, the symbioses among human brains, what about a classroom where the educator's brain and the students' brain are linked and operate in a symbiotic way?

The question is where can responsibility for decisions be assigned. Who is accountable among the several thinking processes interacting with one another?

How can the quality of thinking be measured and proved that it gets better (and who decides what "better" means?) as more thinking processes are pooled together? Notice that we have similar issues in any human communities, team work and we have invented "organizations" to manage them. Can we invent some equivalent of organizations in symbiotic thinking processes?

- Societal

Gallery 1.68 Risks of evolving human thoughts - III

When considering augmentation of humans thinking capabilities ethical and dark areas emerge. Slide credit: Frost & Sullivan – Transhumanism

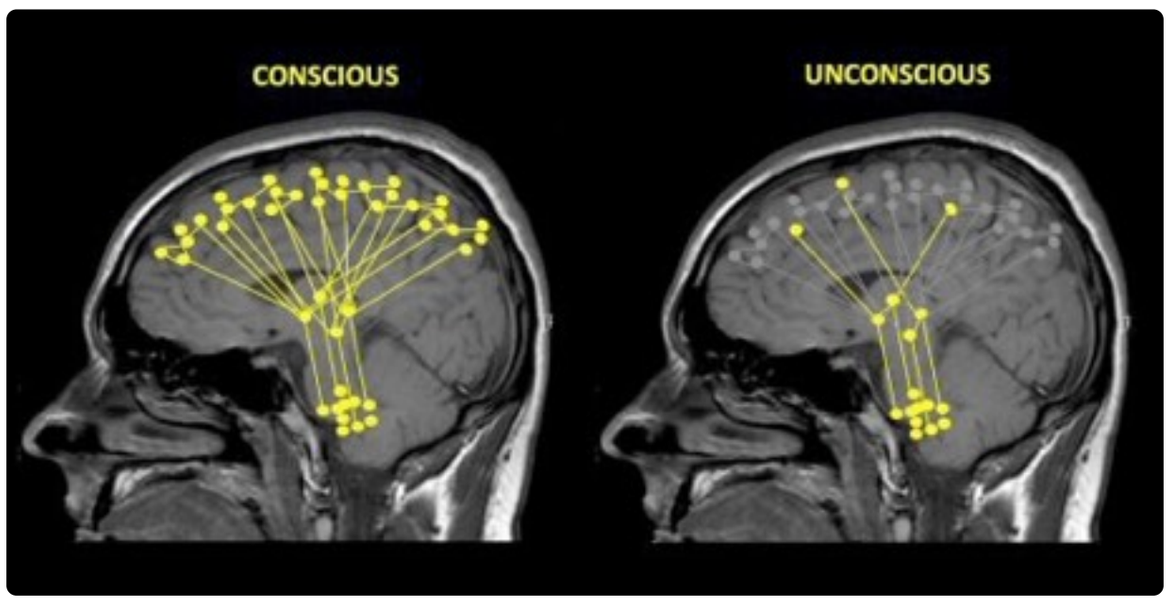
Communications, both explicit - talking, writing- and implicit – gesturing, posture, face mimic-, is generated, managed and "decoded" by the brain. Culture is also playing a role in this, like the facial mimic differs in various geographical areas (in the Western world we nod to mean "yes", in India they shake, wobble, the head to mean "yes"). Communications is what create communities and Society and keep them "functioning". We have seen the changes in Societal behavior resulting from new communications means, particularly in this new century. This changes were foreseen and examined by Marshall Mcluhan, condensed in his statement "The medium is the message" (watch the clip). Mcluahn pointed out that the modern medium are "electrical extension of the brain".

What we foresee now is the possibility of extending the brain even more radically through a symbioses with the cyberspace, its data/information/knowledge and its processing/services/AI. It is obvious that this is going to have profound Societal implications, although it is not clear today what they might be. We have already experienced changes in the human interactions brought forward by SMS, emoticons, tweets, blogs, Instagram. What is it going to happen when communication might no longer require our senses as mediator but a direct brain connection can be established (quite in the future of course)?

