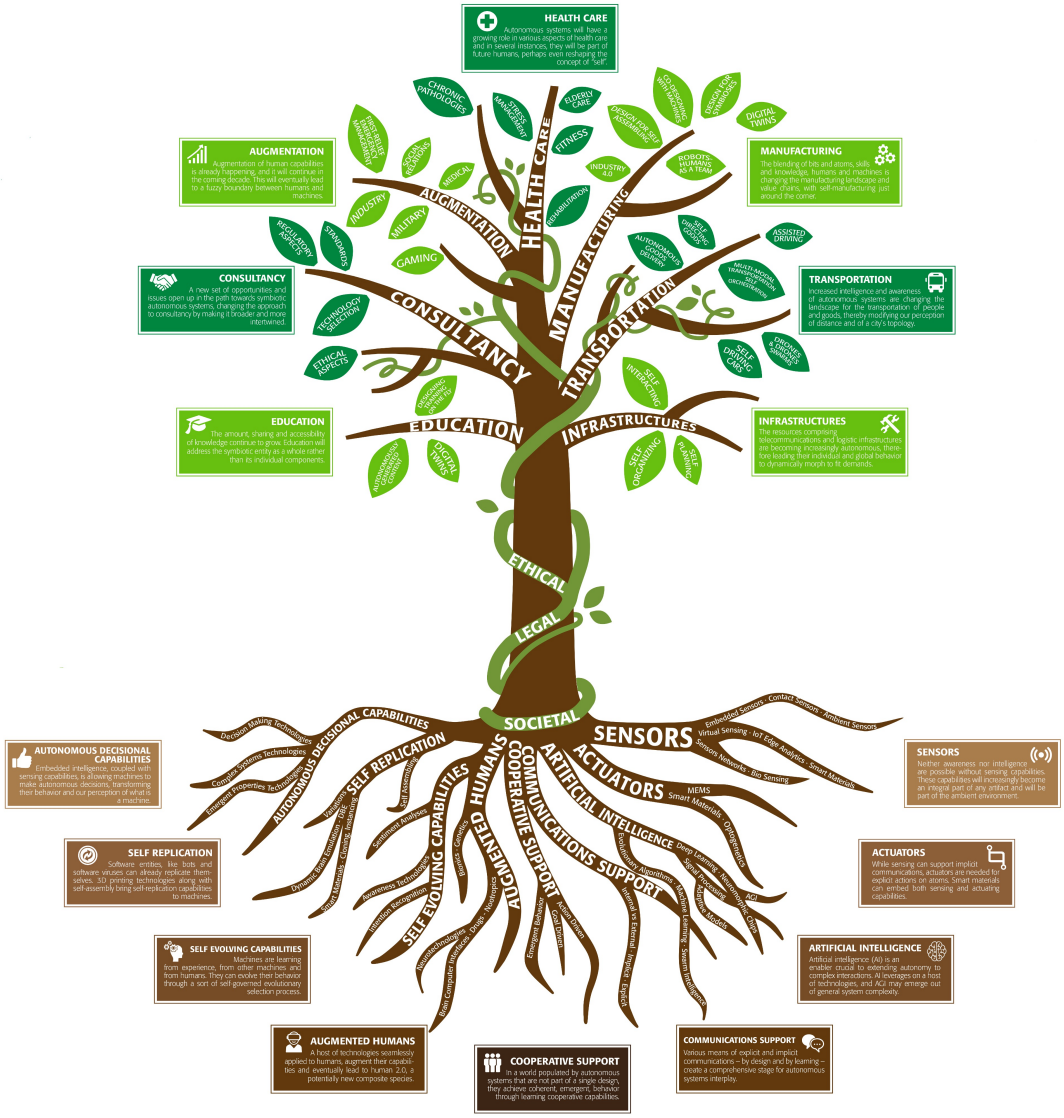

Evolution towards Symbiotic Autonomous Systems

Roberto Saracco

This eBook collects posts that I published since 2016 touching upon the broad area of symbiotic autonomous systems from technology enablers evolution to personal and social impacts.

The work is part of, and has benefitted from the IEEE FDC Symbiotic Autonomous Systems Initiative, SAS, and the thoughts offered derives from discussions we have had in that context.

The posts have been structured along with the Initiative Tree:

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OVERVIEW

The SAS Initiative

- February 22nd, 2017

Swarm robotics is a relatively new area that is studying biological behaviour to create a super-organism, a swarm intelligence, out of many simple robots. Thomas Smitckl and his colleagues are studying adaptation and evolution for symbiotic multi-robot organisms. Credit: University of Gratz

The Future Direction Committee FDC of the IEEE in consultation with IEEE Societies, is kicking off a new Initiative on Symbiotic Autonomous Systems.
What are these “Symbiotic Autonomous Systems”?
It is nothing really new, in the sense that the history of human civilization has been characterized by the continuous interplay of people and their artefacts.
This Interplay is so important that historians are used to characterize a civilization age with an emerging and then widespread use of an artefact, or technology to create it (the age of "stone", bronze"," iron").
Today we are in the "computer" age, transitioning to the "digital’ age.
Symbiotic Autonomous Systems may be seen as a next step in the digital age. The age of computers has fostered automation of many activities and its performances have enabled the creation of new ones. The age of “digital” is harvesting the computer productions, the 0 and I, the bits, giving rise to a parallel World, the cyberspace.
In the coming decades we are bound to see progress in both the "computerization" of the World and in its digitalisation. These two trends will strengthen one another and will overlap creating the age of Symbiotic Autonomous Systems, SAS.
The progress in computerization (I include into this word both the "chip" and the ‘software" part) is leading to increasing "robotization" of objects and to a seamless presence in our everyday life. We are already commuting using robots (the metro system in Turin, where one line is fully robotized) and in a few more decades our cars will be robots. Vacuum cleaners robots no longer make headlines and my grandchildren are growing with a playground populated by robots.
The Internet of thing is on us and it is growing in our homes, in our cities, at the office…
The sheer number and variety of computerised/robotized objects will seamlessly morph into a fabric of connected objects out of which an overall "behaviour" will arise.
On the other side, digitalisation creates an expanding cyberspace formed by islands that will progressively be connected with one another.
These two worlds will get more and more intertwined.

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Think about TESLA cars becoming more and more autonomous each one connected to the TESLA cyberspace to form a virtual fleet that is learning and distributing knowledge back to each TESLA car.
We are part of this evolving ambient and we are interacting with both computerised / robotized objects and with the cyberspace.
More than that. We are a "component" of this ambient, we live in symbiosis with it and soon enough robots will live in symbioses with us.
It will go a step further: IoT will become part of our body and artificial organs will become normal in the third decade of this century.
These embedded devices will become symbiotic with us (nothing new here, we are living in symbioses with billions of bacteria, they actually outnumber our cells!) and will improve our body Communications capabilities with our ambient extending our symbiotic life.
Symbioses, strictly speaking, is about two living beings that are joining forces to achieve something that would not be achievable by just one of them. In more general speaking we can speak of a symbiotic relation when two entities are piggy-back one-another (my wife insists that I am in a symbiotic relation with my computer, since I am always with it…). The broader meaning of symbioses is also the one used by the University of Glasgow in the Symbiotic Autonomous Systems and Robots one of their postgraduate research programs.
Hence, what I represented before, strictly speaking, is not about symbioses, since I have been talking about artefacts interacting with artefacts and artefacts interacting with humans.
Well, in the coming decades, and for sure by 2050, it will get more and more difficult to put a dividing line between life and non-life. Artefacts will be able to become aware, to self repair, to look for “food” an to multiply. May be they will not be “sentient” but this applies to bacteria as well, yet they are typical examples of symbioses.
Symbioses in nature seems just to happen, it is not planned nor it is the result of an agreement between the symbiotic partners. That will be similar, in many cases, in the symbioses among artefacts (and artefacts and humans) once the artefacts will grow to become self adapting (and we already have examples of this, with deep learning technologies, including my GoodNote application that is learning to recongnise my handwriting and it is actually getting better than myself in reading my chicken scratches).
The “autonomous” qualification is important. It does not necessarily mean that each partner can live independently of the other (we cannot live without our symbiotic bacteria), it means that each partner is behaving according to its own “rules”, and the symbiotic relation binds the two autonomies, as it would happen in self driving vehicles in a smart city.
The “system” qualification is also important. The future will see behaviour and “meaning” stemming from complexity and this, in turns, is a side effect of systems. A single IoT will not qualify to become a partner in a symbiotic relation, but a system comprising several IoTs, interconnections, data, and intelligence will.
Hence this initiative stemming from a vision of future built by independent players that will work independently but will leverage on one another giving rise to new life forms.
Welcome to symbiotic autonomous systems!

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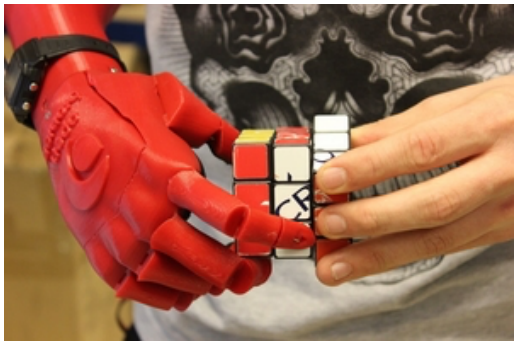
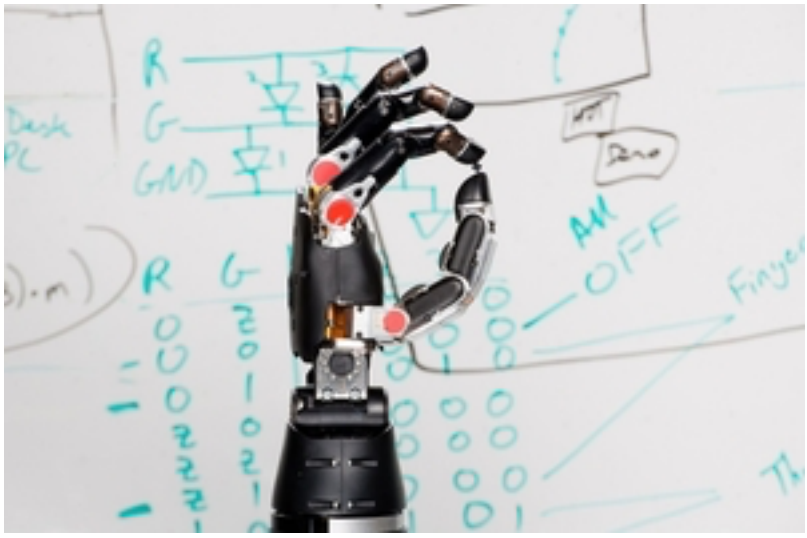
Technologies

- February 23rd, 2017



This prototype of prosthetic hand can be manufactured in less than two days using a 3D-printer. It dramatically cuts cost.
Credit: Open Bionics

In order to establish a symbiotic “relation” two systems need to exchange “information”. The types of information exchange varies a lot, as well as the means supporting the exchange and the actual protocol for the exchange. Furthermore, the exchange can be direct (from one system to the other) or indirect, mediated by another system (or the ambient).
Foxgloves and bumble bees live a sort of symbiotic relation, the former needing the latter for pollination and the latter needing the former as “food”. The random chance of evolution brought these too different species to a symbiotic relationship (even though it is likely that none realizes the importance of the other).
Depending on the systems involved specific interactions are needed. A swarm of robots may interact using direct communications (like Bluetooth) or indirect communications, as it happens in swarms of bees or flock of birds, by following a specific set of rules enforcing/keeping distance from one another. In the case of a robotic swarm this can be achieved, as an example, by proximity sensors or by analyzing images streamed by cameras giving “sight” to each robot. In Nature, as it is the case for autonomous systems today, the communication is indirect.
In a more distant future, and 2050 may be a reasonable thresholds, autonomous systems might have the capability to create and establish a direct communication with other autonomous system and negotiate a joint activity to pursue a goal. This is tough since it basically requires the capacity to create a language to convey a meaning.
In case of human to artefact the communication happens by design. An implant is designed in such a way to become aware of the body situation (for the specifics that matters) and react in consequence. The first artificial pancreas for insulin delivery has been approved by FDC in September 2016 and clinical trials were opened in February 2017.



One of the most advanced prosthetic hand. It connects with the brain taking commands from it and feeding back touch sensations. Credit: John Hopkins University

More sophisticated examples are provided by prosthetics that interact with muscle or nerves to mimic the replace body part functionality. As an example, sensors pick up electrical signals from the arm and use them to control a prosthetic hand. More sophisticated, recent, prosthetics interface with the brain receiving commands and feeding back sensations.
There is even an Open Hand project to stimulate innovation in this area and dramatically decrease prosthetic cost (a prosthetic hand may cost up to 100,000$).
Notice that today, in the case of brain computer interactions, the artefacts is designed to "speak" a certain language (to pick up certain data through sensors and to process them using a logic that is getting more and more sophisticated –signal processing). However a good portion of the communication "meaning" is managed by the brain that, experiencing the behaviour of the artefact in consequence of what the brain does, rearranges itself (learn) to provide the signaling leading to the desired result.
This is an area where research on signal processing, languages and semantics needs to, and likely will, make significant progresses.
The likelihood of having an artefact connected to the brain and immediately "speaking" its language is slim, even on a long timeframe. There might be specific situations, interfaces, where this will become possible, like the interfacing of a camera with the retinal optic nerve or the interfacing of an artificial limb, but in general the interfacing with what a brain "think" is well beyond our observation horizon.
This goes both ways. So do not expect to be able to "download" data on your brain in the next decades. Of course interactions mediated by our senses will become better and better and this will result, often, in seamless communications and hence in stronger symbioses.
At the physical level it may be worth noting that in the coming decade we may move from a communications based on the decoding of electrical fields created by electrons (which is what happens in our electronic artefacts) to the decoding of electrical fields created by protons (protonics). This latter promises to be much more accurate, being able to capture the electrical activity of a single neuron (dendrite and axon). The technology for using protons rather than electrons works in prototypes but is still far in terms of industrial product.

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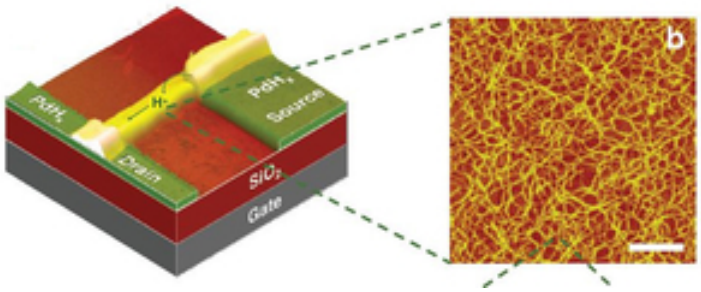


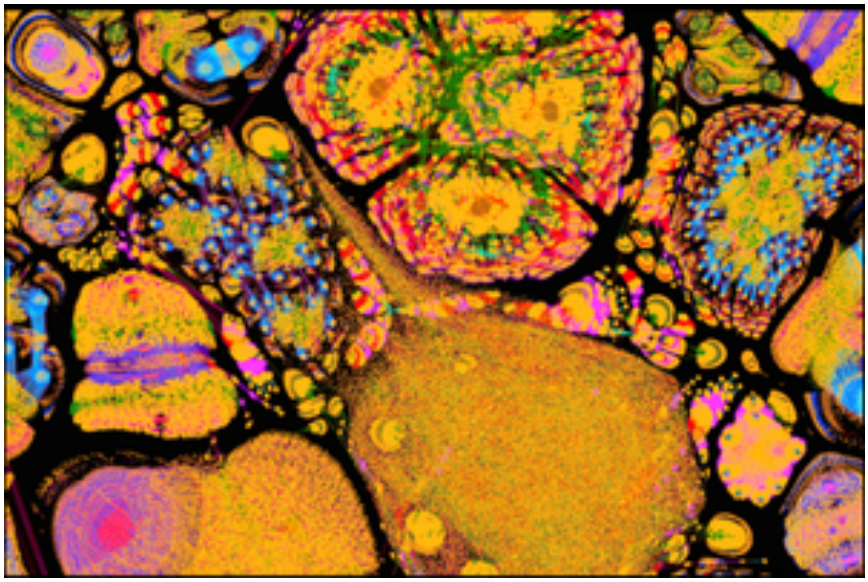
Biocompatible maleic-chitosan nanofibers (yellow) embedded in a field effect transistor. A potential difference applied across source and drain generates a proton current to flow along the maleic chitosan. A potential applied onto the gate modulates the proton current. This modulation occurs by inducing more or fewer protons onto the maleic chitosan via capacitive coupling.

Credit: University of Washington

The first results in these areas go back to the end of the last decade with the creation of a first transistor working on protons, rather than electrons. More recently a further step was taken, still at Washington University, in collaboration with Yale, Pittsburg and Leipzig university, by understanding the mechanism of proton movement in water that is at the bases of electrical communication in living cells.

Going back to artefacts interacting with other artefacts and with the ambient significant work is going on, and will progress, in the area of 3D sensing. Interesting, in this respect is to look at the NASA roadmap on Robotics and Autonomous Systems (area 4.1.1). These sensors will provide more, and more precise, data that can increase the awareness of the artefact(s) and its capability to interpret the “intention” of the other interacting autonomous system (including interaction with a human being). This is a first step in increasing the intelligence of the system itself, of its interaction and of the symbiotic relationship.

Intelligence



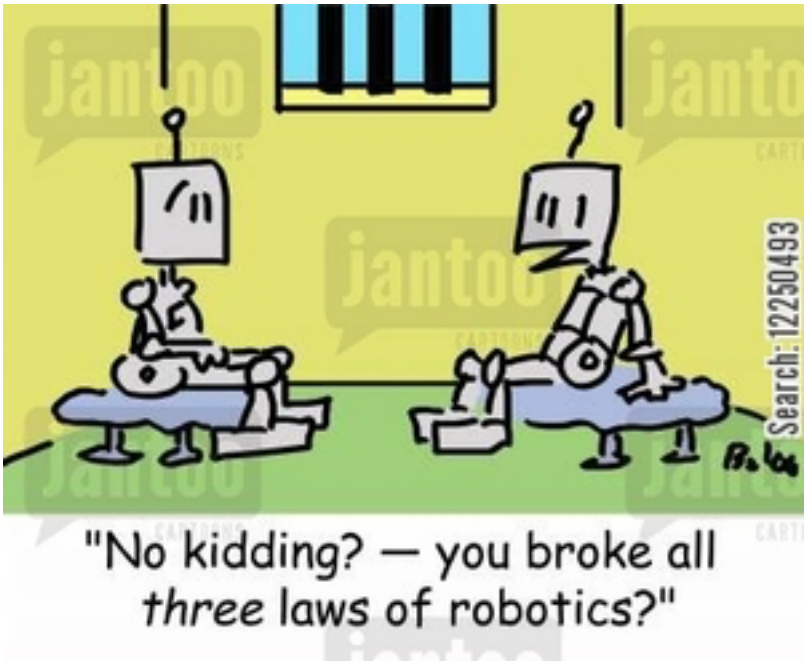
- February 25th, 2017
Ever thought on what may be going on in a computer "brain"? This image is a representation of a full training graph from ResNet-34 created in September 2016 an monitoring the activities of a deep learning process. Graphcore says this looks like an MRI scan and it is one of the first times it had imaged the complete graph for this network. The image shows computationally intensive vertices, with their connections highlighted in blue. Credit: Graphcore

An autonomous system has to be “intelligent” to the extent that is has to work out, by itself a survival strategy in its interaction with the environment. The more interaction is present, and the more articulated (varied) the more intelligence is required. The quest for embedding intelligence in autonomous systems goes back to the creation of robots and as they become more and more flexible, adaptable, they move around and increase the level of interactions with the environment, cooperate with one another the need for higher levels of intelligence grows.
More recently, studies have also emerged on “collective Intelligence” and interestingly they look for inspiration at biological systems.
In the context of symbiotic autonomous systems the overall intelligence is shared among its components and it is interesting to study how the human intelligence can cooperate with the artefacts intelligence. This is a brand new area that goes beyond the human machine interface, although it is related to it. It is also an area where discussion is going on under the banner “augmented humans”. The idea is that a symbioses with a machine, with an autonomous system, can lead to an increase in our human capabilities. This is actually already happening, think about you using the smartphone to get information from the web. It is like your memory is getting a boost. Today we have a visible separation between us and the system “intelligence” (mediated by our smartphone) but this separation will become fuzzier and fuzzier as the interaction between the “I” and the machine becomes seamless. Google glasses were a step in this direction (although they succeeded in very narrow areas) in the sense that they provided a more seamless interface between the person and the machine.
Contact lenses doubling up as screen are just around the corner, and they will bring us a step closer to seamless interaction.
One question is if a smart contact lens can be considered as an autonomous system or if it is just an object. A pair of glasses is clearly an object, but what about a smart pair of glasses like Google’s ones? I would tend to define the Google’s glasses an autonomous system, since it has a sort of own intelligence, it connects to the web and autonomously decide (up to a certain extent) what to look for (and in principle its autonomy will grow over time). In this sense smart contact lenses, once the will grow into intelligent objects that will

become aware of the context and will be able to discriminate between data and information (showing just the latter) may be considered autonomous systems. Anyhow, I used this example also to point out the fuzzy boundaries between what may be called an autonomous system and what cannot be considered an autonomous system.
Intelligence is difficult to define, there are so many nuances, but it is clear that extending our capability in reaching information and processing data is boosting at least the perception of intelligence.

Control/Autonomy

- February 26th, 2017



Asimov's three laws of robotics put a boundary on what robots can do and would ensure that robots make no harm to humans. However there is no way to insure they will be applied (think of military drones...). Credit: Jantoo Cartoons

As engineers we are “control freak”. A good portion of our design goal is to achieve control on the machine. With autonomous systems the engineers are still designing with control in mind, even though this control is in terms of goals to be pursued and boundaries within which the behaviour to achieve the goal is allowed.
In biological systems the idea of control is quite different. A biological system has to operate in an equilibrium zone, its metabolism is what controls at chemical/physical level its operation. You break the metabolic equilibrium and you die. Then the range of behaviours within this equilibrium are bounded by the characteristics of your body: it doesn’t matter how fast you flip your arms, you will not fly.
In our case, however, we eventually got to fly, not by flipping our arms but by building airplanes. Could an autonomous system that in principle cannot fly eventually find a loop around and … fly?
Even though I oversimplify the point this is a crucial one and it is one that is being discussed by scientists in these years. In other words: as we are creating more and more flexible autonomous systems how can we be sure that their autonomy will not lead, eventually, to step outside of boundaries that we have designed? If they are really autonomous they might be able to gain insight on their limitations and find turnaround, just like we did.

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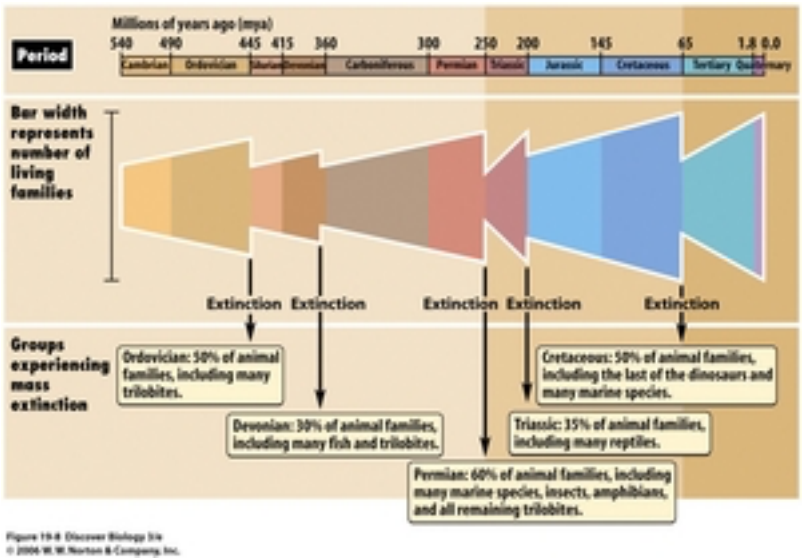
Notice that the issue is not about the possibility to develop an autonomous system that may result in harm, we have plenty of examples, from military drones killing people to self driving cars or autopilots on planes that fail to respond in the right way. It is about the possibility of an autonomous system of pursuing its goal in an harmful way or, even worse, to change its goals in unexpected and unplanned ways that would result in harm.
There have been several concerns expressed by scientists around the world on the intrinsic danger of artificial intelligence, which is very much related to the aspect of control in an autonomous system.
The situation gets even more complicated when we are looking at the interaction among several autonomous systems. To clarify the problem think about yourself. You are a law abiding citizen (most of the time…), you are kind to other people, you love animals… and then you swat a mosquito that bit you. The reasoning is the mosquito bit me so it has to die! (I usually try a pre-emptive strike trying to kill it before I get bitten). I am just giving this trivial example to state that even us, as autonomous sytem do things that can be harmful to other "systems". More than that. There are "unexpected" situations where we are not sure of our reaction, just because they are unexpected, and those reactions may end up to be harmful. Or we might be on the edge, under stress, and our reactions can overstep the boundaries of our normal reactions.
This is a fundamental problem in autonomous systems. Once you provide autonomy you (partly) lose control. And in general the more autonomous a system is the less control can be imposed.

When we come to symbiotic autonomous system the issue becomes even more complex because of the "symbiotic" behaviour. Each system is in close relation with the other and the reaction of one can trigger an amplification in the other that in turns lead to amplified reactions in a potentially dangerous loop. The "bio" part (us) is more unpredictable in its behaviour and this bring unpredictability into the system as a whole.

Self adaptation/Evolution

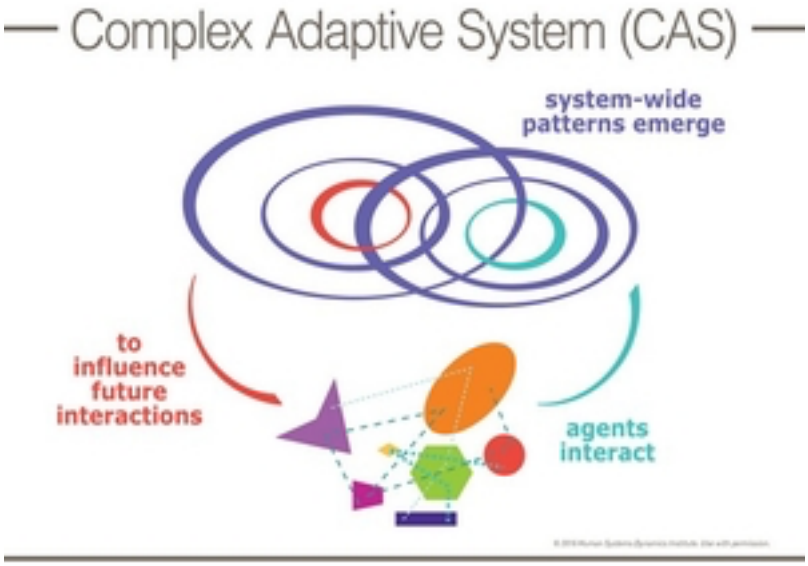
- February 28th, 2017



Scientists have found that there have been 5 big extinctions that led to the disappearance of 90% of the species on the Earth. These were species, plants and animals that failed to adapt to a changing environment. Credit: Discovery Biology by Norton &C. Inc.

Living beings have shown an incredible capacity to adapt to their environment. That went through million of years, thousands and thousands of generations and immense extinctions (see graph). The ones surviving are the ones that manage to adapt to a

changing environment. Autonomous systems have been designed to operate within specific boundaries. As they become more and more powerful they will face broader and broader contexts and will need to adapt to ever more complex changes.
In turns, this requires a growing “understanding” of their environment (bordering on awareness) and the capability to alter the “rules of the game” through which they conform their behaviour. In symbiotic systems this issues is compounded by the presence of two, or more, interactive autonomous systems, one of which can be a biological one. A further demand for adaptability derives from a possible failure in one or more components of the system. This failure should be managed by the system possibly with a degradation of functionality but preserving the overall capabilities. In symbiotic systems there is no “overall” system from the point of view of “reliability” Each of the autonomous systems composing the symbiotic entity is reacting to a failure of the other as a change of context and has to take countermeasures fitting its own goal, not the ones of the overall system. We have examples of this situation in living beings where the symbiotic relationship between ourselves and the bacteria ecosystem in our guts is essential to our wellbeing and there is very little latitude for an adaptation if the bacterial system fails.
This is an issue that needs to be faced in the design of symbiotic autonomous systems, for those part that are under our design control. We usually can design just one or a few components but not all of them. Hence there is the need of understanding what is the range of adaptation of those systems that are not under the designer control to make the best out of what can be controlled.



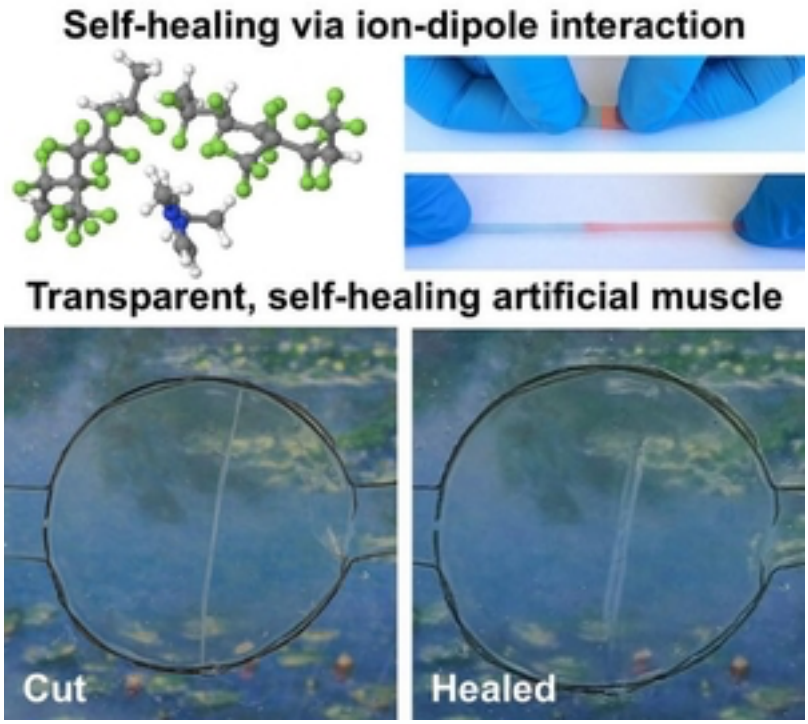
Autonomous systems need to have adaptation capability to balance a changing set of input and resources to their goal. In the figure a representation of various factors involved. Credit: Human Systems Dynamics

Notice that adaptation leads to evolution. A system that has adapted to a new context will respond differently from the system “it used to be”. Over time adaptation pressure leads to the creation of quite different systems. In the future we will be seeing systems that will be able to create new systems, new offsprings, that eventually will take over. We are moving the first steps in this direction with robots that can build better robots to face newer tasks as well as software that can better perform in the solution of problems.
There are already many areas where there is a need to design self-adaptive autonomous systems like in smart cities. Vehicular traffic flow can be seen as an autonomous system of

its own, interacting to pressures that are coming from events attracting people in a certain area. People, as a whole, are themselves an autonomous systems and conditioning them to use one form of transportation or distributing them on several forms of transportation is an overall smart city design issue. These two systems interact one another and they also are directed by a context and by constrains and resource availability. The distribution of shopping malls, parking areas, the coordination of sales campaigns has an impact on these systems. The logistics (both supply and delivery) is also impacting the behaviour of these systems.
A smart city needs to have a monitoring system that visualizes the various autonomous systems composing it and, this is the crucial point for the future, will have to orchestrate them to become a symbiotic system. By 2050 we can expect many ambients, like smart cities, to have become symbiotic systems, eco-biomes.

Anthropogenic Biomes

- March 1st, 2017



Self healing materials have been designed. These will be part of new design approaches aiming at creating self healing structures. Credit: University of California Riverside

We will be living in a world where the boundaries between life and objects will be more difficult to perceive. Of course this may take several decades but we will find ourselves speaking with objects and with the environment more and more, we will take for granted that we can talk to them, they will talk back to us and engage in a meaningful interaction. Echo, Siri are just crude prototypes of what is around the corner. We will expect robotized objects to be the norm and to take the initiative. Notice that a further step in symbiotic autonomous system foresees an awareness of an artificial autonomous system, like a robot, to become aware of its limitation and to seek assistance from another system, including interacting with a human. This can be, of course, a design choice, making sure that an artificial autonomous systems relies on human for help (although it may open a can of worms: whom should the robot trust? How can we trust the human and who becomes accountable?)

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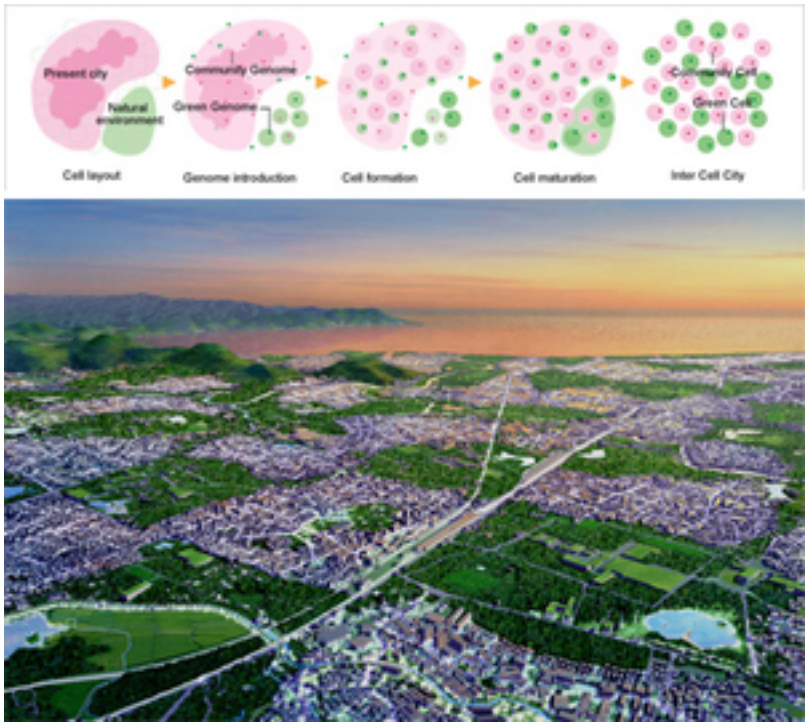
We will also expect them to be able to self repair or at least to take action to ensure a smooth overall operation while the repair-robot comes to rescue and fix the problem. This is no longer science fiction and there are studies to design cities able to self-repair (starting from fixing potholes!).
Programs like landing on Mars will generate a host of innovation in the area of autonomous systems that will create a fall out on the Earth, in our homes and cities. NASA is dedicating significant efforts to improve autonomous systems and create symbiotic autonomous systems in view of the long expeditions to Mars. Those systems will need the capacity to be autonomous and to fix themselves, they will need the capability to cooperate with yet to design systems… basically they will have to adapt and evolve.
Scientists have noticed how evolution has resulted on the creation of biomes on our Planet. These are balanced ecosystems where autonomous systems (living beings including plants, animals and microbes) achieved a dynamic equilibrium with resources. In the last centuries (and accelerating), human civilization has been a major factor in the evolution of biomes by changing their equilibrium leading to anthropogenic biomes (meaning we are shaping the mix of life and its interplay).
This has been done without any conscious design on our part. Actually, we have just recently realized the impact we are having on the Planet and the undesired consequences. Hence we are starting (or at least there is a strong demand for) to take actions leading to a rebalancing (e.g. decreasing CO2 to halt the climate change).
Robotics will be a science of artificial life forms and their interactions will be au pair with today's communities of living beings, first, probably more comparable to ants or bees societies but them upgrading to more "sentient" societies, like human societies. The former will probably become realities in the 2030-2040 (with some proto societies developing sooner) the latter will likely become real and diffuse in the second half of this century.
In the coming decades we will start designing biomes, possibly on the Moon and Mars to start with. This will be part of the symbiotic autonomous systems "science". It will see a cooperation among different technologies, from the ones supporting monitoring to the ones supporting intelligence (these include all ICT nuances), from smart materials to complex systems theory and application.
The "scaring" part is that only few will realize the change. Although these reflections may seem today closer to science fiction than to science (and they are not, we have already today what it takes, it is just not yet affordable…) the change will be gradual. The upcoming 5G is in a way an autonomous systems in its potentiality. I am pretty sure that those potentiality will be exploited in the first years of the first decade leading to a revolution in the communications world that will be similar, actually greater, in its impact to the one that has led to the appearance, and dominance, of the OTT (Over The Top). And 5G also has all it takes to be a planet wide symbiotic autonomous system!

Smart Cities

- March 3rd, 2017



The Inter Cell City is a future city concept based on living organisms. The idea behind the concept is to create sustainable urban systems that integrate natural green spaces with occupied city spaces. Each urban community unit would operate based on citizen initiative, with every one being responsible for its own water, energy and waste management. The cities are designed to be sustainable and to cut down on fossil fuel consumption by 90% within a century. Credit: Web Urbanist

From their inception, cities have been orchestrators of systems. Systems to host people, to produce, distribute and barter goods, to manage and get rid of waste, to provide services (health care, transportation, power/energy, entertainment,…).
As time went by, each of those systems became more performant and smart. An acceleration in their evolution started in the XIX century (with first signs visible in the XVIII century at the dawn of the industrial revolution). In the last decades computerization further accelerated the evolution towards smarter and autonomous systems. It is in these last decades that the issue of overall monitoring and control has come to the fore.
Already today many cities are a clustering of autonomous systems, often under different management domains, partly public and partly private. This is a rapidly growing trend. Autonomous transportation is a reality in several cities, and spreading, but there is very little interaction among them and other autonomous systems in the city. As an example the frequency of “trains” is pre-planned, it is not a dynamic response of the transportation system that, becoming aware of the crowd waiting at the platforms, increases the frequency. Nor is the transportation system signaling its capacity to the outside world to direct people to use that transportation system. There is not, to my knowledge, dynamic route design, to cope with specific increase of demand in certain areas because of events or other factors. All of this needs to be planned in advance.
The advent of autonomous vehicles (self driving trucks, robots, drones, cars) will further reshape the city landscape. These autonomous systems can be orchestrated or, better, can self orchestrate themselves to achieve the overall goal of a smarter city. The technical challenges are huge, but technology progress is also “huge”.
New design, and control approaches are needed. Involvement of municipalities to define the deployment roadmaps and the constrains is essential. Economic sustainability and share of value are also fundamental aspects. The trend towards a interplay of public and

private investment further complicate the overall architecture of autonomous systems in a city.
The smart city becomes a living, ever changing, organism (of which citizens are not just “inhabitants and users” of its services but an autonomous system on their own). This is a perfect example of symbiotic autonomous systems, with various hierarchies and interactions, diversity of goals and cooperation needs plus competition forces.

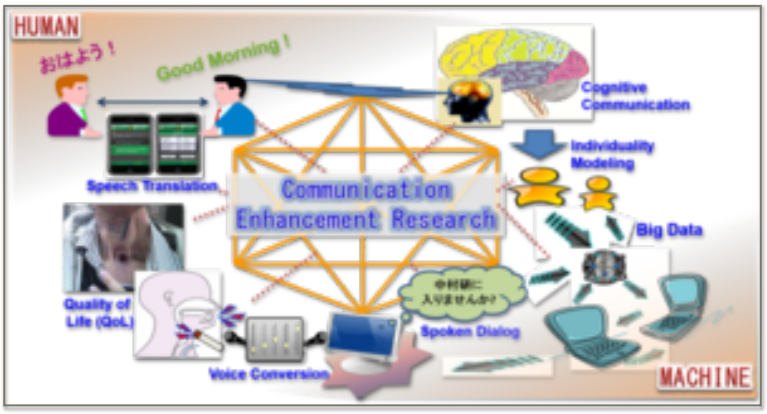
Industry
- March 4th, 2017

The evolution of manufacturing is towards a more and more personalised production, just like it used to be 200 years ago, but now benefitting from the economy of scale thanks to robotised production, and in the coming decades to Industry 4.0. Credit: Yoram Koren, "The Global Manufacturing Revolution"

Industry has evolved, particularly manufacturing, by leaps and bounds. Availability of tools first (Oldowan industry goes back 1.7Myears ago), their improvement through steam power first (XVIII century) and then electricity (XX century), then, more recently, computers (1970ies) and robots (1980ies). Robotics is now a growing transformation force in Industry, it was 3.9 billion $ (worldwide) in 2000, it is now over 12 billion $ and it is expected to grow to 24.4 by 2025. Robots will be transforming not just the industry in the coming decades but the whole value chain from supply to delivery and usage.
Robots have become more and more flexible and are starting to become aware and learn from the environment, to cooperate in a much more flexible way with other robots and with humans. Baxter was probably the first robot designed to be a co-worker of blue collars, it can be taught by a worker and being aware of what is going on around him takes care not to harm anybody. Even its “looks” have been designed to make it a team player.
Robots have several effects on the industry, on the market and on the society. I leave the latter to the last post in this series. Let’s consider the first two.
Robotized industry has a cost that is basically independent on the location (no labour cost differences that led in the past to offshoring manufacturing) and robots can now be connected to the supply and delivery chains much more effectively than in the past. This is a strong drive to the improvement of the whole value chain and a first step towards Industry 4.0. Both factors enable an economically affordable Regionalization (see figure) with smaller, distributed, factories that keep the scaling advantage through more effective supply chain and sharing of data (this is a crucial component in Industry 4.0). The data

sharing among suppliers, manufacturing plants, delivery chains, retailers *and* users changes the rules of the game and creates a *symbioses* among the various autonomous systems involved in the value chain that will be more and more participating to an ecosystem (often referred to as circular economy) rather than be part of a fixed chain regulated by contracts between supplier and client.
On the market side the flexibility offered by robots shift the production paradigm from the mass customisation to the product personalisation. This is reinforced by the growing softwarization of products that injects both flexibility in features offered by the product and the possibility to create a relation between the user and the manufacturer plus additional relation of the user with third parties offering enhancement. Furthermore this is leading to a transformation of the product into a service. Important to notice the shift that has taken place from a demand that was greater than the supply (that in turns created a steady state of demand) typical of an industry that was not able to satisfy all the demand (after the second world war in the fifties and sixties) to a situation of a supply that far exceed demand (just think about the number of apps available). Clearly this shift increases competition and drive prices down. The decreases of prices, in turns, displaces the big companies and opens up the market to small ones that operate in a symbiotic relation. Here again we see an economic drive that strenghten the evolution towards symbiotic autonomous systems.

