Next gen perception and cognition: augmenting perception and enhancing cognition through mobile technologies

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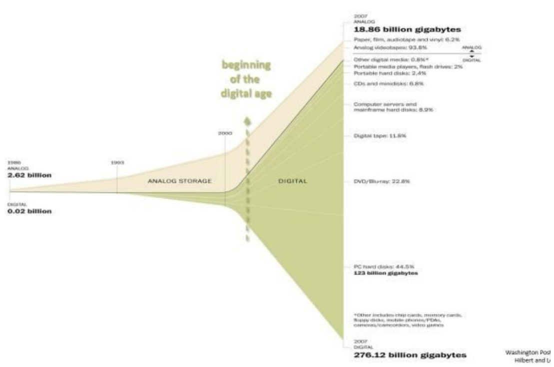
ABSTRACT

In current times, mobile technologies are ubiquitous and the complexity of problems is continuously increasing. In the context of advancement of engineering, we explore in this paper possible reasons that could cause a saturation in technology evolution – namely the ability of problem solving based on previous results and the ability of expressing solutions in a more efficient way, concluding that 'thinking outside of brain' – as in solving engineering problems that are expressed in a virtual media due to their complexity – would benefit from mobile technology augmentation. This could be the necessary evolutionary step that would provide the efficiency required to solve new complex problems (addressing the 'running out of time' issue) and remove the communication of results barrier (addressing the human 'perception/expression imbalance' issue). Some consequences are discussed, as in this context the artificial intelligence becomes an automation tool aid instead of a necessary next evolutionary step. The paper concludes that research in modeling as problem solving aid and data visualization as perception aid augmented with mobile technologies could be the path to an evolutionary step in advancing engineering.

Keywords: mobile technology, thinking outside of brain, perception/expression imbalance, contextual problem solving

INTRODUCTION

Today, with the explosion of mobile technologies, a lot of new devices are introduced, a lot of directions become hot over night only to be abandoned or lose interest over time (e.g. 3D losing interest while 4K TV becomes 'hot' [1]), but mobile devices keep searching for the next application that would take advantage of their increasing computational power and sensor available platform (e.g. 99.5% users of mobile devices are using them to access mobile content/information [2]). This paper intends to offer an engineering perspective on why and where mobile technologies are needed in the larger context of solving the exponentially more complex tasks we are facing on our quest in evolving our own capabilities. Figure 1 is providing a very short timeframe view (~40years) to illustrate the exponential increase in availability of information storage and access to communication services.



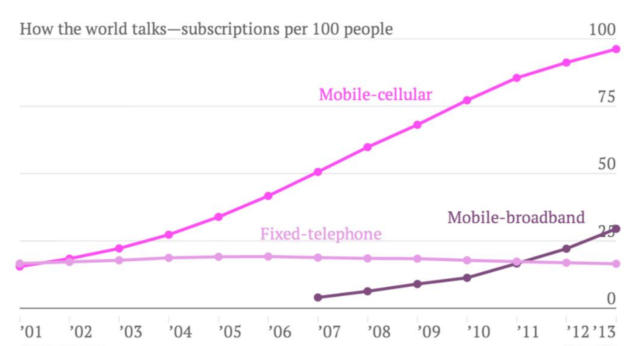


Figure 1: Technology exponential development and availability: (a) information storage capacity [3] (b) number of mobile phone subscription in 100 people for world population [4]

There is a very dynamic landscape of technologies appearing or morphing toward the mobile usage and this transformation is shaping our own behavior and expectations from mobile technology. Today, it is an almost fluid

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landscape – the introduction of iphone, facebook and twitter – to name a few leaders of products and services that touch the hands of consumers - changed our way of communication and social interaction [5]. In the last years, our technology had an explosive development, both in data storage [3] as well as in communications [4] and this exponential growth seems to continue. Humans have been augmenting themselves with tools for centuries not only to make them more productive but to make people's lives better and the next technology to augment us is mobile and wearable [6]. But central to our evolution it is our ability to solve scientific and engineering problems that allow us to create the tools, aids and ultimately the technologies with which we can augment our own shortcomings. In this paper we will focus on discussing where technology can and should help: alleviating the perception/expression imbalance – the proposed solution is 'thinking outside of brain' and aiding problem solving saturation due to complexity (as it applies to engineering of complex designs) – the proposed solution is 'bound and box' concepts and usage of models.

Also, a consequence of the complexity of current engineering designs is that their initial motivation is hard to infer from the final solution. In other words, in complex designs, the 'why' becomes very hard to define as opposed to 'what-how' and the 'why' is associated with 'system-level' view of a problem – in terms of cognition the 'what-how' would be problem solving whereas the 'why' would define the context in which the problem solving should occur, very similar with the H4V model [7], or the goal-directed decision-making [8]. Certainly the rapid pace of development in the industry and the convoluted interaction between the many parties that need to be part of this landscape is making the definition of a specific context for problem solving harder, as it is easier to just follow market requirements without worrying about a 'why'.