As an extreme, just wonder on the implication of reading other people's mind. It would no longer possible to put up a "social" mask in interaction with other people. Besides, we know today that what gets out as interaction is not what is in our brain but it is the result of a processing that makes a message explicit and that often is not "shared" by the whole brain (alternative, often contradictory messages floats at the same time in our brain). What is the message when this is the result of processing partly taking place in a brain co-processor and partly in the brain? Which takes prevalence? Which component of the symbiotic system is in charge of choosing and making a message explicit?

As one can see there are many questions (these are just a subset…) and answers to them are not straightforward. We have been discussing for at least 2 millennia on "free will" (without reaching any agreement, by the way). What will we mean with "free will" in the new context of distributed intelligence and symbiotic autonomous systems?

Gallery 1.69 Consciousness vs unconsciousness



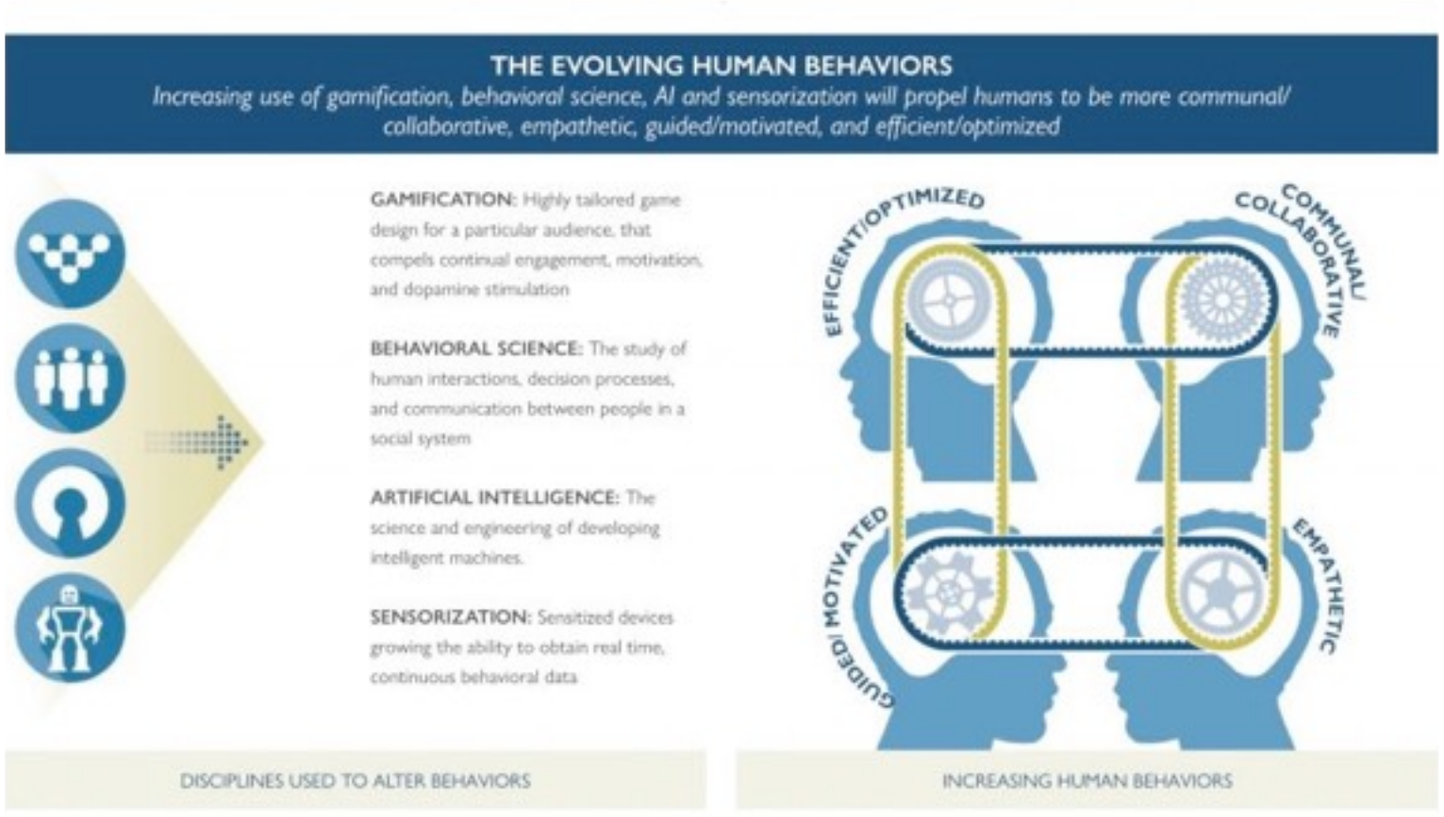
A lot is going on in our brain at every moment, including when we sleep. We become aware of something is going one when the cortical area of the brain is involved. Whatever processing happens outside of the cortical area is not perceived. This can be extended, in the future, when part of the processing might happen in the cyberspace. We won't be aware of it unless its results arrive to our cortex. Image credit: The brainbank. https://thebrainbank.scienceblog.com/2013/03/04/what-is-consciousness-a-scientists-perspective/