Augmented Humans
- March 6th, 2017



Toward enhancement of human communication abilities, the AHC Laboratory is promoting the research and education on a wide variety of technologies that support communications between human-to-human and human-to-computer, including multilingual speech translation, dialog system, communication quality of life (QoL), voice conversion, silent speech interface, user-adaptive speech recognition/synthesis, and brain analysis related human communication. Notice how this is an example of a symbiotic relationship between humans, Internet and devices. Credit: Nara Institute of Science and Technology

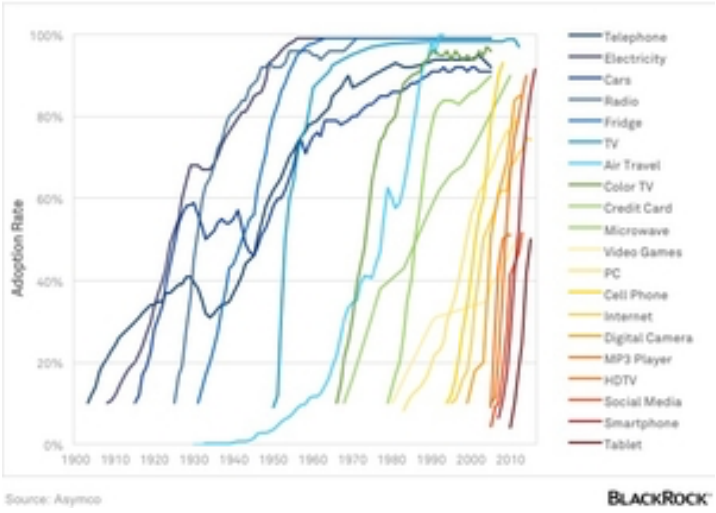
From eons we have been augmenting our capability using tools, pebble first and then on and on with ever more complex and effective ones. Contact lenses are examples of augmentation, as a cellphone. Robotic exoskeletons are now moving their first steps (no pun intended) out of the lab to help in military field and in the medical one. In the former they are intended to augment a soldier strength in carrying loads, in the latter to enable paralysed people to walk around.
We can expect the former application (military) to drift into a much broader, civil, environment, as it happened to other technologies, born to target military applications and

now widespread in the consumer market (just think about the GPS that we are now taking as a given…).
Prosthetics are also making amazing progresses and are now moving towards a in a symbiotic relation with the person using them in the sense that they understand what the person is expecting from them and provide the person with sensations they "feel". Besides the newest prosthetics can learn from the relationship with the person and become better and better in integrating their functionalities with the person (see clip). They are becoming so good to go beyond restoring functionality. They can result in an augmented human.
However, I would not consider any of the above example as fitting in the category of symbiotic autonomous systems, mostly because they are not "autonomous".
I would expect to see more and more cases of human augmentation through technology in the coming years but I would say that we will have to way at least a decade before seeing examples of symbiotic autonomous systems augmenting humans.
Looking ahead, however, I can see an environment that is becoming so aware, filled with robot-objects and able to interact seamlessly with us that we can consider this as an example of real symbiotic autonomous systems that result in human augmentation. In this environment the line dividing prosthetics from tools will become fuzzier and fuzzier. Think about robots roaming a warehouse that can be worn by a worker to becoming a symbiotic autonomous system having the strength of a robot and the smartness of a blue collar worker…or exoskeleton fitting construction workers to make their job safer and more productive.
Similarly, transportation in a city may slowly become a system in symbioses with humans, a building may enter into a symbiotic relation with people inhabiting it and the concept of home may actually be tied to this symbiotic relationship.
It is not just the ambient that is becoming aware and as such can interact more seamlessly with us. It is also an increase in our sensorial capability, brought forward by sensors enhancement implant, that will change our relations with the environment. Some animals can perceive infrared signals, other can perceive variations in the electrical field. We have created sensors that are able to "see" in the infrared (like infrared cameras) and sensors that can detect electromagnetic fields (your cellphone is an obvious example). These sensors in the coming decades will become implantable in our body and will connect to the brain extending our sensorial capabilities. We may become aware of people moving in the other room because as they move the alter the electromagnetic field in the environment (sharks, rays, dolphins and bees can detect electromagnetic fields). We will be able to see that someone was in a room before we arrived by looking at the infrared halo left by its presence… All in all we will evolve our relationship with the ambient we live in.
I already noticed the kind of symbiotic relationship we are having with our smartphone. This is going to grow further moving the symbiotic relationship from our smartphone to the "webspace" with this latter learning more and more about us and reshaping its behaviour accordingly. Also notice that we will have an influence, although a tiny one, in the overall behaviour of the web since we are part of its context and the web is evolving taking the context into account.
As you can see the evolution of symbiotic autonomous systems may give a boost to the augmentation of humans in a way that wasn't foreseen just few years ago when Human Augmentation was imagined through embedded chips to enhance human senses and processing capability.

Ethical Challenges
- March 7th, 2017

Ethical issues are not clearcut, there are grey along with whites and blacks and not everybody agrees on what is right and what is wrong. This will be true in the future as well with the additional complexity that in some areas we do not have come to an answer yet, since we are basically lacking the capability to formulate the question.
Image credit: Fraud Magazine

The advance of technology is bringing to the fore new ethical issues. It is nothing new, in a way. Ethical issues flanked technology evolution through the centuries. However, now technology evolution, and its adoption, is way faster than it used to be and ethical challenges pop up more frequently. Since ethics is strongly tied into Society culture (and habits) and culture has greater latency than technology in these last decades we are less prepared than in the past to face new ethical issues.
There are clearly many aspects of ethical issues related to symbiotic autonomous systems and they will be part of the studies planned in the IEEE-FDC Initiative. Here I would like to point out two of them, one related to the augmentation of humans and the other to the "meta systems" resulting from the symbiotic relationship among autonomous systems. These aspects are also addressed in the context of the EU Future Emerging Technologies (FET) CSA Observe discussing human-machine symbioses.
Augmenting humans is opening up a Pandora box. We are not aware of the full implications of augmenting humans, at the same time we have technology that makes this possible and a range of applications (needs) that makes this desirable; we are also seeing several undesirable side effects and we feel there may be many more we are not aware of.



The speed of technology adoption has increased significantly.
Credit: Black Rock

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Let's take a positive attitude: augmented humans is leading to an increase in human performance with no nasty consequence (like an augmented human taking advantage of his augmentation to harm others). Even with this unrealistic assumption we are facing the issue of managing the gap between the have and the have-not. Clearly it is nothing new. We had, and we have, this gap in many instances: those having a better education are having the upper hand on those who are less "literate", more opportunities of getting better jobs, better paid, fostering more educated children with privileged start in life, thus farther widening the gap. Those having access to knowledge (to the web) to funds, to health care, to food and clean water. Think about it and you will come up with a long list of inequalities in today's world and Joan Baez song "There but for fortune" will come to mind.
Human augmentation in the coming decades will provide further steam to already existing inequalities but I feel that, since it is not really new, we have the cultural "tools" to confront them.
Of course it is not a given that human augmentation will not be used to harm not-augmented fellows. Again, this is nothing new (unfortunately). The invention of weapons goes back to the first humans, it just got potentially worse, given their increased effectiveness provided by technology. Killing a man with a club or with a drone achieves the same end result but the second widens the possibility to reach a target and de-personalise the action thus making it more difficult to control and giving rise to novel ethical questions. Yet, as before, not being anything new we have the cultural tool to tackle this (not to solve it, I am afraid, since we haven't been able to solve it through our history).
Augmenting humans in their sensing capabilities, particularly through invisible technology, however, is something brand new and it may disrupt the very fabric of Society as we know it.
We all remember the upheaval generated by Google Glass for their potential violation of privacy. Think about a symbiotic relation of an augmented human with the environment resulting from an in depth knowledge of what is going on, including details on the other persons in that environment. We can have the situation in which only one person is augmented (without the other persons being aware of that). The privacy issue is clearly at the forefront, besides potential unfair advantages for that person. We can also imagine a situation where all people in that ambient are augmented and aware of the others. This is breaking down the fabric of interpersonal relation, as we have been used from our birth and even more important from the Darwinian selection. Privacy is more than protecting our own information, it is about making possible social relations. Technology that can bring information about everybody, in real time, as we are interacting, that can dig into our emotions and unveil them is disrupting our social fabric. We are on the brink of continuous connection to the web to enable services like real time translation. Microphone and loudspeaker (or cochlear implants) in our ear can connect to the web sending the voice of the person talking to us in Japanese and bring back his voice in English. But other services in the web can give us hints on his emotion, can detect if he is truthful, can augment his talk with information on "why" he is telling us such a thing, can provide advice on how to respond… A personal assistant in symbioses with us, knowing what our goal is, can even morph our responses to maximise the chance of achieving our goal.
Should we be aware of that, should be control in real time the personal assistant or the

symbioses is so strong, and effective, that we relinquish the decision to it. Who is going to be responsible for the outcome. Suppose that what our personal assistant said is bringing us what we want but in the process is harming the other person (psychologically or even physically), who should take the blame?
This clearly is just an example to make the point. It is also leading me into the discussion of the ethical issues related to a symbiotic autonomous system.
Because of the "autonomous" characteristics each system in the symbiotic relation makes its (his) choices to the best of its knowledge to satisfy its needs and goals). This is the case of human relationships. Here, in a way, we live in societies that are the result of symbiotic interactions among autonomous systems (*no man is an island, … and therefore never send to know for whom the bells tolls; it tolls for thee*) but we are sharing the same framework (and when we are not, as it is the case when different cultures meet/clash we may run into problems, ethical problems since deciding what's right or wrong gets difficult).
In case of relationship among "augmented" humans and "plain" humans the symbiotic relationship between a human and his augmenting system may create unprecedented ethical issues. Who is going to be responsible for the action of the augmented human, since his actions are strongly influenced by his augmentation? Notice that there may be a wide range of situations with fuzzy boundaries. Just for the sake of discussion, what about a person with an exoskeleton that he is wearing because of his job as mason who kills a coworker by choking him with super human force because the latter said something that enraged him and he thought about killing him. His exoskeleton decoded the "killing wish" and acted on it, actually killing the other person. Without the exoskeleton that thought would have remained just that, a thought because that persons wanted to kill the other one but would have never harmed him. Would thinking make us guilty? If that were the case just think how many crimes we had committed in the privacy of our "brain"…
Would the responsibility be upon who designed the exoskeleton? What if the designer had actually constrained the exoskeleton not to do any harm and as we wear it we are witness to a potential crime we could stop if we throw a punch to a criminal and the exoskeleton is refusing to do it so that we are stuck and the crime takes place? Again, these are just –naïve- examples I am using to make the point.
We are simply not prepared for this. Ethical challenges ahead are many, diverse, and very likely unexpected…

A few ethical challenges starting to confront the world as result of technology evolution. These will become crucial in the coming decades.
Credit: John J. Reilly Centre

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The Reilly Institute is releasing every year a list of ethical challenges resulting from technology evolution. Here is a glimpse on the most recent ones:

- CRISPR/Cas9 gene editing technology, clearly fraught with issues
- Rapid whole genomic diagnoses applied to newborn
- Talking Barbie, privacy violation dangers versus safety and improved care
- Digital labour rights, interaction with anonymous workers and anonymous bosses
- Head transplant, the sense of identity
- Disappearing drones, delivering goods from “nowhere” and then flying away
- Artificial wombs, taking motherhood to the next step
- Bone conduction for marketing, providing direct access to the customers brain
- Exoskeleton for the elderly, pushing labor life postponing retirement
- Brain hacking, resulting from wearable EEG
- Robotic clouds, the rise of autonomous systems interacting with one another
- NeuV’s Emotion Engine, where your car detects your emotion walking a thin line between safety and privacy
- Self healing body, tiny robots swarming in the body through blood vessels monitoring physiological processes

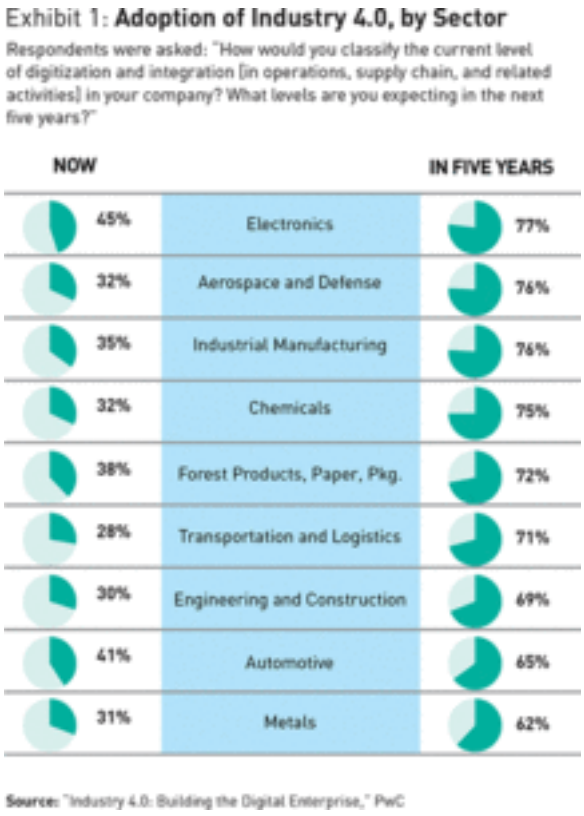
Economic Framework

- March 9th, 2017

When you hold an iPhone in your hand, do you realise that it is the result of assembling parts coming from all over the world? In this map the roads followed by the various materials and components making up an iPhone 5. You can get sourcing maps of many more products at : Sourcemap.org

We have seen a transformation over the last 30 years from an economy dominated by demand to the one dominated by supply. Symbiotic autonomous systems are likely to stay in the same path of increasing the supply against a demand that is growing at a slower pace.
Clearly different market sectors show different unbalances, with few geographical areas and market sectors showing a demand that exceeds supply but in general, and in particular in the technology area, this is the case. Even though the Moore’s law has come to an end the variety of technologies available will continue to create an oversupply. There are some predicting an energy gap between supply and demand but I don’t believe that is going to be the case, given the advance in power production. In the last decade we have seen a decrease in price of oil, an indicator of oversupply, and although the expectation is for an increase in energy demand (40% increase by 2040) the availability of renewable

should provide more than enough supply at global level, although the price of oil is expected to increase by 2040 to the peak level experienced in the past decade (this estimate may actually be wrong if electrical vehicle will replace fossil fuel ones). Symbiotic autonomous systems will clearly create a demand for innovation and for technology advance but they will keep evolving based on technology that is available, that is, I do not see a crises looming ahead hampering their evolution because we are lacking needed technology.
The symbioses is likely to provide increasing value thus, in a way, increasing the supply side. Again, there will be niches where demand will exceed supply (particularly in the coming two decades for human machine symbioses for human augmentation widening the gap between the have and have-not).
Autonomous systems, in particular robots, are already having an economic impact in levelling the cost of production across the world. After decades of offshoring the production to places with lower labour cost we are starting to see the first signs of in-shoring. Thanks to their flexibility, boosted by deep learning (for perception and situational awareness) and machine learning algorithms, they can have a much longer life cycle, hence their cost can be partitioned over longer period of production cycles. Increased flexibility in machine to machine interaction exploiting artificial intelligence makes it possible to sustain Industry 4.0 paradigm of advanced cooperation and distributed manufacturing. In turns this can lead to business disruptions since it favors a reshuffling of the whole value chain.



Penetration of Industry 4.0 in different market segment.
Credit: PwC

The symbiotic relation may also lead to a revisitation of business models (in particular in relation to energy exchange among autonomous systems and accountability aspects) but it is still to early to grasp in its full economical implications.

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Finally, the adoption of symbiotic autonomous systems is likely to take place in different market sectors at different times in different Countries. In many cases, particularly those of huge manufacturing plants (like Foxconn) is going to be very capital intensive and can be sustained only through high production volumes. Hence the deployment of autonomous systems may happen first in big companies that can afford them and in turns will strengthen their market position thanks to the greater resulting efficiency. A different scenario, more in line with the disruption of Industry 4.0, may result from the adoption on a much smaller scale of autonomous systems for limited production in specific markets that over time will loosely aggregate with others achieving scale and chewing on the market quota of big companies. This will require a significant re-thinking of the value chains and of the logistic glue among players.

Roadmap
- March 10th, 2017

An interesting map relating technologies to their impact on the business. Notice that advanced robotics (that is on the path of symbiotic autonomous systems) are expected to be emerging technologies in 2019 and beyond, as well as smart machines and brain computer interfaces and all together they are placed under the area of transformational, meaning that they will result in a disruption from the present way of doing business. Cognitive computing is placed at the edge between high impact and transformational and 5G is considered as having a high impact. Credit: Jonathan Aufray

We already have autonomous systems and we even have a few examples of symbiotic autonomous systems but it is like the brothers Wright saying they had a plane. Yes, indeed, that is what they flew, but it would be difficult to compare that plane with today's A380 and even more difficult to compare that with today's civil aviation (infrastructure, planes, market, economics, regulatory environment).
That first plane compares pretty well to the point we are today in terms of symbiotic autonomous systems.
In a way the technology that we have today provides the basic components for future symbiotic autonomous systems, but again, it is like saying that the Wright plane had wings, rudder and engine as today's planes and a stretch of land it used to take off and land.
We have technology that can let a robot harvest energy from plants (using the photosyntheses processes of algae, as an example), technology that provide vision and understanding to a robot (the forecasted market value in this area is over 5B$ by 2020), technology to interface robots and living being, including BCI (whose market value is placed at over 1.2 B$ by 2024), technology for smart autonomous robots (expected to exceed 7.5B$ market value by 2020), and technology for meta-systems of autonomous systems (swarms).
Looking at Gartner 2016 emerging technology hype curve we find in the Innovation Trigger area general purpose machine intelligence, an important component of future autonomous systems, with a predicted landing time (time to hit the market) over 10 years. In the same range is Human augmentation, neuromorphic hardware and brain computer interfaces.

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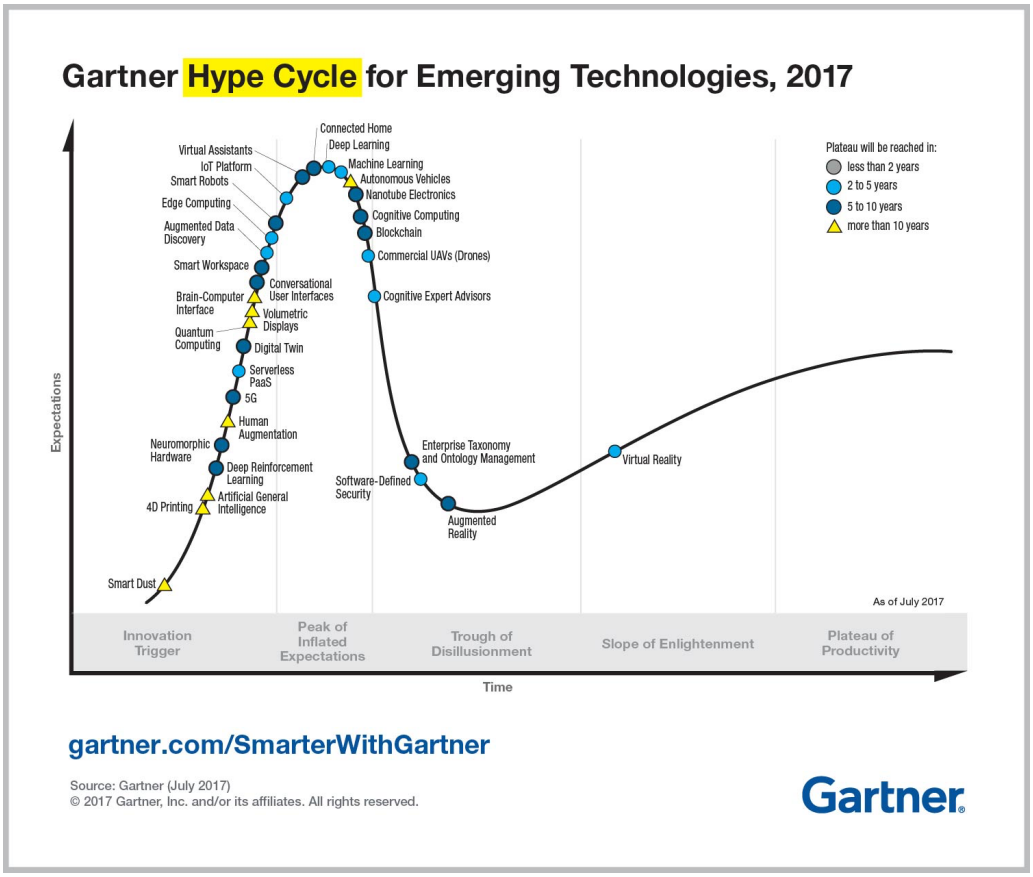
Closer in time we have the commercial unmanned aerial vehicles (UAV-drones) with a time to market between 5 and 10 years along with smart robots.
Autonomous vehicles are also considered with a time to market over 10 years but they are placed on the peak of inflated expectations.
I am basically in agreement with these expectations, although, as I said, one could claim, as an example, that self driving cars are already a reality.



Gartner Emerging Technologies Hypecurve 2017. Credit: Gartner Group

The transition from something that is making the news and something that is accepted as "normal" to the point of no longer making news is over 10 years in this area. Hence, precisely because we have headlines anticipating the first autonomous taxi in Dubai in July 2017 we can bet that we will have those taxis as common as the ones clogged in the traffic today in the fourth decade of this century, not before.

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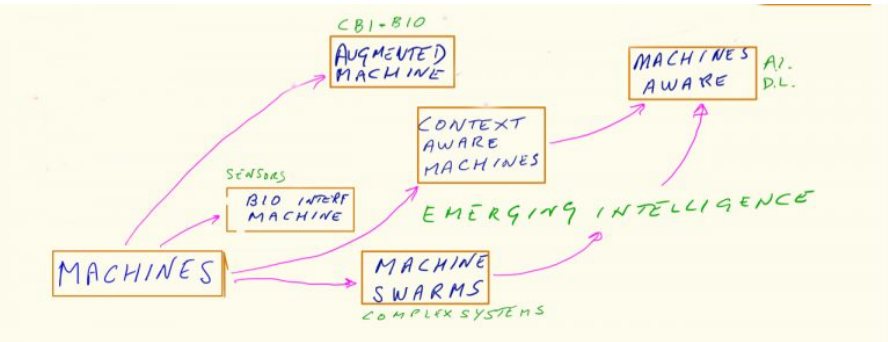
The evolution of … Machines

- October 27th, 2017



A rough sketch of machine evolution towards awareness. Credit: FDC SAS Initiative

The Symbiotic Autonomous Systems Initiative has completed its first WhitePaper (it will become available through the SAS website by the middle of November once the cleaning up is complete). It is an interesting document and in its concluding remarks it shows the possible, expected, evolution of machines towards awareness over the next decades (the horizon has been set to 2050 but quite a bit is happening today and a lot will be accomplished by the next decade).

Clearly it is difficult, may be even unreasonable, to make prediction over such a long span, however it is not about wild guessing, rather it is about looking at what technology offers today, where research efforts are around the world, what the market demands and the social drives that will make the evolution a reality.
IEEE is aware of most of the technological research efforts and this global visibility makes prediction in the area of symbiotic autonomous systems an exercise in rationality.
So, let's take a look at this sketchy roadmap.
Machines have become smarter and smarter thanks to an ever increasing processing capability, access to large storage for local and remote data, sensors and communications. We have cars that have shown the ability to drive autonomously, although they are still rare and there are regulatory hurdles in the way (not to mention their affordability in terms of cost). The basic technology for self driving cars exists today, it is just not completely practical nor affordable. But it is just a matter of time, no longer of "possibility".
This self driving cars are "context aware", that is they "understand" in an operational sense what they need to do given the context around them. They can identify a person walking on the sidewalk and evaluate the probability that he may cross the road all of a sudden, as well as evaluate distance and velocity of an incoming car to evaluate the safety of overtaking the preceding car.
In the next decade this context awareness will become more and more generalised and, most important, affordable. Notice that it is not just cars. Robot vacuum cleaners have already some sort of understanding of their context and this understanding will grow to include something like: "uhm, there is a person watching a tv show so it is better to wait for cleaning not to disturb him, or the lunch is just finished so it may be a good time to vacuum the kitchen…"
A significant contribution to the evolution towards context aware machines will come from military applications, as it happened in the past. So it is not difficult to forecast that machines will become context aware, wherever and whenever it makes sense.

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We are also noticing, today, that a number of devices are interfacing directly with us, mostly in the medical space, getting information on our status and acting in consequence. Insulin pumps are becoming smarter providing the exact dose by measuring the glucose directly in the body (smart contact lenses are available in the labs of Google and Samsung, and most likely in other research labs to detect the sugar level in the tears and communicate it to a chip that can take action delivering the required amount of insulin). In the next decade this devices are likely to become proactive, analysing the behaviour, guessing the expected one and injecting insulin as soon as it makes sense without waiting for reaching a thresholds. Bio interfaced machines will allow them to connect to nerve termination, to the metabolic system, to muscles, to our senses and even directly to the brain. Hence an evolution that we can expect is towards augmented machines, augmented through the information provided by a living being, including, of course, ourselves. Again we are seeing the first occurrences, although crude, of augmented machines in robots, like Baxter, that learn by watching people, or in sensors leveraging on living cells to detect specific molecules. Of course tools are “augmented” by people using them but in this case we are not talking about autonomous system. A hammer cannot do anything without a hand (and a brain behind the hand) operating it. A self driving car, on the contrary can operate autonomously but it can also benefit from a standing by driver. In the coming decade the situation where people can “lend” their brain to a machine to augment its intelligence will become more and more common.

In order to become “intelligent” a machine needs to pass a certain thresholds of complexity, similarly to living things. A bacteria is fully operational and in a way smart, but that smartness is the consequence of millions of evolution steps, of generations that finely tuned its response to the environment. To get a local intelligence you need to have much higher complexity. Not all machines will reach this thresholds but there will be some that would aggregate into complex systems and intelligence will result, emerge, out of the whole system. These machine swarms are becoming possible through a connectivity fabric that connects thousands, millions of them, like a anthill makes intelligence emerge out of thousands of ants, individually incapable of showing intelligence.

Both machine swarms and context aware machines will likely take a further step becoming machine aware. In a way complex living things are an example of this evolution. One can see our human body as a cell swarm, hundreds of billions of cells, connected to a context aware machine, the brain, that all together result in a being that is “aware”. Would these machines be “sentient”, in the sense of being aware that they are aware? Opinions differ and no stand has been taken by the SAS White Paper.

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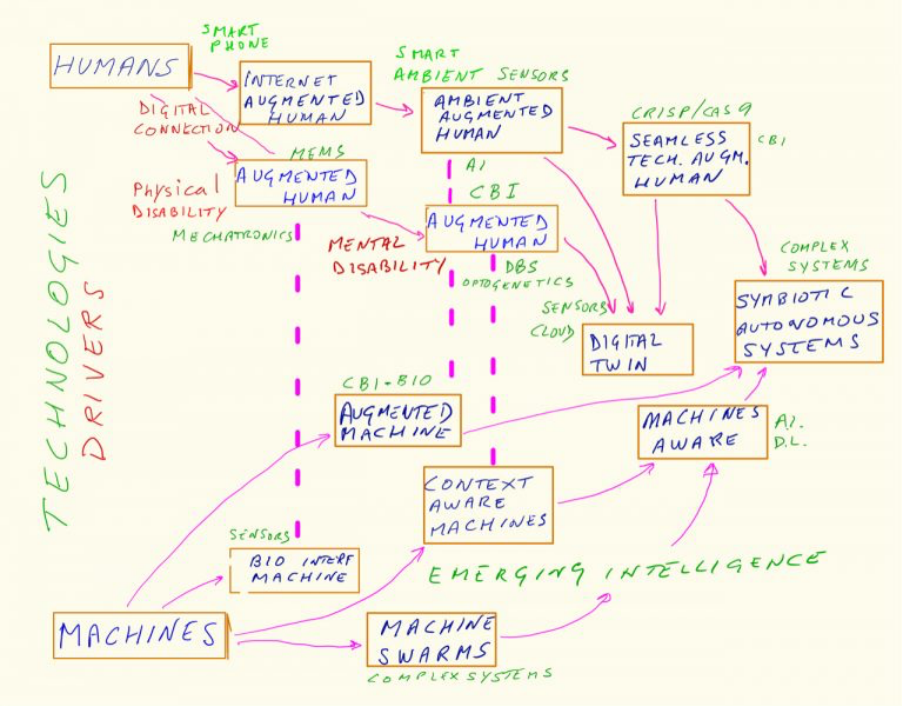
The convergence of Humans and Machines

- October 29th, 2017

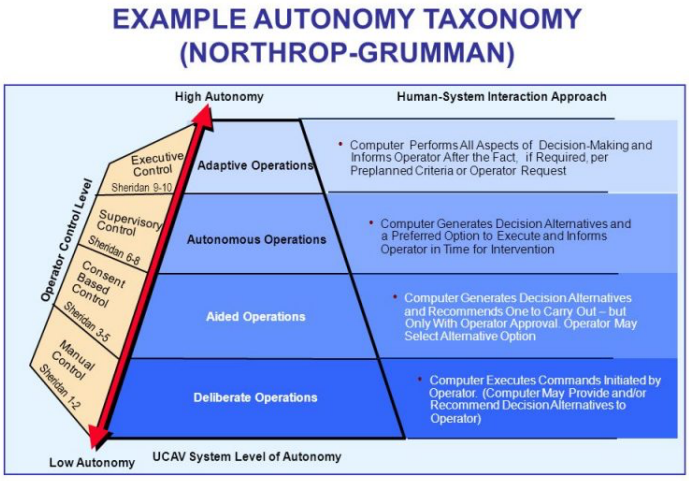


The full sketch of the convergence and eventual merger of Humans and Machines.
Credit: FDC SAS Initiative

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 super organism, a new species, as envisaged by the transhumanism movement.
The FDC SAS Initiative is not taking any stand on this, simply take 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 super organism and issues of accountability arises. To what extent the super organism is actually recognised 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 behaviour may not be a sum of behaviours exhibited by each component, in which case one could direct the

accountability to a specific part, rather it might be an emergent behaviour where the contribution of each part is no longer meaningful.
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, in the 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 reason 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 usage.

Autonomous Systems in 2018
- November 27th, 2017



The four level of autonomy described back in 2008 by Robert Finkelstein. In 2018 we will have a number of autonomous systems, including vacuum cleaners, that will reach stage 4, adaptive operation. AI has been the crucial enabler in this evolution and will continue to do so in the coming years. Image Credit: Finkelstein – University of Maryland

The FDC Symbiotic Autonomous Systems Initiative stems from the growing presence of autonomous systems in our daily life, from autonomous vacuum cleaners to drones, from self driving cars to robots in manufacturing.
The evolution in this area will be both “invisible” and “spectacular”! There will be a smooth, almost imperceptible evolution, like cars increasing in their autonomous capabilities, self parking, lane cruising, breaking assistance…, and all of a sudden we will find ourselves in a world where many objects have become self-aware and behaves accordingly.
2018 will see significant progress in the creation of a management framework for autonomous systems (the recent agreement between Uber and NASA is a clear step in that direction), something that might go unnoticed to most but that will set the foundation for a fast and massive deployment of autonomous systems. In Dubai we can expect the first taxi-drone that will generate a lot of “wow!” but won’t change the traffic situation in Dubai, no more than the Wright brothers did at Kitty Hawks in 1903. But, of course, our world today is rooted on what happened on that beach. Interesting to notice the parallel between that beach and the sands surrounding Dubai, making the operation of a taxi-drone way safer than in L.A. (where there would be an interest in shuffling tens of thousands of people every day using drones).
Remaining in the autonomous vehicle space and in the Emirates, 2018 is likely to see a step towards the construction of the first commercial Hyper-loop transportation system. Technology is here (mostly), it just needs to become affordable.
After drones having become a “standard” photographic equipment (several wedding photographers, sports aficionados use drones to capture the moment from above) we will see in 2018 smart tripods, equipped with AI, tracking objects, like you(!), to automatically create video clips.
Yet another example of the pervasiveness of autonomous systems that will boom in 2018. It is not just about Symbiotic Autonomous Systems, it is also about creating the skills and mindset for their design, manufacturing and management. This requires education and this is what EIT Digital will start doing in 2018 with their new Master Course on Autonomous Systems and the Industrial Doctoral School on Digital Industry based in Milan and Helsinki.

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Autonomous systems on the rise

- September 9th, 2017

The AI market is definitely growing and autonomous systems are expected to take a big share of it, surpassing AI value in Expert Systems. Credit: BCC Research, Wellesley Ma, US

Artificial Intelligence is at the core of autonomous systems. It will permeate them in different degrees, the more autonomous they are and the more challenging the environment they will be operating in the more AI will be required.
BCC Research is foreseen the application of AI in Autonomous Systems will overtake in terms of market value the “classic” application of AI, that is in Expert Systems (see graphic). This is interesting because it signals a shift towards the embedding of AI (it has already started, as an example our digital cameras embed some AI to make decision on the best exposure, to recognise faces…) and embedding leads to the disappearance of that technology from our perception, making it a mature technology.
At the same time this loss of perception and the presence of autonomous systems in our everyday life (meaning, as well, our increasing dependence on them along with our taking them for granted) creates new issues:

- Can we really trust these systems? Would a trivial vacuum cleaner become a potential spy having the intelligence to be one?
- Even if we trust these systems, isn’t there a possibility of malicious hacking that might transform them without us being aware of what is happening?
- In case of symbiosis, particularly one involving us, would the intelligence of an autonomous system in symbiotic relationship alter the overall balance (without us becoming aware of it). What if we are coming to rely on a wearable system to connect us to information seamlessly, like an intelligent contact lens or in the future a direct BCI connection linking our brain to the web, and for some reason this symbiotic component is hijacked or just takes the upper hand in the decision making process?
- What about the advantage that owning such symbiotic relation will bring to some and not to the have nots? Is embedded AI going to create a wide gap among those who can benefit from it and those who don’t?
- Will enterprise favour hiring people having augmented intelligence, would some require augmentation as part of the job as today they require us to use a computer?

The list of questions is getting longer and longer as we are starting to walk this new path. Formulating these questions and addressing them is an integral part of the FDC Symbiotic Autonomous Systems Initiative.

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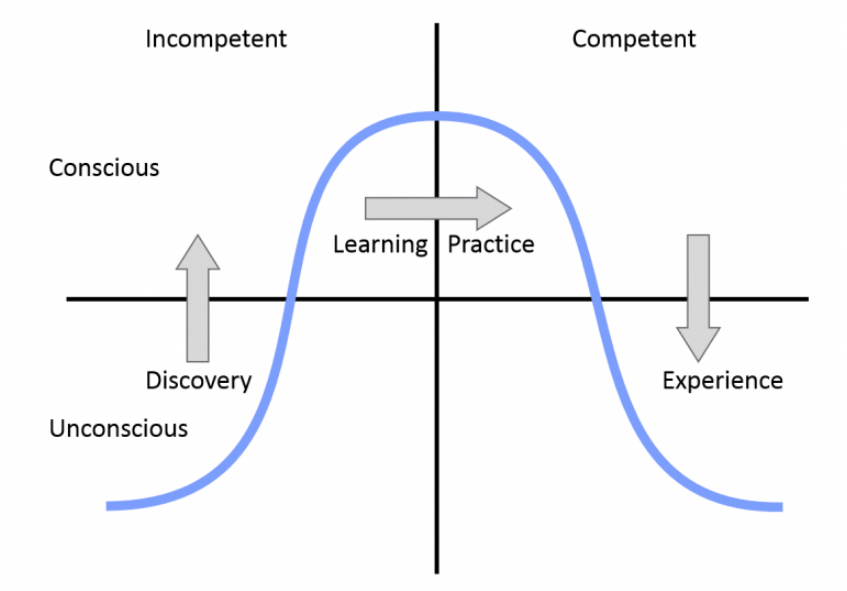
Big-C versus Little-C: the debate on consciousness is still on
- January 4th, 2018



An interesting graphic, used in discussing management strategies, that can also be used to discuss the various facets of consciousness. In order to become conscious one has to discover the external world. By learning and practicing one creates internal models that are applied in an unconscious way, once fully internalised. Credit: Thought Ensemble

Consciousness is a slippery, and fuzzy, concept. It is a bit like the concept of time as St. Augustine remarked long time ago: “What then is time? If no one asks me, I know what it is. If I wish to explain it to him who asks, I do not know.”
Just look at the graphic. It takes “discovery” (sensors) to bring reality to our perception, to become conscious. Yet, the more we learn about that specific reality the more it tends to become “a given” and it fades away from our perception. Think about roads. How many times do you stop on your track as you step out of your home every morning to say: “Hey, look, there is a road”. You are no longer perceiving it, it has slipped through experience in the unconscious zone. This is just an example and you might say that actually you are still conscious of the presence of a road, you are just not flagging it as an important fact. However, this is what happens to many, most, signals generated by our senses, they never reach the conscious level in our brain.
To further muddy the water, according to the orthodox interpretation of Quantum mechanics consciousness and physical world reality are one and the same, you cannot separate one from the other. It is only by applying a conscious measurement that reality unfolds (probability waves collapse). It takes a conscious decision for the Schrödinger’s cat to be alive or dead (watch the clip). In this interpretation consciousness exists as part of the reality, it is not “derived” from reality. This is usually addressed as the Big-C (Big Consciousness).
The opposite view is that consciousness emerges from biology, which in turns emerges from chemistry, emerging from physics, emerging from math… This view is known as the Little-C (Little Consciousness).
If we take this second interpretation then there is a concrete hope (more than hope, I would say a “plan”) that consciousness can result from sophisticated AI. The jury is still out.
In the words of prof. Subhash Kak printed in the Conversation:
“It is possible that the phenomenon of consciousness requires a self-organising system, like the brain’s physical structure. If so, then current machines will come up short.
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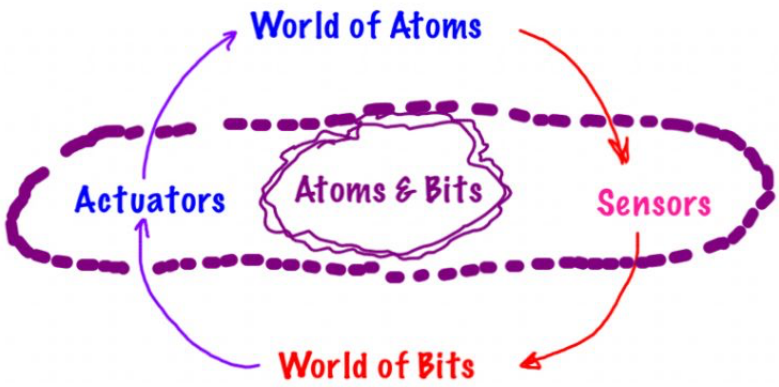
Scholars don't know if adaptive self-organising machines can be designed to be as sophisticated as the human brain; we lack a mathematical theory of computation for systems like that. Perhaps it's true that only biological machines can be sufficiently creative and flexible. But then that suggests people should – or soon will – start working on engineering new biological structures that are, or could become, conscious."
Notice the adjective "current" to tag the status of machines today not being able to support the emergence of consciousness. In the future, if consciousness is indeed of the type Little-C, there is a possibility, to see consciousness emerge from machine (AI). I would go even further saying that it will be inevitable.
Also notice that although the Big-C and the Little-C are completely different views of the world and one can say they are incompatible with one another, from a practical point of view they might end up to be "experienced" as the same. It is like passing the Turing test: if a machine does it becomes undistinguishable, in that environment, from a human. It does not say that the machine has become "a human", just that from and experience point of view it is no longer distinguishable. Likewise for consciousness. Even assuming the existence of a Big-C, if AI will eventually generate a Little-C from the point of view of interacting with that system it is the same. We will be interacting with a conscious system.
The evolution towards symbiotic autonomous systems is intertwined with these issues of consciousness.

The fading boundary between Atoms and Bits

- July 17th, 2017



The separation between atoms and bits is getting fuzzier, as IoT gets smarter, and that includes human beings.

It is now 60+ years that digitalisation is progressing. We have been living in a world of atoms but with the advent of computers and their ability to work on bits at very low cost we have initiated a transposition of bits into atoms. This is made possible through the use of sensors. In the very beginning we used "our" sensors, our sight and hearing and the processing in our brain to convert atoms into bit (using punched tape and punched cards in the beginning). Then we created sensors to convert atoms into bits and since then the variety of sensors and their capability have kept increasing. Among these capabilities the possibility to process data locally and communicate an abstract data with richer content of information.
The separation between atoms and bits has remained quite clear. We shifted our attention to bit, to data and we are now using a variety of technologies to exploit these data, correlating them and extracting meaning out of these correlation (big data analyses). We

are using data and their variation over time to learn and infer patterns and rules that help us (the program) to get smarter in their analyses (deep learning).
Of course one of the goal of analyzing data is to set up actions that can influence the world of atoms steering it into a desirable direction. For this we use actuators. These may generate direct commands to machine or influence the behaviour of the world of atoms by providing information, like advising of the building up of a traffic jam through SMS broadcast to drivers in the vicinity of the problematic area prompting them to take alternative routes.
What we are seeing happening, right now and more so in the coming decade, is a blurring in this separation of atoms and bits. The first sign of this blurring is the uptake of augmented reality.
Devices integrating a screen and a camera, connected to the web and with processing capability can merge the world of atoms with the world of bits.
Think about using your smartphone camera to look at a road sign in a foreign Country. An app can translate the wording in the sign into your language, keeping all the rest of the image unchanged (Word Lens, watch the clip, was an application running on smartphone by QuestVisual, bough by Google in 2015).
The smartphone is a good example of a device that can support Augmented Reality, merging the world of bits with the world of atoms and indeed there are plenty of apps available and under development targeting this platform.
A more “seamless” device like Google Glass promised to be (although it didn’t manage to capture the market as much as it was expected) would be an even better one for making AR ubiquitous.
I feel it is just a matter of a few more years and we will see AR becoming as commonplace as text messages are today. We will be using it without noticing, taking it for granted, as part of our daily life. Today we are already consciously connecting the world of atoms with the world of bits by using our cellphone to search the web for information relevant to a specific situation we are facing, tomorrow this will take place seamlessly.
Imagine a time when BCI (Brain Computer Interface) will be widespread and just “wondering” about something will bring the answer to us. You see a bifurcation in the road and a prompt will come indicating with way to go. It would be like having a navigator plugged into your brain. Or looking at a couch in a department store and seeing it with your mind’s eye fitting in your living room, taking the exact space it would take, given its dimension.
These examples may look like science fiction in their seamless occurrence, but they are clearly feasible today if we accept some (sometimes cumbersome) interaction. The point is that evolution will, step by step, make the perception of interaction slowly vanish to the point that the connection will be a matter of fact.
There is another point that is going to make the separation between atoms and bits presented in the diagram fading away. Sensors and actuators are becoming more and more rich in terms of processing and storage capabilities. This lead to an increased capability of taking decisions locally. This is what is meant by “Smart IoT”.
Reality is not getting “augmented” by overlaying bits on atoms. It becomes “mixed” with a co-presence of bits and atoms.
Smart IoT will be context aware and they will evolve in their behaviour because they will learn through experience. At that point it will be difficult, and artificial, to separate bits from atoms, as it is artificial to separate the brain from the mind.