The main points followed in this paper are:

- Discussion on a quantitative saturation point for a technology
- Discussion on a qualitative saturation point for each technology (complexity of problem solving)
- Discussion on the relation between individual problem solving skills and individual results communication skills (expression ability)
- Discussion on the need for definition of the context for problem solving (the why-what-how paradigm) and the need for training in using CAD/EDA tools as example
- Discussion on the perception/expression imbalance - our ability to absorb information and our ability to express ideas/solutions.
- 'thinking outside of brain' and 'bound and box' abstract concepts with usage of modeling in a virtual medium as solution to perception/expression imbalance and saturation on complexity
- Pushing the boundary further with mobile technology augmentation of the solutions above – also, short discussion on artificial intelligence as necessary step in evolution vs its usage as a modeling aid.
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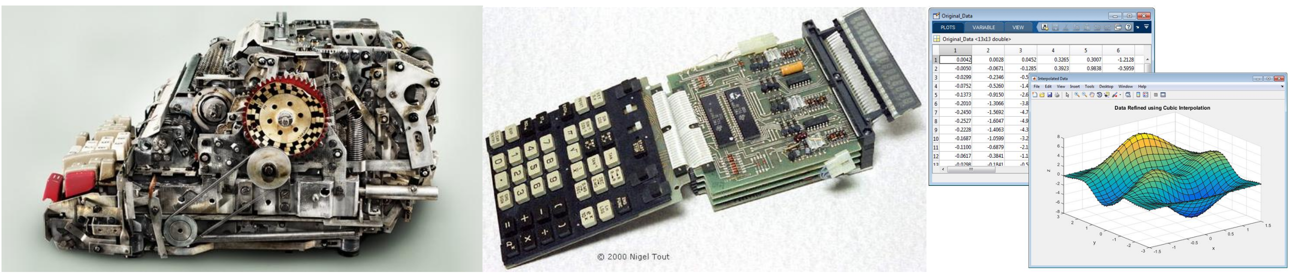
QUANTITATIVE SATURATION POINTS

There is a saturation point for each technology - quantitatively: when a specific technology cannot be scaled in a feasible way anymore - that technology needs to morph into a new one;

Every technological period seems to reach saturation in its usage. Once a new technology is developed and ready to be used, it starts to spread gaining traction and adoption. As time is passing by, that particular technology becomes used more and more and as a consequence, it is improved and advanced (but evolutionary – such that its basic principles are just refined not changed) up to the point the advancements starts to become unfeasible to be developed anymore (the effort required to use this technology becomes greater than the effort required to develop a new one) usually due to fundamental physics limitation. For example, in antiquity people started to build bigger and bigger structures, up to a point where the number of megalithic structures built using the technology available in those times reached a peak then stopped – as we see that just a few of those megalithic structures were built. A similar effect can be found later in the technology used to automate calculations. The automata of the renaissance has evolved up to a point and then morphed into the mechanical clockwork that followed [9]. Mechanical calculators also evolved up to a point (around 1970) then morphed in electronic calculators. Electronic calculators started around 1970 and evolved into complex scientific and graphic calculators in the 1990's and prepared the path to modern mathematical modeling languages – examples of each shown in Figure 2.

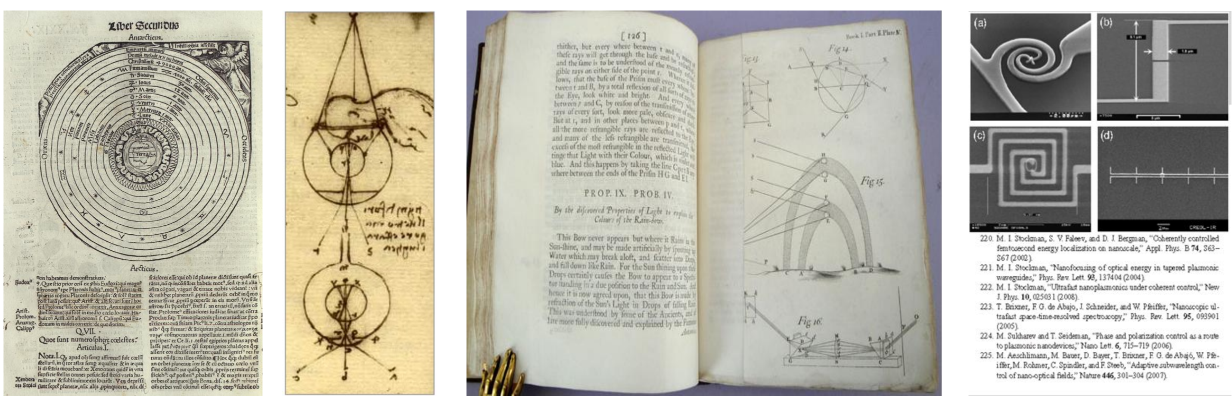
The fact that we were able to evolve each technology is rooted in our ability to use pre-existing solutions – in other words, problems solved by other individuals in different past times. This ability to record solutions and pass them on seems to greatly influence our capacity of tackling more and more complex problems. Fundamentally, at a point in history, our ability to store in our minds and understand everything we learned as a race, has surpassed our individual capabilities in memory storage as quantity and problem solving complexity as quality, forcing us to develop ways of passing and storing this knowledge, so the following generations do not need to start from a blank slate.