- Surprises

The Frost & Sullivan report quite appropriately points out that although we can imagine a number of issues raising in the transition towards Transhumanism we can expect "surprises", new side effects we are not able to foresee today as our brain becomes

"distributed", changes and the sense of self will be morphed into a different thing. In this respect I found very interesting the short stories contained in the "Mind's I: Fantasies and reflections on self and soul" book by Daniel Dennett, Douglas Hofstadter, and Stanisław Lem.

Gallery 1.70 Evolving Human Behavior



The technology evolution and its adoption may eventually create a human 2.0. This "human" will probably have a different social behavior. Credit: Frost & Sullivan

Evolving Human Behavior

I am no sociologist at all but as we are considering technology evolution and their impact in the Symbiotic Autonomous Systems Initiative, the societal aspects are clearly important.

Frost&Sullivan in their 2018 report on Transhumanism point out how technologies will affect human communications at the societal level leading to what they label an "increased human behavior" (see graphic).

More specifically they expect the areas of

- gamification (an approach based on game paradigm to increase the engagement of people's brain in a specific activity),
- behavioral science (moving more and more from qualitative to quantitative analyses, leveraging on huge data availability),
- artificial intelligence (making machines/ ambient more aware, responsive, hence changing the human perception of the environment and the interactions with it),
- sensorization (making possible to monitor almost continuously a variety of parameters on human reactions and interactions).

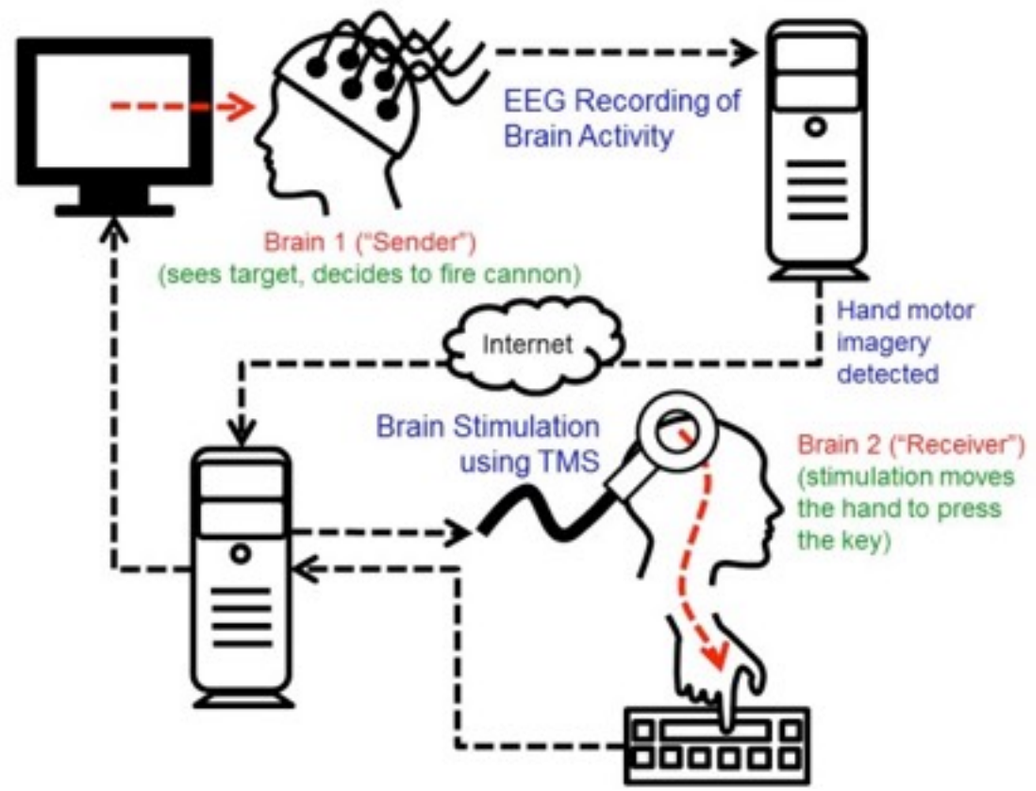
to lead to more efficient communications among people and among people and machines, to create easier communications fabric to support community formation and operation, to better engage/motivate people in communicating and support more emphatic communications. This latter might be a bit unexpected since communications will involve machines (and entities in the cyberspace) much more than today and one would not expect to see emphatic involvement with a machine.