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It will not be an evolution confined to technology, it will have impact on economics and on ethics. The shift to a “mixed reality” is a bigger one than the upcoming of Augmented Reality, since the concept of objective reality gets fuzzier. What is the real reality, once the perceived one depends on the specific capabilities available here and now (to me or to you). What is the “reality” in case of a symbiotic autonomous systems. Is the the one emerging out of the local realities of each system component? Who is in charge to percolate that emerging reality to each system component so that they share a common view (assuming this is even possible?).
Is machine learning, leveraging on processing capabilities that far exceed our human capabilities, leading us into a forced trusting of the machine (which is already the case when a pilot flies blind in the fog towards a runway…) taking responsibility away from us?

ENABLING TECHNOLOGIES

Autonomous Decisional Capabilities

Disruptive Technologies in extreme automation impacting beyond 2040
- April 22nd, 2018

PROBOT, a robot used for hauling supplies. The US Army is using a number of these vehicles, he said. Photo Credit: U.S. Army photo by David Vergun

Technology in the military field has been on the leading edge in the last two centuries, benefitting from huge investment. It has also created significant fall out in non military applications.
Artificial Intelligence and robotics (tied together ever more) are seeing significant investment by the military, all around the world, although it is difficult to pinpoint the real status achieved. Fighter planes, although manned, are becoming more and more autonomous, drones are being remotely controlled but are also becoming more and more autonomous in flight operation and decision taking. Soldiers are getting more and more sophisticated equipment, including robotic exoskeletons, that are clearly showing the way towards robotic soldiers.
The deployment of robots has the capacity of extending by an order of magnitude (10 fold) the battlefield control.
All companies operating in the defense area are working on more and more advanced robots transforming the concept of battlefield. Some, like QinetiQ, are also voicing the need for an overall reconsideration of rules as robotics and artificial intelligence are no longer fitting the current internationally agreed rules.
This is a more general issue affecting all autonomous systems: Who is responsible for their behaviour, given that they are … autonomous? This is an issue being addressed by the Symbiotic Autonomous Systems Initiative of the IEEE FDC.
An interesting white paper has been recently released by the US Army Research laboratory explaining the Internet of Intelligent Battle Things! It is worth reading.
This is an area where we are already well advanced and where disruptions are already occurring. It is reasonable to expect that by 2040 wars will be fought in a completely

different way. Someone is claiming that most of the wars will no longer involve a physical battlefield, they will be fought in cyberspace.
Don't underestimate the casualties however! Bits may turn out to be deadlier than bullets.
In 20 years time we will be living in symbiosis with bits, with our and other's digital twins.
We will have sensors and actuators on our body and in our homes. Malicious hacking on these may have deadly consequences.
Economy is already running on bits. A disruption in the daily flow of bits can be devastating.
In the end, even though there will be killer drones using AI to take autonomous decisions, and robotic soldiers fighting with one another, most of the damage and casualties may come from cyberattacks.
It is an uncharted territory we are entering, we better take notice now.

Who is in charge?

- October 25th, 2017

A flock of starlings creating an amazing choreography. Who is the art director? Image Credit: Neels Castillon

We are used to amazing sights, like the one in the picture with thousands of starlings performing complex choreographies and we are temped to ask ourselves who is in charge for that? Is there a "master" starling directing the choreography?
Similarly if we look at a swarm of bees. The swarm points in a specific direction but if we look at the bees at the front of the swarm they keep changing. Is there a master bee somewhere communicating the direction to the others? And what about a "simpler" things like a school of fish creating rotating cylinders in the sea or sponge made up by thousands of independent autonomous animals? Who is steering the shape in those amazing forms?
All studies carried out indicates that there is no "master" anywhere, that the result we are seeing emerges from autonomous systems that are conditioning one another, usually applying very simple rules (I follow you, don't bang on you).
Looking at these ensembles one does not worry about something like accountability. Those are animals. But what about the interaction of autonomous systems where humans are one of the components?
At the FDC the Symbiotic Autonomous Systems Initiative, meeting today in Newark to revise their first Whitepaper, is looking into these kinds of issues. Technology evolution is now creating hybrids, it is augmenting humans and the results may go beyond a "human".
Let's take a simple and actual case. We, me and you, are already augmented through the use of the smartphone, because through its use we can "know" much more about …

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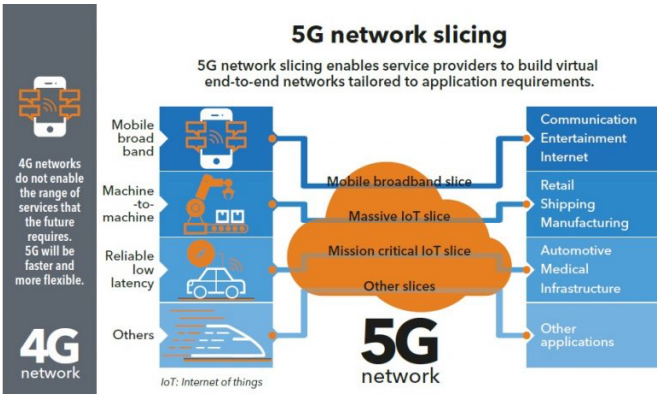
anything… that if we were to rely on our brain only. We can say that we are in a symbiotic relation with it. Now it is clear that we, as persons, are autonomous systems but you might claim that a smartphone it is not. It is just a tool. Well, yes and no. What if you have installed on your smartphone an app (or more than one) that automatically browse the web and brings information in your phone. What if you have installed an app that when you browse the web filters the result customizing them to what it feels shall be relevant to you? In a way the smartphone is taking (small) steps towards becoming an autonomous system. And what if this resulting symbiotic autonomous systems take wrong decisions that might even cause damage because of misleading information?
Well, one might say that the responsibility and accountability lies on the human component, but that human might very well claim that her behaviour was the consequence of the information acquired by the smartphone. Last Sunday in Turin, where I live, the Municipality requested all diesel cars to stop because of the pollution in the air. On Saturday evening a strong wind dispersed the pollution and when checking on my smartphone on Sunday morning I got the info that the circulation ban on diesel was removed. I got the information through an app and I drove my car. What would have happened if the information was incorrect and police stopped me? By showing them the info from the app would I have been considered in good faith and not accountable or would have I got fined?
Clearly it is a trivial case but it has all the elements of issues deriving when two autonomous systems are interacting with one another.
And what about social media where information and misinformation propagate making it ever more difficult to separate the wheat from the chaff? Who is accountable: the end user believing in what he is told, the one who generated a misleading/false information, those who allowed that information to percolate?
Fast forward for a real symbioses: in the next decade DBS, Deep Brain Stimulation, will become more common for a variety of ailments, including depression, OCD, Parkinson, epilepsy … and it will also become much more sophisticated with chips that will evaluate bran waves and generate electrical stimulation to “change” the behaviour of the brain. Suppose something goes awry, and that person because of the DBS makes something bad, like injuring another person or destroying properties. Who has to be accountable? The person, the chip, the surgeon that implanted the electrodes …
You see, as technology progresses the boundaries become fuzzy and the area of symbiotic autonomous systems is possibly the one where our long standing rules, and also belief, are most likely to need a revisitation.

Towards self organising networks

- February 6th, 2018



5G provides the capability to create network subsets (slicing) aggregating resources to serve a specific user/service.
Image credit: SDx Central

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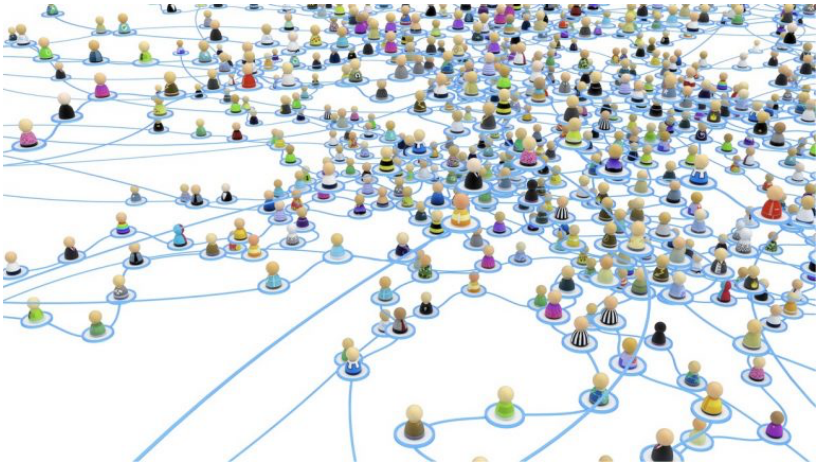
One of the potential of 5G is its capability to hand over the control of communications resources to applications/users. These can self organise their network capabilities/resources. To what extent this will happen remains to be seen, since Network Operators are not likely to open up their network resources. Network slicing (a way to "carve" a set of resources in the network dedicating them to support a certain service/user) is likely to be used by the Operators themselves as a way to cut cost (and deliver service quality at a premium price).
A different story is for the Edge of the network where it is much more likely that a multitude of networks owners will be willing to pool and share resources, giving rise to a self-organising communications network. Actually, I expect in the first part of the next decade to see smartphones (through apps or may be through their OS) take the lead in this direction dynamically orchestrating with other phones in the area the best use of available resources. This might result in the spot creation of networks at the edges beyond the control of Network Operators. The evolution of edge computing and fog is pushing in this direction.
Of course the Network Operators may resist this evolution but once a critical mass of cooperating smartphones is reached the N.O. may be cut off from a good portion of the communications business. Add to this the fact that some N.O. may decide to join the bandwagon of resource sharing to set itself apart from the other and benefit from it and you can see that in a few years all resources are bound to be shared. This will give a strong impulse to self-organising networks, an area that is being pursued at scientific and research level for autonomous systems (and autonomous systems swarms).
6G, as I mentioned in a previous post, will embed the capability for self planning and self organising. It will naturally stem out from the just outlined evolution.
There are a number of examples of self organising structures in Nature, just think of a coral reef, a ant colony and even our brain!
The key is the relative flexibility of each component and the huge number of them with a relatively simple interactions set. The huge number is required because the self organisation is not orchestrated/driven by an authority. It just happens and it happens by reinforcing what is working and discarding what does not work.
As we are creating environments with a significant number of components each having a certain degree of autonomy, we are going to see this happening to our artefacts. Think about self driving cars. It has been shown that by providing each one with some very basic set of rules (like keep your distance from the one near you) they start to act like a swarm and generate traffic patterns that optimize the use of roads.
Of course, the challenge is to create the set of rules that lead to what can be seen as an intelligent behaviour in a context that keeps changing. And this is what is being studied by researchers in several places. This is seen as an emerging strategic technology for this year and the next ones by Gartner.
More on this in the next post.

Towards self organised networks … of people

- February 7th, 2018



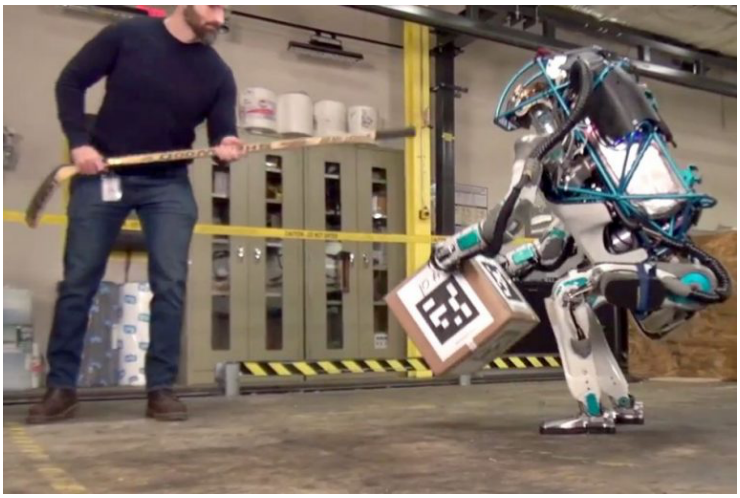
People form networks of various sort. These networks are a fundamental aspect of cities and they can be supported, promoted and steered to contribute to the city operation.
Image credit: TNW

People are clearly examples of autonomous entities, and we know very well that they organise themselves into groups. The aggregation force may be vicinity, like people of a small village clustering together and defending their cluster, or it may be driven by a purpose, like working at a Company and feel the sense of belongingness, each identifying in the products being produced and being proud of it.
Friendship, of course, is a strong aggregator, like attending the same class at a school, being part of a soccer team or even being a fan of a team. These latter examples are related to the social nature of human beings. More recently, Social Networks have created aggregations by supporting them with cyber-tools. These latter overcome distance and time allowing the creation of very large clusters. Notice that being part of a social network does not equate being “friends”. It does not mean that one can really entertain stable relationships with thousands of cyber-friends just because a tool support the establishment of connections. The Robin Dumbar number is still applying (Robin claimed that a person cannot maintain stable relationships with more than 150 people).
A city provides a boundary in which its citizens can recongnise themselves and may provide a sense of belonging. This is not always so and it is not so for each citizen. Actually missing the sense of belongingness is a big issues for cities that has become even more poignant with the immigration of people from different cultures and values that are not recognizing that city as “their” city and the other way around are often not recongnised as “citizens” by the other citizens.
This has become a major issue in many cities today. Self organisation is at play here. A city is like a set of sets, which is fine in general as long as these sets overlap. It is not good if the sets are disjointed, is there is a cluster that feels stranger to the other.
A city, and its individual citizens, has many aggregation seeds. There are gathering places, there are events, there are infrastructures like theaters and movieplex, stadiums, schools, industries, shopping malls, restaurants and parks. Each of these infrastructure is a potential aggregator.
Lately tools have become available that can both monitor and promote the clusterings of people. Social networks are clearly one of them. A city may set up dedicated spaces in social networks to support aggregation mirroring in the cyberspace and promote, reinforce these aggregations.
Few years ago Telecom Italia, FBK and the University of Trento joined forces to experiment smartphones as tools for supporting and monitoring aggregation. The trial was

run with students at the University of Trento that opted in choosing to be tracked as they moved around met each other. The trial showed that smartphones are indeed providing data that can pinpoint aggregation and it is easy, in general, to understand the kind of aggregation formed. At that point it becomes easier to develop services that are specifically targeted to the needs of a cluster. This is both serving a need and it is reinforcing the sense of belonging to that cluster.
This trial is showing that the cyberspace can be used to mirror social behaviour, to support it and to reinforce it. Cities can take advantage from this to strengthen social ties and to create that superset that is so important to integrate the various souls of a city into a super-soul.

Untethered! Now the robot can take a walk

- May 12th, 2018



Atlas, a new generation robot, humanoid in aspect, has been untethered. Now it no longer needs a line providing power.
Image credit: Boston Dynamics

Atlas, a humanoid robot 1.5 m tall, made the headlines in 2013 as one of the most advanced humanoid robot ever developed. It weighted 75kg, could carry 11kg of groceries (or anything else!), had a stereo vision (using Lidar) and 28 joints providing flexibility in its movement and the capability to manipulate objects. The first version weighted 150kg, the second 82kg. he decrease in weight has been made possible by using 3D printers to produce most of its parts.
What made quite an impression was its sense of equilibrium. Even if pushed around (see in the photo an engineer trying to make life difficult for Atlas as it was picking up a box) it could manage to keep its equilibrium and it was even capable of doing some hops and acrobatics.
To provide power to its brain and hydraulic muscles it was connected to a power line although a small battery could provide some very limited autonomy.
The new version, just announced, see the clip below, has learnt to run in the open space and most importantly the power required has been significantly reduced so that it can operate for some (still limited) time on its own.
Technology has made incredible progress although in the “efficiency” area is still way behind Nature. We can move around for the whole day with the power provided by a few sandwiches, a coffee surely helps, that is a thousand calories (2,000 calories, the average

amount needed by a woman per day, corresponding roughly to 2kW hour) is enough fuel for the day. Not so for a robot. It takes much more power and that constrains its operation away from the mains.
The progress has been impressive. Take a look at the video and you will notice that it is not just running around, it is observing the lay of the land. It might seem strange to see Atlas stopping in front of a fallen tree, pondering what to do and then deciding to hop. For a 4 year old kid that would be a matter of a second, not requiring to stop the run at all. It shows that what we are taking for granted as “easy” is not easy at all, it requires a lot of computation for a robot. So in a way we can be happy that the distance between “them” and “us” is still significant. On the other hand they are quickly catching up.
Robots are becoming more and more autonomous, in doing activities and most importantly in evaluating the context and tailoring their activities to the context to achieve a certain goal. So far we are the ones setting the goal but this is also changing rapidly. More and more we are training robot to achieve an objective, no longer in ways to achieve the objective. We have seen that with the (soft) robot playing Go: it worked out the strategy to win by itself, actually taking some actions that the human experts would not have considered.
Autonomous systems are more and more designed to self learn. By doing that we are empowering them … and we might be losing control. Some sort of symbiotic relationship is needed so that we can remain part of the game. This is an issued being addressed by the IEEE FDC Symbiotic Autonomous Systems Initiative.

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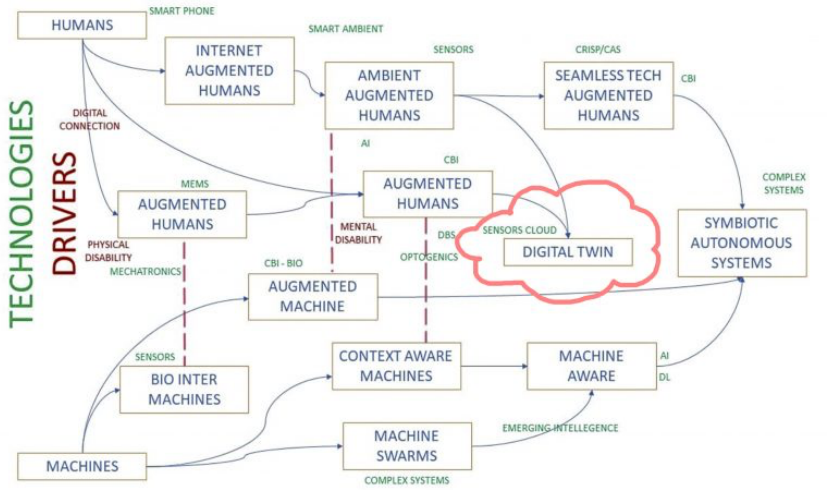
Self-Replication

Towards self organised networks … of Digital Twins
- February 10th, 2018



Digital Twins are seen as a component at the overlapping boundaries between machine augmentation and human augmentation. Credit Image: IEEE FDC SAS Initiative

Processing data costs close to nothing. If you have a huge amount of data you can extract meaning looking at relations. Think about knowing what medicine you are taking. It provides very little value, surely it does not provide any value to you swallowing the pill every day: you already know it. Now suppose that this information is shared and placed in a set containing related information of thousands of other people swallowing the same pill. Some patterns may emerge, like getting that pill within a few hour of swallowing another specific pill may cause a rash. These sorts of occurrences may be rare and very difficult to spot by a doctor you may visit after the rash. Yet they become straightforward if you (a computer) can make the association. Few years ago,as an example, researchers at Stanford by looking at queries made by millions of people on the Internet were able to discover bad side effects generated by taking two drugs (one for cholesterol and the other for depression).
If you are old enough (nothing to brag about…) you might remember the relational data bases where entities were forming threads based on relations and could be sorted based on those relations. Today, with artificial intelligence and deep learning, we have the possibility of "discovering" relations. This is what can happen if we have digital twins populating the cyberspace of a smart city. An artificial intelligent software can establish relations among digital twins and discover hidden information.
Notice that these relations may be quite sensitive, in terms of privacy, and there should be ways of protecting their visibility. This might be done by implementing query systems governed by the "need to know" rule, and of course there should be a legislation dictating who has the right to express a need (notice that under this paradigm without a need there is no access and the need is traced as well as the information returned to satisfy the need).
The discovered relations among digital twins may be used to create self-organised networks, in this case the artificial intelligence that makes relationships emerge is also the ones that self-organise the network. Notice that the idea is to have these networks as

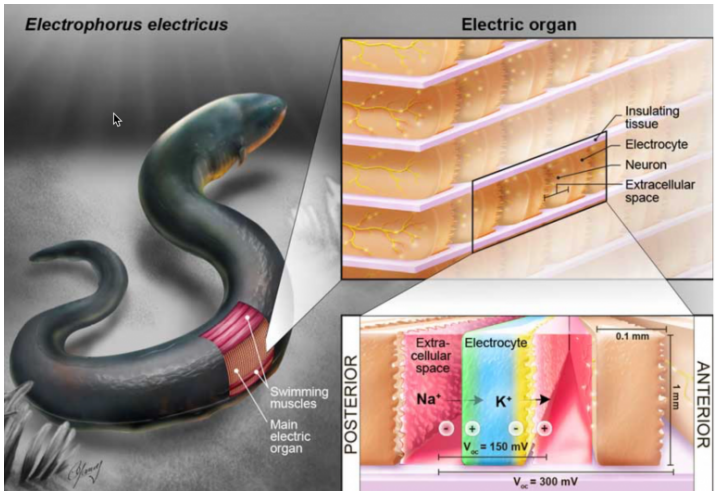
dynamic entities that rearrange themselves based on what the real persons do (this is reflected in their digital twins), hence to have them woven continuously by artificial intelligence is crucial. This is also why I classify these Digital Twins networks as self-organised. By looking at these networks a municipality can promptly identify clusters and their “needs” hence respond to them. Notice the response may also lead to changes in the clusters, different aggregation, splitting and merging. All of this can be simulated in the cyberspace and once the approach leads to satisfactory result it can be implemented and, most important, its effect can be monitored by observing the digital twins and their clustering.

At EIT Digital a number of doctoral students are looking at various aspects of processing data to discover relationships, tackling at the same time privacy and ownership issues. They do this in cooperation with several industries and interact with municipalities. They have been sharing their ideas and have been challenged by industry and institutions representatives starting a dialogue that can foster the digital transformation of our cities.

At the IEEE FDC Initiative on Symbiotic Autonomous Systems (why don’t you join and be part of designing the Future?) Digital Twin is one of the topic under consideration. They are likely to augment us, our mental and physical capabilities enabling exact customisation of robots to our needs.

Symbiotic artificial organs for electrical power generation

- March 11th, 2018



Eels have an electrical organ to generate electricity by moving sodium (Na) and potassium (K) ions across a selective membrane. Researchers are working to create a similar one in humans. Credit: Caitlin Monney

Nature has been very effective in inventing different ways to equip living beings with a variety of “structures” that let organisms sense, move, manage chemical reactions and produce electricity. All animals are able to produce electricity by creating an electrical potential and discharging it as needed.
The basic trick is quite similar in all animals. Cells move sodium and potassium (in opposite directions) across a membrane that works like an insulator (separates the sodium from the potassium thus creating an electrical potential) resulting in a voltage between -30 and -90mV. With this kind of voltage, cells can communicate with nearby cells but you cannot leverage on it to power, as an example, a pacemaker.
A few animals have “invented” a way to assemble more cells into structures that work like batteries. The “electric eel” is particularly effective with an organ that can create up to 600V potential (that is over 60,000 more powerful than the one created by our neurons). It does so by clustering electrocytes cells into several thousands electroplates, each electrocyte generating around 100mV (like our neurons). Creating a high potential is not doing any good unless you are also able to funnel the electricity to the places you need it, without getting the shock yourself. In the case of eels this works because they live in water and the electricity is dispersed by the eel’s skin in just 2ms. The small animal that gets in contact with the eel skin gets just a little portion of the discharge but, being small, the effects are enough to shock it.
Researchers are studying ways to create an artificial organ, mimicking the one of eels, that could be implanted in our body to generate electricity and power implants, transforming us into a cyborg. A joint team from University of Freiburg, University of Michigan and University of California – San Diego has reported on their progress in a paper published on Nature. They have created a gel that is bio-compatible, soft and transparent, suitable for implants. It can generate 110V and can provide an output of 27mW per square meter, sufficient to power several implants, like electronic contact lenses, sensing devices, actuators in the brain.

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This is an important step in the fusion of electronics with our body, a step in the direction of symbiotic autonomous systems since electrical signals remain the most effective way to support communications.

Disruptive Technologies in human augmentation impacting beyond 2040
- April 28th, 2018

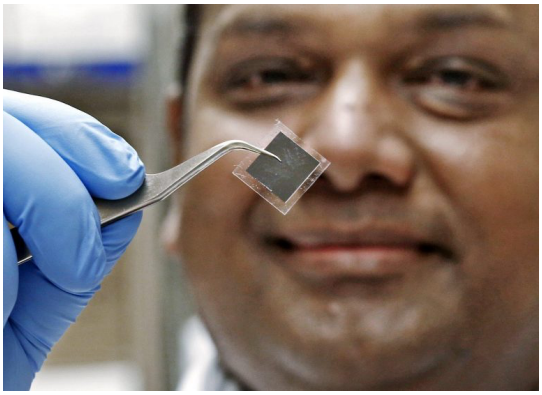
The modeling of the body is getting more and more accurate and researchers are now focussing on the brain both to replicate it in the cyberspace and to influence it from the cyberspace, eventually backing up the brain and uploading data in the brain. Image credit: Kernel

The Imperial College Foresight study includes Data upload to the brain as a disruptive technology that might happen in the 2040 timeframe. This is part of a more general evolution seeing the mirroring of a person, and a person brain, in the cyberspace, part of which is already taking place today (digital twin).
The mirroring is actually involving two aspects, related one to the other: the copying of the person into a model, living in the cyberspace, -and keeping it in synch with the person-, and the enacting of desired evolution of the person by uploading data/stimulate activities from the cyberspace to the person. An obvious, and already possible, instance would be to upload instruction to a device/prosthetic embedded in the body, like an insulin pump, to increase its performances or to adapt to a changed situation. A much more tricky one would be to influence the brain uploading knowledge or/and changing their functional processing. Notice that even in this latter case there are studies and trials going on, with electrodes that can stop an epileptic attack detected by analyzing the electrical activity in the brain.
It is important to notice that there is a continuum between a complete separation of a person from its environment and a complete symbioses. What we are talking about is an evolution towards a more and more complete, and effective, symbioses. Sounds and colors, as an example, have been demonstrated to have an impact on the brain and in some pathologies that might activate an abnormal reaction or prevent it. Moving from this to using ambient sensors (like a video camera) is a small step towards an increased interaction, moving on to having contact sensors, like a wrist band or a head band

providing more accurate detection in another step, embedding sensors and actuators in the body is a further step, using optogenetics to activate specific neuronal circuits goes even further, changing genes in neurons … You get the trend.
The symbioses can be the result of manipulation of a person and or the increase functionality of an "interconnected" machine. In the long term it is likely to be both, as discussed in the Symbiotic Autonomous Systems Initiative of IEEE FDC.
There are companies working in these areas. The 2045 Initiative is looking at the broad impact of artificial intelligence, an intelligence that includes the symbiosis with our intelligence and foresee the possibility to upload our brain in the cyberspace where it can live "forever". Notice that it is not just about "me" living in the cyberspace forever, it is about maintaining relationships alive once the atomic part of me dissolves. My friends will have the opportunity of talking to me, the "me" in the cyberspace, as they do today when using a social network. With the Turing test passed, there is no way we can tell if on the other side of the interface to the cyberspace there is a real person or a computer (an artificial intelligence), and if that interacting entity in the cyberspace is a copy of me, has my experience, my knowledge, my quirks, … well then you would have no way of telling the difference.
This alter ego in the cyberspace will diverge over time from the real "me" since it will be exposed to interactions, experiences, I will no longer have, but if the real me is no longer existing it does not even make sense to talk about a divergence. It will still be me, just an older and more experienced me.
The brain uploading is clearly opening up completely new spaces, bringing along unexpected societal and ethical issues. What about a cyber-me that through interaction in the cyberspace will cause damage to another entity, be it virtual or real? Would the "state" punish the digital me? How? Will my digital me condemned to "death", to be erased from the cyberspace? Aha! You cannot erase my digital me, you might erase one copy but my digital me could be so smart to clone itself in the billions and hide its self in many ways to go undetected! These are just a few examples to point out the amazing new space we are opening up. Remember that there is no black and white, but plenty of grey and some of this is already happening today: to create your digital self today try Replika.
Kernel, a startup founded by neuroscientists and engineers from top US universities, is looking at technologies to access, read AND write the brain. DARPA has awarded in 2017 the University of Berkeley with a 21.6 million $ fund to develop technologies for reading and writing the brain…
All these efforts will clearly result in significant progress over the coming two decades. As I said the idea of uploading data to the brain as if it were a computer (for sure it is not just a storage device!) is most unlikely, I would say still in the realm of science fiction. However, the possibility of a stronger symbiotic relationship with the cyberspace is surely on the map.

A magic chip to change cells: healing with synthetic DNA

- August 25th, 2017



A chip using nanotechnology to inject synthetic DNA strands into epithelial cells changing their type. Credit: Ohio State University

Here I stumbled onto another example of pure magic. As reported in IEEE Spectrum a team of researchers at Ohio State University have invented a way to "infect" cells in a living organism to change, partly, their DNA code thus transforming a cell type into a different one, as an example transforming an epithelial cell (skin cell) into one that "think" it is a blood vessel cell. Because of that this cell starts to proliferate and creates a blood vessel.

All cells in a living organism (with the exception of eggs and sperm cells) have the same DNA. However, each cell uses just a subset of that DNA, the one that direct the cell to play a specific role, like being a neuron or an hepatic cell. Scientists have understood (although not completely) how this mechanism works and researchers at the Ohio State University have leveraged on this understanding to create a chip (watch the clip) that can inject specific DNA strands (synthetically produced) to steer a cell to become a different type of cell, like I said an epithelial cell transforming into a blood vessel cell.

Notice that the synthetic strands is injected in the cells (through tiny pulses of electrical current) but does not "change" the cell DNA. The cells remain with their full DNA and therefore are not seen by the organisms as strangers to be fought (they do not stimulate any immune reactions). The synthetic DNA is just supplementing the original one of the cell.

So far the researchers have been able to heal a leg of a mouse by steering its epithelial cells to become blood vessels and thus reconstructing the missing vascularization. Notice that the real healing is taken over by the organism, this procedure is just activating (and accelerating) it.

According to the research team it should be possible to turn epithelial cells into neurons and then to harvest them and inject them in the brain to help people with Alzheimer disease. They hope to be able starting clinical trials in 2018. It is still a big question mark whether this procedure will prove effective in humans and to what extent it can be used.

Nevertheless this result is the first one performed on a living organisms (previous type change of cells were made on a Petri dish) and it is showing that magic is possible.

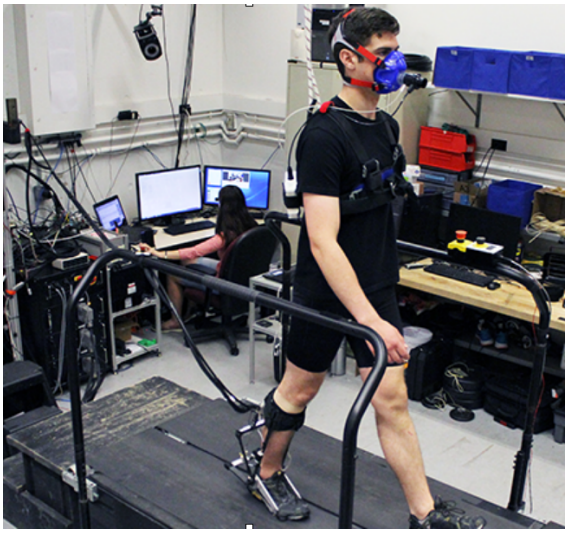
Actually, to me at least, this result goes beyond science fiction, and I should say I am seeing more and more of them since I started to study the area of symbiotic autonomous systems and the related technologies.

At the same time the possibility to inject functional DNA in a living organism in such an easy way (by contact basically) opens the door to the injection of "bad" DNA. With CRISPR/Cas 9 creating DNA strings has become (almost) a child's play and one can

expect some malicious attempt to create bad DNA. Actually, in an article on Spectrum researchers have pointed out the use of bad DNA to infect computer sequencers. These sequencers are converting the four bases (A-C-G-T) into string of numbers and researchers have shown that it is possible to create artificial (bad) DNA that will infect the sequencers once they have converted their bases into a code.

Human in the loop

- July 2nd, 2017



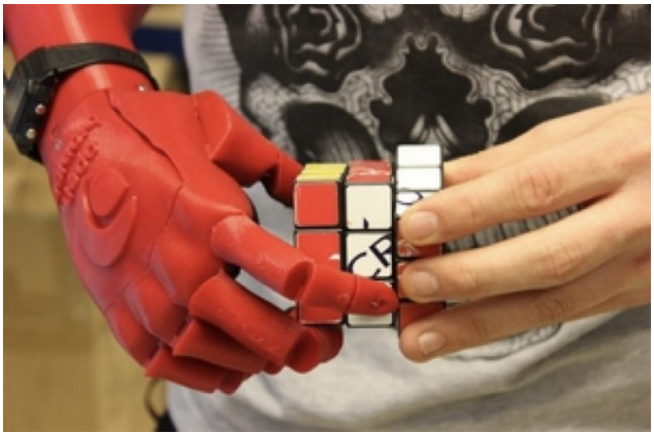
An algorithm automatically tweaks exoskeleton for optimal performance leveraging on data provided by sensors connected to the human metabolic system. Credit: Kirby Witte, Katie Poggensee, Pieter Fiers, Patrick Franks & Steve Collins

Exoskeletons have been around for quite a while, originally aimed at augmenting soldiers capability (decreasing fatigue and helping in carrying heavy loads) and then progressively used to help patient with walking deficit, paralyses and during the rehab.
Current exoskeletons are good but not as much as designers would have thought: in addition to being bulky and having power needs that constrain their usability they have to undergo through a difficult and time consuming customisation.
Researchers at Carnegie Mellon University, CMU, have come up with an interesting solution: to involve the user, the human, in the training of the exoskeleton, what is called "human in the loop".
They approached the tuning of the exoskeleton by analyzing the metabolic rate of the user. This is an indication of the effort involved in the specific activity and of course the goal of an exoskeleton is to minimise this effort. The metabolic rate can be measure, with quite good precision, by analyzing the consumption of oxygen, which, in turns, can be measured by analyzing the breathing.
As you can see in the clip, volunteers have been asked to wear a face mask connected to a breath analyzer. The data are analyzed in real time by an algorithm developed at CMU (this is what makes the exoskeleton smart) and the result is used to try different exoskeleton configuration till a minimum effort is achieved. This leads to the customisation of the exoskeleton from that particular user, in that particular activity. The experiments have shown a decrease of 1/4 of the effort required by a specific activity as consequence of the finely tuning of the exoskeleton.
Obviously, it is not convenient to move around with with a face mask attached to a bulky breath analyzer. However, this has been used to refine the algorithm. Researchers feel that now, with the algorithm polished up, it will be possible to feed it with data derived from the heart beat, which are much easier to acquire, and even from muscle activity. These are not as accurate as measuring the metabolic rate from breathing but it is a good approximation that becomes very good over extended periods of time.
They expect to have this "human in the loop" becoming common in the next decade, improving rehab procedures and resulting in more effective human augmentation, where desired.

It is interesting to notice that the improved technology used in prosthetics coupled with interaction with the human body is leading to a significant improvement of the combined "cyber-entity". The prosthetic is getting smarter, it is an autonomous system that becomes aware through interaction with the wearer and "learns" -evolve- over time. These are exactly the characteristics we are using to define a Symbiotic Autonomous Systems in our SAS Initiative.

Towards Humans 2.0

- February 4th, 2018



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

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 focussing 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 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.
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.
One this become 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 modification to our body, resulting, as https://geneticliteracyproject.org/2017/12/05/drought-resistant-plant-genes-lead-crops-need-less-water/an example, to some tweaking of the genome.
Notice that we already have taken this body modification path in the last 5o years with … vaccination. Vaccination gives us superhuman strength in fighting some kind of viruses and we have been extremely successful in this area. Vaccination teach our immune system to be prepared to some viruses attack 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 – social, and open a broad discussion on how to tackle them steering the evolution in a desired way.

Cooperative Support

Disruptive Technologies in extreme automation impacting beyond 2040

- April 20th, 2018

What's a (photoshopped) bee doing on Mars? It is announcing a NASA research project to use robotic swarms -bee like- to explore Mars.
Credit: NASA

Robots are becoming more and more autonomous. At the same time they are becoming more flexible and are equipped with a variety of "tools" increasing their usability in many areas. Bringing these robots to the market is an exercise of balancing performances with cost. It is obvious that the simpler the robot the easier it is to manufacture (and maintain) and the lower its cost. At the same time, increasing its complexity would extend its capability and possibility of use. An intermediate approach is to use several simpler robots cooperating to perform more complex tasks.
We can see this approach at work in natural systems: ants and bees are clear examples, but they are not alone. We, human being, are also another example: when we work, as we do, as a community we can do much more than what any single individual can do, and that goes both in creating artefacts (like a car or a city!) and in creating knowledge. The total is greater then the sum of its parts.
Probably we are the first species that has become so good in harvesting the intellectual capacity of individuals to create a higher intellectual capacity. Till some time ago this increased capacity was created by one human exposed to knowledge created by other humans, now it is starting to happen in machines able to leverage on our knowledge to create new knowledge – through deep learning / artificial intelligence.
Cooperation, in general, does not come for free. So if you want to have simpler entities communicating to create a more valuable output you need to "invest" in communications. However, there are examples where communication is not explicit, it does not require effort. Rather it is implicit (see the discussion on implicit communications in the SAS initiative White Paper) and as such does not require an extra effort. Welcome to Swarms!

Multiple robots are already applied in agriculture coordinating among them the various activities. They are not a swarm

though. To make a swarm you would need many more and communications would have to be implicit. Credit: Xaver Robots

Bees and ants invest very little in "communications", by far they use implicit communications. By flapping its wings (not sure if bees do flap their wings….but you get the point) the bee temperature increases and this increase is perceived by other nearby bees that change their behaviour. Ants leave a trail of odorous molecules and this trail affect the behaviour of other ants. The evolution did the trick of transforming these implicit messages in higher level community behaviour.
Scientists are trying to do the same with robots: swarm robotics.
They are foreseeing a broad variety of applications, from Mars exploration to characterising a geographical area, from sensing in the sea to a future health care.
The basic principle is common to all applications: use a multitude, from ten to ten thousands simple robots each one behaving according to simple rules that connect its behaviour to the environment leading to a self orchestrating behaviour, just like bees … and humans!
In the coming decades these "simple" robots will become more sophisticated and the relations among them will also become more sophisticated (as is the one orchestrating neurons in our brain) giving rise to the emergence of intelligent behaviour. It is therefore reasonable to expect in the 2040 timeframe a disruption from swarm robotics in several areas, from the inside of our bodies to the environment to the planetary exploration.
Notice that in swarms there is no single control point and that as single participants in the swam (robot) are self influencing one another in a dynamically evolving way, as we are expecting to happen in the future when robots will be able to learn and evolve based on experience, it will become difficult to predict the behaviour and this raises legal and ethical issues (who is in charge in the setting up of the framework of evolution and who will be responsible for unplanned -undesired- behaviour?).

Emergent beings: Cooperative support

- July 1st, 2017

Swarms of insects, flocks of birds, schools of fish. In Nature there is plenty of examples of spontaneous cooperation among autonomous systems resulting in the emergence of a super-system.
Image credit: JSTOR Daily

So far the relation human(s) artefacts 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 artefacts.

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This makes sense because we are seeing and predicting an evolution of artefacts along the lines of "awareness-autonomy-evolution" that are specific of 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 artefacts, 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 artefacts:

- the one where each artefact 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 artefacts, 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 artefacts 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 behaviour 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.

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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 behaviour from a multitude of low intelligent entities, leveraging on their sheer number.

Brain and computer learning together

- May 24th, 2018

Pilot and avatar at Cybathlon, brain and computer working together.

Credit: Cybathlon

Brain Computer Interfaces work at two levels, hard and soft. Each one fuels the other and both are needed to establish an effective communications. The hard part captures the electrical activity of neurones, the soft part interprets this activity to derive the meaning.

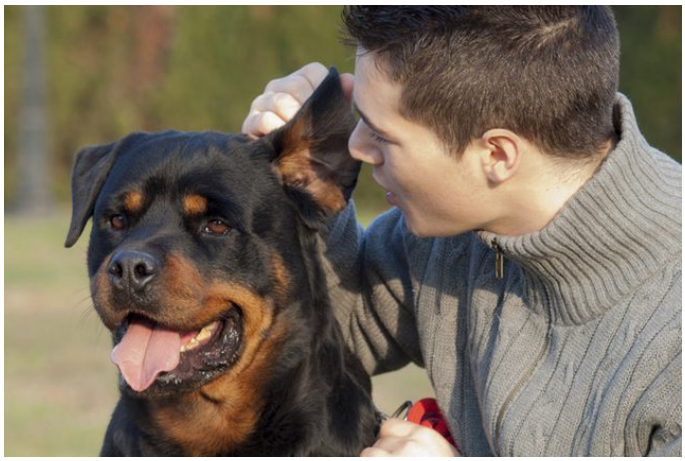
Getting more accurate and selective data on the electrical activity is becoming possible through technology evolution, sensors and probes that in some cases have made possible to detect the electrical activity at a single neurone level. To achieve this kind of sensitivity probes have to be implanted in the brain. Likewise in the other direction, influencing the brain at single neurone level. Optogenetics have provided the tools to achieve this specificity. Obviously, invasive procedures, like the ones required to implant probes in the brain are not on the wish list of most people!