(a) (b) (c)

Figure 2: Technology saturation example: (a) mechanical calculator (b) electronic calculator (c) mathematical modeling language

This is also supported by the evolution of written (scientific/engineering) work among time. From ancient word of mouth to scrolls in antiquity to sketches in the renaissance evolving to treaties at the dawn of the industrial age up to today's published journal papers this evolution is following the magnitude and complexity of our problem solving, highlighting in last century the hierarchical structure current solutions have - supported by looking at the evolution of referenced/cited work in current publications.



(a) (b) (c) (d)

Figure 3: (a) Aristotle's vision of the universe – in *De Caelo* (b) Leonardo's 'contact-lens' concept - in *Codex of the eye, Manual D* (c) Newton's explanation of rainbow - *Opticks* (d) Nano-antennas paper example with explicit references

In the context of the scientific method, Figure 3 illustrates this point: starting with Aristotle vision of the universe which is one of the first to follow a scientific method [10] (a) then going to Leonardo's sketches (b) to Newton's optics treaty (c) ending with a recent paper describing optical antennae (d). The scientific method is present in all, but in the last example [10] (d) the referenced work of predecessors is explicitly listed (for this paper it passes 200 [11]) and indicates the evolution of documenting scientific solutions.

This example shows how the complexity of the problems we are solving today is increasing but also how previous solved problems are used as a starting point for current problems, and as a secondary point, how the solution expression increases in complexity, as seen in the last publication (the referenced publications are also at the similar level of complexity, but as the last one refers multiple previous ones, the new solution increases in complexity and adds something new).

A similar evolution can be found in utilization of previous work (similarly to documentation of previous work) – one example is through the use of inventions. Figure 4(a) illustrates the mass use of inventions as they start to be used from the time they have been conceived – as we approach current times, the time between an idea and its use in the society is exponentially shortening [26], practically showing that as we evolve our technology, its complexity increases and a hierarchical structure, where each new idea is adding on top of many existing ideas, becomes imperative. This hierarchical structure seems to be consistent in problem solving, in problem expression and in solution usage and it proves that using hierarchical structures is not only necessary, but its usage is exponentially increasing. The question that comes to mind is how long can we sustain this growth in complexity using current methods of problem solving and solution expression?

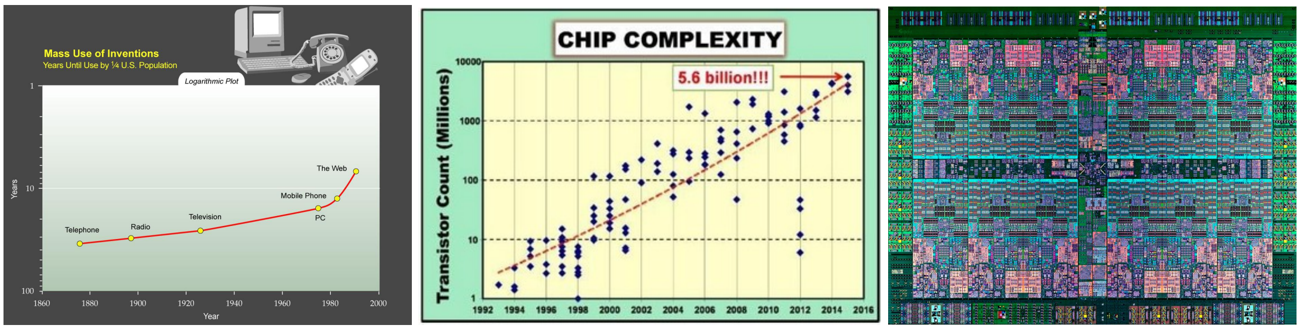


Figure 4: (a) time to mass use of inventions (b) current silicon chips complexity (c) IBM's Power8 CPU – 5bilion transistors

As technology is aiding us in providing more data, more computation power and more storage capacity can we pick a few shortcomings we have that we could augment with technology such that it would provide us with a necessary boost to pass a possible saturation due to problem complexity? After all, we still have a limited life span, memory and expression abilities – of course, until biological evolution would provide us with the necessary means to overcome those shortcomings. Comparing the current rate of biological evolution for our cognition [12] with the exponential growth in complexity we see in our times, the conclusion points to technology augmentation, as biological evolution is too slow to prevent saturation in complexity.