I'll let the experts discuss on this .

I'll just point out, since it is much more technology related, that one of the vision coming up from the Frost&Sullivan report is the possibility of making the first steps towards telepathic communications. This vision is based on the assumption that there will be seamless Brain to Computer Interfaces, implying that by coupling two of them we might achieve a Brain to Brain interface.

There have been a few experiment involving monkeys and rats that seem to demonstrate the technological possibility of a Brain to Brain interface. Some limited experiments have involved human brain to brain communications (watch the clip).

Gallery 1.71 Brain to Brain Interface



A schematic of the brain-2-brain interface developed by University of Washington researchers. Watch the video of the actual experiment at: https://www.youtube.com/watch?v=rNRDc714W5I

For now, let's assume effective and seamless brain to brain communication in humans will be possible. What would be the societal implications?

Our social relations happen in a cultural environment that masks and twist what we might feel. You are not telling a person you are meeting "Wow, just look how ugly you are!". It wouldn't be nice and for sure it is not a good opening statement to promote a collaborative exchange. Hence we "mask" our thoughts and vocalize just those that fit within our cultural framework.

This is already an issue since it is not a given that our cultural framework matches the one of the person/persons we are interacting with. This is clearly the case when a Westerner meets a person from the Far East Asia. Cultural

differences are noticeable and unless one is aware of them the interaction may turn awkward.

A direct brain to brain communications may not take into account these differences leading to problems.

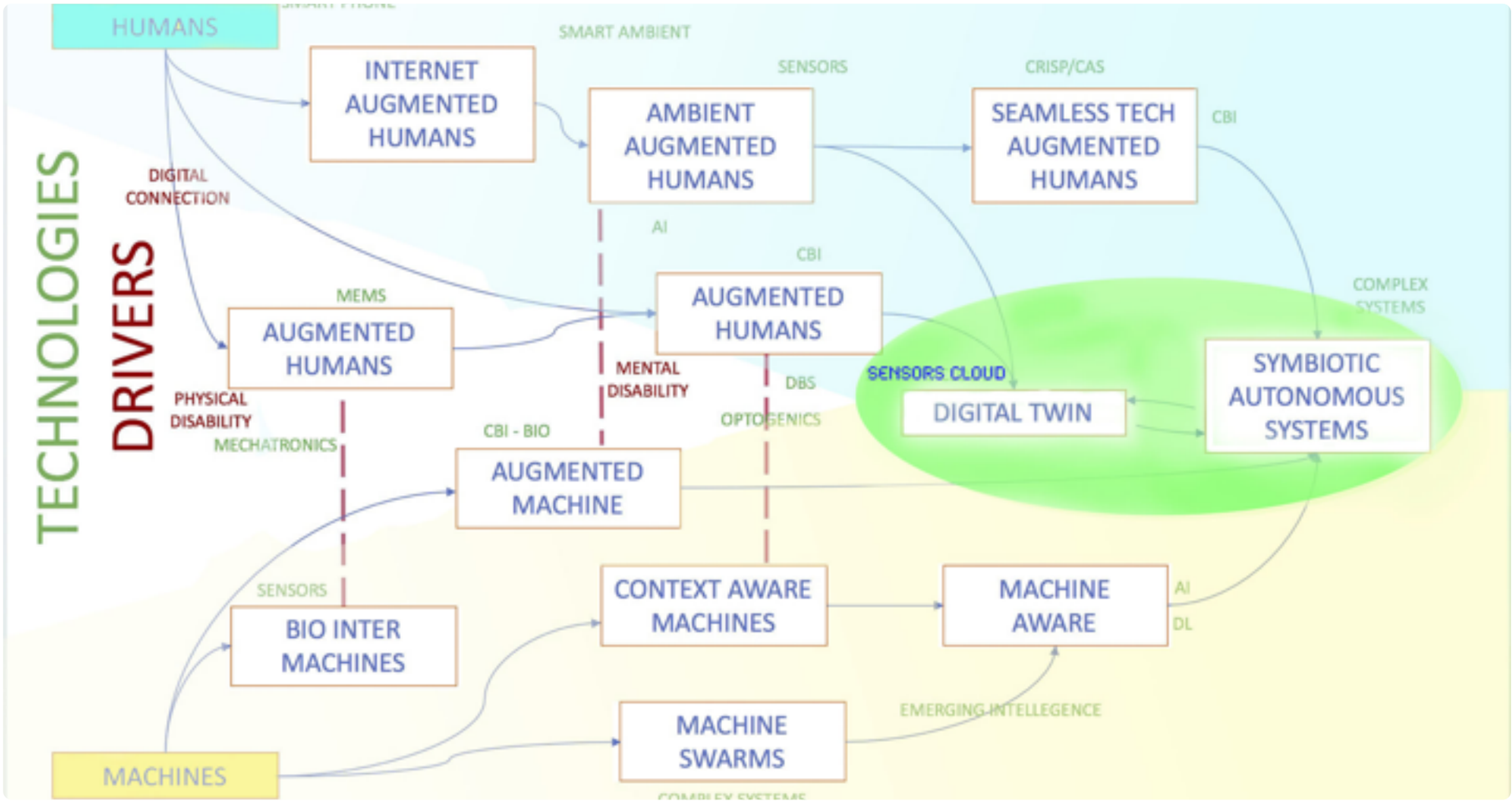
More than that, much more actually. When we interact there are many parallel thoughts floating in our brain. What would a brain to brain interaction do with respect to them? Transfer them all? Pick and choose (how)?