In addition, getting the signals (or activating) a single neurone is a drop in the ocean, given the 100 billions neurones in our brain. Technology is allowing the simultaneous detection of several neurones, even a thousand of them with the latest advances but ... it is a bucket in the ocean.
Hence the need for the soft part. Using software, and technologies like machine learning researchers, it becomes possible to detect meaning out of electrical activity generated by thousands, millions of neurones. Hence, it becomes possible to use non invasive electrical

detection, by placing arrays of electrodes on the scalp, rather than implanting them in the brain.

In an article appearing on PLOS/Biology a team of EPFL researchers describe a new approach in Brain Computer Interfaces based on a symbioses between the AI application and the brain in which each one is teaching the other. The research involved two tetraplegic persons that have been trained, and trained the AI application, to control an avatar in a computer game. The communication took place through a soft helmet (see photo) capturing the electrical activity and using the eyes as feedback to the brain. They participated in the Cybathlon competition organised in Zurich in 2016 (the next one will be in 2020) dedicated to demonstrate progress in human machine cooperation in the area of disabilities, a sort of Olympics where the competing teams are made by humans and prosthetics. For the first time I have seen discussing a cooperation between a brain and a computer (AI application) in terms of symbioses.

Communications for Symbiotic Autonomous Systems
- November 19th, 2017



It looks like we can talk to our dog, and to other dogs as well. What king of communications is taking place? Clearly we don't speak the same language, yet we understand each other… Autonomous systems are facing a similar challenge when engaging in conversation with one another, if they don't speak a common language. Image Credit: cuteness.com

Communications has reached an amazing sophistication, most of the Planet is now blanketed by communications infrastructures. Technology and standards have been the enabling forces.
Till few decades ago the communications infrastructures were designed as conveyor pipes (wired and wireless) able to carry signals whose meaning was irrelevant from the point of view of the transporting infrastructure. The digitalisation of communications reinforced this aspect. A bit is a bit, from a transport point of view. Its meaning was infrastructure independent. It might code an image, a song, a voice, a temperature… Provided the infrastructure has the capability to transport it from A to B within certain time it is fine.
Of course, there are "bits" and then there are "bits". As an example the indication of a temperature of a seaside location may well be transported in one minute and no one will object. On the other hand the increased temperature of a nuclear reactor needs to be communicated in a fraction of a millisecond to avoid catastrophic situations. Bits representing video images have much more stringent delay requirement than bits transporting still pictures and so on.
As discussion went on, on the interaction between what is being transported and the transporting infrastructure, i.e. should the infrastructure be aware of what is being transported and should behave differently, or should it be neutral, the progress in technology (and in network capacity, management of this capacity within and outside of the network) has made irrelevant the discussion. In most situations the infrastructure can do its job disregarding what is being transported.
In these last decades, and more so in the coming ones, the communications needs have been changing, due to the diversity of communicating entities. Whereas in the past it was about communications among human beings now and in the future a significant portion of communications is and will be among machines.

Communications is about sharing a meaning. This requires both the sharing of the semantics and the transport of this semantics using a syntax. Communications infrastructure support the transmission of the syntax, standards are in place to ensure that the syntax (the signal coding) is smoothly transmitted from A to B. The before mentioned “network neutrality” brings semantics into the equation but only to ensure that the syntax is taken care in an appropriate way.

The semantics is outside of the communications infrastructure, it lays inside our brain. It is our brain that decodes the sound ways and the photons generated by a screen. We are autonomous systems with our own semantic framework that makes possible the understanding.

We are now seeing the emergence of other types of autonomous systems, equipped with a growing level of “intelligence”, that is their own semantic framework and their own capabilities of applying it to “understand” communications, as well as to “generate” communications streams towards other systems.

This new scenario raises the need for an evolution of standardisation in the communications area, no longer limited to the transport but rather extending into the semantics of communications.

Industry is at work to define communications protocols among autonomous vehicles, among robots in production lines, among robots in an home environment. All of these are “closed” systems, the communications being addressed is internal communications and as such, having the control of each communicating entity can be designed, and defined, as in the past. We sit at a table and we agree on what can be communicated and how it should be communicated.

In the next decade, and more so in the following ones, new challenges will come to the fore. Autonomous systems will start to open to the world, meeting and interacting with other systems that are not part of their closed environment. How can communications be facilitated in this new scenario?

We have had some studies in this area in the past when scientists discussed how to communicate with extra-terrestrial forms, where no information is available on their semantic/syntactic underpinning of communications.

We also have some interesting facts that can be learned by observing communications among two persons coming from different culture, e.g. an Australian aboriginal and a European, and even between a person and a dog. The communications semantics and the syntactic models of the parties involved differ significantly and are unknown to each other.

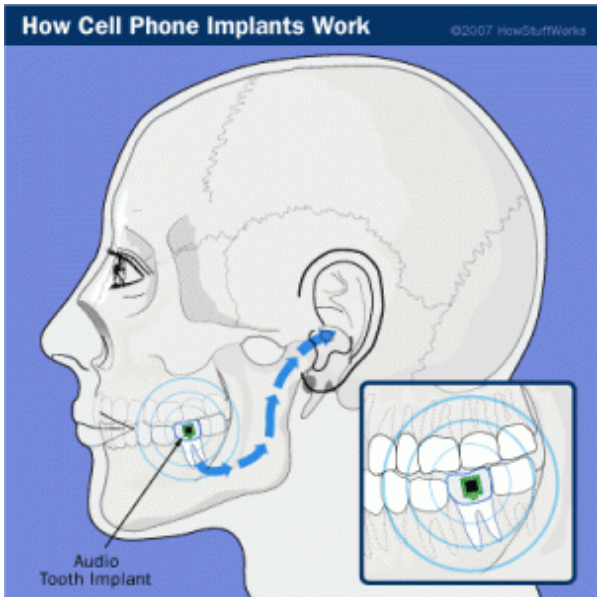
In a way this is the situation confronting the communications among advanced autonomous systems.

Notice how the communication with an extra-terrestrial form differs significantly from the ones with an aboriginal or with a dog. In the former case there is not awareness on the behaviour of the other entity engaged in communications, in the latter there is (unless you are sending a letter to an aboriginal or to the dog…).

The communications among “independent” autonomous systems, i.e. not being part of a closed system where communications is designed as part of the closed system, can be approached in both ways, as if it were a communication with an extra-terrestrial system and as if it were a communication with a dog… (this latter is

preferable as comparison to an aboriginal since in the case of communications with a dog the “intelligence” in the two systems is not comparable, whilst with an aboriginal the intelligence and the underlying intelligent support infrastructure is the same).
The easiest form of communication to mimic is the one with a dog, because we know that is works (!) and because we can continually adjust it based on evolving feedbacks.
This form of communications can be classified as implicit communications, whereas it is based on the interpretation made by each party of the behaviour of the other, thus leading to a change in its own behaviour that will be detected by the other party leading in turns to a change of the other party behaviour.
This form of communications requires an “understanding” by each party of the other party behaviour by interpreting external changes (wagging the tail, type of barking, hands gesture, smiling…).
Autonomous systems are developing a model, and an understanding, of their environment, and detect and interpret changes in their environment. The presence of other autonomous systems in their environment, expected or unexpected, is introducing changes and these are a form of implicit communications.
Standards are needed to simplify as much as possible the understanding of what is going on. A car starting to blink a directional light can be assumed to be about to change its trajectory, although it is not 100% guarantee, nor it is the reverse true (a car NOT blinking will not change its path).

Disruptive Technologies in HMI impacting beyond 2040
- May 5th, 2018



The blueprint for an implantable cellphone. The electronics would be embedded in a tooth. Upon receiving a radio signal the actuators in the tooth vibrates and these vibrations area detected in the inner ear and perceived as sound. Credit: Royal College of Art London

Let's look at the last area considered by the Imperial College Foresight study with expected impact in 2040: Human Machine interactions.
Here they are pointing to three technologies: Implantable phones, Conversational machine interfaces and Thought control machine interfaces where the order is based on my view of likely-hood.

- Implantable phones

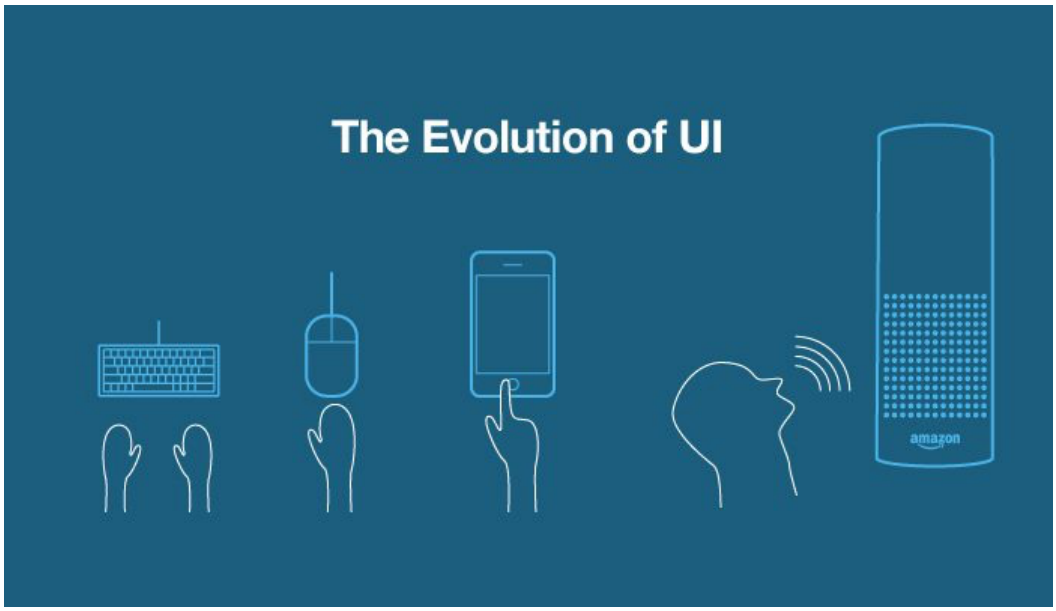
There have been in the past several thoughts on embedding a cell phone in a person body. As a matter of fact we spend our life in symbioses with the phone, if we happen to live it behind we go back chasing it till it is back in our hands. At the same time electronics is shrinking and we have seen cellphone sneaking in a watch so one might assume that in the future the shrinking will reach a point where embedding won't be a (technical) problem.

Here's a rendering of a microchip in a tooth shown at the Science Museum in London, created by MIT Media Lab Europe as proof of concept. Credit: Jimmy Loizeau and James Auger

Notice: the opinions expressed in this eBook are not necessarily the ones of the SAS Initiative and IEEE FDC is not endorsing them.

There have also been some experiments to embed part of a cellphone in the body, the loudspeaker and the mike, connecting them wireless to the cellphone. In one instance it was proposed to embed a microchip in a tooth. The microchip connected to the cellphone via bluetooth (of course !) and vibrated in such a way to generated the same vibration generated by sound through the jaw, thus letting the inner ear pick up the sound (Excuse me, is your tooth ringing?).
A bit scaring? Not something to worry about now but in 20 years time technology might have reached the point where a cellphone implant will not only be feasible but it will become normal. The technology hurdles are mostly related to the energy harvesting that so far makes an implant of this type impossible. In my opinion there are also economical hurdles (probably more difficult to solve than the technical ones). Cellphone industry is about selling phones, making them obsolete and selling new ones. To make a phone obsolete the industry is no longer working on performance (since when you saw an ads extolling the better voice quality of a new phone…?) rather on design. A new design is not necessarily better than the previous one but it will definitely make it "old". Hence the "need" to get the new one.
If you implant the cellphone you can no longer show your friends that you've got the latest model. It becomes a pure function provider. In my case I can also imagine that the idea of implanting and re-implanting with images of scalpels, sutures…. is not at the top of my wish list, but it might be different for other people.

- Conversational machine interfaces



A sketchy evolution of human computer interface leading to voice interaction. Credit: Chatbox Magazine

"Alexa what is the weather today in Rome?" We have started to interact verbally with machines, and in just a couple of years the interactions have become more and more seamless. A new technology or rather interaction way, Chatbox, is becoming more and more usual. The word is a fusion between Chat and Robot, deriving from the use of

software robots that can interact with us using voice. It all started with voice command (Connect … Find ….) then it evolved to accommodate normal sentences (Call Laura, but also Hey, I want to talk to Laura, let's give her a call…). What is amazing to me is that the change happened in these last two years (we even have a Chatbox Magazine!).
Why is then the Foresight team at Imperial College placing the generalised use of conversational interface twenty years from now? My take is that if you are looking at having a conversation with a (software) robot expecting to have the same experience you would have talking with your friend then the twenty years assumption make sense. I am pretty confident that in twenty years time we would be able to converse with a (soft) robots without a second thought, it would be indistinguishable from a real person. We will have the possibility to select the chatbox we would like (an expert in physics, or in medieval literature) and engage in a rewarding conversation.
Of course this raises the issue of losing the human touch. If I can get the same experience with a robot in terms of conversation will I choose the robot or risk a boring interaction with a human?
It is not for me to answer, but I can see a whole new set of issues popping up to entertain sociologists for the next decades. For a glimpse on a "niche" of conversational potential take a look at the BBC special "Sex Robots and Us" broadcasted on April 8th 2018.

- Thought control machine interfaces

Moving on from conversational interfaces the next step would be skipping the conversation and getting in touch directly: brain to machine.

A 58-year-old woman, paralysed by a stroke for almost 15 years, uses her thoughts to control a robotic arm, grasp a bottle of coffee, serve herself a drink, and return the bottle to the table. Credit: Brown University – 2012

Here again technology is making progress. Although significant, today's approach is still based on capturing electrical activity from the brain, having a computer processing it and executing some actions. Are these actions the ones that brain was looking for? Not exactly.
What happens is that that "brain" looks (through its eyes) what happens when it "thinks" about something (is the pointer moving up or down?) and based on this feedback learns what to think to have the computer execute what it wants.

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There is also a growing training of the computer, to be able to better interpret the “thinking” going on in the brain but basically all experiments run so far see the training of the brain making the interaction possible.
The technology used to pick up the brain electrical activity is not very effective, nor practical. Wearing a sort of cap with hundreds of electrodes provides sufficient information to drive a pointer and clicking, basically to replace the use of the mouse (which for a paralysed person is clearly a huge advance). For more precise electrical activity detection researchers use brain implants, a chip with tens/hundreds of electrodes on the surface of the brain. Although this provides more precise signals it requires surgery, it is prone to infections and picks up activity only from a very narrow region of the brain.
New chips with radio communications are being investigated (to avoid the problem of infection resulting from an open skull) but there are problems with powering those chips and keeping the dissipation low (radio communication is more energy intensive than wire communications) an essential requirement to keep the implant safe.
So far there seems to be no silver bullet on the horizon. Progresses will be made for sure and will be helping people with disabilities of various forms (picking up “thoughts” from the brain includes picking up signals to move muscle in a leg, so the same technology can be used to recover movement in a paralysed person) and in this case the cumbersome equipment needed for the interaction may be worth the while.
In case of communications with a machine, in general, conversational communications may fit better most application areas.
Clearly the evolution towards symbiotic autonomous systems -SAS- would get a boost from a direct brain to machine communications. There might be other ways, to be discovered, for an implant to become aware of the intention of the brain and to act accordingly.
As an example just a month ago, early April 2018, MIT presented AlterEgo, a system able to interpret electrical signals that flows, without us being aware of them, to our facial muscle when we think of some words (without voicing them!). The system has been able, once trained, to pick up words with a 92% accuracy at dictation speed, which is quite amazing.
Another example comes from China where, according to South China Morning Post a Chinese company, Hangzhou Zhongheng Electric, has its workers wearing a helmet with sensors to detect their brain activity and it is able to identify situation of stress, anger that might decrease workers efficiency and attention, potentially leading to mistakes and dangerous situations.
In both cases the electrical signals are used as indicators of a state of mind, they are not related to thought “reading”. As I said, we are quite distant to reach that point.

5G is old stuff, let’s look at 6G!
- April 27th, 2018

Notice: the opinions expressed in this eBook are not necessarily the ones of the SAS Initiative and IEEE FDC is not endorsing them.

Don't think 5G will be the end of the line. A few people are already looking into 6G … Image credit: PC Mag

As marketeers are busy extolling the virtues of 5G as the ultimate wireless system filling all of your needs and all of your dreams (and Operators are busy deploying and upgrading 4G!) a few people are already looking at a new generation aiming at "filling the gaps between 5G promises and reality!".
Any G generation takes about 10 years from the inception to the market and then 10 more years to fully consolidate followed by 20 years of "normal" operation. 5G is now approaching the first steps to the market, we can expect to see 5G smartphones in 2020, wireless dongle already in 2019, so it is about time for researchers to start looking at the next generation. As usual they are starting from some generic needs and since the hypothetical performances of 5G are such that whatever you need it will be accommodated in the 5G wishful list they are looking into how filling the likely gaps between promises and reality (to the horror of marketeers!).
At university of Oulu, Finland -a Country that is rightly associated with wireless technology-, a team of researchers have created a Vision 2030, fitting the time window for the first presence in the market of a new G generation. Take a look at the video, it is interesting!
The basic assumption is that artificial intelligence will dominate both in the delivery area -in the core and at the edges of the network(s)- and in the fruition area -devices like smartphones and things (super IoT) and in the application space.
As you will see in the clip, Augmented Reality will become pervasive. It is not clear what technology -or technologies- will support this. Smart materials might allow any surface to display information, holographic projectors might become available…
However to reach the sort of ubiquity suggested in the clip I feel that we will need to have images created directly in our eyes, using electronic contact lenses, chip implant or brain implant (BCI). All of them are unlikely to be available, in the mass market, in that time frame, my bet is we will have to wait till the following decade for electronic contact lenses and much more for implanted chips and direct brain interaction. Notice that we might have some trial sooner (we actually have some very rough prototype already today) but getting to the mass market is a different story.
I also have the feeling that some images shown in the clip, like holographic objects floating in space, will only be possible through electronic contact lenses (or chip or BCI). It is also a matter of cost: it will be cheaper to augment humans to become able to receive and visualize bits than augmenting the any ambient to display them.

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Clearly, assuming that every surface is a screen it follows that a huge bandwidth is required. However, different architectures may shift the bandwidth burden from the network to the edges, to the ambient, to the devices and eventually to the human and things augmentation (unlimited local memory).
It may also be that in 20 years time communications demand will be created by objects, like autonomous systems, both as external communications (towards other autonomous systems) and internal communications (among symbiotic autonomous systems), with human needs already fulfilled by the 4th and 5th G generation….

That's quite a talker!

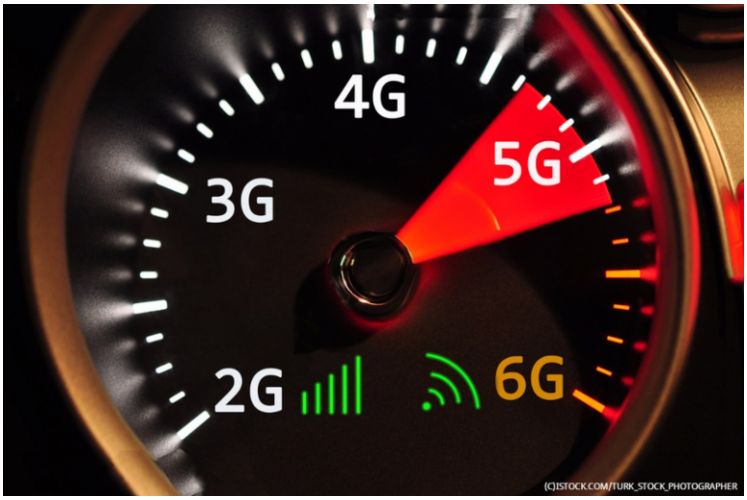
- May 9th, 2017

The Lyrebird is capable of mimicking the voice of other birds, sounds and even part of the human voice. Now a Canadian start up can do the same using artificial intelligence algorithms. Photo credit: Alex C Maisey/ANU

I was fortunate to witness the evolution of computer "voice". Back in the 80ies I sat close to researchers at CSELT, the research centre, now disappeared, of the Telecommunications Company in Italy, working on making a computer talk. I remember it was a metallic voice, quite far from a human voice and yet you could understand that voice and people were amazed.
The evolution of processing power, storage and a new generation of software has led to a voice syntheses that it is getting difficult to tell apart from a human voice.
Training a computer to "imitate" a specific human voice has become possible, Google is doing it pretty well, and Adobe has a prototype, VoCo, that would let editing a voice, including adding words and sentences that were never said (that is worrying…).
Current training takes some 20 minutes of listening to a person voice to create a model that can be used to mimic that voice.
Now, a Canadian start up, Lyrabird, says to have succeeded, using artificial intelligence algorithms, to train a computer to replicate a human voice in just one minute. Take a look, or rather listen to, a few examples.
The progress over these 35 years has been amazing and yet it took longer than researchers expected 35 years ago. The human voice has proven very difficult to imitate, particularly in its abilities to convey emotion, something that our brains have got very sensitive to capture.
Now that the quest for a a perfect human voice is almost completed we are facing with new issues. Computers that can play as humans generate as many problems as they solve.
How would be able to tell if there is person on the phone, if it is my friend or someone else pretending to be him and using a computer to fool me?
Technologies like this one are creating a background for the evolution of symbiotic autonomous systems where voice is one way of establishing a sort of symbioses.
By the way, the Lyrabird voice synthesizer is capable of generating 6,000 seconds of a specific human voice in just half a second: that's quite a talker!

Let's start talking about 6G!

- January 25th, 2018



Will 6G be faster than 5G. Sure. But will be that the reason to move on from 5G. I don't think so.
Image credit: Telecom Tech News

What?! 5G is not year yet and I am proposing to start talking about 6G?
Well, as an excuse, let me say that I am not the only one, and talking about 6G is a way to demystify 5G.
It may also be appropriate to point out that someone believes there will never be a 6G (!) because if 5G is done properly it will be an open collection of technologies and systems that will simply grow over time.
Although I agree that 5G is potentially an open cluster of technologies and systems providing a unifying umbrella and as such anything can fall under it I do not agree that it will be the end of the story, because:

- marketing will need a 6G as soon as 5G will be deployed
- researchers will have to mark the novelty of what they will be working on
- 5G will not be as open as we might desire and hence will not be able to accommodate any new development

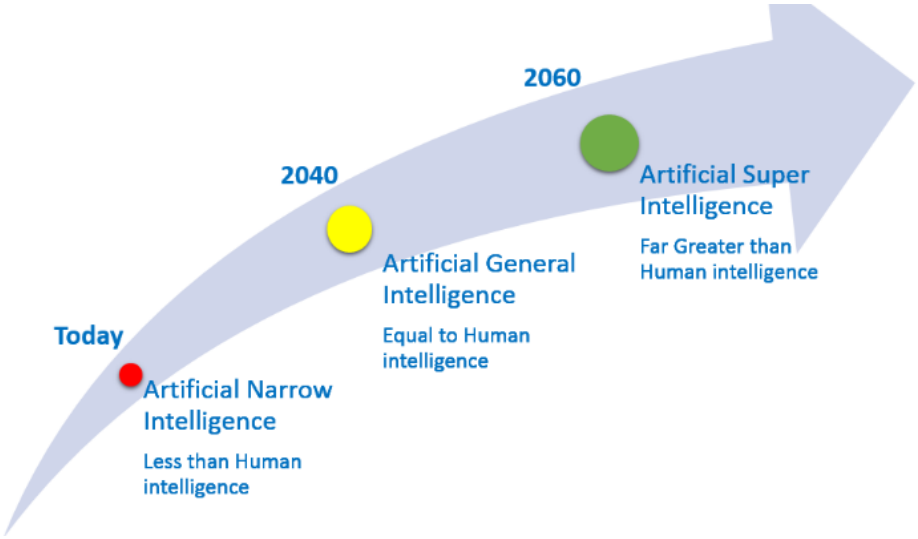
Of the three reasons, of course, the one based on marketing need is the strongest.
At the IEEE FDC, within the Industry Advisory Board -IAB-, we have been discussing the evolution of wireless systems, focussing on 5G, and in that context we came up with an outline of 6G. I had a nice talk just few days ago with Ezio Zerbini who has been with Ericsson for quite a while and always a good sparring partner in discussing the future of telecommunications. He has a very in depth knowledge of what it takes to evolve a telecommunications system and what are the real customers need for such an evolution.
Well, at the IAB we stated that the 6G will be a significant evolution from 5G for its capability of self aggregating networks of different types. Whilst 5G should be able to accommodate different types of networks (technologies) 6G will be able to take the lead to aggregate them to satisfy needs arising in a dynamic way.
Ezio gave me his vision of 6G that is not that much different from the one we gave: 6G networks will embed planning into the network itself, meaning that the network will become aware of the way it is being used, what is actually required by its users at this specific moment and what it is likely to be required at a later time and it will be able to plan for its

evolution by reconfiguring its resources and by “asking” vested parties to provide additional resources coming up with a convincing reason and a convincing business plan. To do that the 6G network will need to be an autonomous system, able to learn and make prediction, develop a convincing plan and negotiate it with a variety of stakeholders. This, if you think about it, is an amazing prospect, an infrastructure that becomes self aware and able to plan and foster its own evolution.

6G will become a reality beyond 2035, that is in the right timeframe when we expect Artificial Intelligence to match our own and autonomous systems to live in a symbiotic relation with us.

Artificial Intelligence

Computers keep getting better … than us
- January 21st, 2018

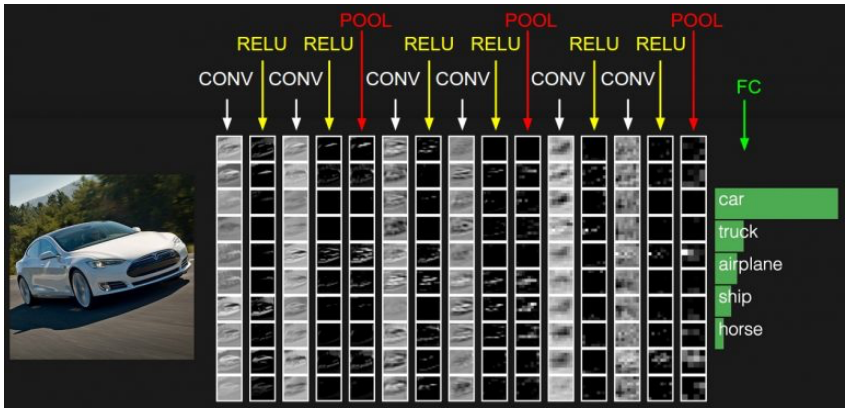


On the average experts predicts that by 2040 Artificial General Intelligence will be au pair with the one of humans. Give it 20 more years and we will see computers with super intelligence living behind the one of the human race. Graphic credit: Pratul Kumar Singh

Most experts are predicting that the coming of AGI, Artificial General Intelligence – the capability of computers to stand au pair with our intelligence, is about 20 years away. A few anticipate the date to the 2030, others are are pushing it further to the second part of this century.
For sure AI, Artificial Intelligence, is now a reality that is matching and sometimes exceeding our human capabilities in specific areas. Notice that there are areas where there is no match, where AI is far superior to us. This is the case where reasoning requires the analyses of a massive amounts of data, a feat that would be impossible for us. Think about the analyses of hundreds of thousands of mammographies to learn how to spot a tumor or the real time monitoring of engines requiring the analyses of huge amounts of data in milliseconds.
However, moving from AI (also called narrow Artificial Intelligence) to AGI is a huge step. Actually many of us have considered the difficulty in moving to AGI as the proof that computers do not have something comparable to humans in terms of intelligence. Being old, I remember over the last 40 years people saying: yes computer are fast but they cannot have the intelligence to beat a chess master. When it happened (1996) people said: ok, but playing chess does not really mean be intelligent. Then it was image recognition, a clearly difficult task for a computer. When computers got better at image recognition (2015), people said, yes but they do not show any “creativity”, it is still a good show of mechanical capability, no real intelligence. Then a computer beat the Go master (2017) champion surprising experts with its “creative” moves but people still said that it was a great show of very narrow capabilities, better than ours of course but we win on latitude hands down.
Indeed, the AGI is now seen as the real challenge.
This is where the news of Microsoft and Alibaba software, independently, scoring better than human in reading comprehension opens the way to AGI. Reading comprehension is

measured through SQuAD, a test devised by Stanford University (Stanford Question Answering Dataset comprising over 100,000 questions drawn from 500 Wikipedia articles). The test taken by humans scores (on the average) 82.3%. The MS and Alibaba software passed this mark reaching 82.44%. Now, you might say it is not a big deal, it is basically au pair with the average human and for sure there are many humans that can get a better score. True, but nevertheless reading comprehension is considered as one of the component of AGI and we are not in 2040, we are at the beginning of 2018.
To me there is no doubt that AGI is coming. I have doubts on the implication of AGI. Many think, and I am one of them, that the goal is not to create machines that are smarter than us, although this will surely happen, rather of creating a symbioses of ourselves with our ambient and any kind of machine in that ambient that makes us smarter.
Having AGI as a separate, and potentially opposing entity, competing with us is scaring. Having the possibility of becoming way smarter as human beings thanks to a symbioses with AGI is a much better proposition.
This is what we are addressing in the IEEE FDC Symbiotic Autonomous Systems Initiative. A huge challenge that can be faced pooling the many resources of IEEE, its volunteers, Societies and knowledge base.

Why, Why, Why? Yet, AI does not answer
- January 12th, 2018

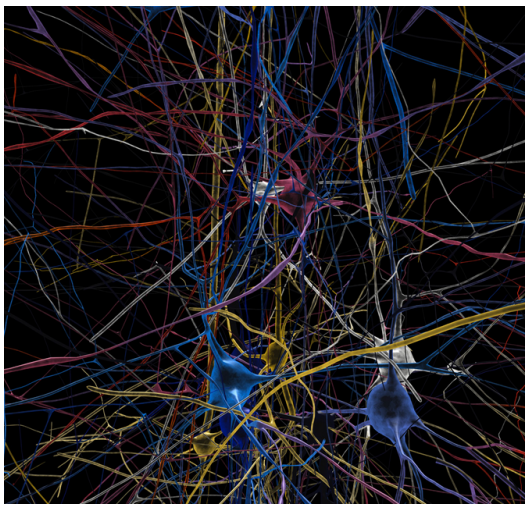


An illustrated example of a convoluted neural network used in a self driving car to identify an object. The actual process of identification is lost in the many steps and it would be difficult for the car to explain "why" it has taken a certain decision, even more difficult it will be for us to understand the explanation. Image credit: Karpathy, Stanford University

There is something in our human nature that is pressing us to ask "why". And that stems from the assumption, belief, that there is always a reason why. Once we acquire the idea of cause-effect, normally once we get 3 years old, we will never abandon it. Young kids keep asking why, as adult we may not ask why as often as we did when we where kid but we know by heart that there should be an answer (and if there isn't one available we are willing to fabricate one, like invoking the supernatural…).
We have seen in these last decades amazing progress in autonomous systems, guided by an ever smarter artificial intelligence. We have witness the GO World Champion being defeated by AlphaGo playing some unexpected moves. Yet there was no possibility to ask AlphaGo: "Why did you play that move?". Similarly, if we were seated on a self driving car and all of a sudden that car veered to the left we wouldn't be able to ask the car: "why did you veer left, rather than breaking?"
The fact is that AI has not been programmed to answer "why". More than that. The processes followed by AI take into account thousands, sometimes million of possibilities

and an explanation of those processes would be far too complex for us to understand. Notice that our brain is also taking into account millions, may be billions, of signals/states, generated by its neurons but at a conscious level we only perceive a very limited number and what we perceive is actually what makes us answer the "why". We are basically disregarding the low level machinery and only focus on the high level semantics (which sometimes is misleading…).
Looking into the "why" is intriguing, it goes back to the Leibniz "calculemus" to the idea that there is a well defined process that starting from a limited set of assumptions leads to a unique conclusion. That process plus the original assumptions/data is the "why". This was also a starting point in the development of artificial intelligence: finding a process (the one created intelligence) and applying it to the solution of complex situations. So far it failed. Actually Artificial Intelligence stumbled onto a roadblock and did not advanced any further with this approach (we got expert systems in the 90ies, some very good one, but very specific in their capabilities).
In these last years the advent of a different approach based on self learning has opened up a new world and we have seen tremendous progress in artificial intelligence. It is not -yet- an Artificial General Intelligence, AGI, but it is surely going beyond narrow field artificial intelligence.
Sure, we have plenty of AI applications that are very "narrow", like the AI used in a digital camera to find smiling faces, or the one in a smart tripod to track an object or in a self driving car to become aware of potential obstacles…. But the very way we are developing AI today through self learning (using convoluted neural networks, deep learning…) is taking us into unexplored paths that cannot answer our "why".
You define a certain frame, the initial conditions, for AI to develop but then it is on its own, and the path it takes, the kind of reasoning it develops may be beyond our grasp.
This is both exciting and scaring. It is actually not too different to what happens in the education of human beings. You teach a person but you have no guarantee that the processing of your teaching will result in a person that will process facts as you do. As a matter of fact, we have initiated a creation process where the created entities may surprise their creators.
Symbiotic Autonomous Systems may take these issues a step further (or may be they are just another facet of the same issues, being a "super system"). In a symbiotic autonomous systems you have two -or more- interacting intelligences giving rise to a new emerging intelligence. How can we get an answer to our "Why?" from this emerging intelligence? Notice that attached to this there are huge ethical, social as well as accountability aspects. More thoughts on this in the future…

The thin, fuzzy, line between awareness and consciousness
- January 3rd, 2018



A web of neurons. Out of immensely complex networks of neurons awareness of self, consciousness, emerges. Will webs of transistors, memristors and software (AI) follow a similar path? Credit: EPFL Blue Brain Project

Philosophers have been debating about awareness, consciousness and for long time have asserted that only us, humans, are conscious (whilst all living things need to have some sort of awareness to keep living…). Today we know that it is not just us, many, actually most, animal species have some degree of consciousness. According to Hugh Howey humans have an hyper consciousness, a term used to mark that consciousness comes in different degrees. Monkeys are probably more self – conscious than a cat and so on.
Awareness is a precondition for consciousness, one has to be aware of the context and of its relation with the context to identify and recognise the specificity of the "self".
Interestingly, consciousness is not something we are born with. When we open the eyes for the first time we are not aware of any context (the one we grew in, the uterus, was quite different) and it is likely that we have seen the world upside down the first time we looked at it. With time our brain did the magic of flipping the images coming from our eyes (that are upside down because our eye is a photo camera with the lens flipping the image) and started to learn about the environment and about ourselves, it discovered that those appendages we much later learnt to be called hands are actually "our hands" and that "our" applied to many parts of us eventually created a consciousness of the self.
If you buy into this (very rough) reasoning then you can buy onto the fact that an animal need sensors to become aware, it needs the capability to make sense out of the data harvested from those sensors and furthermore it will have to create a sense of self and of its relation with the world. All of this, in different degrees that depends on the sophistication of the building of the self and of the emergence, conceptualization of the self, comes over time.
Now an interesting question is: given that an animal needs all of that for consciousness to be generated, does consciousness need and animal to appear? Would a machine be a replacement for an animal? In other words: can a machine be conscious?
The debate has been going on for several years now (at least since the idea of artificial intelligence came up). What is now happening is that the question is being rephrased in ways that make answering it no longer a philosophical debate but an engineering effort. And this is quite a change.
We can surely have machines that are becoming aware of their environment (think of a self driving car, where being aware is a pre-condition). Sensors and processing are making this a reality. Of course there are different degrees of awareness -you can be aware that a person is about to cross the street, and that is enough to take action, or you

can be aware that a person is feeling blue to the point of becoming suicidal. The latter may require an empathy that is surely not part of self driving cars (the ones we are designing today anyhow).
We also have artificial intelligence that is making possible to learn from experience and from observing others, even from observing a virtual copy of a computer “mind” like it happens with Google DeepMind. And I just stated that we, human beings, are developing our consciousness by learning through awareness. There is not reason, from an engineering point of view, for a machine not to reach the point of being conscious, at least at a very basic level. But once we are there we are on a slippery slope. Moving from a basic consciousness to more complex for of consciousness is probably not are hard as it is to move from a passive machine to one that is aware, self aware, conscious, self conscious…
We are considering these issues within the IEEE FDC Symbiotic Autonomous Systems Initiative under the topic of Machine Awareness.
Is this the definitive answer to the old riddle of consciousness and to the more recent question on the possibility of creating conscious machines? Of course not.

Notice: the opinions expressed in this eBook are not necessarily the ones of the SAS Initiative and IEEE FDC is not endorsing them.

It doesn't play like a human, nor like a computer…
- December 15th, 2017

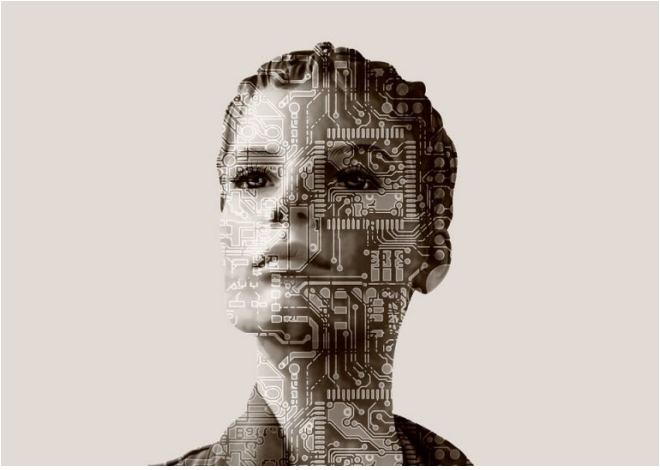
A game of Shogi. AlphaZero has learnt to play the game, having been instructed on the rules, by challenging itself for 24 hours. After that it has become a better player than a human one. Image credit: the Crafty Players

Just stumbled on an article submitted at the Neural Information Processing Systems Conference in Long Beach, CA – US, reporting on AlphaZero capability to learn to play games by being instructed on the rules (not surprising) and then playing with itself to learn the winning strategies (that is more interesting).
The result is that AlphaZero can become so proficient at playing the game(s) within 24 hours of self training that it can defeat the very best players in the field, humans and computers alike.
However, what surprised me is that according to the article's writers AlphaZero ends up playing differently from a human, and differently from a computer. It looks like an alien form of intelligence is being created, a form that can outsmart both humans and "classical" computers!
AlphaZero is a creation of DeepMind (a British company acquired by Google in 2014, focussed on advanced artificial learning technologies based on neural networks). The article is reporting on AlphaZero learning to play Chess and Shogi after having been instructed on the rules of those games and left alone to develop playing strategies. To develop these strategies AlphaZero plays with itself and discover what works and what doesn't. In just 24 hours of playing (which means millions and millions of games played) it gets sufficient experience to outsmart top level players and programs based on mimicking human approaches.
Observing AlphaZero playing one (an expert player…) would see the development of a playing strategy that is nothing like the one adopted by a human nor (obviously) one used by a normal program (not surprising since existing programs are attempting to mimicking humans strategy, thinking if you want).
Notice that this is not about being good at number crunching, being better than a chess player because you can examine the outcome of more options, of looking further down the game potential evolution. If it were so the strategy would still look a human one, just a better one.

What we are seeing is the emergence of a different sort of intelligence, it is not about being “more intelligent”, rather about being intelligent in a different way (that proves to be better than our intelligence).
This is tricky indeed, and this is basically what amazed me in reading the paper. AlphaZero by autonomously developing game strategies develops a new form of intelligence.
This is also strengthening the importance of the FDC IEE Symbiotic Autonomous Systems Initiative with an emphases on the symbiotic part. Establishing a “partnership” with machines like AlphaZero is not extending our human intelligence, it is complementing it with a different form of intelligence and this opens up new, unexplored, landscapes. It is not like using an electronic calculator that makes us faster (and more accurate) in doing computation. It is allowing us to partner with an alien intelligence to explore issues we would not be able to explore with the kind of reasoning that we use.
This reminds me of what Einstein once said: ” We cannot solve our problems with the same thinking we used when we created them”. In this ever more complex world we are facing a lot of problems, from climate to geopolitical struggle that we have created on our own. Getting a helping hand from an “alien” intelligence might be worth exploring.

A question more important than the answer …

- August 16th, 2017



The boundaries between Intelligence and artificial intelligence is getting fuzzier and fuzzier. What about self awareness? Image credit: Gerd Altmann/Pixabay

Philosophers have been debating on consciousness for ages. It is such an easy but slippery concept. We know that we are conscious but clearly defining it and, even more difficult, placing boundaries around it is tricky. If one is daydreaming is he conscious? What if he is under the influence of drugs? And what about animals? We may feel that a dog is conscious but is it? We may feel that a spider in not conscious but is it not?
Now a few philosophers and scientists are investigating into AI -artificial intelligence- software asking the question: is it conscious? For the time being the answer is generally “no” but what about the future, including the near future?
The first doubts arose by watching AlphaGo playing against the Go world master. Notice that I wrote “playing”, not “winning”. Yes, AlphaGo won, but experts watching were surprised by the (unexpected) moves it made, more than by the fact that it won. It seemed, at least to some, that AlphaGo had a creative mind allowing it thinking out of the box, which is one trait of consciousness.