QUALITATIVE SATURATION POINTS

We are approaching a complexity saturation point, where the complexity of the problems we are trying to solve is too much for the methods we are using

Considering our current level of technology which is dominantly based on silicon or silicon-like materials, we are also approaching a complexity saturation point, where the complexity of the problems we are trying to solve starts to exceede the methods used. Today's complex problems are solved using computers and those computers are based on silicon components. Their complexity is increasing so much, it becomes harder and harder not only to build them but harder and harder to deal with their complexity. To illustrate that, in Figure4(b) the number of transistors of a single chip has reached 5.6 billion [13]. Figure4(c) depicts a chip that approaches that complexity.

An essential step in our evolution was increasing the knowledge past our natural limits: preserving solutions to solved problems and passing them to other individuals are essential part of that. Each method of passing knowledge, at a time, seemed to have reached saturation (e.g. passing knowledge only through language then using drawings then using treaties then using references to work of others and now, in information age, using computer models) . Current stage of technology requires complex problem solving skills and we are faced with complex engineering problems that start to stress our limits of solving them.

Beside problem solving skills another central problem is the ability to pass knowledge. To illustrate this relation, we use the chart in Figure 5(a) where the X axis shows an example of 10 individuals (numbered from 1 to 10); each one has two abilities associated: problem solving and the ability to express solutions to problem solving – all referenced to particular times. A horizontal bar is set at level 25 – which in this example, would be the level of complexity of the novel problems that need to be solved in those times. Individual number 3 is not able to contribute to overall evolution, as he doesn't have the problem solving skills needed to tackle those problems, but all others can do it. However, number 1,4,5 and 6 can solve the problems and could contribute to overall evolution, except they do not have the ability and/or means to express their solutions. As a consequence, only individuals 2,7,8,9 and 10 can actually contribute to overall evolution, by both solving problems of that particular time and recording the solutions such that other individuals can benefit from that knowledge.

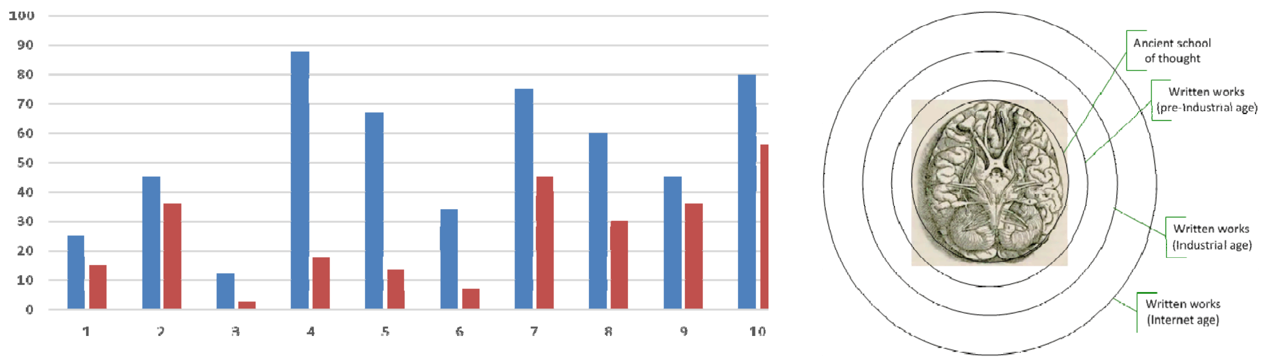


Figure 5: (a) problem solving ability vs solution expression ability (b) periodic saturations in passing knowledge

As humans, we need to learn fast and get to a level where we are able to understand the technological level of present times, but also we need to learn to express the solutions of the problems we solve – in order to contribute to our evolution as a species, and, as we seem to be way more equipped to absorb information than to formulate and impart experiences, saturation can be reached.

In Figure 5(b) each circle represents a saturation point in the expression of engineering or scientific solutions for a specific period of time. The radius increases to illustrate our ever increasing recoded knowledge but also the boundary in complexity of the problems that need to be solved in order to expand that circle of knowledge further – and thus allowing us as species to evolve further. The brain in the center is a symbolic representation of the knowledge that can be contained in a single human – and the intent is to show that in current times we are way past being able to know and comprehend the whole amount of knowledge we have been accumulating in our evolution. As a side comment, in Figure5 (a), let's say that the circle of knowledge in a specific narrow filed is at level 40 – to push this level further (that is to solve current times problems in this filed) an individual needs to develop the problem solving skills to be able to pass that level and he needs to develop communication (expression) skills that would allow him to express a solution to that level of problems, or his solution could not be used, practically wasting that individual problem solving ability and effort.