We actually often have contradictory thoughts and it is only after some evaluation that we make up our mind and decide what to vocalize. Actually, there may be even some hidden thoughts that haven't come to our perception level floating around (this has been demonstrated in several experiments).

Would a brain to brain interface transfer also those hidden thoughts, leading to a communications that we are not even conscious about?

As it can easily be seen, and without stepping into societal considerations, the issues are many.

Gallery 1.72 The evolution towards Human Machines symbioses



The roadmap diagram developed by the IEEE FDC Symbiotic Autonomous Systems Initiative

Acronyms

Image credit: Dreamstime

5G: 5th Generation wireless system

ACM: Association of Computer Machines

AGI: Artificial General Intelligence

AI: Artificial Intelligence

AR: Augmented Reality

ASI: Artificial Super Intelligence

BCI: Brain Computer Interface

Cas9: CRISPR associated protein 9

CBI: Computer Brain Interface

CMOS: Complementary Metal-Oxide Semiconductor

CO2: Carbon dioxide

CRISPR: Clustered Regularly Interspaced Short Palindromic Repeats

DBS: Deep Brain Stimuation

DC: Direct Current

DNA: DeoxyriboNucleic Acid

EEG: ElectroEncephaloGram

ELS: Ethical Legal, Societal

FDC: Future Direction Committee

f-MRI: functional Magnetic Resonance Imaging

GAN: Generative Adversarial Networks

GDP: Gross Domestic Product

HMDB: Human Metabolome DataBase

IEEE: Institute of Electrical & Electronic Engineers

IFR: Instrument Flying Rules

ILS: Instrumental Landing System

IoT: Internet of Things

IQ: Intelligent Quotient

IVF: in Vitro Fertilization

ME/CFS: Myalgic Encephalomyelitis/Chronic Fatigue Syndrome

MR: Mixed Reality

OECD: Organization for Economic Cooperation and Development

RFID: Radio Frequency IDentification

RPA: Robotic Process Automation

SAS: Symbiotic Autonomous Systems

SITN: Science In The News (Harvard University)

SMS: Short Message Service

TMS: Transcranial Magnetic Stimulation

VR: Virtual Reality

Artificial consciousness

Artificial consciousness is a consciousness created, and experienced, through artificial means. It is associated to machines (computer with artificial intelligence). Awareness is considered to be an essential component of consciousness but it is not sufficient to reate consciousness.