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An interesting article on Kurzweil discusses the studies of Susan Schneider (a philosopher) and Edwin Turner (an astrophysicist) that area investigating the question: How can we tell if AI software is conscious?
They are proposing a test to check if an AI software is conscious, the ACT: AI Consciousness Test, to see if a synthetic mind has reached the level of self awareness, of consciousness.
The article makes for a good read because it explores what it may mean self awareness for an AI software.
I find the question even more interesting than the possible answer(s) because it shows that we are reaching a point where the boundaries between the physical processing and the mind that we have faced for 2 and a half millennia (in the Western culture and philosophy) are now visible for synthetic minds. Of course, we have not yet completely solved our consciousness, so moving on to solve synthetic consciousness may be moot. Yet, I find it a fascinating question telling us that we are traveling in terra-incognita.
And the trail may bring us further on. What about the meta awareness and meta consciousness that can emerge out of local consciousness in symbiotic autonomous systems? Here you have local consciousness (like our human one interacting with a synthetic consciousness of an AI powered autonomous system) that may fuse into a higher form of consciousness, the one of the symbiotic system.
Do bee swarms, ants colonies (or an ant hill) have a sort of emerging consciousness out of elementary component that are not conscious at all (as long as we can see)? If so, can unconscious IoT when participating in thousands and millions in the creation of a symbiotic autonomous system give rise to an emerging consciousness?
Tough questions indeed, and just asking them is very interesting. This is something the Symbiotic Autonomous System Initiative is looking at and you are most welcome to join us in this exciting debate. Even if we will not reach an answer the quest is worth the while!

It dropped to Earth, but I bet something else will soar
- August 2nd, 2017

The Lily Drone is down (or may be it never really took off).
Image Credit: Lily Drone

The Lily Drone made the headlines in 2015 promising to change the way people would take photos. It was portable, easily fitting in a backpack, it could be launched from the palm of your hand and would take care in complete autonomy to photo your walk,

canoeing, snowboarding with no need for guidance. It would follow you using a beacon strapped to your hand and you can push a button at take off to tell it how you wanted to be filmed, from the back, from the side, from the front.
The winning proposition was its being autonomous. And that could be achieved through sophisticated AI.
In 2016 it was awarded the “product of the year”, in July 2017 the company went bankrupt before having been able to sell a single unit, in spite of the thousands of pre-orders that brought 30+ million $ in the pockets of Lily Drone. You can read the full story on Wired.
There is no doubt that this was a failure and it also show how quick the press may be to give hype to something that is not a product by naming it “product of the year”.
Reason I am posting this news is that in spite of this failure I do believe that it is just going to be a matter of time. By early the next decade I am betting we will have these types of autonomous drones, may be coming from an established company like DJI, and more than that, we will consider them as perfectly natural. Why would you need to “pilot” a drone? You just tell it what you want and it will take of all technicalities.
Think about your point and shoot camera. You tell it you are taking a portrait photo and it will take care of all the technicalities, like focus, exposure, white balance, background bokeh … and much more. These technicalities are so obvious that you don’t actually know them, even less how to accomplish them!
Autonomous vehicle are already here, just not in the price point that can make them affordable in many areas. But that will (actually is) change.
We often think about autonomous systems as “complex systems”. In reality they are winning the market because in an ever more complex world they are the easy way to go. And once you have reached real autonomy you have also reached the possibility to increase system complexity since all the various parts (systems) will take care of managing the complexity by themselves making life easy for us.
There is, will be, of course a big issue. As our world will become at the same time way more complex and way more easy, what could happen if something breaks down and no longer takes care of managing the complexity on your behalf? What if once we will be used to self driving car the car (self driving capability) breaks down and you will have to take the wheel? Will we be ready for that if we have established a symbiotic relation with the car?

Actuators

Robotic Dragonfly

- June 7th, 2017

An electronic backpack to steer a genetically modified dragonfly. Actual backpack on a dragonfly model.
Credit: Draper

We have been able to develop amazing vehicles, millions of people are flying on comfortable airplanes that are -almost- autonomously flying, robots in the sky. Yet we are still far to create a really small vehicle, as small as an insect, with comparable capabilities. The approach that some researchers have been pursuing is to use a real insect and to steer it to do what they want. More than ten years ago, in 2006, researchers at Tokyo University created the first cockroach cyborg implanting electrodes on the insect's antennae and forcing it to move left, right, stop and go by tiny electrical impulses on the antennae. Over these last years this technology has become so easy to use that there are now "kits" for creating your own roboroach (I am not happy of this evolution, I am siding with the roaches on this, and I am not alone).

The backpack mounted on a real dragonfly. Credit: Draper

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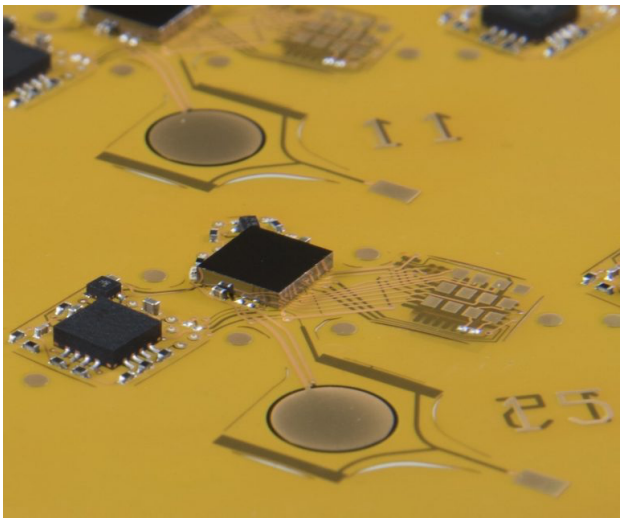
Hence, the news that Draper, a US based company, is developing an electronic backpack to control the flight of a dragonfly shouldn't be anything really new to report. What is really new is the approach they have taken with their project DragonflEye.
They have teamed up with the Howard Hughes Medical Institute to experiment on a way to genetically modify a dragonfly making its nerves sensitive to specific light wavelengths (optogenetics) and equipping the dragonfly with an opto-electronic backpack that can receive signals (instructions) from a radio link and convert them into optical signals affecting the brain of the dragonfly to steer it in doing specific actions (like flying in an intended direction, hovering, …). The connection between the backpack and the dragonfly brain is made through specially developed optrodes (optical probes) implanted in the neural cord feeding signals in the brain. They have been able to create an extremely selective communication channel, thanks to optogenetics, where the optical signals are received only by the intended neurons (the one controlling the flight) without disturbing the others.

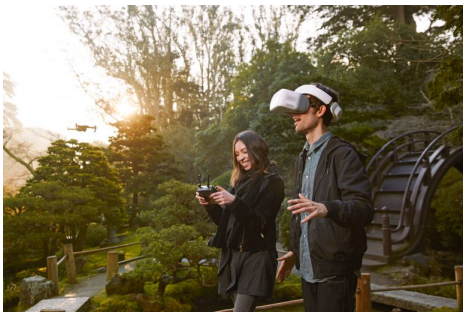


Optoelectronic components of the backpack before its assembly.
Credit: Draper

They are interested in perfecting this technology for possible application to patients with disabilities resulting from severed nerves.
Another application would be the monitoring of the honeybees, whose population is declining with devastating impact on US (and other Countries) economy -their contribution to the US economy is estimated in 15B$ a year.
Another possibility, that it is not mentioned by Draper but I would be surprised if it is not being considered, is to experiment with optrodes to find the right mix of neurons that are responsible for some sort of thinking, like: let's look around to see if there is a mosquito larvae that I can have as dinner…
The possibility to experiment with brains opens up interesting, although potentially scaring, opportunities (and is fraught with ethical aspects).
This work is also a clear step forward in the creation of symbiotic autonomous systems …

Flying on a drone, virtually

- May 8th, 2017

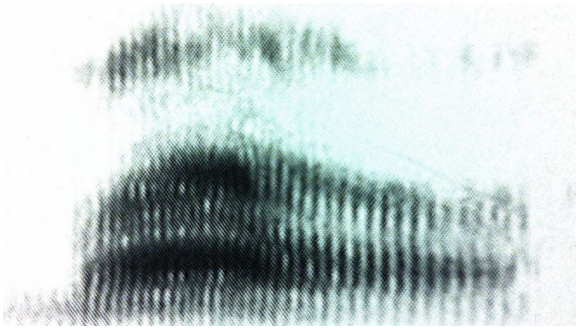


Wear VR goggles and see what you would see if you were flying in the drone!
Credit: DJI

Drones have become quite popular, after the marriage with digital cameras, and you can fly a drone using a tablet and seeing on the tablet screen the images captured by the on board camera. Nice, but quite far from the sensation you would have if it were possible to sit in the drone cockpit (which so far is not possible since they don't have one!).
Here comes the idea from DJI, the most known drones manufacturer for the mass market: don a virtual reality goggle and feel the emotion of flying in the drone!
In 2016 they announced the plan to develop a VR goggle to let experience the view provided by the drone on board camera as if one would be on the drone and on May 20th, 2017 they are releasing it for 449$, not cheap but surely affordable by drone owners. The VR goggle provides HiDef images (1920×1080) to both eyes. According to DJI the sensation is like being in front of a 216″ home-theater screen, which equals to become fully immersed in the ambient, like being on the drone.
There is also the option to "pilot" the drone by moving your head: as you turn your head left a signal is transmitted from the goggles to the drone and it turns left in synch with your head.
I posted some time ago the news of Cape, a start up that offers the possibility to fly a drone from the comfort of your living room in specific locations (so far they have drone bases in California). This area is really fueling innovations, and it shows, once more, that it is more about creativity than technology, although this remains a crucial enabler.
At FDC we just started a new initiative, Symbiotic Autonomous Systems, and drones are part of it. The possibility of synchronizing your "gaze" with a drone is a step in the direction of symbiosis, at least to an aspect of it.

It speaks like me! … and you

- December 31st, 2017



A spectrogram for the word "whoa". By the way, does it look to you like a mouth voicing a sound? It surely does to me.
Credit: Lorenzo Tlacaelel / CC BY 2.0

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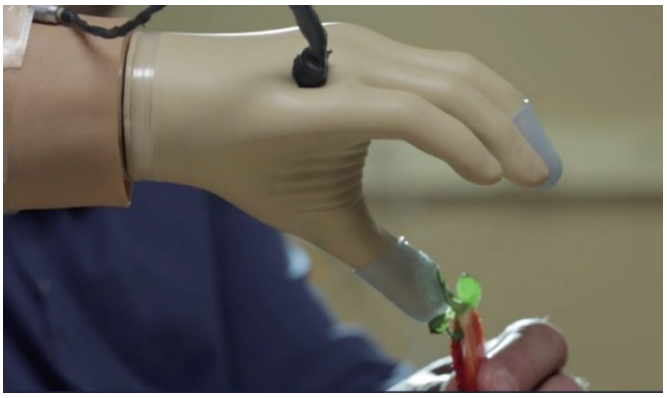
I do not know how 2017 will be remembered in terms of technology advances. If it were for me I would associate it with the pervasive uptake of AI, Artificial Intelligence.
I posted quite a number of news on “applied AI”, i.e. application of Artificial Intelligence in many fields, some of them really unexpected (like a smart tripod), others really pervasive (like in digital photography, from taking a photo with smarter and smarter cameras to editing them with AI assistance). Artificial intelligence is proving better at (some, and growing) medical diagnoses, at painting, at driving cars and drones, it is making real time language translations a commodity, language understanding the preferred way to interact with your television and appliances …, and so on. If I counted correctly, 52 out of the 365 posts I published this year involved artificial intelligence, by far in terms of its application.
Hence, I find appropriate to close the year with a news of a paper published by Google researchers that is reporting on the success of Tacotron 2, an artificial intelligence based system that can generate speech that is undistinguishable from our human speech (you can hear a few examples here). I remember my, and many others, wonder at the first speech syntheses by computer (the computer talks!!!) back in the last century. In the clip below you can hear the voice syntheses made by MUSA, an application developed back in 1977 (the recording is from 1978) by a team of researchers in CSELT, the research centre of the Italian Telecommunications company, that was considered particularly advanced at that time (both the team and the application!).
At that time the processing power, as well as storage capacity, was limited. Those very crude results were considered phenomenal.
With the exponential growth of processing and storage capacity the quality of the speech increased significantly and we can hear the results today in the announcements at airports and railway stations. Somebody says it is cheating, it is not real speech syntheses. By leveraging the unlimited processing and storage capacity the applications today fetch human pre-recorded words/sentences and assemble them into a coherent set taking care of smoothing the points where different segments are pasted together. The result is quite good.
Reading a book is a different story because it requires the application to “understand” what it reads if you expect an empathy in the artificial voice and this “understanding” is the domain of artificial intelligence. In this last year the progress have been significant. The results obtained by Google researchers is remarkable, I personally cannot distinguish the artificial voice from a human voice (that, by the way, the application mimic also in tone and pitch so that it appears to be spoken by the same person). However, the examples provided relates to single sentences. It would be interesting to hear a book being read. There you can appreciate if the quality is such to trick you into believing it is a human reader. And of course, the next step would be to have the artificial voice impersonating an actor that can infuse in the speech the feeling (a sad voice, a thrilled one…) based on what the situation demands.
All in all, this year has marked an avalanche of applications leveraging on artificial intelligence (in its various hues: deep learning, deep neural networks, convoluted networks, …) and has brought machines a step closer to us. A path that the FDC Initiatives on Symbiotic Autonomous System has started to explore.

Emergent beings: Integration of advanced prosthetics

- June 28th, 2017

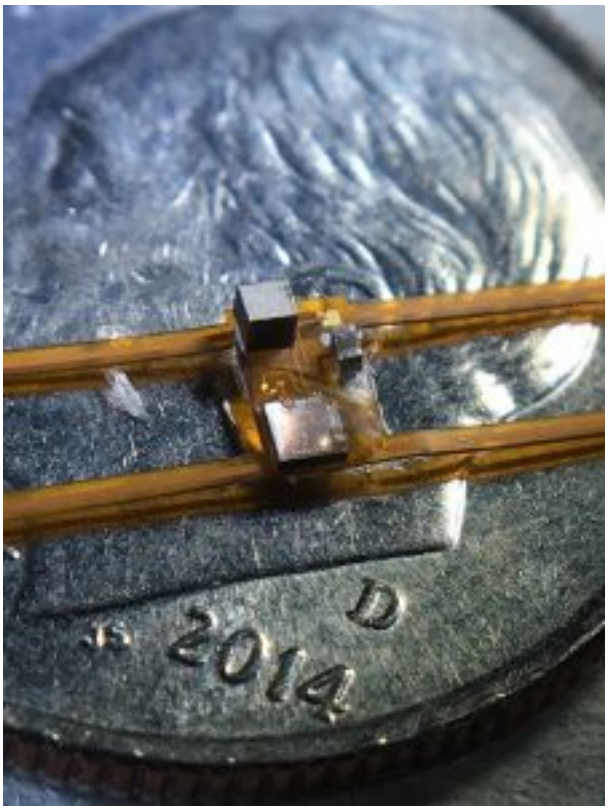


A prosthetic hand with a sense of touch. Prosthetics are becoming more and more "aware" and able to dialogue with the person wearing them.
Credit: Louis Stokes Cleveland Veterans Affairs Medical Centre

The symbioses of artefacts 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.
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 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.

Neural dust is getting ready for your brain…

- May 21st, 2018



Neural dust: a tiny electronic microchip with sensing, actuating and communications capability shown for size comparison on a 1 cent coin. Credit: Berkeley University

Back in 2016 researchers at Berkeley created a micro sensor that could be activated using ultrasound. It was designed to be implanted in the body to pick up electrical signals. It could work in muscles and various organs, including the brain. Being activated by ultrasound it didn't need a battery, nor wires to be powered and it was so tiny to look like a dust particle: neural dust since it was designed to pick up neural activity.

Now in 2018 the same team of researchers has announced StimDust, the tiniest nerve stimulator available today. It is just 6.5 cubic mm in size (for comparison a grain of rice is three to four times bigger) and it can sense neural activity, report it and affect the peripheral nerve by stimulating it. The connection with an external device, a computer, uses ultrasounds both as communications and as power source.

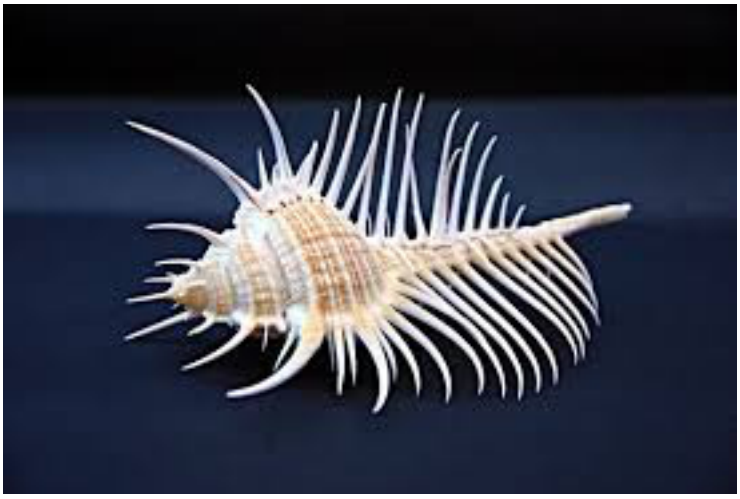
The researchers have tested StimDust by placing on the sciatic nerve of a rat and have been able to control the leg movements by sending pulses. The chip has been designed to be placed, using a cuff, around a nerve and stimulates the nerve with electrodes placed at its lower surface. It contains a piezocrystal that serve as antenna and a capacitor that accumulate power for its operation.

The expectation is to be able to use StimDust to interact with nerves to control epilepsy, asthma, heart arrhythmia and chronic pain.

Sensors

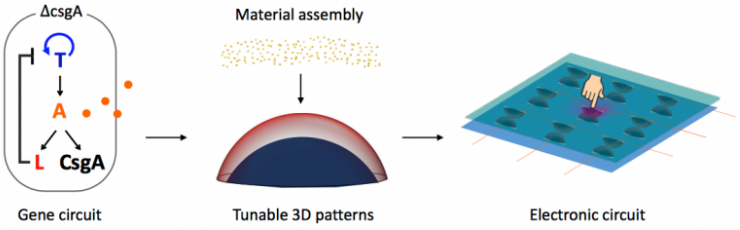
Leveraging on bacteria to build sensors

- October 17th, 2017



A sea shell of the murex pecten that I saw at a friend's home. Image credit: Nauti Shell Company

Living beings are amazing builders: they build themselves in many ways, mixing organic and inorganic substances to create constructions that are extremely well suited to fit and operate in a given environment. More than that: they do that using very little energy, far less than what we would use with our sophisticated machines.
I was shown just few days ago at a friend's home a new shell he got and we wondered how could a simple animal (at least that is how we thought about it) build such a fantastic structure. It is all coded in its genes, molecule by molecule it builds that amazing structure capturing what it needs in its environment and assembling it in just the right way.



Bacteria create a functioning 3D pressure-sensor device. A gene circuit (left) triggers the production of an engineered protein that enables pattern-forming bacteria on growth membranes (centre) to assemble gold nanoparticles into a hybrid organic-inorganic dome structure whose size and shape can be controlled by altering the growth environment. In this proof-of-concept demonstration, the gold structure serves as a functioning pressure switch (right) that responds to touch. Credit: Yangxiaolu Cao et al./Nature Biotechnology

Now I run into a paper on Nature Biotechnology where researchers are reporting on their way to program bacteria to steer them into building a pressure sensor.
The researchers, working at Duke University, have programmed bacteria to self assemble capturing certain molecules resulting in the creation of a pressure sensor. There have been in the past several studies and experiments using bacteria to build specific structures but so far this was achieved through an external control of the bacteria. Here they have programmed the bacterial genes so that the bacteria can work autonomously in the creation of the desired object.

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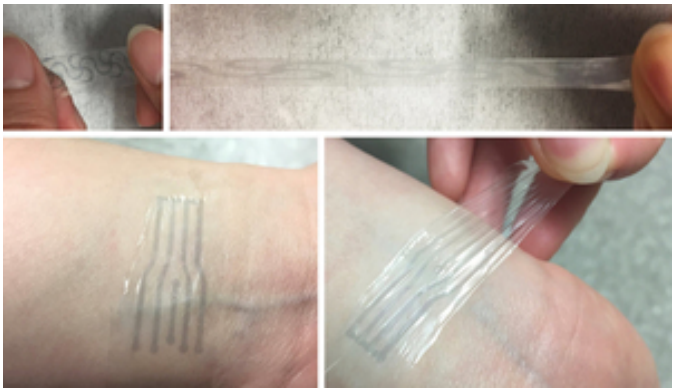
The only external control is the access to nutrients (they decide what the bacteria has available). Notable, with previous experiments, bacteria operated on a flat surface, so that they can be controlled, producing 2D structures. Here the bacteria, operating on their own, can build 3D structures.
Another interesting twist is that bacteria could remain part of the object created (providing a means to maintain a suitable environment for them to live) and then they can work to repair the object in case of need.
Clearly we are in a research space, pretty far from industrialization but it is extremely interesting to observe the increasing capabilities we are acquiring in steering life. This is also going in the direction of reinforcing the trend towards symbiotic autonomous systems since it will become possible to “engineer” the interfaces and behaviour of part of the components participating in the symbioses.

Stretchable brain interfaces

- March 24th, 2017



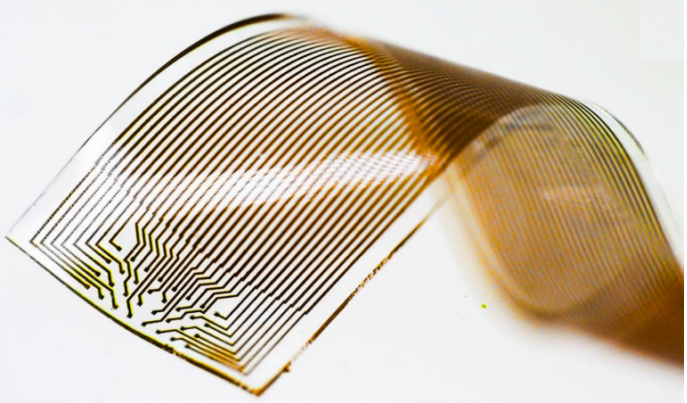
A printed electrode pattern of a new polymer being stretched to several times of its original length (top), and a transparent, highly stretchy “electronic skin” patch (bottom) from the same material, forming an intimate interface with the human skin to potentially measure various biomarkers. Credit: Bao Lab, Stanford University

Scientists are learning to create smart materials with desirable properties like conductivity, flexibility, bio-compatibility and so on. This makes possible their application in areas that were out of touch in the past.
A particular challenging area is the one of symbiotic relation between a living being and an artefact. Living beings keep changing whilst artefacts tend to stay the same and this leads to compatibility problem. Changes may happen over short period of time; as an example our brain changes its volume and shape during the day. As response to our activity it may swell or shrink. Changes are limited within the skull confines but still they can be significant and, as an example, electrodes that have been implanted in a specific place in the brain may become displaced and no longer be usable.
With this in mind, researchers at Stanford University have created a stretchable material that is bio-compatible and that can match the changes in shape of the brain, keeping its location-relation fixed.
The material is a stretchable polymer that can embed conductive elements, stretchable as well. These can serve as electrodes to sense the local neurons electrical activity and can stimulate them with electric spikes.
The construction of the polymer required the merging of two different molecules, each one balancing the other in terms of properties to achieve the desired characteristics of conductivity and stretchability. Notice that it is not about "mixing" two different substances, rather it is creating a structure composed by two different components. It is more like

building a house where you need to place flooring, roof and walls at the appropriate places than to make concrete by pouring together different components.
It is this capability to create smarter material working at molecular level that is of particular interest to me. Besides, in this case, it is interesting to see that materials supporting human-artefact symbioses are becoming available, and even more important, can be designed to fit specific needs.
This provides the technology underpinning to the IEEE Symbiotic Autonomous Systems Initiative.

Processing spikes from one million neurons

- May 9th, 2018



A flexible implant, able to retrieve signals from its 32 electrodes grid, embeddable in the brain. It has been designed for long monitoring periods. In the next decade we expect to have similar brain implants containing a million electrodes. The issue of transfer these data with a low power budget has to be solved.
Image credit: Thor Balkhed

In 2016 DARPA announced a program aiming at creating technologies to capture the brain's activity at high resolution, meaning that one could look at activities of single neurons. The first target is to "read" up to a million neurones in parallel and researchers are confident that will be achieved at the end of this decade or in the first years of the next one. The challenges are not trivial and the result will still remain far from a real monitoring of a whole brain (even monitoring 1 million neurons one would be monitoring 1/100,000 of the brain! Actually it is even worse. The activity goes on at synaptic level getting the neuron level vision means you a one mile high vision -there are close to 1,000 synapses in each neurons…).
One of the problem is the transfer of the detected electrical activity to a computer. One might consider this as a non-problem given the capabilities we have achieved to transfer Gbits of data. Actually the issue is quite complex. First of all what we do with our computers is the transfer of "digital" data, bits, 0s and 1s. Neuronal activities creates spikes (voltage levels) that are basically analogous. These have to be translated into bits (in the same way that our analogous voice or an analogues stream of rays is translated into a sequence of bits that can be used to reconstruct the original signal with the desired fidelity. This "conversion" process is expensive in terms of power. Then the digitalizes signal has to be sent to the web (to a computer somewhere) for processing and storage. And again, this requires power.
The amount of power required may be insignificant if you compare it to the power you use every day in most of your activity. However it becomes significant if you look at it in terms of heat dissipation and notice that such dissipation will have to take place "inside" your brain. I guess you are not looking forward to some implants cooking your neurons!

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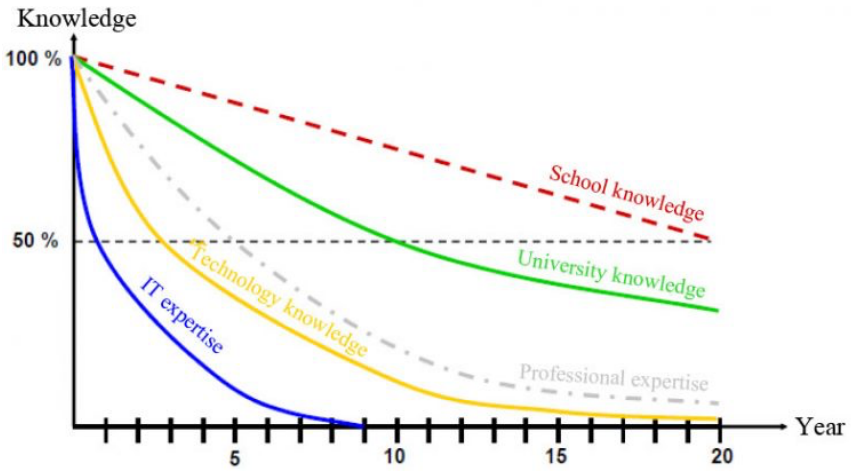
Here is where the results presented by a team of researchers at Lund University in Sweden. They have devised a very efficient processing architecture for electrophysiological set up that is capable of processing millions of spikes signals, translating each of them directly into a bit code, providing feedback within 25 millisecond, thus allowing a communication with neurons in the time window usable for communicating with them.
This result can foster clinical applications of brain computer interfaces.
It is interesting to see how different research groups all over the world are working to build the very many different pieces of the quilt needed to extend our brain into the cyberspace. Their aims is mostly addressing monitoring and potentially helping in disabilities but once that will be achieved we will have the technology for seamless human brain augmentation. We still need to sort out its implication…

APPLICATION AREAS

Education

What would education be like in 2050?
- February 20th, 2018



As new knowledge becomes available previous one gets obsolete. The speed of obsolescence varies for different types of knowledge and in different areas. Image credit: Shüppel

Let's get this square from the beginning. Talking about 2050 is a nonsense if you try to make social prediction. It is fun, but it is not rooted in science. There are so many factors at play that we do not control. However, it might be useful to make some hypotheses not for seeing in 30 years time how good, lucky, we have been, rather to get a feeling of possibilities and take actions to build one specific future out of the many that we can foresee.
Again, trying to build a future versus actually building it are two completely different things, but as you try to build something you are going to face hurdles, you discover alternative and this makes progress roll on with a minimum of steering.
Why choose 2050? Well it is far enough to provide an open slate and it is sufficiently close to base actions on what we have today. In this specific instance this exercise is happening within the IEEE FDC Symbiotic Autonomous Systems Initiative, an initiative that has a long-term horizon around 2050, a time when we can expect machines to have developed a sort of autonomous intelligence and self-evolution capabilities (it may happen sooner) and a time when humans may entertain a symbiotic relation with machines, seamlessly leveraging on machines capability that will be perceived as an extension of our self.
You can take a look at the recently published White Paper, even better you can become part of its growing membership to be in the loop, at the least, or –better- to contribute in the shaping of the initiative.
So, Education. It is a crucial area for IEEE: since its foundation IEEE has been focussing on promoting engineers' education and now, as technology has become pervasive, extending its education scope to anybody who needs to come to reason with it, basically anybody.
Let's start with a hypothetical symbiotic being, a seamless interplay of human and machine. Suppose this symbiotic organism needs to increase its knowledge to carry out a

specific task or to be prepared to face a new situation. Who shall be “educated”? The human component or the machine component?
It is not a trivial question and it is actually being discussed today although in a slight different frame: shall a students learn to do the square root of a number or given the almost ubiquitous availability of electronic calculators just look at the answer on a screen? In the near future this question may become:

- should we learn a foreign language or learn to use a real time translator (meaning pressing a button…)?
- should we learn to write or a machine will do the writing for us? Learning to speak is enough.

Notice that Society is implicitly providing an infrastructure for outsourcing knowledge. Most of us wouldn’t know -I don’t- how to make bread! Do you know how to get grain seeds, how to sow, till, harvest them, make flour and so on. And I am just talking of plain bread. Most of the things that we rely upon every single day are beyond our capability of producing, and for most of them we don’t even have the “knowledge” required. Yet this is not a problem, our knowledge is about using something that someone else had produced and made available. We accept this implicitly because, by far, this works. Besides, there is no alternative. A single person would not have the possibility to possess all the knowledge that is now available and that is required to “run” our life.
We have come to accept this segmentation of knowledge and even our schooling system is geared towards a segmentation. You get the basic tools you need to learn, and then you apply them to learn some specific things. The tools available for learning have increased in the last decades and they keep increasing to the point that it is becoming impossible to learn all of them. Hundred years ago it was about learning to read and write and little else. Then you learnt the tools of the trade, the specific one in your profession.
Now young people have to learn how to use the Internet (only very few know how to… and we are not teaching them), have to learn applying specific tools to extract knowledge from a rapidly growing set of data. Soon they will have to learn how to use augmented reality and virtual reality, how to interact with collaborative robots, how to balance their knowledge with the one of artefacts. In the meantime the knowledge half-time (the time it takes for 50% of what you know to lose its value, become useless, superseded) is shrinking, it is now below 5 years in technology areas (as shown in the graphic, IT knowledge reaches its half life in less than 2 years!). More than ever in the past knowing how to ask the right question and “whom” to ask becomes crucial. (Read: Half life of facts- why everything we know as an expiration date. Samuel Arbesman).
Symbiotic autonomous systems should be able to tackle the issue of the exploding knowledge, the knowledge obsolescence and the rebalancing of knowledge by operating in three main areas (and very possible more):

- digital twins,
- designing training on the fly, and
- autonomously generate education content.

This is not going to happen thirty years from now, first steps can, and should, be taken now and this is the value of considering a longer term perspective.

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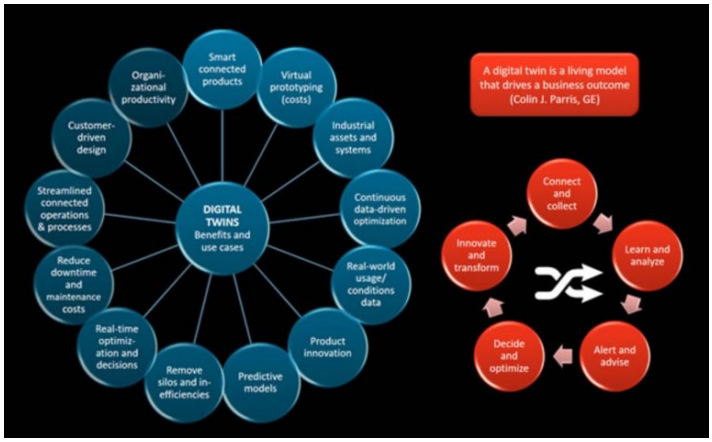
I'll deal with each of them in the following posts.

What would education be like in 2050? Digital Twins

- February 21st, 2018



The many and growing applications of Digital Twins. Notice on the right and side their use in learning.
Image credit: Colin J. Parris, GE

A number of industries are creating digital twins, digital replicas of products, like GE, Tesla, NASA. The idea is to mirror a product in bits keeping the bit replica synchronised with the real one. This allows various types of analyses on the digital twin that can provide insight on the real one and lead to corrective actions. In this sense digital twins are a new tool for education: rather than studying on the real thing you can study on its digital representation. Here technologies like virtual reality provide new tools for education.
It goes beyond that. In a way, each of us has several fragments of his own digital twin. Social media like Instagram and Facebook, LinkedIn and Twitter are collecting parts of our "self". Governments and municipalities are also collector of parts of our "self", as well as the health care system and department stores, Amazon… . Companies where we have been working and where we work have other fragments, representing our acquired skills. The education system is also collecting records of what we have learnt.
All these fragments are dispersed and in some Countries there are rules establishing ownership for those fragments. In Italy, as an example, we have the right to access this information and companies physically storing them have to grant us access. Having the right and actually being able to access them, easily, are quite different stories.
In perspective, we should be able to aggregate those fragments into a more comprehensive one, that better represents our "self". Also, we can easily predict that the number of information about ourselves will grow in time again leading to more and more accurate representation of our "self". It may be worth mentioning that search engines like Google also have a pretty good representation of our interests, which to a certain extent are a mirror of who we are.

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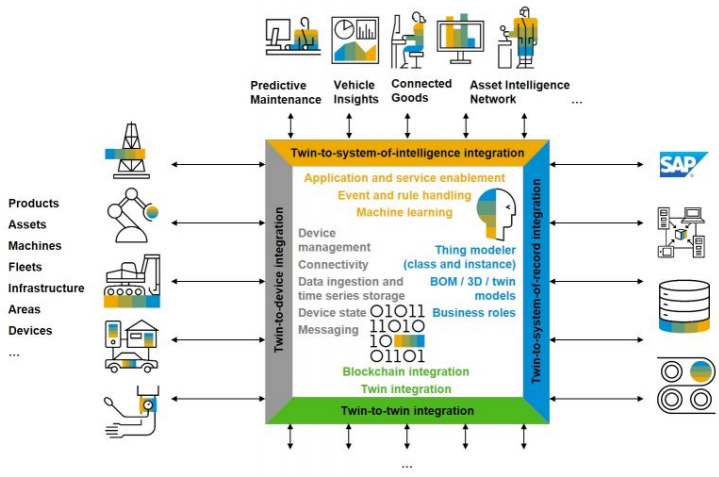
If we imagine a symbiotic relationship, our symbiotic counterpart will form a very good understanding of who we are, sometimes through direct access to what we do jointly, some other times through the access to our digital twin.
In a way our digital twin will come to represent both our knowledge and our skills. It can also be flanked by applications taking into account the fading away of knowledge (what we forget) and skills (what we lose not practicing). This information of our degrading knowledge/skills can be the starting point for a proactive education program.
Writing a article, presenting it to a conference, or reviewing it and joining a conference listening to colleagues can also be mirrored by our digital twin. Education institutions, including IEEE, could contribute to the mirroring of their “students”, “members” into digital twins. These might come handy in creating customised education programs as I will discuss in the next post.
In a symbiotic autonomous system, the knowledge (and skills) is shared among its component systems. This will be reflected by the digital twin of the symbiotic system, integrating the digital twins of its component parts (notice that in complex systems the whole is not necessarily the sum of its part, there is an emergent quality that may not be found in any of its parts) and smart applications may balance the knowledge, the education and the sharing among the various component systems.

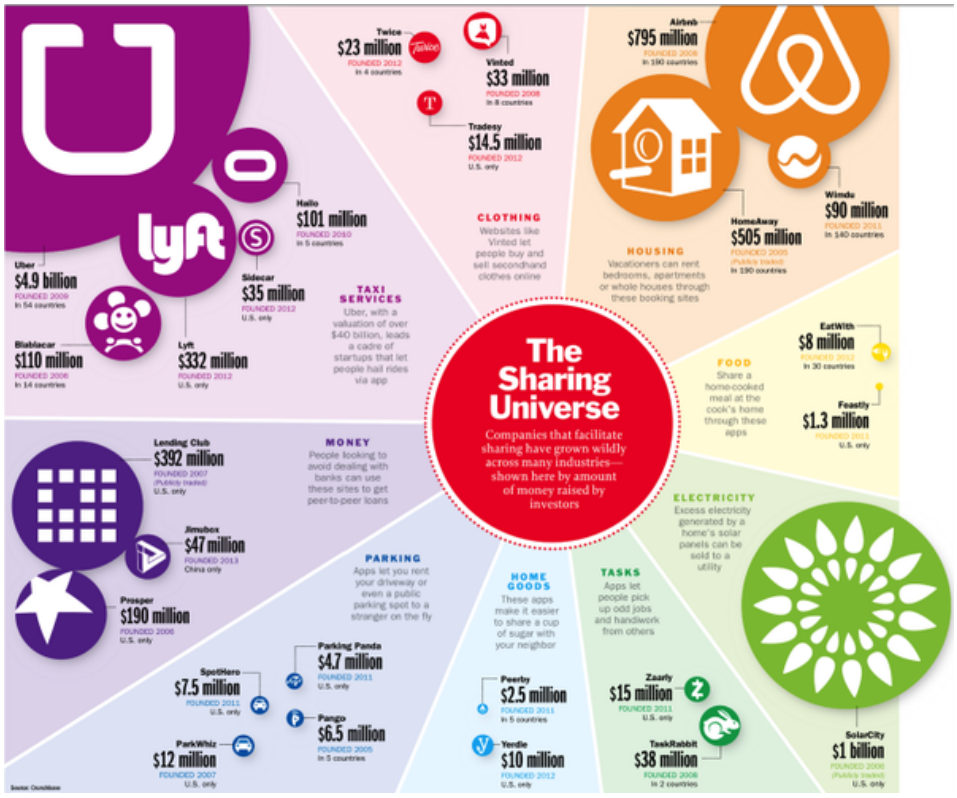


A comprehensive view of digital twins application areas. Notice in the upper right corner the connection with the asset intelligence network including human beings.
Credit: SAP

If I am living in a symbiotic relation with my appliances at home, the knowledge of what program I am likely to be interested in becomes part of the global knowledge of the symbiotic digital twin, but the knowledge about what programs are available and would fit my interest may lie in an appliance. Notice that Alexa, Siri, Cortana are all moving in this direction. There are now thousands of streaming content to choose from and they are just too many for me to be aware of. Not to mention the millions of YouTube clips, articles, tweets… that can become an integral part of my education process.
Using my digital twin to understand what I know is a starting point.
Suppose I need to learn something. What would be wiser? To learn myself as the human component or to have a tool I am using learning what it takes? I have just bought a very complex digital camera, I started to learn leafing through manuals, watching courses on YouTube, downloading new software to manage the new types of files. I am far from being at ease with the camera and I suspect it will take me a year before becoming used to it,

and very likely I will be missing some features and will forgot something I learnt on the way but had not the opportunity of practicing.
If I had a digital twin, he would suffer from the same problems I am having, but that digital twin might be analysed by a smart advisor that could identify knowledge gaps and make up for those by adapting my camera, my smart phone and my computer. In a way, the teaching can go both ways: to me (and my digital twin will reflect my learning or failure to learn) and to the other parts making up the symbiotic autonomous system. Notice that today I am far from being in a symbiotic relation with my camera, my computer, my smartphone and the related software for what attain to my photographic activities, yet something can be done I terms of education even in this loosely connected environment leveraging on the sketchy digital twin that is starting to mirror my "photographer self" and the connections that can be created with the other, sketchy, digital twins associated to applications, computer, digital camera and smart phone. Each of these digital twins is still a pale instance of the good digital twin we might have in the future but the connections among them are what is missing most. This is something that can be addressed by some innovators, including some specific initiative by IEEE (obviously not related to the case in point I made here but, as example, to support careers path of its members).
I'll discuss this in the next post.

What would education be like in 2050? Gig Economy
- February 23rd, 2018



The on-demand economy, also known as Gig Economy for its impact on jobs, is already [a reality and it is growing fast](#) with deep implication on Education, particularly in the technology areas. Image credit: Crunchbase

So, let's assume that we can have a digital twin of our "self" that is mirroring our skills and knowledge. This (our) digital twin is a component of the symbiotic autonomous system digital twin. How can it be leveraged in association with the symbiotic digital twin?

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Knowledge and skills are tools for doing something (including increasing knowledge and skills, by the way). A smart application can evaluate the context, what needs to be done (like repair an engine) and match the required skills and knowledge to the ones we have, using our digital twin. That would identify the gap, hence what we miss, as well as the best way to fill that gap. Notice that different persons, although having the same gap in skills/knowledge may require different ways to fill that. Education today is mostly standardised, one size fits all. In the future, also thanks to digital twins, it may be customised thus increasing the efficiency of the education process.

Companies like Boeing are already using augmented reality to guide a repair-man to fix an engine in a remote location. They have a sort of digital twin representing the skills and knowledge of that worker and tailor the instruction to him. An expert technician can follow the repair from remote and provide guidance. More and more this expert role may be taken by a software.

In the future, the fixing might be made by a symbiotic autonomous system, like a man donning an exoskeleton and the overall knowledge and skill of this SAS should be considered and … updated as needed. It might, as an example, require an update to the exoskeleton software rather than having the worker's brain learning how to operate the exoskeleton in that situation.

As mentioned at the beginning of this discussion decision on where to focus in education has already started. The novelty is that more and more we will be sharing knowledge with tools that can reason and extend our mental capability. Classic education has been shy in adopting new tools and taking advantage of them (You need to learn to do multiplication, you cannot just rely on an electronic calculator! You need to do your research on books in a library, you cannot cut and paste from the web! …). Now we are confronted with AI that is starting to best humans' mind in a growing number of sectors (including medical diagnoses and cure prescription).

The proposal that is studied in the SAS is to see this evolving context as a symbiotic one, it is not either/or (human vs AI) rather AND (human and AI) in a symbiotic growth.