In other words, the more complex problems we solve, the more complex ways to store and express the results we need.

Our technology is at the point where we can change/augment the 'input' (e.g. change the available data by updating data gathering technologies - sensors) or/and the whole system (e.g. redesign at system level), but that needs a good understanding of 'why' we built the system like this in the first place. A good example is the CRT/LCD raster scan heritage: to display information using a CRT monitor, a raster scan technique is used, fundamentally due to the fact that the CRT technology is based on an electron beam than needs to scan in a raster pattern the surface of a display, hence the raster-scan term. As CRT devices are replaced with LCD devices, the raster-scan method is still used, even though the LCD devices are random addressable and do not need a raster-scan. More, the LCD devices are modified to support raster-scan. Even though this example has additional practical justifications the main point remains: the complexity of the systems engineered today is quite big and as a consequence they are hard to understand and change.

Due to miniaturization and integration we have now SoC systems – one piece of silicon that encompasses a full system that due to its complexity follows a similar pattern with the CRT/LCD raster scan example: the system complexity is so great, that its system-level optimization becomes exponentially difficult. As a consequence, understanding why the system needs to be build like this becomes a hard and harder task. Currently, problem solving is thought through the **education** process – which covers the what -> how part, but the more complex our technology becomes, the more options to solve a problem we have, thus contextual problem solving becomes a necessity and this is the main point highlighted here: we are at a point where contextual problem solving is required, but this skill is today developed through **training** and is most found targeting 'leadership' [14]. We need to be at the point where if a problem is given, we need to track and identify the 'why', then for that context solve and abstract the problem - this would be the 'bounding and boxing' a solution allowing its reuse.

As a summary of those points, contextual problem solving and hierarchical solution use would need the following steps:

1. Create abstract blocks: bound and box a solved problem such that solution can be passed as knowledge

2. Use abstract blocks without necessarily understanding them

To do this, a new type of training needs to be developed – instructional design is a close resemblance to this [15]. Step 2 is needed as we want to be able to use our problem solving capacity at a higher, conceptual level. We refer to the usage of most technology today as example: we use cell phone without fully understanding how they are designed or work.

The goal is to create the tools and techniques that can help us manipulate enormous data sets from different sources or sensory systems across different time and scale dimensions in a way that supports real-time interactive exploration.

Of course, understanding the perceptual and cognitive factors is key to effectively couple the human with their data.

PERCEPTION / EXPRESSION IMBALANCE (IN/OUT BANDWIDTH RATIO)

There is an imbalance between our ability to absorb information and our ability to express ideas - our input data bandwidth is much more than our output data bandwidth.

A good example of how technology can augment perception through models is the well known 'Cosmos: A Personal Voyage' TV series presented by Carl Sagan [16]. This particular series had a remake after ~30 years as 'Cosmos: A Spacetime Odyssey' presented by Neil deGrasse Tyson [17]. What is remarkable about this example is that both series follow the same storyline, present the same concepts and use the available technology of the time to express the same message. The modeling abilities that technology adds to expression of ideas are impressive.

The important point here is the fact that our ability to express today's solutions to problems we solved is closely tied to available representation technologies and this can be a problem limiting us in the complexity of the solutions we can impart and the limitation is on the expression side. In the last years we developed modeling technologies and productivity tools to allow us to overcome this limitation, but the time we need to construct those models and visual interactions we use to communicate ideas is still a limiting factor.

We have methods of absorbing and digesting that information once it is available, thanks to our visual system, but we are very limited in comparison to the means we have to impart the same information once we acquired it through our current communication means. The point here is that our expression abilities in the context of problem solving (our information output bandwidth) is vastly exceeded by our visual system ability to perceive information (our information input bandwidth) or our abilities are heavy on acquiring information fast (e.g vision) but way less developed on passing acquired and developed knowledge (e.g. speech).

There could be an evolutionary reason for this: for survival, acquiring data fast seemed to be more important than passing solutions (supported by language developing relatively recently compared to sensorimotor knowledge [18]). It follows that our knowledge would evolve faster if our ability to express our own contributions would improve, or it could saturate if our abilities to communicate experiences would not evolve – in which case we are faced with a dilemma: even though we could solve more complex problems we would be stuck on communicating the results. Can technology help?