So far the jury is still out on the possibility of creating artificial consciousness although discussion on the ethical implications arising from it are already being studied.

https://en.wikipedia.org/wiki/Artificial_consciousness

Related Glossary Terms

Artificial Super Intelligence, Awareness, Self-aware, Sentient Machines

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Index Find Term

Artificial General Intelligence

Artificial general intelligence (AGI) is the intelligence of a machine that could successfully perform any intellectual task that a human being can.

Source: Wikipedia

Related Glossary Terms

Artificial Super Intelligence, Sentient Machines

Index Find Term

Artificial Super Intelligence

Artificial Super Intelligence, ASI, is an artificial intelligence that surpasses the brightest human minds in any area. It goes beyond Artificial General Intelligence, that is au pair with human intelligence.

A few researchers observe that computers today are better than humans in several areas (like calculus) and are getting better and better in several more areas. This implies that once AI will reach the AGI stage as a matter of fact it will also be ASI. Hence, AGI will never happen, the shift will be from AI to ASI, skipping AGI. This is the “singularity”.

Machines will not become as smart as we are. All of a sudden they will move to be inferior to us to be superior to us.

Notice, however, that ASI does not imply Artificial consciousness.

Related Glossary Terms

Artificial consciousness, Artificial General Intelligence

Index Find Term

Augmentation

Increasing the performances and extending the capability of an entity.

In our context we are referring to both humans, human augmentation, and machines, machine augmentation. In the longer term a symbioses between humans and machines may augment both.

The natural process of random mutation and selection has extended living beings capabilities and performance. In our context augmentation is achieved by design. This is a superset of the natural evolution processes and includes, in the case of machines, random changes and selection processes, either controlled or open (self learning, self adaptation, self replication).

Related Glossary Terms

Drag related terms here

Index Find Term

Autonomy

The ability of a system to be able to act independently and intelligently in dynamic, uncertain, and unanticipated situations. In addition, an autonomous system should be able to detect when its goals stand in conflict with the laws that govern its behavior and must have a way to “fail” gracefully in those situations.

Often varying levels (modes) of autonomy are used in the literature. There are four modes of operation: 1) in the Fully autonomous mode, the system operates without human intervention while adapting to operational and environmental conditions, 2) in the Semi-autonomous mode, the human operator and/or the system plan(s) and conduct(s) a mission which requires various levels of human-robot interaction. It should be noted that the system is capable of autonomous operation in between the human interactions (also called “bounded autonomy”), 3) in the Teleoperation mode, the human operator, using sensory feedback, either directly controls the actuators or assigns incremental goals on a continuous basis, from a remote location, and 4) in the Remote Control mode, the human operator controls the system on a continuous basis, from a remote location via only her/his direct observation.

Related Glossary Terms

Drag related terms here

Index Find Term

Awareness

Knowledge and understanding that something is happening or exists.

Source: Merriam-Webster

In our context we refer both to machine awareness (and self awareness) and to human awareness of being part of a symbiotic entity.

Related Glossary Terms

Artificial consciousness, Self-aware

Index Find Term

BCI

BCI, Brain Computer Interface is a means through which information/data is transferred from the brain to a computer. There are several technologies being used and more are being studied. The goal of a BCI is to be able to capture the information required for a given goal, e.g. controlling a robot to operate on behalf of a paralyzed person, or to study the working of the brain and its neuron/neuronal circuit.

The interface can be based on external sensing or may require invasive (implant) sensing. A given BCI is characterized by the technology and protocol used and its performances are measured with respect to the sensitivity and resolution provided.

Related Glossary Terms

CBI

Index Find Term

Bio-interfaces

Interfaces that can establish a communication path between a biological entity and an artifact. In general they act as a transducer between a living entity and an artifacts. The two channels, from the living entity to the artifact and from the artifact to the living entity may be using different technologies and protocols.

Examples of bio-interfaces are the protonic chips that use protons (ions) rather than electrons to communicate with living cells. Interfaces used in smart prosthetic limbs are another example of bio-interfaces, since they adapt the communications to the one supported by muscles in a limb or nerve termination.