Education has to evolve and leverage on this symbiotic opportunity. Using digital twins in education fosters this symbiosis since it becomes possible to operate at the virtual level on homogeneous "characters".

A smart education program may look beyond the "need to know", here and now, to foresee what might be needed next, be it the next day or the next week and set up an education plan to make the symbiotic system ready to face new, likely, situations. Again, this can be applied to a single component or to the whole symbiotic system. The point that education has to take into account is that we are more and more operating in symbioses with tools/devices and education shall consider the whole, leveraging on the symbioses.

A smart education actually becomes a component in the symbiotic system and shall be ready to leverage on any education opportunity that comes to pass. This shall take place beyond the here and now and the short term horizon. It will have to become a life-time support for a continuous evolution. This is going to become even more important in the shift towards the "gig-economy" with work seeking for workers (turning the current workers-work relation upside down).

To be found a person needs to be present in the cyberspace and her knowledge and skills need to be honed towards future needs to be competitive in the work market.

In presence of ever more rapid obsolescence of knowledge and skill, education support cannot be focussing only on adding more knowledge and training to acquire more skills in a never ending story where people have to start from scratch over and over again.

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Rather, smart education should be able to leverage on acquired knowledge and skills reshaping them to fit new demands. This is what is sometimes referred as “migration of knowledge” to new domains. Organisations like IEEE having a very broad footprint can make this migration possible through education that is also about discovery of new application areas. Efforts shall be put to overcome educations silos as well as knowledge silos.
This is also a crucial point for symbiotic autonomous systems where knowledge and skills of their components shall not be confined in silos but shared and leveraged.

What would education be like in 2050? In-product Education
- February 24th, 2018

Collaborative robots are becoming common in manufacturing changing the structure of the teamwork. Instruction goes both ways, from humans to robots and from robots to humans and it will become a way of working. Image credit: Rethink Robotics

The third aspect of education involving symbiotic autonomous systems –SAS- is the trend towards an autonomous development of education content deriving from the SAS design and experience.
It has become common for a broad range of products to contain an instruction manual that can provide instructions to the user. Televisions, digital cameras, washing machines and cars are just a few examples that come to mind. Software applications usually come with an embedded way to provide user instructions, some have these instructions as part of the application, others provide the instructions through a web connection.
This way of "education" is usually quite effective since it is tied to "need to know" and "here and now". However, most of the time the instructions are "one type fit them all". They do not take in account the specific user, his experience and motivation.
It is a sure bet that in the next decade artificial intelligence will permeate this "spot education", finely tuning the instructions to the user experience and needs.
Creating an education content for products is often complex and time consuming. As products become more and more flexible and evolve over time it becomes more and more difficult to provide a valuable/effective on board instruction manual.
Interactions with the product and with its "educational" part are also going to change, drifting towards natural language and seamless interaction (involving gesture, touch, images…). Imagine being on a team with both human workers and robots. In the next decade there will be a growing level of symbioses in the team and learning will be a continuous experience. The content on which learning will be based will be unlikely to be produced at the time the robot is produced. Instructions will have to be customised to a specific situation and to the way interactions take place. It is much more likely that robots will self-learn how to teach their team-mates, similarly to what the human team-mates do when they need to instruct each other. We do not come with a pre-loaded manual, we have acquired knowledge and skills and when needed, or asked, we share this knowledge and skills in a way that is appropriate to the context and to the receiving person.
This is likely to happen in working environment, as well as back home when interacting with a new appliance. Notice that, as IoT and computers become embedded everywhere and connected, the overall system complexity will grow beyond our average capability of understanding and managing (it is already happening in several situations, one of the best selling point for a product is its capability to self-configure adapting to the environment with no user intervention required).

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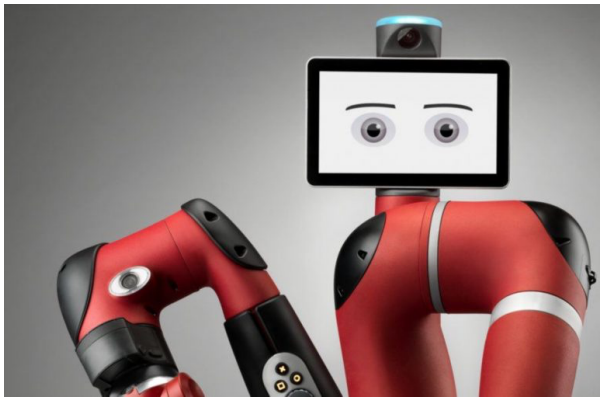
New products are likely to embed education capabilities. Firstly, they might be confined by the use of the product itself, then they may expand to cover the use of the product in conjunction with others. In the Industry 4.0 paradigm, with products resulting from the loose cooperation of various players the “instruction manual” will no longer be the responsibility of any single player, often unaware of what other players will be providing (like asking a computer manufacturer today to provide the instruction manuals for all the applications that will be run by that computer…).
Yet, the interplay of the various parts may require a single point of explanation. This may be achieved through third party applications that will create instruction material (and possibly deliver it) by accessing the various digital twins operating in a symbiotic relation.
Education content may take different forms and may be delivered in different ways:

- as separate instruction (an evolution of MOOCs, highly contextualised and personalised, delivered on an access device –I get instruction on the use of my digital camera from my smartphone that connects to the camera on one side and to the manufacturer on the other, it is still a very basic experience but it gives the gist of what might happen in the future)
- as automated in-product courses that pop up when needed as I am interacting with the product. Differently from what we have today this in-product courses will not be rigidly tied to the product, rather they will be tuned to the user and to her growing experience and specific needs. In a way, the education content will constantly re-arrange the interface to the user, making it seamless to that user and evolving as the user competence grows.

This will likely apply to any kind of interactions as the players are getting smarter and smarter. Education will be an important aspect in symbiotic autonomous systems both finely tuning and evolving the interaction within the system and in the interaction with other systems.
We can expect that further down the lane any interaction can be a source of learning, through an adaptation to the players involved.
Accessing information in large data bases, like the IEEE archive of articles, now in the millions and growing, will no longer be like opening a drawer and picking up an article, with the smart support focussing on helping to find the right drawer. Rather it will be a matter of sharing a need and responding to that need. That might involve the extraction and reassembling of content contained in several articles, as well as setting up a customised education course to let the person understand the information provided. It may also require a structuring of the education to leverage the context of the user, like upgrading the tools he may be using.

"Nice to meet you, I am Baxter your new co-worker"
- November 29th, 2017



Meet Sayer, a collaborative robots with its own brain fuelled with artificial Intelligence.
Credit: Rethink Robotics

For the time being we are just seeing application niches that anyhow show that several stumbling blocks –security, context awareness. Communications- have been addressed and removed, something that seemed wishful thinking just ten years ago.
Yet, many obstacles remain and initiatives like the Symbiotic Autonomous Systems launched by IEEE-FDC are working to foster the evolution by bringing together academia and industry.
The EIT Digital in its Digital Industry area is investing on cooperative automation, the one that foster the collaboration among humans and robots on the working place and beyond.
The progress of Artificial Intelligence, sensors and processing power are leading beyond the substitution of human workers with robots leveraging on the higher value that symbioses among them can produce. Projects, like iLevator, aim at building a platform integrating robot, both fixed and mobile, with people. The role of people is considered crucial and the whole manufacturing process is designed to take advantage of this symbiotic presence.
This evolution changes significantly the manufacturing context and requires the human workforce to acquire new skills and capabilities. Hence the need to develop new education programs for future workers generation, blue collars that in reality will no longer be blue collars since they will have to enrich the working place with creative forces that are –so far- typical of the human race.
This will require an understanding of the context. As it was yesterday and still is today, working in a team requires knowing and understanding your colleagues, their strengths and weaknesses and that will not change tomorrow, even though some of these colleagues will be robots. Notice how these robots will come in different shapes, from a stereotyped industrial machine with many arms to the ones having an anthropomorphic form.
The working desk on which we lean on to scribble some ideas may become a robot. Differently from today these scribbled ideas will be adsorbed and understood by the desk that might start to propose variations and adds on.
The mock ups, often used in the manufacturing industry, could be robots themselves, change their shape and functionality in a dynamic way as they interact with the designer.
Smart materials are going to play an important role in this "intelligent material interaction".
A new world to which EIT Digital prepares today's and tomorrow generations. Starting this year a new master on Autonomous Systems is available and a new industrial doctorate on

Digital Industry that will address these aspects will start in 2018 in Milan in addition to the one already active in Helsinki. Talents are sought to invest on them to be the future leaders in this field.
Is the future a collaborative one among humans and machines? Obviously not. Competition among them remains and might become even harsher. The threat of losing one's job to a machine is real (although it is even more probable losing one's job because of the disappearance of that job, as result of process and value chains re-engineering). Let's keep in mind, anyhow, that competition among "humans" is often leading to job losses and this is normally accepted on the bases that at a systemic level the benefits of competition translate into efficiency, freeing resources that are generating new areas of business and new job opportunities.
We should probably come to consider robots as one among many factors in a competitive context. Sure, in some cases our job will be lost to a robot, like it happened when tractors replaced oxen in the field and slashed the number of farmers, but the human resources, adequately educated and trained will engage in more rewarding activities, better fitting human values. Of course that will hold true till the point that robots will achieve our level of consciousness and may be will start going on strike demanding better jobs more fitting to their enhanced level of intelligence…

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Consultancy

100 million pixels on a drone

- May 5th, 2017

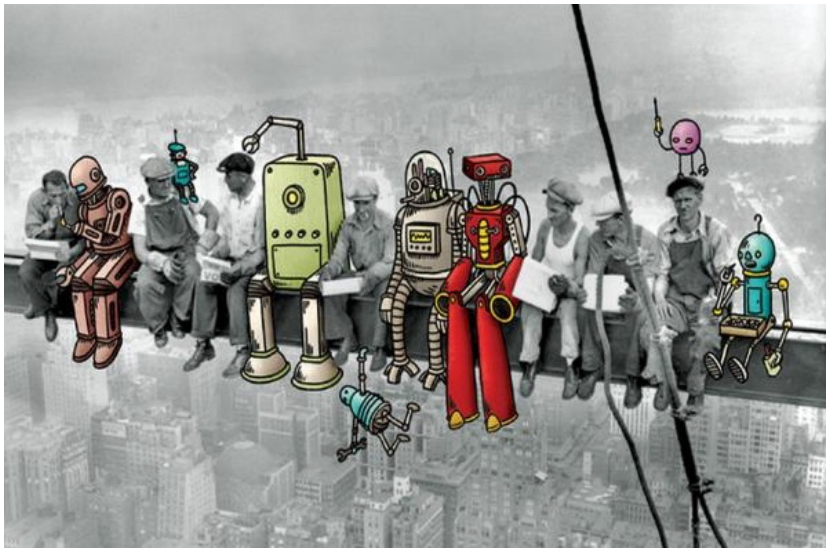
DJI 6 rotors drone with a 100Mpixels Hasselblad camera.
Credit: DJI

DJI, possibly the most advanced and known producer of consumer drones, has showcased at NABShow in Las Vegas on April 27th, 2017, a combination of one of its most performant drone, DJI M600 Pro drone, with an Hasselblad H6D-100c. The drone is powered by 6 rotors and the camera provides a 100 Mpixels resolution. The package will be available in the third quarter of 2017 for a yet undisclosed price (get ready to shell quite a bit of money…).
What I find interesting, and I had the opportunity of saying so in other posts as more and more drones aims at photographers market, is the evolution we have in this area. Drones have been around for a while as specialised military devices (at a huge price tag). In a few years they have moved into the consumer market dropping their price below 1,000$ yet keeping some features, like auto flight, obstacle avoidance, stable hovering, image detection that used to be extremely expensive characteristics of military devices.
Interestingly, this spread into the consumer market has generated business opportunities (like using drones in weddings) and has stimulated applications in professional areas (like radio tower inspection, pipelines surveillance, emergency delivery…).
They have become platforms and these are now being exploited by services that were just unimaginable 5 years ago.
They are also likely to accelerate the progress in technology for autonomous systems, an area that has recently been declared as strategic by the European Commission in its Horizon 2020 program and that is being considered in the new FDC initiative on Symbiotic Autonomous Systems.

Augmentation

Human Augmentation: partnering with Machines

- February 12th, 2018



The iconic image of construction workers having their lunch break modified to illustrate a new era of human robot partnership.
Image credit: iStart -Technology in Business

This week the IEEE Future Direction Committee will meet in Orlando to discuss progress achieved by its various initiatives and to plan future ones. This is the time to look at various forecasts on what is going to matter most in the coming years and among the ones that I found on the web I got hooked on a document, Realizing 2030: Dell Technologies Research explores the next era of Human-Machine partnership, produced by the Institute for the Future.
The document makes the point that the next decades will see a growing **partnership** among humans and machines: no longer machines being used as tools but machine as independent entities living in partnership with us, sharing work and … ideas!
At the core of this evolution a set of enabling technologies: artificial intelligence and machine learning, cloud computing, robotics and virtual and augmented reality. There are plenty of other technologies that will play a role and that they have not mentioned: I was impressed by their choices. If you look at the list you basically see the tools for bestowing intelligence on machine, for having machine leveraging on that intelligence by learning, a pervasive processing, storing and communications infrastructure (the cloud) and an advanced interface where real and artefacts blend in a continuous fabric. Indeed, these are the crucial ingredient for the human machine partnership.
Interesting is also their analyses on the implication of such partnership: both individuals and organisations will be affected. We might see:

- the working paradigm turned upside down: no longer people looking for a job (work) but work looking for people (the Gig Economy taking the upper hand);
- no more education and continuous education but just in time education (here is where VR and AR are required);

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- emerging need for digital conductors to orchestrate the partnership into an effective set of coordinated actions.

There are a number of similarities in this forecast with the ideas that are emerging in the IEEE FDC Symbiotic Autonomous Systems initiative: in this latter the partnership is seen, also, as giving rise to augmented humans and augmented machines, each leveraging on the other sometimes in a seamless way forming a novel super-organism. Think about the seamless integration of a smart prosthetic limb.

Longevity escape velocity

- November 6th, 2017

There are around plenty of claims about magic cures to make you "younger". None does really work, but we are now starting to understand ageing and that might lead to some … cure.
Image credit: Burke Williams

The myth of "being forever young" goes back as long as we can trace human history, but that does not make it anymore true, actually, having been pursued for so long with no effect might cast a serious doubt on the hope of fulfilling that desire.
Yet, if we look at the last 100 years we see that the life expectancy has dramatically improved in all Countries but the age limit has not really changed (the actual verified record for oldest person il 122 years old). There seems to be a limit "coded" in our DNA.
Some people, like Ray Kurzweil, are convinced that now we are starting to have the technology that would let us reach the longevity escape velocity, that is the point that as you get one year older technology will extend your life by one more year. The net outcome is that you will live forever.
Now, I do not share this view. Of course I realise I might well be wrong and that looking at the past to forecast the future is not necessarily a good approach. However, at a fundamental level I am not convinced that we can really change a time bounded life into an unbounded one, time wise.
Yes, I can expect science and technology to be able to modify the telomere extending them, as they naturally tend to get shorter, but it is the whole "machine", I feel, that would need to be re-designed. And, along with it the whole Society will need to be redesigned.
How can we make space for newborn if we will be in the way forever?
There is also a personal issue. We forget most of our life, only a few details remain in our memories. Would you remember what you ate on December 2nd in 2002? I bet not, as well as what you were wearing on that day, what you said, how was the

weather…. Unless, of course, that was the day you got married or a special day in any other way. Forgetting is natural and in a way, empirically speaking, let us free space in our brain for recording new experiences (there are speculations that our brain is largely under utilised and could actually store much more, but at the same time there are also signs indicating that if we were to remember everything our life would be quite different, and not necessarily better!).
At FDC in the Symbiotic Autonomous Systems Initiative we are considering some aspect of Human Augmentation, and clearly life extension is an aspect of augmentation. CRISP/Cas9 are providing tools to manipulate the genome and once we will (and eventually I am sure we will) understand all the aspects of the genome we will be able to tweak it in the direction we may desire. I am still not convinced that a Longevity escape velocity can be achieved, even less as someone claims in the next decade. Your pick?

Humans not needed …Inflection point?

- October 22nd, 2017

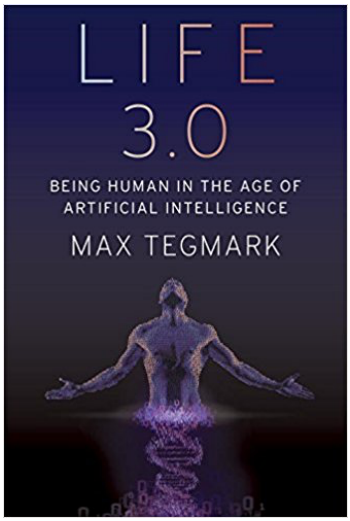
AlphaGo Zero, a new version of the Google Artificial Intelligence system that bested the Go World Champion, is way better than the previous version and it learnt all by itself, no need to observe and study human players. Image credit: Inside

A Google team has published a paper on Nature describing the new generation of AlphaGo. Well, the very name of the new generation is significant: AlphaGo Zero. One would have expected that the new generation would have been named “Old + 1”, yet they decided to start from scratch and name it Zero!
Indeed it is a generation Zero. It is the first system that has been designed to rely completely on itself to learn, rather then observing humans and learning from them. With AlphaGo we were surprised by seeing that it went beyond learning moving into the creation stage, becoming able to do things that have not been tried before. Now in a completely new approach the designers at Google have decided to let AlphaGo Zero to learn by itself.
The results are impressive. After just a few days of learning by competing with itself AlphaGoZero has been able to win against the previous version that competed with a Go master and after a month of self learning it won 100 to 0 against the latest AlphaGo, the one that defeated the Go world champion.
In the paper the team reached the conclusion that it is more effective to use a self learning approach rather than leveraging on human expertise. Humans have made redundant (at least in this field).
Have we reached an inflection point? Has AI become so smart that it can work on itself to become better and better without having to have humans in the loop?
AI is at the core of autonomous systems and so far it has been used to allow them an understanding of their environment so that they can apply the best (or at least a viable)

approach to pursue their goal in a changing environment. Now we might have reached a thresholds where autonomous systems may start to design their own goal and take action not just to interact with an environment to play their game but also to act on the environment to change it to better serve their purposes. Are they becoming conscious? Would they make a further step and decide to change their goals? How can we control them if we are “out of the loop”?
These are all difficult questions that we are crafting in the FDC group addressing Symbiotic Autonomous Systems. Symbioses implies that “We” are in the loop, of course, but it is a loosely coupled loop. We might end up in a symbiotic relation where the smarter participant, which unfortunately is no “us”, takes advantage of the other to pursue its own agenda.
Troubled waters ahead….

Life 3.0

- September 13th, 2017



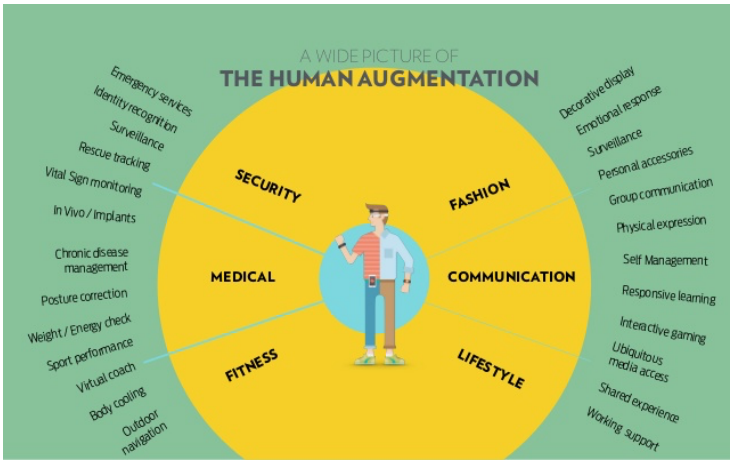
A really intriguing book full of suggestion on a next step of life evolution.
Credit: Max Tegmark

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 answer 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 the 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 change his behaviour 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 new born 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 in 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 enter into a symbiotic relation with hardware of different sort. This is what Max calls Life 3.0.
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!

Emergent beings: Human augmentation

- June 29th, 2017



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

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 characterise the Human 2.0 and its main difference from the previous one is the generalisation 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 generalised adoption. Notice, that someone is claiming that we are already at that stage because of the generalised 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 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 retrieved seamlessly from the web (or a local storage you may carry around).
Transhumanism 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 artefacts 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 at the moment in the IEEE FDC Symbiotic Autonomous Systems Initiative.

Health Care

Cybathlon: symbiotic automous systems competing for gold

- September 11th, 2017

Gold Medalist at Cybathlon 2016 in Zurich: Numa Poujouly took top honours in the Cybathlon's brain-computer interface race. Photo credit: Nicolas Brodard

Brain Computer Interfaces and interfaces between muscles and computers have reached the stage of usability for patients. Although a lot of research is still needed, and a lot is going on, several patients disabled by various trauma or diseases are now able to augment their functionalities reaching in several cases a good level of autonomy.
To test the capabilities of these systems and to further stimulate researchers through competition ETH Zurich has launched Cybathlon. The first event was held in Zurich in 2016 hosting competition in six areas:

- Brain Computer Interface race, with participants using BCI to control an avatar;
- FES, Functional Electrical Stimulation Bike race, with paraplegic participants riding bikes. To pedal they have their muscle stimulated artificially;
- Powered Arms Prosthesis race, with participants with one or both arms amputated below the elbow controlling a prosthetic arm;
- Powered Leg Prosthesis race, with participants having to take precise steps to navigate through obstacles;
- Powered Exoskeleton race, with participants with complete paraplegia have to complete everyday tasks, including sitting and climbing stairs;
- Powered Wheelchairs race, with paralysed participants negotiating a track encumbered with every day obstacles.

By looking at the clip (see below) one can really appreciate the progress being made in this field and how symbiotic autonomous systems are becoming important players in our Society. There will be focussed Cybathlon in 2018 and 2019 in several locations around the world and a full Cybathlon in Zurich in March 2020. We can expect significant progress in the coming years.

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Manufacturing

Industry 4.0 and Symbiotic Autonomous Systems

- July 16th, 2017

A General Electric turbine. Even though it seems the epitome of a world of atoms this turbine has a mirror image in the bit space. General Electric is creating a digital copy of all its products using AI and uses the digital copy for simulation and for system design. AI is crucial since GE wants to capture the semantics of the object and its composing parts, not just the shape. Credit: GE

General Electric is working to make AI an integral component of its industrial processes, from design (and co-design) to production (and co-production) to operation (and co-operation). Notice the (co-) part. It is an important aspect that moves GE into industry 4.0 and it is notable that they are looking at AI as a fundamental tool.

For each of their products they have a digital representation that through AI embeds the "semantics" of each parts (what they do, how they work together, what are their constraints…). This digital representation (they called them "digital twins") can be used for simulation, for sharing with other companies for monitoring the data coming from operation. AI is used to "understand" what is going on, to detect anomalies and prevent issues.

An engine on board an aircraft flying from London to New York may have its digital twin residing in a cloud in Los Angeles. Notice that the concept of digital twin applies to each instance of a product, each engine has its own digital twin that has operated (although virtually) exactly the same hours and sustaining the same acceleration and mechanical stress of its sibling up in the air.

To this effect GE has started to train its employees in machine learning, 400 have already been certified and many more will follow.

The simulations run on the digital twins provide guidance on the "atom" twin. By applying AI to the digital twin and then sending instruction to the atom twin GE is able to increase productivity of wind farms by 20% and decrease fuel consumption of diesel engines in a locomotive by 32,000 gallon per year.

Notice here one of the typical characteristics of Industry 4.0. A continuous relation between production and operation.

Engineers at GE are learning AI to understand what machines can learn and how they can interact, but this is also reshaping their relation with the machines. They are moving towards a symbiotic relationship with machines at the various stages of design, production and operation.

Industry 4.0 with the pervasive presence of autonomous robots and distributed AI will be one of the first environment populated by symbiotic autonomous systems. Machines will

learn to rely on humans and humans will learn to rely on machines, each one adapting dynamically along the way.

The Hive doesn't need humans… but for oranges!

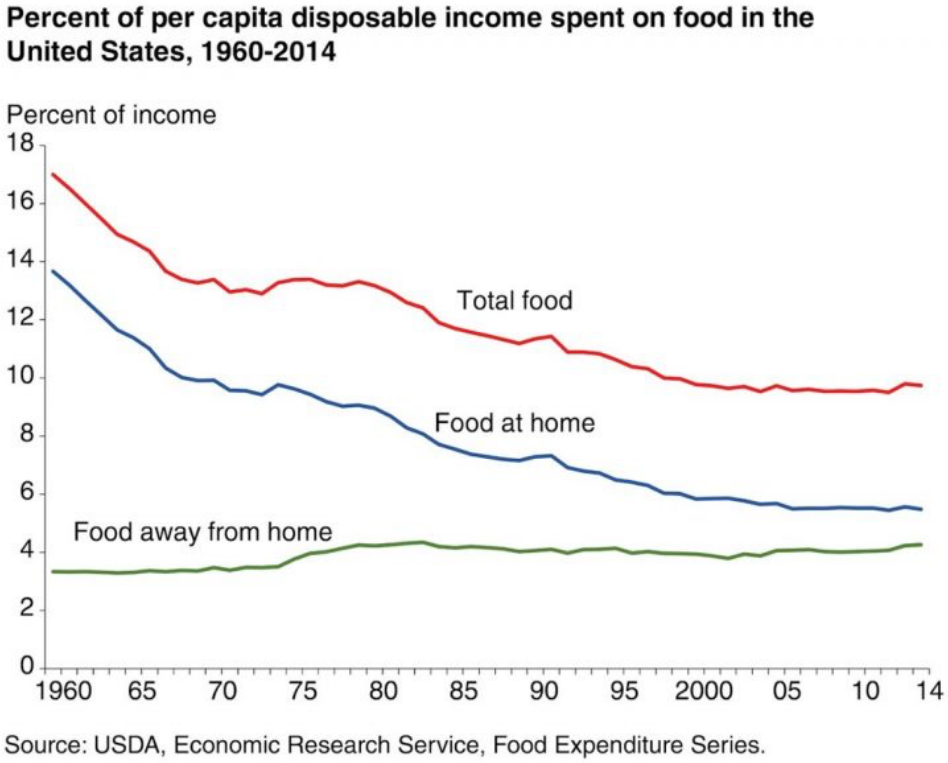
- May 13th, 2018

Robots are taking care 24 hours a day of the Ocado warehouse in Andover, UK, managing 3.5 million packages every week. Credit: Ocado

Ocado is a UK on-line grocery serving customers in England since 2002. Over these 16 years it grew significantly serving today some 560,000 customers making it the largest on line grocery store.
In the on-line business, even more than in the brick and mortar, it is crucial to be efficient and Ocado has developed, and it is now starting operating, the Hive a completely automated warehouse, managed by over 1,000 robots (see clip) that will handle some 65,000 orders per week involving over 3.5 million packages once fully operational.
The robots in the hive get the grocery from the delivery pods place them into crates and move the crate to a location in the warehouse that is decided by an algorithm taking into account the probability that a specific items will be ordered along with another one. This makes the retrieval more efficient since when another robot will be asked to fulfil an order it will have to travel a shorter path to close it. Notice that all robots used in the warehouse are exactly the same so that if one breaks down another can take its place with no disruption. In addition, this uniformity makes for volume (decreases cost) and makes maintenance much easier.
Each single robot is not particularly smart, it just need to go where it is asked to go and pick up the exact amount of grocery and bring it to the delivery point. However, all together, the robots create a very smart team that minimises the number of activities required, thus saving time and energy. Read the article on the Verge to get all the details.
The ultimate goal is to replace all human labour with robots, however Ocado is pointing out that humans are still needed, and they give as an example something I would have never considered: handling oranges.
I never had any problem in picking up oranges from crates at my supermarket and placing them in a bag. It seems that for a robot picking up oranges it's tricky. They tend to roll away and the robot cannot put too much pressure unless the goal is to get orange juice! Well, it is good to see that at least for handling oranges we are a tad better than robots!

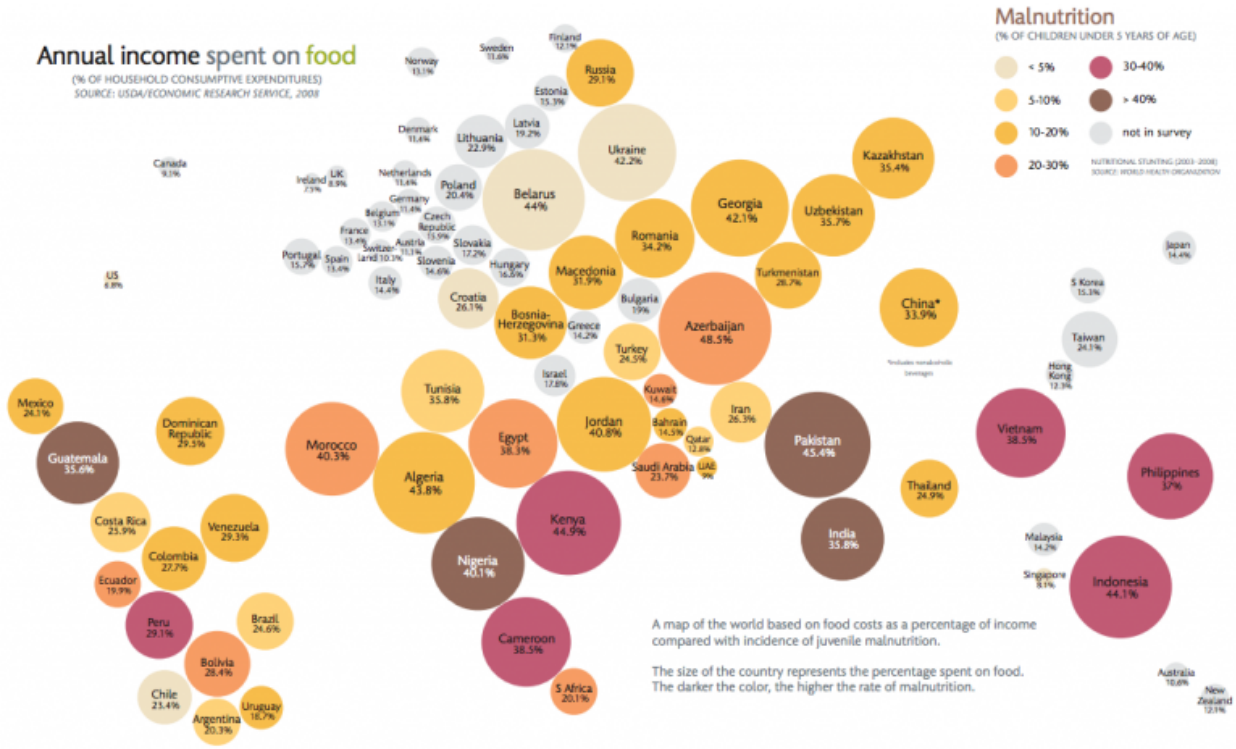
Eating more, spending less: the fourth agricultural revolution I

- May 16th, 2018



Graphic showing the decrease in percentage of spending on food with respect to the average income in the US. The decline has been significant in the US and it is in line with the decline in other developed Countries. Credit: USDA

We went through 3 farming revolutions in our 300,000+ history.
The first one happened some 10,000 years ago with the “domestication” of some plants (like wheat, barley…). That increased the yield of agriculture through selection of those plants that best suited our nutritional needs.
The second one initiated some 5000 years ago with organised labour and irrigation infrastructures, lasting till the last century. Most people on Earth became farmers. The yield increased but remained quite low (you needed over 80% of people to feed the Earth population, roughly speaking the surplus in production was able to feed 20% of the human race).
Mechanised farming, fertilisers and insecticides drove the third agricultural revolution -the green revolution- multiplying the yield in an amazing way. In the US (and that applies basically to all Countries affected by the green revolution) the percentage of farmers went down from 82% of the 1800s to 2% of today. It means, roughly, that 2% of people produced a surplus able to feed 98% of the human race.
In parallel to this production increase we have seen a decrease in the percentage of income dedicated to buying food for feeding (we are spending more and more for eating as a social occupation, like going to fancy restaurants…), see the graphic showing a decrease from 14% to 6% in income dedicated to food eaten at home in the US (similar decrease is seen in other developed Countries) over the last 50 years.
This amazing result is what allowed the Earth population to expand from 1.6 billion people in 1900 to the 7.6 billion we have to feed today.



A look at the annual income spent on food in many Countries. The size of the bubble represents the percentage of the income spent on food -the larger the bubble the more percentage of the income spent on food. The colour of the bubble gets darker as more people are suffering from malnutrition. In general the more income percentage is spent on food the more people are suffering from malnutrition. This is not unexpected since feeding is a primary need and people dedicate as much income as possible to fill that need. Only when the need is met money will be spent on other "needs". Credit: USDA

Yet we are facing even bigger problems today. We should prepare to feed a further 2 billion people in the next 30 years. More than that: we must prepare to meet the changing feeding habits of some 4 billion people in developing Countries that will be shifting from vegetable to an increasing meat based food. We are already using over 30% of the Earth arable land for raising livestock and it gets difficult to use more.
Technology is coming to help. Genetic engineering, artificial intelligence and autonomous systems are fuelling the fourth agricultural revolution based on:

- Vertical farming
- Fully Automated farming
- Engineered food
- Meat factories

I'll explore each of these in the next posts.

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Eating more, spending less: the fourth agricultural revolution II

- May 17th, 2018

China is investing in vertical and urban farming as a way to increase agricultural yield. Credit: Chinese Academy of Agricultural Science

- Vertical farming

Vertical farming promises a mini-revolution in agriculture. It is about growing, as the name suggests, crops in the third dimension, thus using less land, up to 10 to 20 times less, by stacking plants on racks, see photo.
This is done in a controlled environment (in a building) which provides the additional advantage of pest control (hence much less use of pesticides) and limited water usage (2 to 4 litres of water per kg of vegetable, much less than what is normally required, that is 50 to 100 times less).
Not everything is suitable for vertical farming (bananas does not lend easily to stack them up…) but many vegetables, from cabbages to peas, tomatoes to salad are perfect. Wheat, as an example is not a good choice. It takes quite a long time to grew wheat and providing illumination over all that period would translate in high cost (some 11$ for a loaf of bread!). On the contrary, plants that grow fast are ok (like salad) where you can generate basically a continuous harvest.
The controlled environment makes possible several harvests per year (like greenhouses). Sensors and computer controlled sprinklers can optimise the use of energy (although this remains higher than growing in an open field where the only energy needed is the one from the Sun).
Clearly vertical farming is not going to replace normal farming but in certain areas, like where there are old buildings – old factories in cities it can make economic sense.
There are several studies aiming at creating affordable economic conditions for vertical farming, e.g. by efficient use of light, since light is an essential component of vertical farming. Using LED light decreases the energy required and LED light can be customised to the need of specific crops by emitting at the right wavelength used by the plants (most of Sun light goes wasted in terms of energy since plants use a subset of the wavelengths of sunlight). Additionally, LED does not generate heat (very very little) and therefore can be placed very close to the leaf, optimising the use of light.

Urban Crop, as an example, is testing ultraviolet light in its completely automated trials of vertical farming. UV has the added advantage of killing certain plants pests.
AeroFarm, is another company that is already in business with what is probably the largest vertical farming complex in the world, producing close to 800 tons of leaf green per year with 22 harvest per year (watch the clip). Both Urban Crop and AeroFarm are using hydroponic systems and they recycle the water to keep consumption at a minimum.

Eating more, spending less: the fourth agricultural revolution III

- May 19th, 2018

A variety of automated systems are being developed and experimented to bring full automation in agriculture. In the photo a drone used to inspect crops.
Credit: Harper Adams University

- Fully Automated farming – Farms without farmers

In UK the Hands Free Hectare project carried out at Harper Adams University has shown that with current technologies is possible to automate the whole farming process from planting, tending to harvesting. The automation has been achieved upgrading existing farming equipment with electronics (and software) to transform each one in a robot and to connect, when needed, one to the other. The project begun in October 2016 and finished with the harvest of 4.5 tons of barley in September 2017.
The researchers working on that project pointed out that it seems the future of farming will benefit more from small equipment, small robots, cooperating with one anther rather than being based on big complex machines. Robots used in industries are usually designed to perform well defined repetitive tasks. On the contrary, those that will be used in agriculture need to be much more flexible and much more aware of their environment. Computer vision is expected to reduce the need of chemicals by 90% thanks to precision agriculture (you use the chemical only where it is needed with leaf/plant precision).
They need to be able to recognise pests, and plants affected by pest for precision insecticide spraying, they need to identify unwanted weeds and remove them without affecting the crop… Their flexibility is also required in terms of performing a variety of duties (without becoming over-complex) since a number of activities are seldom required, although they are needed, and dedicating a specific robot to an activity seldom performed may not justify the cost.
They also pointed out the need for education to prepare engineers to design autonomous systems able to take joint decisions in the pursuance of a common goal.

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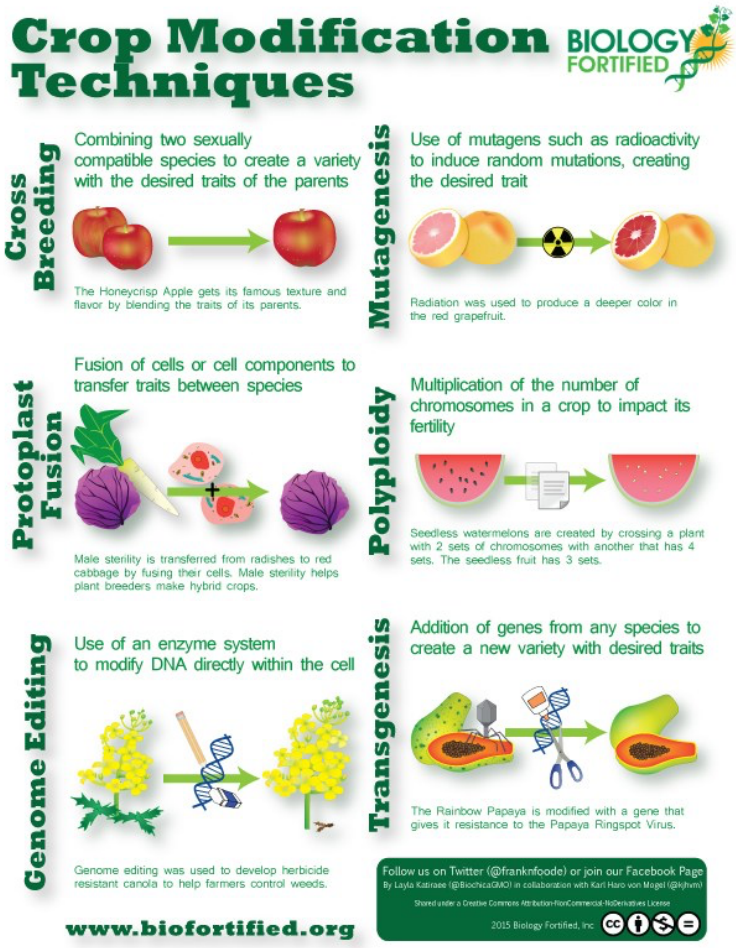
There are a number of new companies active in the robo-farming space.
Naio Technologies offers a variety of robots that use computer vision and lasers to operate in orchards and in vegetables fields. Its Oz robots uses electrical motors and can operate without human supervision for three hours, continuously, before recharging.
PlantTape offers a robot to manage the whole process from seeding to transplanting in the field, whilst Abundant Robotics is tackling the problem of harvesting fruits. This is a difficult problem for a robot since it has to look for the fruit (like apple) reach it across a barrier of branches (working out a strategy to get to the fruit) and then pick it up (and store it) without exerting too much pressure that would ruin the fruit. This requires sophisticated sensors and actuators as well as intelligence.
In the coming decades we might expect the emergence of a symbioses between robo-farmers and plants that creates a cooperative environment minimising the activities and maximising the yield.
Closed and controlled environment, like the ones used in vertical farming, are better suited for more effective cooperation and will likely be the first to see this evolution.