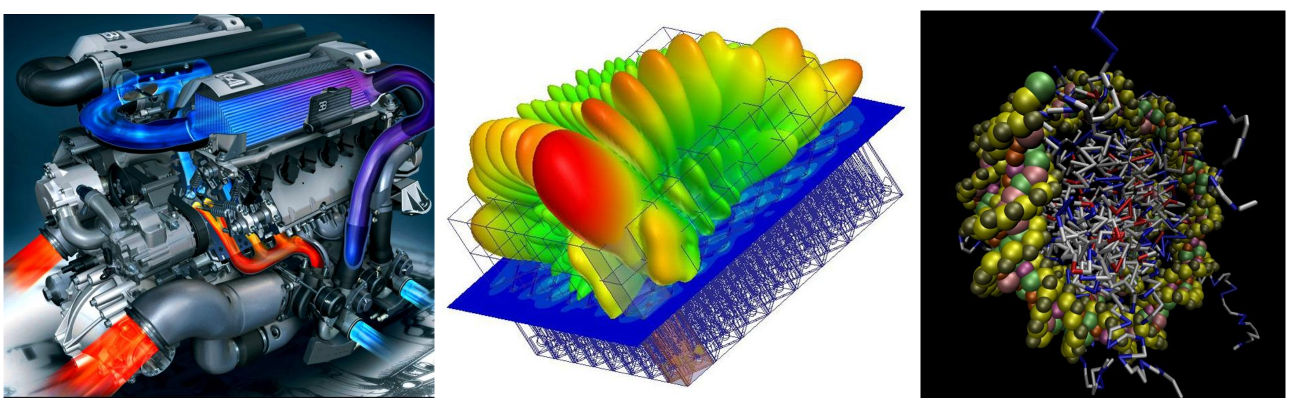
A solution would be to move the whole problem in a virtual medium that does not have our limitations and solve it there. In that case, there will be no need to communicate the results, because the results would be readily available. It sounds obvious and in engineering this is already done through the usage of CAD and EDA tools. What is particular about their usage, is that the problem to be solved is modeled inside a computer and several engineers contribute to problem specification (model definition phase) then problem solving (implementation phase) in a collaborative way, but the **communication is implicit** as it happens through the data available in the virtual medium as opposed to having the **communication explicit** (e.g. through natural language and visual aids) if the process would not benefit from a virtual medium and each contributor would think and elaborate a solution independently.

A direct consequence of the former is that at any time, the current state of the problem solution is already available for anyone to use, so the expression imbalance problem in this context is implicitly solved – however, there is a long learning curve (in CAD/EDA denoted as training and later experience) in guiding the problem through the computer interface.

The other remarkable aspect is that a lot of the complexity of problem's components is abstracted into some visual representation (the bounded and boxed idea discussed earlier).

In today's engineering world, the iterative work that enables modeling and simulation is done using computers in CAD software packages – for a brief history of CAD see [19] – and because of its iterative and automated nature, it is very efficiently done [20]. Of course, in current times, for engineers, modeling languages are learned in universities as part of the education program and this provides a significant advantage to future engineers [21].

What is important to note here is the 'virtual' aspect of the design. CAD and EDA tools are enabling **digital prototyping** to the level engineers can create digital prototypes of the products they develop so they can evaluate their performance under real-world conditions.



(a) (b) (c)

Figure 6 Digital prototyping and modeling: (a) a full engine evaluated under real world condition as a digital prototype (b) evaluation of the electromagnetic field generated by an antenna array (c) nucleosome simulation allows DNA interactions with proteins

'THINKING OUTSIDE OF BRAIN' – POSSIBLE SOLUTION TO PERCEPTION/EXPRESSION IMBALANCE

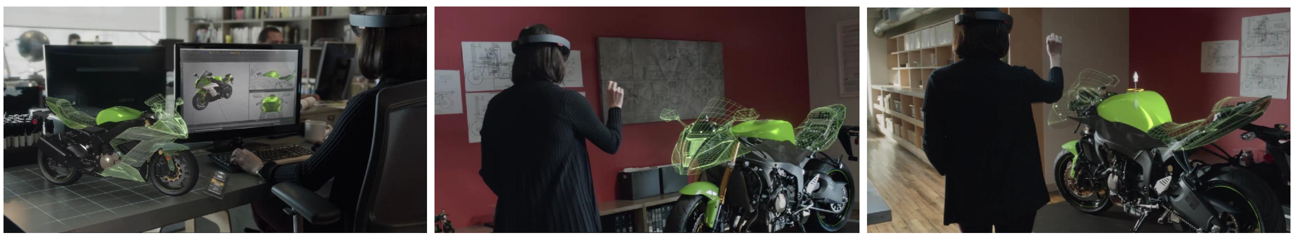
The concept of digital prototyping is an example of 'thinking outside of brain'. The digital prototype has three main advantages:

1. It exists only in a virtual medium, so the scale of its rendering can be changed in order to be examined (e.g. Figure 6 (c) – nucelosomes are on a nm scale) and is no longer bound to physical visual properties (Figure 6 (b) – electromagnetic radiation is not visible)

2. Once the digital prototype is built, it does not need to be expressed since is already available to be used – as opposed to a problem solved by an individual, where the result still needs to be expressed in order to be used. Most CAD/EDA tools have documenting abilities included as part of the design.