Other interfaces, like sensors to detect electrical activity (such as EEG, ECG) are not considered as bio-interfaces.

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Bio-Machines

A Bio-Machine is a machine that has been engineered using bio components, like bacteria, to acquire/deliver a specific functionality. As an example, bacteria (and genetically modified bacteria) can be used in symbiosis with artifacts to detect specific molecules.

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Bioengineering

Bioengineering is the application of principles of biology and the tools of engineering to create usable, tangible, economically viable products.

Source: Wikipedia

Related Glossary Terms

CRISPR/Cas9, Genetic engineering

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Brain implant

An artifact that is designed to be implanted inside the skull, either on the meninges or inside the brain. It may be used to monitor brain activity and/or to influence it. It can be a temporary implant or a permanent implant and has to be bio-compatible with brain tissues.

Related Glossary Terms

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CBI

CBI, Computer Brain Interface is a means through which information/data is transferred from a computer to the brain. Like in the case of BCI the interface can be based on external actuators or may require invasive (implant) actuators.

So far CBI technologies can only influence, tamper with, the working of the brain in some of its functions. As an example CBI are used to block an epileptic seizure by interfering with the electrical activity underlying the seizure, another example is to alter depression (although no conclusive assessment on the effectiveness is available as October 2018).

The stumbling block in creating a generalized CBI is due to the massive distributed nature of most brain functionalities making it practically impossible to interfere with all the involved neurons/neural circuits. Additionally, in most cases, any given neuron/neural circuit can participate in several functions, hence tapering with one to influence a function is likely to influence another function, often in a non-desirable way.

Related Glossary Terms

BCI

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CRISPR/Cas9

CRISP/Cas9 is a technology used to modify DNA strings (now also being used to modify RNA strings adopting a slightly different protocol). It is the current tools for genetic engineering.

CRISPR is an abbreviation of Clustered Regularly Interspaced Short Palindromic Repeats and was discovered within the genomes of prokaryotic organisms such as bacteria and archaea that developed this “technique” to defend themselves from virus infection.

Cas9 is an enzyme that uses CRISPR sequences as a guide to recognize and cleave specific strands of DNA that are complementary to the CRISPR sequence.

Related Glossary Terms

Bioengineering, Genetic engineering

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Deep Learning

Deep learning is part of a broader family of machine learning methods based on learning data representations, as opposed to task-specific algorithms. Learning can be supervised, semi-supervised or unsupervised.

Source: Wikipedia

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Digital Twin

Digital twin refers to a digital replica of physical assets, processes, people, places, systems and devices that can be used for various purposes. The digital representation provides both the elements and the dynamics of how an Internet of things device operates and lives throughout its life cycle. Source Wikipedia

A more business oriented definition from General Electric, one of the first companies to use Digital Twins:

Digital twins are software representations of assets and processes that are used to understand, predict, and optimize performance in order to achieve improved business outcomes. Digital twins consist of three components: a data model, a set of analytics or algorithms, and knowledge.

In our context a Digital Twin is a digital replica of any characteristics of a real entity, including human beings. The characteristics represented by a digital twin are a subset of the overall characteristics of a real entity. The choice of which characteristics are digitalized depends on the purpose of the digitalization, i.e. the intended use of the digital twin.

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Emergence

Complex systems, i.e. those systems composed by many parts that cannot be reduced without a loss of function (complex systems cannot be simplified without losing some of their characteristics, while complicated system can), often show characteristics that are not present in any of their components. This is often the case when one or more of their component is autonomous. The behavior of a system that is not the result of one of its component but that results from the interaction of the behavior of its constituent parts is called emergent behavior and the property of these systems in creating a whole “behavior” is called “emergence.”

In our context we talk of:

- Emergent Intelligence, meaning the intelligence that is created by the interaction of the various components of autonomous systems when acting in symbioses, and
- Emergent Behavior, meaning the behavior shown by autonomous systems when acting in symbioses.

Related Glossary Terms

Smart City, Smart prosthetics

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Exoskeleton

An exoskeleton is a rigid external covering for the body in some invertebrate animals, especially arthropods, providing both support and protection.

In our context an exoskeleton is a robot shaped in a way to wrap around part of a human body to increase the human strength (and relieve from fatigue).

There are already many areas of application of exoskeletons, mostly in healthcare, manufacturing and military.