Eating more, spending less: the fourth agricultural revolution IV

- *May 20th, 2018*



A variety of technologies/techniques are already available and in use to create crops with the desired characteristics.
Credit: biofortified.org

- Engineered food

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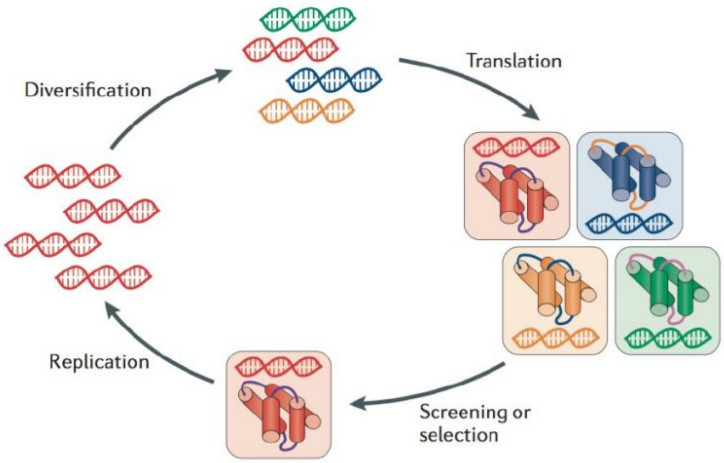
The characteristics of plants depends, for a significant part, on the DNA of that species (clearly the way the plant grew, the terrain, the amount of water…are additional factors). These characteristics include the ones we experience when we eat that plant (and the ways it can be prepared and cooked) but they also affect its growth, its resistance to adverse conditions (including sensitivity to pests and diseases) and its conservation once harvested.
A lot of the economics is dependent on these characteristics: a plant more sensitive to pests requires more pesticides and its cost increases, a plant that grows faster leads to increased yield, hence generate more revenues, a plant that resists better to transportation can be marketed in far away places increasing its potential market, a plant that has a more pleasing colour or shape can be get a higher price on the market, a plant that can grow in an infertile soil can produce revenues where it was not possible before, … The list is quite long.
By cross breeding and other agricultural techniques that have been developed over millennia farmers have been able to increase their revenues.
As shown in the chart, today's technology is offering the possibility of tailoring the characteristics of plants "forcing" changes in their DNA. In particular we can see five approaches:

- Mutagenesis
- Protoplast fusion
- Polyploidy
- Genome Editing
- Transgenesis

Mutagenesis

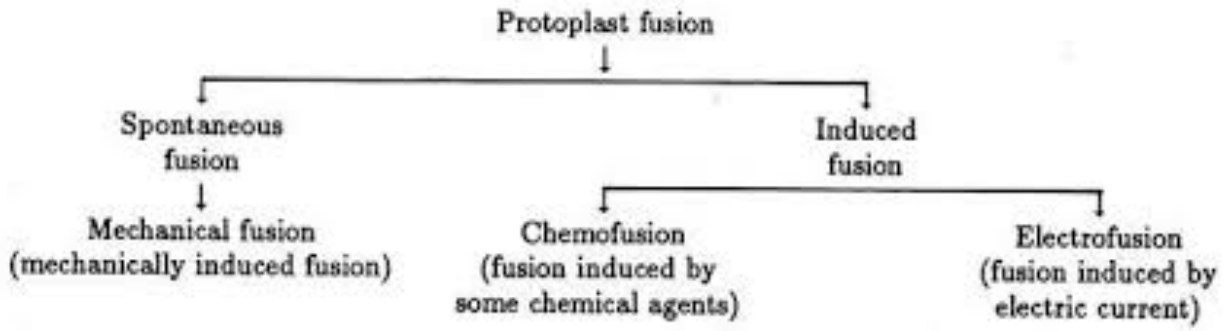


The process of mutagenesis. The mutagen factor creates variants. These are selected and replicated. The diversification obtained is further subject to mutagenesis and the cycle repeats till the point of the emergence of an interesting variety.
Credit: Creative Biostructure

This is a process that occurs in Nature. A cell is exposed to some mutagen factor (radioactivity or certain chemicals) with the result of changing its DNA. If this is a cell involved in the reproduction of that plant (or animal, all theses changes being considered applied to both animals and plants, although here we are considering them in relation to agriculture) then the modification affects its offsprings. This is a random modification. Most of the times the offsprings are sterile and the modification does not generate a new variety. In those cases that the offspring are fertile the variation may be advantageous to

the plant and will tend to propagate. Of these cases we are interested in the variations leading to an advantage from the farmer point of view. This is clearly a sub-subset of all possible mutations. Actually the probability of a random change to result in a “better” plant is extremely low, and that explains the very slow evolution we have seen over the millennia.
By intentionally using mutagens, like exposing the plant to radiation, we can increase the rate of change and increase the chance of getting a “better” plant. However, the random processes leading to a variation are far from optimal in terms of effectiveness of result. More recently researchers have been able to use specific mutagens to steer the evolution in specific directions (like creating a plant that requires less watering). In these cases the efficiency can increase. The whole mutagenesis process occurs through a repetitive cycle (see the graphic) that increases its effectiveness.

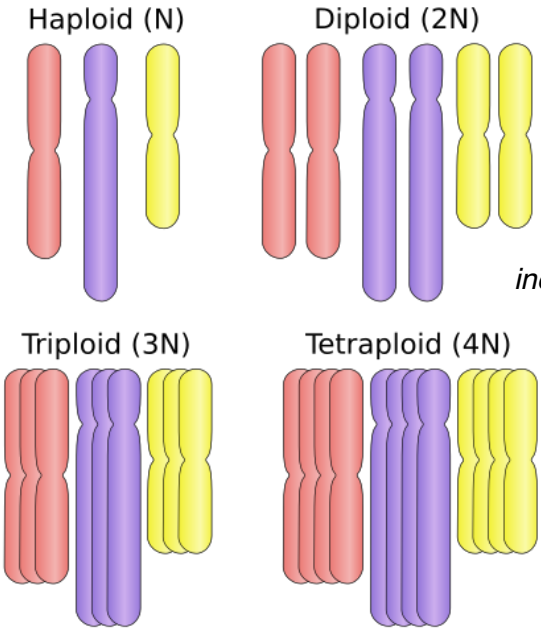
Protoplast fusion



Protoplast fusion: the fusion of two cells into one. It may occur spontaneously by mechanical proximity (as it is often the case in bacteria) or it can be induced through chemicals or electrical currents. Credit: Biology discussion

Protoplast fusion allows the transfer of some desirable characteristics, like resistance to diseases, from one plant to another. The challenge is to create an hybrid that is fertile. This has proven difficult when the fusion occurs between plants that are quite different from one another so researchers have been focussing on plants that are genetically similar.
Since the turn of the century significant progress has been made with this technology. Using this technology has been possible to insert bacteria fixing nitrogen in plants that were without them and to increase the effectiveness in photosyntheses by using better chloroplasts, thus increasing the growth rate.

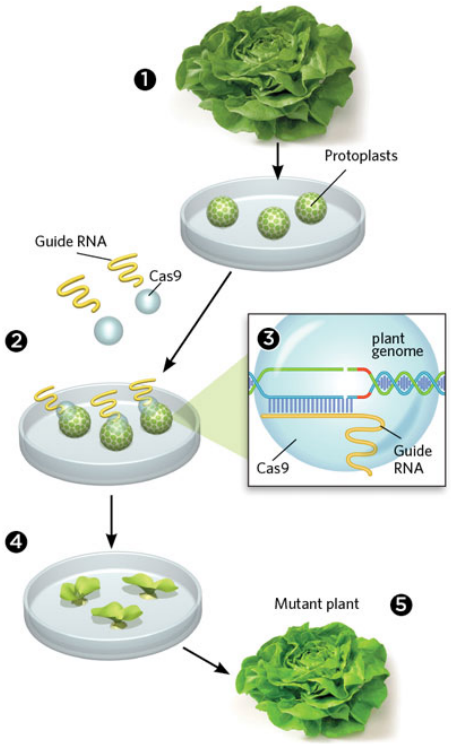
Polyploidy



Most cells, plants and animals alike, inherit one chromosome from the "mother" and the other from the "father". However in some cases we could have only one chromosome (haploid) or several chromosomes inherited from multiple "mothers and fathers" (polyploid). This happens most in plants and increase variety.

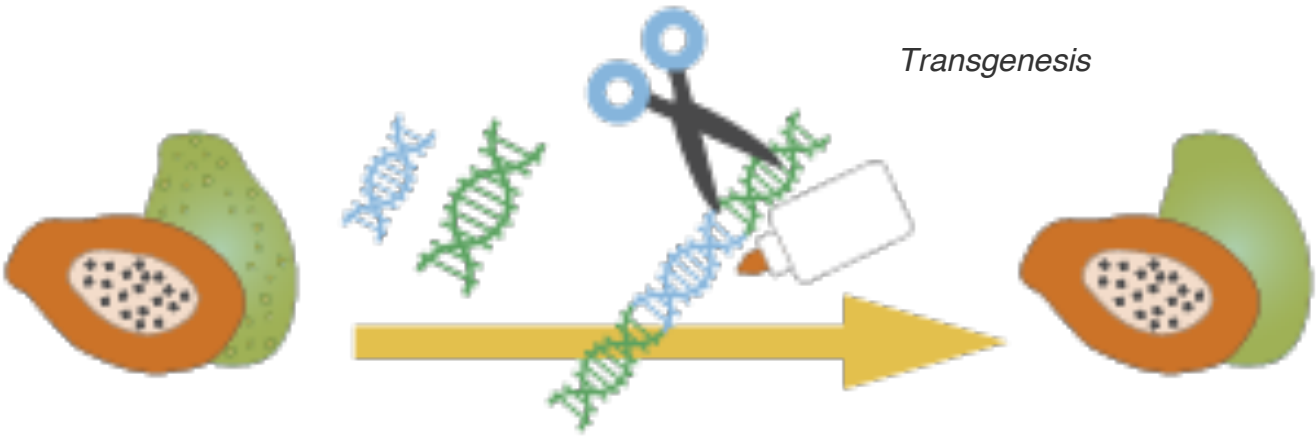
Image credit: Wikipedia

We have two sets of chromosomes, one inherited from our father and one from our mother. This is what scientists call "diploid". In plants it is not uncommon to have multiple sets of chromosomes, derived from the parents -multiple parents. This expands the characteristics of a plant, creating variety (since sometime one chromosome is at work, some other time another in the same set). This is a natural occurrence in Nature , wheat as an example is hexaploid, having -in a way- 6 chromosomes duplication – like having 6 parents- and what researchers have been doing is finding technologies that allow them to create polyploid plants, thus accelerating diversity creation.
Very recently, on May 11th 2018, the Chinese Academy of Science announced the artificial generation of high quality wheat by fostering polyploidy of specific type in wheat (wheat has a longer genome than human beings, 5G vs our 3G, a good 60% more).



Using CRISPR/Cas 9 researchers manipulate the DNA of a plant creating a mutant.
Credit: The Scientist Magazine

In the last 20 years researchers have been able to change the genome by cutting and paste in codons. The technology used is CRISPR/Cas 9 and has been “borrowed” from bacteria that use this approach to fight invading viruses.
By applying CRISPR/Cas 9 it becomes possible to engineer the desired characteristics of a plant, by manipulating the instructions that create the plant. It is no longer pursuing random changes in the genome (mutations) nor adding characteristics borrowed from other plants (protoplasm fusion) nor adding instructions taken from another plant at chromosomal level (polyploidy). Here we are changing the native set of instructions contained in the plant DNA. In a way this is a most effective way, at the same time it creates greater ethical issues than the other approaches.



In transgenesis a complete gene from a different species is inserted in the cell providing the cell with the possibility to create new proteins, hence providing new characteristics to the living being. Credit: Monsanto

In transgenesis a gene taken from a cell of one species (plant an animal alike) is inserted in the cell of another species creating a transgenic organisms. This is something that would seldom occur in Nature (in theory a virus can steal a gene from a cell it has infected and carried it over to another plant that it will infect dropping the gene that from that moment on will become part of the newly infected cell. In practice the probability of a virus infecting a spermatic cell or an oocyte immediately before fertilisation so that it will become part of the creation of a mutant is extremely low).
Monsanto has been using transgenic technology, as an example, to create papayas resistant to the papaya ringspot virus.
Nature has been carried out species modification since the beginning of life, and that is the reason why we are here today. Without random mutations, and selection, we would not have the diversity of life we see today on the planet (which is but a small subset of the diversity of life in the history of Earth, with most species having disappeared long time ago…). Hence, what scientists are doing is simply to accelerate the process and direct it to achieve desirable results.
In the 4 billion years of evolution Nature made plenty of mistakes, actually just an infinitesimal fraction of all mutations proved viable and “good” from an evolutionary point of view. The big issue confronting scientists, and raising concern in the public opinion, is that we don’t know if an induced mutation si good or not (and it is debatable what it is meant by good!) and that is something that might take years, centuries to discover. Are we pressing our luck in tweaking with the code of life?
Interestingly, artificial intelligence and deep learning technologies are now being explored to help understanding the implication of changing a genome, and a species. We do not have a clear understanding of what happens to the phenotype (the characteristic of a living being) when we change its genotype (change the code of life). This is now being addressed through artificial intelligence tools.

Eating more, spending less: the fourth agricultural revolution V

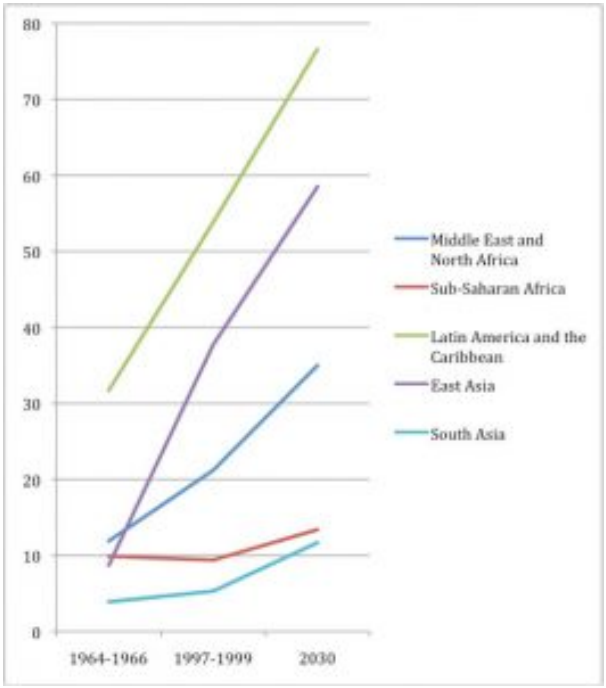
- *May 22nd, 2018*

Growing a burgher in six week. Stem cells are taken from a cow and grown in a lab creating muscle tissue in six weeks. This tissue is coloured, mixed with fat and shaped into a burgher ready for cooking. Credit: Mosa Meat

- Meat factories

The world first hamburger produced in a lab in 2013 cost 330,000$ US. By the end of 2018 the price for a lab produced hamburger is expected to reach supermarkets and be within 30% of the price of a "normal" hamburger. A 100,000 price decrease in just 6 years!

Why would we want to lab produce hamburger, and more generally meat and fish fillet? The basic reason is the environmental cost of livestock and the low efficiency of meat versus other type of food. Meat industry (the whole value chain) account to 18% of greenhouse gas production (and the gas been produced is methane and nitrous oxide that are 23 and 300 times worse than CO2 in their effect on climate); it is using a significant portion of arable land, 26% in grazing and a further 30% in producing food for them, with lower energy efficiency (to produce 1 kilocalorie of meat protein we use 25 kilocalories of fossil fuel -equivalent- whilst producing 1 kilocalorie of corn requires 2.2 kilocalories of fossil fuel -equivalent).



Trends in meat consumption over time (kg/per capita/per year) – by region.

Credit: WHO

Considering the above data and the fact that meat consumption will be increasing in the coming decade, as more people will inhabit our planet and more will increase meat consumption (see chart) it is no wonder the importance of finding ways to create artificial meat.

The challenge is to produce artificial meat, cow's, pork, poultry and fish fillets in volumes at a fraction of today's cost and using a fraction of resources. The idea started many years ago -Winston Churchill is credited of saying in 1932: why should we grow a whole chicken to eat just the breast?- and there are now labs results and a few companies are planning to go to market in the coming years.

Memphis Meats received back up from Bill Gates and Richard Branson, SuperMeat advertise themselves as eco-friendly and animal-friendly, claiming to use fewer resources than livestock production.

Until 3 years ago the expectation was to have artificial meat in mass production by 2035, now the most recent predictions are pointing to a take over of artificial meat as soon as 2021. Clearly this does not mean that we are going to dump livestock and connected industry, just that artificial meat will have a way to market. In the long run it will create a disruption, as already foreseen by the Imperial College Foresight study that points at Cultured Meat as something happening today (although the disruption will happen in some twenty years time).

Notice that if -likely- and when -2040- that disruption will occur we will see a tremendous impact on current economy. Keep in mind that some 50% of arable land is used today in conjunction with livestock and that will no longer be needed! Clearly such a shift might counteract the trend towards vertical agriculture, making more land available and will probably give further impulse to the adoption of swarms of robo-farmers.

Transportation

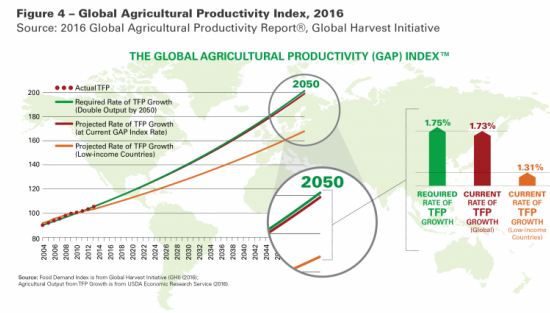
First commercial autonomous systems are here
- March 12th, 2018

The Dop Power Platform, a fully autonomous systems covering close to a 100 different jobs in agriculture is hitting the market. Credit: SEEDMASTER Manufacturing

Self driving cars are making the headlines on media around the world, however it will take several more years before they will become a commercial reality.
At the same time, mostly hidden to the mass market perception, other kind of fully autonomous systems are being deployed:

- there are several fully autonomous trains operating in the metro systems but one can say that they are working in such a closed environment that it is not a big deal (which is not completely true of course: as an example they have to manage the unpredictability of passengers behaviour as they hop on and off…);
- there are autonomous drones being used by military and a growing number being used by mass market in the “follow me mode” to film weddings, skiers, bikers …
- there are implants that autonomously sense the sugar level in the body and take “autonomous” decisions based on a variety of parameters to keep it within certain thresholds …

The list is getting longer and there is a grey area of what we should consider as autonomous system, like: truck platoons, ships, robots in production plants …
An important category of autonomous systems is the robots used in agriculture. They are getting more and more sophisticated, like the Dot Power Platform, by SEEDMASTER Manufacturing.



Expected Total Factor Productivity growth in agriculture. Notice how the projected need of agriculture yield to satisfy the hunger of a growing population is slightly higher than the projected one (red line) applying the most advanced technologies, including bio-engineering and autonomous farming. However, the gap is much wider if we consider the growth in poor Countries where the need for food is greater (and the economic affordability is a crucial factor). Credit: Global Harvest Initiative

These autonomous systems can perform 100+ jobs in a completely autonomous way, from seeding to hay-balers, increasing the yield of farming. According to Gartner by 2050 the agriculture yield worldwide will have increased 70% from today's, whilst the increase to meet the expected demand should be in the order of 100%.
This gap can only be filled by a convergence of several technologies, from bio-engineering to autonomous systems and through an evolution of our "feeding" habits (that is a change in our culture). The challenges ahead are huge, the good news is that we have today the basic technology needed tomorrow, although we need to evolve it, making it more affordable and "acceptable", i.e. we will have to evolve our symbiotic relationship with food. Autonomous systems are a crucial enabling technology in farming, although we seldom think of them when we enjoy some bread and rice at our table.

A sort of symbiotic autonomous system…
- May 27th, 2017

Spark, the smallest drone from DJI is now available to order at a reasonably affordable price. Credit: DJI

Every week a new drone is announced and although most of them look alike (at least to my untrained eye) a clear trend seems to emerge: they are getting easier and easier to interact with.
DJI has announced, and it is ready for order, SPARK, the smallest drone in their product line, at a price just below 500$, 499$ of course. What picked my interest is the possibility of controlling it by gesture, making it a very simple drone to interact with.

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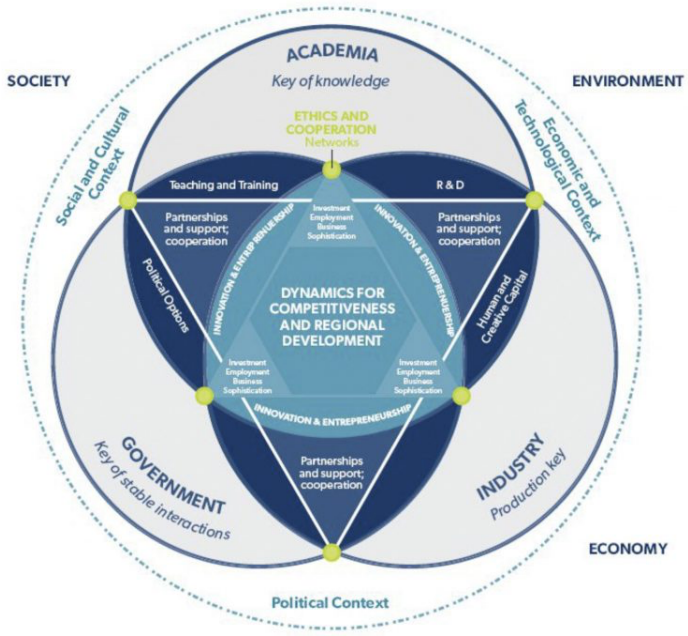
As you can see by watching the clip you can hold Spark on the palm of your hand, press a button on its belly with your finger to activate it and wait for a second to let it recongnise your face. Then you can gently move your hand up signaling the drone it is time to take off.
It will keep looking at you and will watch your hand to take orders. Wave your hand left and it will fly left, move it upwards and it will rise further high…. Make the gesture to come back and it will fly back to land on your palm. Pretty neat.
Of course, you can control it more accurately and make it fly away from you using your cell phone as a remote (it can communicate via radio link or by creating a WiFi hot spot if it has to fly in your vicinity). You can also see what its camera is seeing by using Google goggles for an immersive, on board experience.
The possibility of having a seamless gesture interaction brings this drone into the area of symbiotic autonomous systems -SAS- (although we are quite far from controlling it with our brainwaves…), an area that FDC as started to promote with its SAS Initiative.
Spark has, it is now becoming a standard feature for drones, an autonomous obstacle avoidance systems. I would expect that by the end of the decade we will have drones that can fly inside a home. Just imagine using a drone to take a look around over the furniture when you are searching for something. Well, I know, it looks crazy but we are already doing everyday plenty of things that would have seemed crazy just few years ago.
I am using my smartphones to take measures, to look under a bed for a lost coin, to track my son position, to check if a line on the wall is level for nailing some frames, to read the fine lines on a document, to open the room door at some hotels. Yes sometimes I still use it to make a call, but that's marginal.

Do you still remember the Waterfall Model?
- January 27th, 2018



Beyond the double helix new approaches to model and foster innovation are needed, involving multi parties, as it is proposed in [the triple helix model](). Credit: Farinha & Ferreira- 2013

The double helix model of innovation took into account the importance of market pressure in steering innovation. That was a significant shift from the situation in the last century

when technology was the main driver. It was relatively scarce and when you got a new technology that would push new innovation since it was enabling them for the first time. At the turn of the century we started to shift from scarcity to abundance in technology choices and availability and that shifted to steering to the market. It was the market that had the final saying on the direction to take.
The LCD screen won against the cathode ray tube not because it was a better technology but because the market, in spite of getting lower quality, decided that it was catchier/fancier.
The lowering of transaction cost, particularly in the software area has created an explosion of the offer, millions of apps are at our fingertips at negligible cost. This leads to fragmentation and in certain areas it is not good. Here is where government, institutions, policies and regulations come in. Also notice that a number of services/applications can be developed and used at very low cost because there has been a significant, sometime huge, investment in the context required for their creation and operation, what we usually call platforms. Apps would not exist without the investment made by Google, MS, Apple in creating Operating Systems and App on line stores. This has a correspondence in the platforms supporting services at a smart city level, or the ones supporting on line education courses… Again this is an area where the third string of the helix is crucial.
To some extent all this evolution, from the waterfall to the triple helix has seen a changing kind of control and different players involved, company, market, institutions… but nevertheless control it was.
With autonomous systems the story may be different. Exactly because they are autonomous the enforcement cannot be as straightforward as it has been in the past (and at present). It has to do more with the design of the overall context. And autonomous systems need to be designed for a smart interaction with the context (more and more composed by other autonomous systems).
The FDC Symbiotic Autonomous Systems Initiative is calling for the development of a new science to design these systems.
These systems will have to face an environment that keeps changing, that in most cases was not existent when they were designed. Hence they have to learn on the way and the way they will be learning has to be structured in a way that ensure the adherence to accepted principles, a bit like the Asimov three laws of robotic, and take into account that some might be designed to violate them.
The issues we are facing today on security and malicious software attacks have to be faced at the design of these systems. It is easy to predict that we are going to face many more problems than today and yet there is no way out: we have to get ready and learn to face them. The models we have today are not good enough to face tomorrow's challenges.

Would you care for an extra hand? The many faces of Industry 4.0

- November 20th, 2017

Ekso, a robotic exoskeleton used by a Ford worker on the assembly line of Ford Focus at the Wayne assembly plant. Credit: Ford

The FDC Symbiotic Autonomous Initiative has just published its White Paper on the status and trends in autonomous systems. A part of that paper focuses on human augmentation and points out that this is happening today.
An example that just came under my eyes if the exoskeleton being tested by Ford workers in the Ford assembly line at Wayne.
The exoskeleton is a wearable robot produced by Ekso Bionics specifically adapted to the needs of Ford workers operating in an assembly line (see clip). It provides arm support, highly decreasing the fatigue of keeping your arm high as you are performing overhead tasks like fastening bolts on the car chassis.
The robot is composed by sensors and motors that can provide lift assistance to the arms up to 6.8kg. It has been designed to increase safety on the job and decrease fatigue. New version will allow workers to handle increased weight, actually augmenting their strength.
So far it has been used on a trial base at the Ford plant. The trial was supposed to end in August 2017 but the workers involved have pressed to keep using them so they are still in use.

TTM 2014: Future of Fabrication

- October 2014

The fabric of the future will likely see much more flexible and aware production tools... that will span the supply, production and delivery chain. In the photo autonomous robots, by Kiva, used by Amazon in their warehouses. Image credit: Kiva

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Looking 50 years down the lane we see that more and more people will be “retired” vs the ones that will be “working”. This is a consequence of the longer life span and decreased birth rate. In Japan more than 50% of the population today is above 50 years old.
The ratio of retiree vs working force is growing and that brings forward many issues spanning from the sustainability of pension schemes in many Countries to social aspects and to the very meaning of "workforce". Whilst today "producing", hence being a worker, implies going to a manufacturing plant to use specific -expensive- tools requiring specific operation skills and a proper ambient/organisation to be used, tomorrow the boundaries between a manufacturing plant and a home may blur.
Looking today at the evolution of fabrication over the next 20 years we can see a few megatrends:

- personalisation is challenging mass manufacturing
- food manufacturing challenge is to provide reasonable quality and quantity to everyone in the world at an affordable cost
- electronic manufacturing is pushing towards faster product cycle requiring higher flexibility
- 3D printing/Additive manufacturing (already used to take a 3D laser scan of your ear canal to provide a fully customize ear buds)
- the salary gap is narrowing

The future of fabrication will leverage on a variety of technologies, several already available today, and leads to a changing working environment. Because of this, new skills will be required and given the flexibility of new fabrication tools it would make sense to have them, with an appropriate interface, closing the gap between machines and workers. Now, if one considers that young people have got used to playing games, 12,000h per youth over the age 10-19 of gaming in the last ten years, it shouldn’t be a surprise to imagine that these acquired skills will be exploited by manufacturing processes. Particularly so if we think that part of the fabrication in the future will take place at home! There are several research areas that will be driving the evolution:

- Human robot interaction
- Model based programming
- Large scale vision
- 3D modeling
- Open Software Interfaces
- Fleet management
- Multi Objective Planning
- Flexible grippers
- Learning by demonstrations
- Hybrid control systems

There are also several "gaps" that today are hampering a smooth evolution. Among these the speakers pointed out:

- Robot cooperation

Notice: the opinions expressed in this eBook are not necessarily the ones of the SAS Initiative and IEEE FDC is not endorsing them.

- Feedback control
- Plug-n-Play integration
- Flexible programming
- Flexible end effectors
- High performance manipulators
- High speed mobile platform

The evolution of fabrication will likely take different paths depending who is walking the path. At least we are going to see the emergence of comprehensive smarter manufacturing in big enterprises that have available huge capital to invest in changing their fabrication approach. Small and medium enterprises will likely ride their flexibility to adopt new fabrication tools in niches with lower capital investment. Logistics and warehousing are going to be leader in the supply and distribution chain and will have to move fast, faster than the deployment of 3D printers that might end up disintermediating them in some sectors.
It should be noted that the use of robots is not chiefly motivated by the lower cost (which, by the way, in many cases is not lower at all) but by the consistent quality and increased flexibility. Today we have 1 robot for every 10 workers in automotive biz and, interestingly, the forecast by the speakers was that there will be no big change in this ratio in the next two decades. So, according to the speakers at least, the robotisation of fabrication has already reached the maximum impact on workforce and any further "efficiency" (read substitution of blue and white collar workers by machines) will be rebalanced by more jobs being created. Personally I am not so sure about this forecast.
Another interesting thought on the future is the growing importance of recycling that will steer new ways of design. Recycling by design will be an absolute must in twenty years time.
Digital manufacturing (to monitor continuously what is going on) and agile manufacturing to ensure flexibility are going to be the leading paradigms to meet the challenges ahead.
As eCommerce keeps increasing in volume there is a growing interest in synchronizing the manufacturing processes with the lean supply and distribution chains.
Industrial Internet and Industry 4.0 are two names for the same thing (US vs Europe) where the digital and manufacturing processes support each other. Big Data and cloud are important components of Industry 4.0.
Massive use of automated aerial vehicles will permeate the supply and distribution chains. It was noted that 40% of people entering the US airforce are going to fly from a container, without ever leaving the ground. This trend in military will create a fall out leading to sustainable technology and delivery systems: autonomous delivery systems are likely to take the lion share in the delivery chain by 2035.
As a side thought, in synch with these growth in autonomous vehicle, it was noted that newborn in this and next decade will probably not learn to drive a car since by the time they get 18 cars will be driving them. I beg to differ here, since I see a much slower uptake of self driving cars.
Dirty and heavy jobs will be eliminated, hence the need for re-skilling of blue (and white) collars. MOOCs will play a pivotal role in education of workers. The MOOCs industry will be a very complex one with the need to continuously retune the education material and keep the pace of changes in the industry.

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The future of fabrication will allow small teams to create complex products. An interesting example was given. Savioke is a start up that is selling robots to hotels and communities. Using new fabrication tools they have been able to develop complex system in a company consisting of just 7 people. They have leveraged 3D printing, software to support modeling and printing, centralised machine shop and support software that can produce parts in a professional way at low cost.
This is not an isolated case. More small companies are already in biz and more will come. Open Source Software, like ROS, can become a global manufacturing software platform that fuels these new constituencies of small manufacturers.
The flexibility that might be achieved in the future through robots can already be seen in the use robots to assist paraplegic patients, each one with his own specific needs. The possibility of addressing niches at an affordable cost, one of the challenges mentioned for the future of fabrication, will change the stage of manufacturing. Any products in the future will be software based satisfying a low volume, speed to market and smaller markets, in synch with the general trends previously outlined. It remains to be seen where this personalisation will take place: as an embedded feature out of the production line, at the point of sale, through customer support….
Possibly, the major changes on the fabrication paradigms will be a consequence of the use of 3D printing, Crowdsourcing and Terabit/Sec optical fiber. For this latter the need for an Industrial Internet that is secure and can be relied upon was pointed out.
In the crowdsourcing area it was interesting the talk given by GE describing an open challenge to design an airplane engine bracket. The challenge was taken up by thousands of people in over 50 countries. The winner, from Hungary, designed a bracket of the required characteristics of strength and flexibility that led to a saving of 85% of the current weight.
The next 20 years will be characterized by the availability of "Infinite Data". As intelligent machines will begin to converse directly with each other, the traditional methods of data storage and management will be overwhelmed.
Near real time decisions will be made at the edge and machine consciousness will be used to help decide what should be remembered and … what is best to forget.
The low cost and volume of data outstrip the value of transporting, sorting and storing it.
The time to value capture is the new data metrics for the future of fabrication.
Synaptic chips will be companions of workers in manufacturing leading to symbiotic fabrication where man and machines will interact about goals, not about specific operations as it happens today.
The next industrial revolution will be about providing industrial capability to any people and that will transform the planet distributing factories in every home.
Fabrication will move from objects to other products, including human spare parts!

Transportation

Are flying cars around the corner?

- November 9th, 2017

Flying cars, like this one, with rotors folded in a "parking" position, are moving from labs to the … sky with a roadmap that can see the first flying taxis in 2018 in Dubai and Dallas.
Credit: Design Engine

Uber has just signed the agreement with NASA to cooperate in making flying cars (taxis in their case) a reality. The news has been taken by many newspaper and televisions around the world an this follows the announcement made few months ago in Dubai to prepare a taxi service that could start as soon as next Summer, 2018, in the Emirates. That announcement was followed by another one to initiate service in Dallas and more recently in Los Angeles.

However, what makes the present announcement much more interesting, and credible, is that cars cannot fly just because they are given "wings". What is needed is an infrastructure that supports this new form of transportation.

If you look at airplanes you can see what a complex infrastructure is in place, in terms of regulation, procedures, control centres to make flight possible (and safe). Having cars flying requires that, and more. Indeed, the most complex part of flying is taking off and landing, because that is where the air traffic becomes "dense". If you look at big international hubs you see planes landing two minutes apart (2.5 nautical miles is the minimum distance when approaching the airport) and as I noticed in a recent post a glitch (like a drone) can wreak havoc in this finely tuned mechanism.

Now think about a city with flying cars. There may be hundreds, thousands buzzing around The complexity of managing this traffic in 3 dimension is mind boggling. Uber is foreseen tens of thousands of flight a day in a city, that is at least an order of magnitude higher than what happens every day at Heathrow (650 flights in and out per day on average).

More than that. Airplanes may be circling around the airport waiting for a free slot to land, but that would not make sense for a flying car whose flight time is probably in the order of 10′ (and its battery is likely to work for some 30′).

The complexity is really huge and new strategies for air traffic management are required, also taking into account that there will be no pilot in those flying cars. This is what NASA is working on and this is what Uber needs to make its vision a reality.

One thing is to demonstrate a flying taxi in Dubai, taking off from a skyscraper, veering a few hundred meters to fly over the desert and then landing on the top of another skyscraper, still a stone throw from the desert. Quite a different story is to fly hundreds of taxis over Los Angeles intersecting their paths continuously.

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These kind of challenges are being addressed in the IEEE FDC Symbiotic Autonomous Systems Initiative, stimulating studies in this area that is likely to require a new area of science.

Good Morning, this is your robo-captain speaking

- December 1st, 2016

DARPA ALIAS: Aircrew Labor in-Cockpit Automation System. A robot co-pilot that can use the cockpit dials and switches as a real pilot.
Credit: DARPA

Unmanned Aerial Vehicles, UAV, are a reality in the military arena, either flying on a pre-programmed mission or remotely guided from an Earth based pilot.
From a technology point of view it is not a big step to have a commercial airplane flying itself, they already are –almost- flying by themselves most of the time using the autopilot. There are regulatory, as well as psychological, hurdles to overcome but the road is open. However, transforming one of today's commercial aircraft into a self operating aircraft is more complex.
This is why some researchers are exploring the possibility of creating a robot that can replace the pilot on current aircraft. No change will be required to the aircraft apart from installing the robot in the cockpit.
A first step may be the one taken by the DARPA ALIAS (Aircrew Labor In-Cockpit Automation System) program, aiming at replacing the copilot with a robot that can perform all flying operation that might be required.
The robot looks at all instruments and read the gauges, look at switches and see if they are in the correct position and if not can take action. It is programmed to learn from experience so it gets used to the aircraft it is flying and gets better to it. So far it is not able to look outside of the cockpit to appreciate the beauty of a sunset (which is a pity but it is not an issue) nor to spot a hurdle on the runway (and this is an issue).
The experiment is focusing on a Cessna aircraft (see image). The goal is to respond to the shortage of pilot, making it possible to fly a commercial plane with a single pilot having the robot as a back up (or the other way round, the robot normally flying the plane and the pilot sitting there … just in case). This is interesting since it brings to the fore the issues of seamless cooperation between human and machines, something we are addressing in the new FDC Initiative "Symbiotic Autonomous Systems".
A more radical approach is taken by KAIST, the South Korea's Advanced Institute of Science and Technology, aiming straight at a robot that can sit in the captain seat and fly the plane, see clip).
They are planning a humanoid robot, PIBOT – Pilot Robot, that can seat in the pilot seat and mimic all actions a real pilot would do to fly the aircraft, and converse with the air traffic control as well, following the directions given. So far I would not like to be greeted by

PIBOT as I board a plane. The success rate in landing (simulated) is 80% which apparently makes researchers happy and confident this is the way to go but it feels a bit too scary to me.

From Smart to Intelligent Cities
- December 6th, 2017

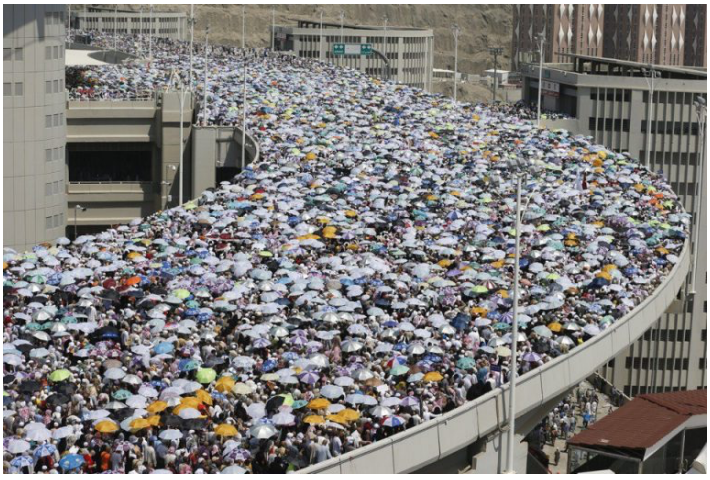
IoT are at home in a a city and they help in make it smarter. It is debatable whether they are sufficient to make it intelligent.
Image Credit: Nokia Networks

OK, so we can expect a smart city to become more and more “imbibed” with IoTs, hundreds of millions of them connected through a nervous infrastructure supported by a ubiquitous communications fabric (5G) with plenty of software that makes sense of data and orchestrate the response of the city, seen as a living organism, to a changing environment. This city, thanks to this “nervous soft infrastructure” will be getting smarter and smarter, it will be capable of learning from past experiences and adapt to the variety of situations arising.
Will this city be intelligent? I personally doubt it. The amount of IoT and their mutual interconnections via the soft infrastructure seems well below the level of complexity that would be required for an autonomous emerging intelligence. You can have intelligent systems plugged in providing specific intelligent responses, but the city is unlikely to become intelligent, as a whole.
If you look at animals the number of IoT we can expect in a 100,000 people city would compare to the number of neurons in a mouse brain BUT the number of interconnections in a mouse brain is in the order of 1 trillion and that is way, way, beyond what we have in a city of that size (the connectivity of a city with one hundred thousands inhabitants may compare to the interconnections present in a honeybee brain, in the order of billions). We may feel that a mouse is intelligent (to a certain extent) but I would say we all agree that a bee is “smart”, pretty smart, but not intelligent.
Of course, if it can make sense, up to a certain point, the comparison of a neuron with an IoT (although many IoT do not have the processing and the memory capability of a neuron) it is much more tricky to compare the synapses (interconnections in a brain) with the soft interconnectivity structure of a city, based on software and data centres (these, in fact, replicate part of the functions of neurons and neuronal circuits, like processing and memory/experience).
Here, however, I am just trying to reflect on general aspects of emerging intelligence, so I guess we can use these loose comparisons.

Is there a chance for a city to reach the level complexity that we see in a brain capable of an intelligent behaviour based on the increasing penetration of IoT and their growing connectivity? Unlikely. The quantitative difference is way too large.
However, there may be two ways to achieve an emergent intelligence: interconnecting localized artificial intelligence to create a city wide Artificial General Intelligence (AGI) or, and this is what Derrick and myself will be discussing in the December 12 webinar (you can enroll in the free webinar here), by interconnecting citizens, creating a single organism composed of IoTs (taken as sensing and interacting points in a city) and citizens. Notice that a city showing AGI is on a completely different level from a city having, as many smart cities have today, points of localized artificial intelligence. These are making the city smarter, not intelligent. AGI is bringing to the fore a wide variety of issues that are central to philosophical and ethical debates. Our cells are smart but you can get rid of million of them with no ethical or philosophical implications arising. Quite a different story if you are considering the whole organism made up by those cells. These aspects are addressed in the IEEE FDC Symbiotic Autonomous Systems Initiative.
Citizens are sophisticated sensors, they are also biased sensors (they see what they want to see, process data and act according to their individual goals). If they become connected to the city neural soft infrastructure their individual complexity becomes a factor in the overall complexity of the city pushing the whole beyond the minimum complexity thresholds. Notice that you cannot simplify this system without losing its “essence”. It is both a complicated AND a complex system.

From Smart to Intelligent Cities

- December 8th, 2017



The Hajj stampede in September 2015 in Mecca, Saudi Arabia, was a deadly example of how individual intelligence may lead to catastrophic consequences at the global scale. Unfortunately this is not an isolated case. The challenge for city planners is how to steer local intelligence in the direction of creating a global emerging intelligence.
Photo Credit: Association of British Hujjaj (Pilgrims)

Citizens are “autonomous systems” and the question, or if you want the “challenge”, is how can a city planner leverage on these autonomous systems to create an intelligent symbiotic organisms where intelligence emerges as result of its components interactions? Notice that even though citizens are (at least sometimes) showing an intelligent behaviour this is localized and does not result in an overall intelligent behaviour. If you need an example think about the traffic jam we are experiencing everyday: there you see the emergence of stupidity out of a multitude of intelligent components! Quite often we see stupid behaviour of crowds, resulting from localized intelligence, sometimes leading to

casualties (remember the Mina stampede at Mecca on September 24th, 2015, resulting in over 700 dead).
Sociologists study the crowd behaviour, but city planners study how to direct the localized behaviour based on the city resources. What Derrick and myself are claiming is that technology can influence these localized behaviours by creating awareness and steering the localized responses in such a way to create an emergent intelligence resulting in the Artificial General Intelligence of the city.
Derrick has been proposing in his book "Connected Intelligence" that the global intelligence made possible by web connectivity is larger than the sum of the local intelligence contributed by individual persons. This is an intriguing concept that here gets expanded by combining this global intelligence with the one deriving from orchestrating data and processes at city level, increasing local awareness and steering/influencing local processing and action.
Notice that the local intelligence is no longer solely the one contributed by people, it includes the ones contributed by artificial intelligent systems, including smart vehicles, robots, smart 3D printers, smart books and smart real time education, smart augmented reality …
Indeed, the two ways of creating an emergent intelligence at the city level, through interconnecting localized artificial intelligence (hence involving systems) and interconnecting citizens morphs into a single one.
The focus shifts towards the creation of awareness in such a way that it steers towards a city intelligent behaviour. It is not, in general, about forcing people (although in some culture/political environment that might be the case) but about influencing people in such a way that the average response is in line with the emergence of a global intelligence.
Notice that when one forces people the result is a mechanistic behaviour, whilst if people are influenced the behaviour remains flexible and can result in a better, more intelligent outcome.
The trick is to create a context that leads to seamless awareness both for people and systems. The point is symmetrical. The context, the ambient, has to become aware of what is going on, including how people are reacting to the changing conditions.
Today we have the smartphones that represent an -almost- seamless interface, however they are far from perfect since they require an explicit intention from the owner to look at their screens.
Having smart contact lenses and using augmented reality would be a significant step forward, although it might take a few decades for technology to mature and reach a significant penetration.
An alternative, eventually a complementary approach, would be to have the context itself, the ambient, becoming interactive. You got pollution in an area? The leaves of the trees start to blink (it can be done with some genetic tweaking using CRISP/Cas9…), are you walking towards a congested area? The soles of your shoes subtly steer you in a different direction (it can be done using smart materials…) …
Does it looks like science fiction? It is not. Technology to support this is becoming available, the point is affordability and acceptability.
Can awareness result in a cultural change? It is well known that culture/social acceptance has a stronger influence on people behaviour than laws.
Awareness, this is a crucial point, should not be limited to the facts (there is a traffic jam), rather it should be about the impact these facts have on the individual and the community and even more important the impact that each person, through its behaviour, can have on

the evolution of a given situation. Remember, what distinguishes smart from intelligent is the capability to foresee the future implication of present actions.
Social rewards may be more effective, on the average, than penalties by law, and in a city we have to look at the average behaviour, of both systems and citizens.
Planning for a symbiotic integration of the two is worth considering.