3. Its replication is seamless

To explain further the idea of 'thinking outside of brain', we consider the example of a designer that uses a VR helmet [23] to interact with a design in a virtual medium through a CAD program as shown in Figure 7. In this example, the digital prototype is a motorcycle and the designer can get a look and feel of it as it would have in the real world. At a point, the designer decides the gas tank needs to be enlarged and pulls the top of the tank, which follows designer hand. This action actually hides all the calculations necessary to redesign the tank under some new constraints that are not in an absolute form, but loosely based on a high level decision. The designer, if disconnected, from the virtual medium has no details of the design – all those details exist only in the virtual medium, but at any time they are available to be recreated, evaluated, simulated and communicated to other designers.



(a) (b) (c)

Figure 7 Example for 'thinking outside of brain': (a) designer evaluates a digital prototype (b) the digital prototype is examined in real world conditions (c) the gas tank is redesigned through a simple gesture

This example is relevant as an aid to cognition: a designer is manipulating a boxed concept that is bounded by complex rules (the reservoir shape) without needing to know the concept details. Using technology (the VR helmet and CAD software in this case) as an aid, the designer is able to focus on the added value and not spend time and effort on already solved problems.

In this way, a possible saturation on complexity can be avoided, as the complexity of the design is abstracted in a hierarchical way.

(a) (b)

Figure 8 Example of mobile technology as an aid to perception (a,b) the information perceived is augmented with its model from a database

In Figure8 a similar example is shown: similar type of device [24], a VR helmet, but this time an operator is using it to augment perception. What is important here is the ability that mobile technology acts as an aid to perception: each time an object is recognized, a model is pulled from a database and displayed over the real one – in this way, the operator can manipulate abstract objects that exist in a virtual medium and through that interface interact with the real object. Figure8 (a) a water plan installation is recognized modeled and the information pulled out of the model is matched in the real case; (b) a part of a complex assembly is recognized, its model is pulled from a database and the operator can evaluate its status and find on the spot details about its components and its state, such that once its state is acknowledged, it needs no longer to be expressed by the operator in order to be communicated to others – it is already available in the virtual medium.

The mobile technologies used in those examples are already here, using them in a way that becomes an aid to perception and then cognition to enable 'thinking outside of brain' is what makes the difference that could solve the exponential increase in complexity we are facing (at least in science and engineering).

Even though the examples in Figure 7 and Figure 8 are not today implemented, the technology that would enable them is, but this is not enough. We need to understand 'why' we need to use those technologies – the discussion on complexity saturation and perception/expression imbalance - also we need training to use those technologies properly. This would require a slightly different mode of thinking, where we use 'bounded and boxed' concepts in a hierarchical way – much like we use today complex technology we do not necessarily fully understand and, in our problem solving, we need to understand the context we are solving for in order to 'bound and box' a solution that can be used further.

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CONCLUSIONS

Today, not only the ability to build requires technology augmentation, but also ability to understand all details of a complex design requires technology augmentation. In this paper, the following points were discussed:

1. there is a saturation point for each technology - quantitatively: when a specific technology cannot be scaled in a feasible way anymore - that technology needs to morph into a new one;
2. we are approaching a complexity saturation point, where the complexity of the problems we are trying to solve is too much for the methods we are using;
3. the more complex problems we solve, the more complex ways to store and express the results we need;
4. with this complexity, it becomes hard to really understand the full system, but that is needed in order to utilize the technology - the why-what-how paradigm;
5. there is an imbalance between our ability to absorb information and our ability to express ideas - our input data bandwidth is much more than our output data bandwidth;
6. thinking outside of brain - this is a possible solution to 5;
7. thinking outside of brain uses technology to create designs and complex solutions in a virtual medium (a computer) making us manipulating abstract quantities to generate real solutions.

There are arguments that the only way out the saturation that is imminent due to the exponential increase in complexity of current technology (law of accelerated returns [26] is where we create an artificial intelligence – a technological grown intelligence that would be able to pass this saturation point [25]. The referenced discussion ends on this argument for mainly two reasons: humans have a limited life span (our biological evolution is much slower than our technological evolution) and our expression ability is limited (e.g. language). Sure, some technological bridges can alleviate the first problem, but the ability of humans to communicate is practically their limitation when it compares to machines [26]. The argument is valid in current conditions, but once we identify this limitation as a problem, solutions can be found – 'thinking outside the brain' is a 'bridge' in that direction, and augmenting perception and cognition with mobile technologies can become a 'bridge' to a next generation of technologies that can allow us to pass the 'singularity' [26] using artificial intelligence as an aid not a replacement.

Definitely future work and research is needed to use efficiently 'thinking outside of brain' and contextual problem solving not only as technology aid development but also to develop new training methods with new goals and objectives.