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Generative Adversarial Networks

Generative adversarial networks (GANs) are a class of artificial intelligence algorithms used in unsupervised machine learning, implemented by a system of two neural networks contesting with each other in a zero-sum game framework. They were introduced by Ian Goodfellow et al. in 2014. This technique can generate photographs that look at least superficially authentic to human observers, having many realistic characteristics (though in tests people can tell real from generated in many cases).

Related Glossary Terms

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Genetic engineering

Genetic engineering is the direct manipulation of DNA to alter an organism's characteristics (phenotype) in a desired way.

Related Glossary Terms

Bioengineering, CRISPR/Cas9

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Metabolome

The metabolome is the total number of metabolites present within an organism, cell, or tissue.

The Human Metabolome project has resulted in the creation of the Human Metabolome Database (HMDB) a freely available electronic database containing detailed information about small molecule metabolites found in the human body.

http://www.hmdb.ca

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Nootropic

Nootropics (colloquial: smart drugs and cognitive enhancers) are drugs, supplements, and other substances that may improve cognitive function, particularly executive functions, memory, creativity, or motivation, in healthy individuals.

Source: Wikipedia

Related Glossary Terms

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Optogenetics

Optogenetics (from Greek optikós, meaning 'seen, visible') is a biological technique that involves the use of light to control cells in living tissue, typically neurons, that have been genetically modified to express light-sensitive ion channels. It is a neuromodulation method that uses a combination of techniques from optics and genetics to control and monitor the activities of individual neurons in living tissue—even within freely-moving animals—and to precisely measure these manipulation effects in real-time.

Source: Wikipedia

Related Glossary Terms

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Self-aware

Being aware of existing as an independent entity, having feeling, desires, purposes.

In our context we address machines' self-awareness.

Related Glossary Terms

Artificial consciousness, Awareness, Sentient Machines

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Sentient Machines

A sentient machine is a hypothetical machine that exhibits behavior at least as skillful and flexible as humans do. It is often associate to Artificial General Intelligence -AGI- and to artificial consciousness.

“Sentient” connects to the idea that a machine can have feelings and can appreciate that other entities can have feelings as well. It is a blurred area: we have computer (programs) that can feel the mood of people interacting with them but they do not feel anything in our sense of feeling, they just react in an appropriate way taking into consideration those (expression of) feelings.

Related Glossary Terms

Artificial consciousness, Artificial General Intelligence, Self-aware

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Smart City

In this context a smart city is seen as a complex system, an emergent entity, resulting from the interplay of autonomous systems that all together create a symbiotic being, i-e- the smart city.

Related Glossary Terms

Emergence

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Smart prosthetics

Smart prosthetics are an evolution of prosthetics that embed processing and decision capabilities. In order to do that they have sensors and actuators, the first reporting data to a processing units, the latter executing orders provided by the processing units.

More recently smart prosthetics have become equipped with technologies to interact with the person's body (and brain), i.e. to understand the intention of the person, acting in consequence, and providing sensation to the person.

We can expect smart prosthetics to become smarter in the coming decade, embedding intelligence and acting in symbioses with the person, eventually giving rise to a more intelligent symbiotic behavior.

Related Glossary Terms

Emergence

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Superorganism

A Superorganism is an organism composed by the symbiotic relations of several organisms. In Nature we have plenty of examples, in a way most living being are symbiotic expression of a multitude of organisms (from sponges to human beings).

A superorganim can be composed by a multitude of similar entities (think about a hive, a superorganism composed by thousands of bees) or by different living entities (think of a cow needing bacteria to digest cellulose).

A superorganism can be an abstract entity like a smart city, emerging from the loose inter-relations of different infrastructures and players (citizens, business...).

In our context we are interested in superorganism emerging from a mixture of atoms and bits of living entities and artifacts.

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Transhumanism

The belief or theory that the human race can evolve beyond its current physical and mental limitations, especially by means of science and technology.

Source: Oxford Dictionary

In our context we are not expressing a belief, rather we are pointing at the possible implication of technology evolution on humans.

Related Glossary Terms

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Turing test

The Turing test, developed by Alan Turing in 1950, is a test of a machine's ability to exhibit intelligent behavior equivalent to, or indistinguishable from, that of a human.

Source: Wikipedia

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