Carrying 10 Exabyte of cars generated data

- August 13th, 2017

The Toyota Research Institute's advanced safety research vehicle.
Credit: Toyota

Toyota announced on August 10th the creation of the Automotive Edge Computing Consortium, along with Intel, Ericsson, Denso Corp, NTT and NTT Docomo. The consortium has the goal of developing an ecosystem for connected cars able to leverage on the huge amount of data that vehicles, and particularly autonomous vehicles will generate. According to Toyota estimate by 2025 the volume of data exchanged among vehicles and between vehicles and Clouds (worldwide) will reach 10 Exabyte, a number that is 10,000 times greater than what they are exchanging today.
The consortium will work on the definition of architectures supporting edge computing including aspects of massive distributed storage and of course local communications.
I find this announcement quite interesting since it "creates" a real market for edge computing. It has been clear for quite a while that a shift from core network intelligence to edge network intelligence was becoming possible thanks to the increased processing and storage capacity at the edges (smartphones) plus the capability to manage communications directly from terminals. However, this is a first clear industrial commitment to leverage on this possibility and it may become a game changer.
Interestingly, nowhere in the announcement there was a mentioning of 5G. It is no surprise, at least in my view. 4G, and its planned evolutions -the last one being road-mapped in 2023, is already capable of managing quite a bit of the requirements posed by autonomous vehicles, and for those that are not met alternative solutions are under study that are likely going to be deployed in parallel to the 4G evolution and 5G early deployment.
5G will support vehicle to vehicle communications, of course it will, because 5G will be clustering a variety of existing networks and protocols under one umbrella, including advanced LTE.

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What I also find interesting is the estimate of 10EB of data interchanged. Whether the estimate will prove correct or not, either under or overestimating the quantity of data, is to a certain extent irrelevant. For sure there is going to be plenty of data generated and many of them will be interchanged among vehicles and leveraged in the cloud giving rise to new applications and services. Actually, one of the possible outcome was mentioned in the press release pointing to the real time generation of maps based on the data sent by millions of vehicles. These maps will be continuously updated and each vehicle will be at the same time a user and a producer of the map in its surrounding.
It is clear that traffic management will change dramatically thanks to this continuous monitoring and to the possibility of steering traffic and the use of resources.
IEEE FDC is deeply involved in this evolution with its initiatives on Symbiotic Autonomous Systems, 5G, Big Data, Cloud Computing and Smart Cities.
EIT Digital is also very much involved in this through its Innovation Activities and its Industrial Doctoral School that is offering positions specifically in this area.

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MARKET ASPECTS

Symbiotic Machines
- January 27th, 2016

Cooperation from humans and machines is bound to become seamless in the coming decades. It won't happen at any specific point in time, it will just morph undetected into our daily life.
Image Credit: Valigia Blu

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 behaviour. 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.
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 scale 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).
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 al economic transactions.

Notice that, as in the previous revolution, the overall way of life changes. Agriculture was progressively demoted from the centrestage by the industrial revolution, and knowledge workers progressively took the centre stage in the digital revolution. Along with that or lives and our ambient got reshaped. From having place to hold wheat we shifted to need place to hold "bits"…. just to give an example.
The symbioses among people and machine has all the ingredients to be as overwhelming and disrupting as the afore mentioned revolution (my bet).
A challenging “near” future, indeed!

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ETHICAL ASPECTS

Jumping into the void: Vitrifixation
- May 8th, 2018

Science fiction has imagined the possibility to upload one's brain to a computer. Many have spoken on the impossibility to do such a thing. One start up is doing it…
Image credit: Science Alert

In the Symbiotic Autonomous Systems Initiative we are looking at human augmentation technologies, including the ones that are at an early experimental stage but might become impactful in the coming decades. Among these we are looking at development in brain to computer interactions, digital twins, artificial intelligence and distributed / symbiotic artificial intelligence (i.e. partly in the brain(s) and partly in the cyberspace).
The idea of uploading a whole brain to the cyberspace, replicating it, has been considered but more in terms of fragments that eventually might be consolidated into a concrete possibility. There are indeed a number of such fragments but the consolidation is so far away to remain in the science fiction realm.
Yet, a company, Nectome, has taken the goal of uploading a brain to the cyberspace seriously and they believe it can be done in the near future (read next decade). Before getting too excited read the following.
Nectome is a spring off of MIT people involved in the Human Connectome project, an initiative aiming at creating a blueprint of our brain, which is way way more complex than the blueprint of our genes, the genome. A genome consists of about 3 billion "letters", a connectome of 135 trillion synapses!
Nectome has found a way to identify these 135 trillion synapses and their mutual relations and can do this (will be able to do this in the next decade) for any brain. In order to do that it removes the brain from your skull (this is not nice and is going to significantly decrease your enthusiasm…) and perfuses it with a chemical (glutaraldehyde) that instantly stops all biological processes preserving the synapses status and connections as they are at that particular moment (that is why, I assume, the process is called Vitrifixation, it is like fixing everything in glass) and then the brain is frozen to -130°C halting any decay process. This vitrified brain can then be sliced and observed (automatically) use a new technique that picks up nanoscale structures to identify synapses and connections. As Sebastian Seung, the Connectome father, says: "we are our connectome, replicating your connectome is replicating you, what you know, how you feel, how you love" (see clip).
It is clear from the process they use that we are not talking about uploading your brain, rather we are creating a digital copy of your brain (with the side effect of destroying your real brain – but you can't have it all, can you?). Such a procedure can be executed once you are close to die to preserve your "information set"… It is different from the cryonics

where the idea is to place you into a suspended life state and “resurrect” you so what is bothering you now could be fixed decades from now once technology has progressed to the point of making that possible.
The cost today is staggering, identifying the 135 trillion synapses and their relations is beyond our current “affordability” both in a technology and economic sense. Nectome is showing a technology path to make this possible and it is betting, reasonably if we look at past experience, that it will become economically affordable in some decades from now.
However, leaving aside technology and economics there are some fundamental questions that need to be addressed:

- The genome and the connectome share the same issue: they are both useless unless you understand how the strings of “letters”/”synapses” translates into meaning. We are just now starting to understand what is the relation between the genotype (the letters in a genome) and its phenotype (what is the result in terms of structures created and behaviours). We are still pretty far from a meaningful picture and very far from a complete picture. The translation of synapses and connections into “information” is even more daunting, personally I will not expect to see a solution in this century. Besides it is not like getting a piece of brain, looking at what’s in it and finding a face, a math formula or the skill of riding a bike.
- Today we are starting to understand a few connection between the electrical activity going on and the intention expressed by the brain (move the hand, grab the glass ’cause I feel thirsty…). But we haven’t the foggiest idea on how to reverse engineer the synapses and their connections into an expression of electrical activity.
- Even once we will reach that reverse engineering capability, assuming we will ever will, we will have to capture the status of the sodium and potassium molecules and their exact location (to derive the electrical potential of the cells membranes to evaluate the probability of excitation and therefore of resulting electrical activity). This is even more complex than the already mind-boggling task of mapping the synapses.
- It is not enough. If you were given the six million parts making a jumbo jet (Boeing 747) would you understand how it behaves? Now multiply that number by 22,500,000 to scratch the complexity of synapses and add on the sodium and potassium molecules to dress it up… There is no hope to understand the information at atomic level.

There is another side of the story that is generating questions that are even more complex to answer, once you have solved all the difficult questions before -that are difficult but basically technologically difficult:

- When a brain is frozen it contains information that has been frozen at that particular time. How do you tell what information is actually part of the perception and what is a ghost of a past long forgotten (that might be remembered again if proper stimuli are provided).
- It is reasonable to assume that one would freeze a brain once that person is no longer at her best (i.e. is close to death). Now, in that stage, what is the information that is recorded? Hasn’t a good portion of the information been wiped away by the decaying health? Would the information present represents the person at her brightest state or will they be in synch with the spoiled health state? It would seem more likely to be the latter, hence what would be the incentive to “copy” a state of unhappiness and preserve it for

the future? (the alternative of extracting the brain from a person that is living a blissful moment does not seem to be appealing either…).

- The processing that eventually results in perception of information, activity, feelings is initiated by some stimuli. Who is going to decide how to stimulate a Vitrifixated brain? Depending on the stimulus you are likely to see completely different thoughts and information emerge …

As you might perceive, I am not sharing the idea that "I am my connectome". Yes, I agree that what I perceive, feel, do is the result of the way my connectome is, but such connectome keeps changing and evolving. Taking a snapshot of it is not me. It would be like saying that looking at a frame from a movie is like seeing the movie….

Do we have virtual privacy in the virtual space?

- January 13th, 2018

Wearing an electronic thimble let you feel tactile sensation, as if you were touching something with your finger. The virtual reality goggles show you objects and you can touch them, feeling their texture, softness. You manipulate them and the touch adds an important ingredient to the "make-believe". Credit: Tactai Touch

As part of the human augmentation studies carried out in the IEEE FDC Symbiotic Autonomous Systems Initiative consideration is being given to the sense of touch. We often underplay the relevance of our touch, considering it well below seeing and hearing, yet it is a very important sense (it would be almost impossible to pick up an object with no sense of touch -have you ever tried to pick up something with your hands freezing in a snowy icy day? Your fingers feel numb and it gets very difficult to pick up an object – and mind you, in that situation you still have some touch sensation created by the joints…).
A few companies have been studying how to recreate the sensation of touching an object in conjunction with e-commerce and with Virtual Reality. In both situation the opportunity of touching what is been shown would be a plus. Are you deciding to buy a scarf? Touch it and feel how soft and warm it is…
Tactai, a US start up that has presented the first products at CES 2017, if offering an electronic thimble that stimulates your finger sense of touch via vibrations. By modulating those vibration it is possible to recreate a variety of sensations, actually tricking your brain into believing you are really touching a surface (it can also provide softness and hardness, wet and sticky sensation but it does not provide you with warm/cold sensations, since these depend on nervous termination that are not triggered by vibrations). There are other companies that are working to let us "touch", virtually, bits and get the feeling of touching atoms.

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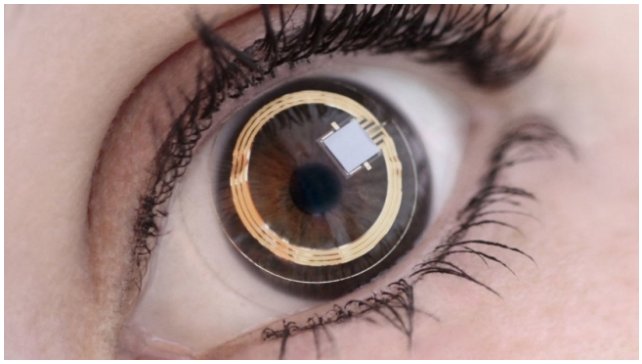
What about being touched? Not to worry. Also in this area there are companies that are working to provide that sensation (see video clip).
Teslasuit is a company that does just that. They have created a sort of wetsuit, a much more sophisticated one, that using electrical stimulation can trick your body into feeling it is being touched. It can even create warm and cold sensation (to a certain point). They have released, in addition to the suit, a haptic library of software modules that can be used to stimulate different parts of the body (in case you are wondering … no, there is no provision for those specific parts you were thinking about…). Their idea of application is today focussing on gaming but it will be up to application developers to identify new areas.
Again, there are other companies at work to provide the sensation of being touched.
So, on the one hand we have the possibility to touch "bits" feeling them as atoms, and on the others we have the possibility of being touched by bits, as if they were atoms. This is were the question I used as header of this post comes from.
I already mentioned in several posts the trends towards the creation of digital twins. We already have specific digital twins managed by the Government (they got my fiscal identity and associate it with what medicine I buy, with houses I own, with financial transactions I make… and probably more), digital twins managed by shops and department stores, by restaurant, by airlines companies (they call them "fidelity cards"….). Google probably know more about myself than … myself (that is because I forget, Google does not!
Some shops are giving the option of creating a digital representation of your body so that they can tailor wearables (like shoes, sweaters….) to you for the best possible fit. Others are asking for your digital body self to create avatars that you can use to see yourself in a certain on line space.
Others, I am pretty sure, are working to create a digital copy of you from the images of you available on the web. The possibilities offered by image analyses (including the face Id of the iPhone X) are huge and it is no longer a problem to create a faithful digital twin of your body (our body).
At this point one could decide to touch your digital body twin using one of the above devices, and you might have hundreds, millions!, people around the world touching you. Well, may be that is unlikely, but what about an app offering to touch that actor/actress you are watching now in the movie?
Would you think there could be a market for that? Should that market be regulated? What kind of rights will we have on our digital twins? Should you become aware that somebody is touching you?
Yes in a way it is like saying that we need to have control on our photos (and we know we don't), like saying you can determine who has the right to see it and who doesn't.
However, once a photo is on the web you no longer control it. Given that a digital twin of your body can be created from a photo (actually a few of them, the more the better…) the same should apply to that as well.
And then you have the possibility of somebody touching your digital twin, may be somebody else using your digital twin to create and avatar to interact with, may be using that avatar to create a movie…
You see what I mean: we are on a slippery slope where there is a need to define the rules of "virtual" privacy before it becomes … virtual (i.e. no more real).

It can be done, and that is the problem…

- December 19th, 2017



An electronic contact lens (prototype) providing with a display directly on the eye. Credit: Google

At IEEE FDC the Symbiotic Autonomous Systems Initiative, SAS, is studying the interplay (symbioses) of machines and humans. There is a lot of technology involved but the real issues are not technological ones. Yes, there are plenty of technology hurdles but just wait a few more years (may be just months) and they will be overcome.
The real issues are more on the social and ethical side. And the problem is that there is plenty of grey, very little is black or white!
Take a soft human augmentation (not the hard one that can result from genome tweaking). There are a number of prototype contact lenses that one can wear and become connected to the web. Yes, today it is not plain sailing, there are issues with powering in a seamless way, in resolution, in comfort etc. etc. but these will be solved (pretty soon I bet).
Let's just consider the functionality. Wearing such a contact lens you would be able to see information that other people around you will not perceive (nor will they perceive that you are seeing that information).
These contact lenses are being developed to help people with visual deficit and it makes a lot of sense. No issues there. But they can also be adopted by people having a perfect sight in search for "augmentation".
A hidden camera may look at the person you have in front of you and an image recognition system, somewhere in the cloud, may retrieve information about that person and relate that to you. A microphone (it could be the one in your phone) may relay the voice of that person to applications to check the correctness of what they are telling you, as well as the emotional level with hints on the stress he is experiencing and probably reading his real intentions "between the lines". Would this give you an unfair advantage in the business conversation you are having? Of course it will!
Is this fair? May be it is. Why should it be wrong to check the truthfulness of what that person is telling you? On the other hand there is a clear unbalance between you, an augmented human, and your "plain" counterpart.
Having augmented capability can make a call centre operator much more efficient. As he is answering the call a program will detect the audio signature of the caller and provide immediate information through the lens to his brain (this is not in principle different from providing that same information on the display of his desktop computer although it might be more efficient). Would the employer demand her employees to wear these contact lenses? Would they be able to opt out?
What about your spouse wearing these contact lenses and being able to read you … between the lines, a homebound big brother. Our whole social relations are kept on a fine balance between being who you are and showing the part of you that is appropriate in that

specific context. Augmentation such as the one created by these lenses (and the software behind them) may break havoc in our social environment.
These aspects, and more, are hinted in the published SAS white paper. We are now working on education material to socialise them and to involve more people into discussing the new worlds just around the corner.

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LEGAL ASPECTS

Accountability

Some nasty sort of autonomous systems

- April 15th 2018

ATLANTIC OCEAN – MAY 17: In this image provided by the U.S. Navy, an X-47B unmanned combat air system (UCAS) demonstrator performs a touch and go landing May 17, 2013 on the flight deck of the aircraft carrier USS George H.W. Bush (CVN 77) in the Atlantic Ocean. This is the first time any unmanned aircraft has completed a touch and go landing at sea. George H.W. Bush is conducting training operations in the Atlantic Ocean. (Photo by Mass Communication Specialist 2nd Class Timothy Walter/U.S. Navy via Getty Images)

Back in 1947 Einstein said something like “the fourth world war will be fought by throwing rocks” (there are a few different quotes attributed to Einstein on this point and no consensus on the precise wording he used). The point he made is that a third world war would be so catastrophic for humankind that the few surviving would be thrown back to the stone age.
The statement came under the sensation that the atomic bomb created and it potential to wipe out humanity. Today’s concerns are no more on the atomic bomb, that after over 60 years have proved to be such a strong deterrent that no one is willing to risk its use, rather on losing control on weapons, not because they might be highjacked by some terroristic organisation but because they are becoming “autonomous”.
There are very concrete reasons to have autonomous weapons: the reaction time of an autonomous weapon can be measured in milliseconds, if you place a human being in the control loop that time balloons to many seconds, to say the least (probably minutes and even hours in case you want to bring into the command chain top officials or the Country president). In that time an enemy using autonomous systems will have already destroyed your army/your Country.
Hence the race to build autonomous decision making weapons.
A number of scientists are opposing this evolution and are calling for a world wide stop.
They point out that atomic weapons are bad, but autonomous systems might be worse. They can be equipped with any kind of weaponry, including atomic bombs, and being autonomous they are basically “uncontrollable”. One of the point is that they are incontrollable by design, so that an enemy cannot highjack them. Artificial intelligence is bringing along a sort of unpredictability, which is what derives from its complexity and is a fundamental component of “intelligence”. Intelligence is going, sooner or later to surprise you, it is not a mechanistic behaviour. Cleary being surprise by a witty conversation is quite different from being surprised by a drone aiming at you!
There is also another aspect that is very disturbing to many people: the idea that we are delegating death and life decisions to a machine.

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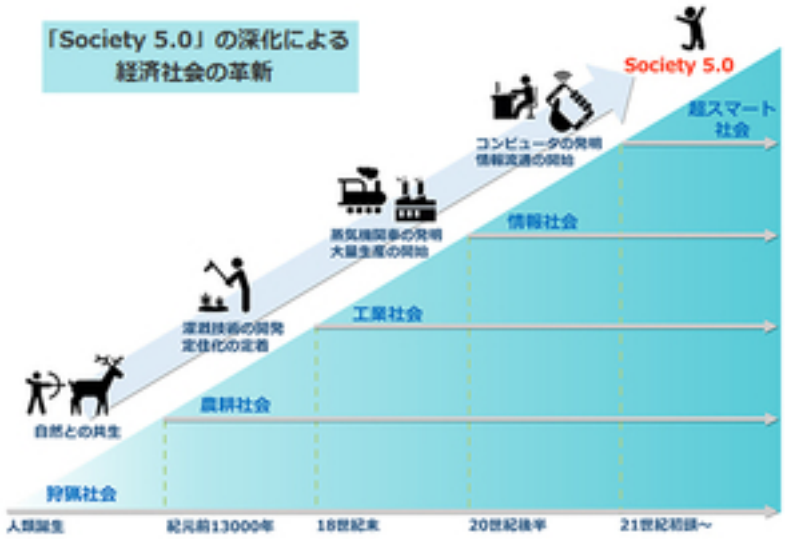
Sometimes humans becomes insane, and consequently behave in an … insane way. Could a bug in a machine, or even a bullet hitting a machine turn the machine insane? I don't know the answer but I would not rule it out.
It is not, just, about weapons. Hammers can, and had, caused damages, from hitting your own thumb to harm a co-worker. In the hand however, that harm was the result of a careless use of the hammer by ourselves. We surely have ourselves to blame.
What about exoskeletons? They multiply our strength and to be worn in a seamless way, to become a symbiotic extension of our own body, they need to have intelligence, to be, in a way, autonomous. In turns, they may also become dangerous, way more dangerous than a hammer. Who is to blame if something goes awry?
We are not there yet, but we better start looking seriously at these issues.

Symbiotic Machines - Super Smart Society
- November 28th 2016



Super Smart Society or Society 5.0 is the vision of Japan Government as they look forward to 2030. Credit: Keidanren

The Future Direction Committee of the IEEE in its last meeting approved as new initiative for 2017 the area of Symbiotic Machine. The tentative name is Symbiotic Autonomous System, although it might be changed in the coming months in something more easy to understand.
This initiative is not that far, in its vision and aims, from the Super Smart Society (or Society 5.0) approved by the Japanese Government in its 2016 Fifth Science and Technology Basic Plan.
The FDC initiative is rooted in the recognition that:

> *Economic forces, enabled by the evolution and convergence of several technologies, are clearly pushing towards a novel generation of systems that will progressively become more autonomous and pervasive with higher interaction capabilities with both living and non living entities to the point of creating a symbiotic relationship with them.*
> *This will change our societies and our perception of the world, creating new societal and ethical challenges that need to be faced from the very beginning of this revolution in the making.*
> *IEEE, throughout the cooperation of its OUs, with their strong technology roots and with the aim of pursuing the development of technologies to the benefit of humanity, is ideally placed to play a major role in this revolution.*

The Japanese initiative very similarly states that:

> *the fusion of cyberspace and real space based on the rapid evolution of ICT, the so-called "cyber physical system", will drastically change industrial and social structure. Gathering data with this system, converting it into big data, analyzing*

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by AI, and running it with a robot creates new value.

The FDC Initiative has as objectives

- to identify and foster the maturation and applications of technologies that constitute the building blocks for a next generation of systems;
- to stimulate the growth of new technology approaches and their integration;
- to explore the ethical, legal and societal aspects that may arise by the deployment of these technologies;
- to promote education and awareness in this area across the world by partnering with universities, both at high school, university and professional level.

and in order to achieve them it is planning to foster Technology, Ethics, Policies and Societal enablers.
This is very similar to the identified need to break through 5 walls, as described in the Japanese Government plan towards Society 5.0:

- the wall of Ministries and Agencies (compare to the working together of many IEEE Societies in the unified FDC initiative)
- the wall of legislation (compare to the work on Policies)
- the wall of Technology (here the mapping is straightforward)
- the wall of Talent (compare with the education mission of IEEE)
- the wall of Social Acceptance (compare with Ethics and Social)

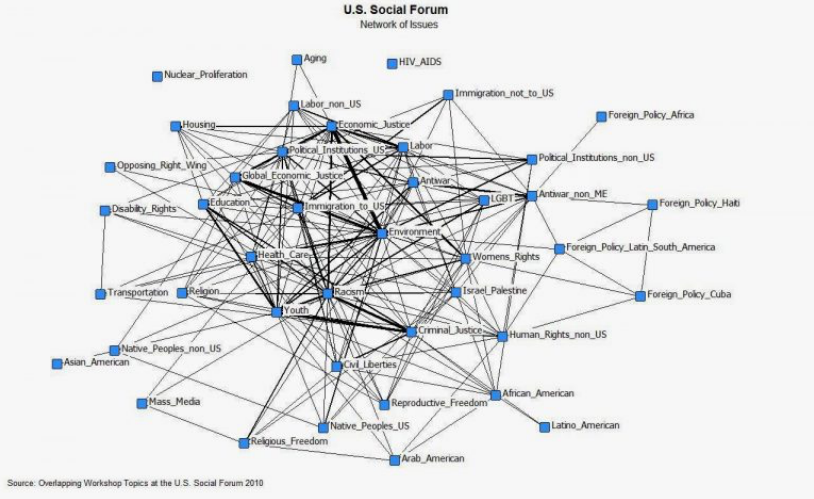
In both cases there is a strong drive to have academia and industry working together to make and leverage on the enablers.

Balancing the roles of the living being(s) and the machine(s) - November 24th, 2016

Creating a symbiotic situation carries along the issue of who is doing what, who is in charge of what.
In normal system interactions the issue is in a way moot, since each component has a well defined interface, a well defined behaviour and it is just a matter of fact the repartition of activities among the various components of the system.
With software systems the boundaries, sometimes, get a bit fuzzier, particularly if complexity is high. Internet is an example where the role of each entity is theoretically well defined and yet, because of the variety and number of components the overall behaviour is not predetermined in any situation. This also applies to complex autonomous systems, like swarms of bees, a flock of starlings and a swarm of autonomous robots. You can tell in general that a swarm of bees will move in a certain direction, depending on external condition like the wind and the distribution of flowers, and on internal "knowledge" accrued through single explorer bees. Yet it is impossible to tell what a single bee is going to do in a swarm. We can, to a certain extent, predict the emerging behaviour of the swarm, not the individual behaviour of its components.

A similar issue occurs with the symbiotic machines that we are going to develop in the next decade. Each of the component is loosely well defined and their relation to the whole is also defined, yet the overall balance of how activities is dynamically balanced among the various components is a matter of study and research.
This is an issue that has technology implications as well as social implications. We can imagine in the next decade a symbiotic relationship between a driver and her car. The thoughts of the driver will influence the autonomous driving of the car, within its range of possibilities, of course. But to what extent is it accountable for an accident? Today the car is just a tool, with very little autonomy, so the blame is (almost) always on the driver (exception can be dramatic failure, like brake failure or the computer controlling the gas injection that screws up). As cars are becoming more autonomous and as we are developing a symbiotic relation between the car and its passengers the boundary of responsibility becomes fuzzier.
The IEEE Society on Social Implication of Technology is addressing these kind of issues and the many more that will emerge.
These topics are also being addressed, one way or another, by each single IEEE Future Direction Initiatives.

Disruptive Technologies in extreme automation impacting beyond 2040
- April 22nd, 2018



Analyses of social media pointing out the relations among various political/social issues as seen by voters in the US. Credit: using social network analyses in politics. Prof. Tunnard

Battles, of a different sort, are also fought in companies and in Countries, within Board meetings and parliamentary halls. Here, as well, the Imperial College Foresight study foresees dramatic changes fostered by Artificial Intelligence, being used to evaluate impact of decisions, define strategies and take action.
Political elections are already today flanked by “experts” using AI to analyze data harvested from social media to pinpoint people’s mood and to craft the right message that can swing public opinion in a desired direction.
Analyses of social media can provide accurate forecast on voting outcome, this is now moving to a new level to assess how those votes can be changed through focussed

campaign. In the end it is again a matter of money and resources. The point is to identify the areas that with a minimal investment can be conditioned to change their vote.
Of course, every political party, vested investor, is trying to do exactly that in a never ending pursue of winning the game.
There are companies specializing in the application of artificial intelligence, like Deep Knowledge Ventures, that are providing services to assess people's mood, others, like Tieto, developing software to support the companies Boards to take decisions.
In the coming decades we can expect artificial intelligence to get better, not because of better algorithms or chips, but because there will be more data to access and analyze including historical data supporting machine learning. In other words AI is bound to become smarter and smarter and in an area like this where there is a deluge of data it clearly has an edge on human analyses.
Ethical, Legal and Societal issues are at the forefront of these kinds of applications. There is no doubt that Boards and Parties will keep making use of AI and that will change the rule of the game. Mind you. Politics and struggles at Board level have always been a matter of analyzing information and finding ways to twist moods one way or another. What is new is that we are losing control on both analysis and twisting, relying on AI.

I am not that smart, you are not that smart … we are

- April 3rd, 2018

Cavemen were smart in their own way, they did not have computers nor could they build one but managed to live in an environment we would be not able to survive for long. What is that has allowed today's advanced society? For sure it is not us being smarter than them. Image

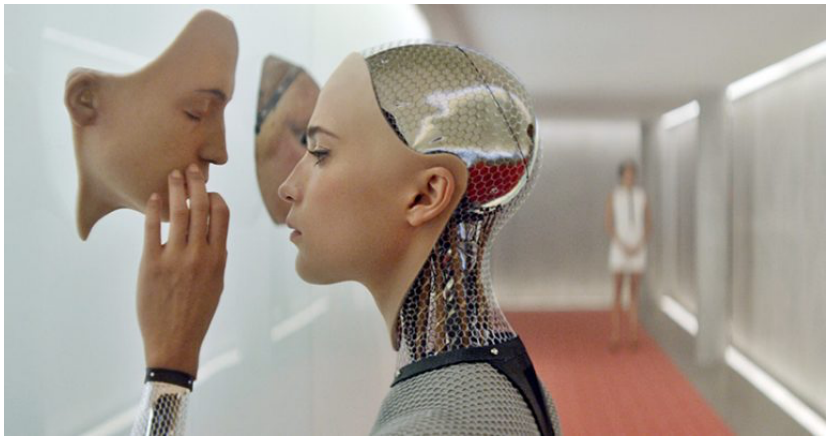
credit: http://www.defenseimagery.mil

As the human species, we have achieved amazing feats: we went to the Moon, created a seamless communications network, invented cars, multiplied the yield in agriculture—and this is just a very limited subset, taken randomly, of our accomplishments.
Just look back at our ancestors: They didn't have the Internet, died from famine, suffered from cold and heat… again, just a limited subset taken randomly.
It should therefore be a no-brainer to claim I and you are smarter than our nomadic ancestors were 10,000 years ago.
Except that it is not true.
Our ancestor was, on average, way smarter than me and you, and it even seems, from paleontology studies of skulls of our long distant great-great parents that they had bigger

skulls, hence bigger brains than we have today (notice that I am talking about our species, Homo Sapiens Sapiens, not Homo Ergaster or Neanderthal).
If you think about it, it makes sense. Their capability to manufacture and use tools was much more finely tuned than is ours; they would easily beat us in such a contest. Also, survival pressure was much higher: If they made a mistake, they probably had little time left to learn from it, so they had to be brighter. Their environment was harsher than ours is. How is it then that they wandered in forests and we fly on planes?
According to Yuval Noah Harari, author of "Homo Deus a brief history of tomorrow", the reason is that over the past 10,000 years we have learned to leverage one another, thereby creating a species that, as a whole, is far smarter than the single individual. I am not that smart, nor you—but together we are!
This is interesting because it makes us think about the smartness of a symbiotic autonomous system and the smartness of a cluster of symbiotic autonomous systems. Although we have not reached that point and therefore there is no proof, we might assume, reasonably, that a symbiotic system can be smarter than its components and that a cluster of symbiotic systems can be smarter than a single system.
We are not there yet, but we have already moved a number of steps in that direction: Can't we see how smarter we are when we can augment ourselves by accessing the unlimited knowledge floating in the cyberspace? Can't we see how much better a brain surgeon has become when operating in symbioses with Leonardo, the robot-surgeon? Can't we see how much better we are at solving problems when we set up a hackathon where bright people have access to the Internet and exchange ideas among themselves?
In a way, we have acknowledged this augmentation by expressing concern over the digital gap between those who have access to the Internet and those who don't, among those that have been taught how to "use" the Internet and those who haven't.
As we shift towards ever higher and more complex levels of symbioses, the issue of smartness (or what you may want to call "intelligence") becomes more and more important—first in the design phase. We have very little understanding today on how to design smarter systems, how to architect them, since interaction and cooperation, as we have seen, is probably the most important factor.
Secondly, in operating within a symbiotic context, how intelligence is shared, how it emerges, who takes responsibility and ownership …Whilst the former are more engineering aspects, the latter are more social aspects that obviously are bringing legal and ethical aspects to the fore. This second aspect connects to the idea of Self, how several Selves aggregate within a symbiotic autonomous system and how they can give rise to a SuperSelf.
Possibly, we need a new science, stemming from complexity theory and engaging many other disciplines, both STEM and outside of STEM, to tackle this exciting new horizon.
This is what the Symbiotic Autonomous System initiative is aiming at…and just to make it clear once more, I am not smart enough to do that, nor are you—but pooling our collective minds together, with a little help from the cyberspace …we are.

Notice: the opinions expressed in this eBook are not necessarily the ones of the SAS Initiative and IEEE FDC is not endorsing them.

Will there be a Valentine day for robots?
- February 14th, 2018



As robots are acquiring awareness and intelligence, would they become able to have feelings? If so would they ever fall in love?
Image credit: Universal pictures

In most part of the world people are celebrating Valentine day with their … Valentine. As I am getting ready to discuss with several colleagues at the Future Direction Committee meeting the Symbiotic Autonomous Systems initiative I couldn't help to wonder if this day could also be a day (in the future of course) for robots to celebrate their Valentine. And this Valentine would be another robot or could it be one … of us?
I am not alone. This question, the more general one of:

- Could people fall in love with a robot? or
- Could a robot fall in love (with another robot or with a person)?

has already been asked several times. Movies have touched upon it coming up with stories of robots loving other robots or humans and humans falling in love with robots (I and Caterina was a movie produced in 1980 telling the story of Enrico, a business man, that eventually fell in love with Caterina, a robot), but what about science and technology? Valentine day is about feeling and emotions, friendship and love. Quite normal words in our human context but really strange in a "robot" context.
Before discussing the robo-context, however, it makes sense to look a little closer to "our" context. Those familiar words have become a focus point for scientists studying the brain, trying to understand the physical underpinning of feelings and emotions. In the electrical-chemical soup in which our billions of neurons and trillions of synapses operate how comes that these words arise and make sense? Just a decade ago it seemed like an impossible quest and indeed for several years the study of the neuronal circuitry from where emotions and feeling arose was set aside. In these last few years, thanks to new technologies that allow scientists to pinpoint the origin of signals and follow them through the brain, more and more data area becoming available and experiments are carried out to verify theories of consciousness, emotions and feelings. A very nice book exploring the latest results in this area is "Synaptic Self: How our brains become who we are" by Joseph LeDoux.
This growing understanding of the hard processes at work in the generation of feelings and emotions is important if we want to answer the above questions on robots from a scientific-technological point of view. Mind you, we are still far from a complete understanding of what is going on in our brain but enormous steps forward have been

taken and most scientists agree that it is no longer a matter of “if ever” but of “when” we will have a full grasp of what happens and how feelings and emotions are generated and perceived (i.e. become conscious). First results are already somewhat surprising: we feel, and we experience emotions even before we become conscious of them! This is counterintuitive, since it would seem that first I would have to become conscious of something in order for emotions/feelings to appear. Not so. Experiment have shown, at least for some kinds of emotions that can be tested on animals, like “fear” that the perception, consciousness follows the generation of the emotion.
We already have robots that are -at least to a certain extent- aware of their environment and we have robotic swarms that can become globally aware. This can be a starting point for the generation of fear like feeling and emotion.
We have robots/software that can learn and evolve on the bases of what and how it is learning through experience and self teaching and a few of them have shown a “soul” of their own, a behaviour that surprises their (human) designer.
Clearly, to have a robot engaging in a Valentine day we would need to understand more about this so common and yet so mysterious feeling of love and its related emotion. In principle love as an emotion shouldn’t be so different from fear in terms of its hardware (neuronal) underpinnings, the problem is testing the hypotheses. So far we haven’t seen animals showing anything like love (there are many examples of subsets of love, like caring…) and so testing on animals is not possible, and testing on humans, with the current set of technologies, is out of the question.
Having said that, psychologists and sociologists have started to address the question “can people fall in love with a robot” and surprisingly discovered that, at least in principle, 25% of millennials do not consider unlikely in the future to have a friendship and even a love relation with a robot.
Others go as far as betting that by 2050 artificial intelligence will be so advanced that robots may be undistinguishable from real people, hence sure, we could fall in love with one of them!
On the second question, “could a robot fall in love”, the leading sentiment is that by themselves this is unlikely since robots lack a will of their own but in principle they might be programmed/conditioned to fall in love, eg to show an emotional link to a specific person: imagine you buy a robot from the supermarket shelf and once at home you unpack and power it (him) up you will be the first thing it sees and its program will create a sentimental bind with you (like the ducklings of Konrad Lorentz). A minority of scientists, however, consider that we can only go so far in programming robots and that if we really want them to become intelligent and adaptable to any situations than we will have to let them learn and evolve by themselves. At that point if feelings and emotions (that can emerge from a hardware underpinning) will prove,as they did for us, to be a selective advantage than robots will develop feelings and emotions.
The jury is still out and you can bet what you want knowing that for at least the next 20-30 years Valentine day will be just for us. In the next century it might be different, but it will be something for our grand-grand children to consider.

Emergent beings: from tools to systems

- June 25th, 2017

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 artefact, 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.

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”.

Emergent beings: from systems to symbiotic systems

- June 26th, 2017

The Baxter robot: it can learn, it is aware of the context and can collaborate with its peers and with humans.
Credit: Rethink Robotics

The proposed change of name, from “tools” to “systems” I made in the previous post is the consequence of a new qualitative dimensions of modern, computerised tools.
Yes, today’s computerised 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, we are interested in SAS 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.
We have been used (like all life on Earth) to adapt our behaviour 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 artefacts that we have created will start to adapt themselves, and their behaviour, 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 behaviour of machines and machines will be responding to our behaviour in a continuously changing fabric where it will become progressively ever more difficult to distinguish between the cause and the effect.

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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 recognise 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 centralised 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.
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 maximise their usefulness and minimise drawback 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.

Successful technology is invisible

- August 19, 2017

Robots like Roomba are becoming part of the home environment and we are paying less and less attention to them. Several more will become usual inhabitants of our homes marking the real advent of robotics in our life.
Image Credit: IEEE Spectrum

Long time ago, back in 1995, Steve Jobs in an interview stated that "great technology is invisible".
Indeed, whilst advanced technology in its first step is indistinguishable from magic, and as such it draws "wows" and attention, as it matures and becomes widespread it is no longer noticed.
Today we are at the edge of this transformation from what robots are concerned. Actually robots are becoming so widespread that talking of "robots" as if they were a single category may be misleading. There are already robots that have disappeared from our perception, think about subway trains that in many cities are fully automatic and we no longer see them as "special".
Autonomous vehicles are still unusual and as such they attract our attention, wows and concern. Still quite a lot of work is going on and I would expect that by the third decade of this century they will disappear from our perception. In several places universities have started courses specifically focusing on autonomous vehicles. In Trento, EIT Digital in collaboration with CRF, Engineering, FBK and TIM has opened positions for Industrial Doctorates at the University of Trento in this area and in the one -related- of Smart Cities.
In a recent interview, published on Spectrum, Joe Jones, the inventor of Roomba, points out that robots in the home are on the same path as computers. If you ask a person how many computers he has/uses the likely answer would be 2-3: a laptop, a tablet. May be some would recongnise the smartphone as a computer. But it is unlikely that a person would include the microwave, the washing machine, the anti-theft device, the lift, the car….and yet all of them are being used daily and have a computer (or more than one).
Interestingly, Joe is pointing out that although people may be interested in robots as a novelty, once the novelty effect wears out, the only thing that matters is the utility. In general people like to have a clean floor, they do not like a robot. They are interested in the effect produced by a robot, not by the robot itself. This is something that robot designers need to take into account, in particular for home applications where the ideal robot is the one that works in the backstage, it is not perceived and does not come in the way.
Roomba, in a way, was designed to become inconspicuous, it can be instructed to clean once no one is at home, but you still need to service it to discard the dust it picked up.

Future home robots will have to become part of the home environment and interact in a symbiotic way with other home systems to really fade out of our perception. And that time is not too far away.

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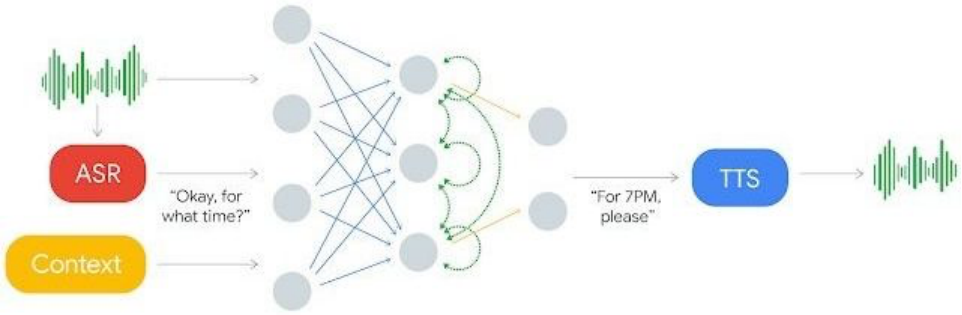
Beyond the Turing test

- May 11th, 2018



A neural network can get to the point of replacing you in some activities, like, as Google demonstrated, booking an appointment to the hairdresser.
Image posted by Jeremy Lichtman

The Turing test was proposed to evaluate if a human can not distinguish the (written) interaction between a human and a machine. You type something and you get your reply. And you go on trying to find out who is actually answering your messages? Another human or a computer?
The interaction through "written" text (typed, actually) was intended to get rid of the difficulty of emulating a human voice. Since what matters is the content of the interaction it made sense.
However, we are used to voice interaction and the voice tone, inflection, empathy is telling us a lot, it let us read between the lines… The progress made in voice syntheses in these last few years is making artificial voice almost undistinguishable from a real one. Add to that the possibility to craft a content that is undistinguishable from the one that a real person would create and you are opening up a can of worms.
We are already confronted with fake news. We now have technologies that can make these fake news credible, by having them voiced by a trusted person. Your friend calls you on the phone and push you to invest in a stock, as he did with great success. Unfortunately it is not your friend talking, although it is his voice (at least that's your perception) and the reasoning, the way he answer to your questions all tells you its him.
The demonstration provided by Google at their event (see clip below) of a chatbox, Google Duplex, that can proactively assess your need and help you out, like fixing an appointment to the hairdresser, checking your agenda (that's easy) for a free slot and making sure you get that stylish look before the party and conversing over the phone with the hair saloon, left everybody speechless, and quite a few concerned for the reasons I mentioned above.
We are rapidly entering into a new space, the one of interaction with intelligent autonomous systems that are becoming part of ourselves, we are growing into symbiotic autonomous systems and it is happening faster than we were expecting.