Most of the technology needed is already available, fully transitioning to mobile technology requires future work, but the usage of technology to augment perception and cognition along with new ways of thinking (e.g. 'thinking outside of brain') are the components that make the difference.

REFERENCES

[1] Williams, O., "3D TVs are dead at CES 2015 with the fight moving to 4K and curved displays," Retrieved from: http://thenextweb.com/insider/2015/01/07/3d-tvs-dead-ces-2015-fight-moving-4k-curved-displays/ ,(2015).

[2] Murtagh, R., "Mobile Now Exceeds PC: The Biggest Shift Since the Internet Began," Retrieved from: http://searchenginewatch.com/sew/opinion/2353616/mobile-now-exceeds-pc-the-biggest-shift-since-the-internet-began (2014).

[3] Hilbert, M., López, P., "The World's Technological Capacity to Store, Communicate, and Compute Information," Science 1, Vol. 332 no. 6025 pp. 60-65, (2011).

[4] Fernholz,T., "More people around the world have cell phones than ever had land-lines," Retrieved from: http://qz.com/179897 , (2013).

[5] Misra, S., Cheng, L., Genevie, J., Yuan, M., "The iPhone Effect: The Quality of In-Person Social Interactions in the Presence of Mobile Devices," Environment and Behavior, (2014).

[6] PSFK, Labs., "The Future Of Wearable Devices Will Be Human Centric," Retreived from https://iq.intel.com/the-future-of-wearable-devices-will-be-human-centric/ ,(2014).

[7] Verschure, PFMJ., Pennartz, CMA., Pezzulo, G., "The why, what, where, when and how of goal-directed choice: neuronal and computational principles," Phil. Trans. R. Soc. B 369: 20130483, (2014).

[8] Pezzulo, G., Verschure, PFMJ., Balkenius, C., Pennartz, CMA., "The principles of goal-directed decision-making: from neural mechanisms to computation and robotics," Phil. Trans. R. Soc. B 369: 20130470, (2014).

[9] Bedini, SA., "The Role of Automata in the History of Technology," Technology and Culture, Vol. 5, No. 1 Winter, pp. 24-42, (1964).

[10] McCue, JF., "Scientific Method in Aristotle's De Caelo, I, I-II, VI," Master's Theses, Paper 1419 http://ecommons.luc.edu/luc_theses/1419, (1957)..

[11] Alda,J., Rico-García, JM., López-Alonso, JM., Boreman, J. "Micro- and Nano-Antennas for Light Detection," Egyptian Journal of Solids, Vol. 28, No. 1, 1-13, (2005).

[12] Sherwood,CC., Subiaul,F., Zawidzki,TW., "A natural history of the human mind: tracing evolutionary changes in brain and cognition," J Anat. Apr;212(4):426-54, (2008).

[13] Merritt,R., "ISSCC Tips Hot Circuit Designs - Chips advance video, medical, communications," Retrieved from http://www.eetimes.com/document.asp?doc_id=1324643 ,(2014)

[14] Sinek,S., "Start with Why: How Great Leaders Inspire Everyone to Take Action," Portfolio; Reprint edition ,(2011).

[15] Silber, KH., "Using the cognitive approach to improve problem-solving training," Perf. Improv.,41,28–36, (2002).

[16] Sagan, C. "Cosmos: A Personal Voyage," Retrieved from http://cosmolearning.org/documentaries/cosmos/ ,(1979),

[17] Tyson, NdeG., "Cosmos: A Spacetime Odyssey," Retreived from http://channel.nationalgeographic.com/channel/cosmos-a-spacetime-odyssey/ ,(2014).

[18] Lieberman, P., "On the nature and evolution of the neural bases of human language,"Am J Phys Anthropol.;Suppl 35:36-62,(2002).

[19] CADAZZ, "CAD software history 2008," Retrieved from http://www.cadazz.com/cad-software-history.htm ,(2004).

[20] Hanna,R., "Tools as Design Instruments: Computers and Cognition?," Global Design and Local Materialization Communications in Computer and Information Science Volume 369, pp 1-12, (2013).

[21] Yaz, EE., "Utilizing MATLAB in two graduate electrical engineering courses," Frontiers in Education Conference, Proceedings Volume:1, (1995).

[22] Hope, N., "The Intersection of Lean and Green," Manufacturing Business Technology 27.1; 14-16. Print, (2009).

[23] Microsoft, "Microsoft Hololens," Retrieved from http://www.microsoft.com/microsoft-hololens/en-us ,(2014).

[24] DAQRI, "DAQRI Smart Helmet," Retrieved from http://hardware.daqri.com/smarthelmet ,(2014).

[25] Kurzweil, R., "The Age of Spiritual Machines", Viking, New York, (1999).

[26] Kurzweil, R., "The Singularity Is Near: When Humans Transcend Biology", Penguin Books, New York, (2005).