MAN-COMPUTER SYMBIOSIS AS A WAY OF HUMAN COGNITIVE ENHANCEMENT

by

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The purpose of the paper is to introduce the history of man-computer symbiosis conception which is closely related to the idea of human cognitive enhancement and human intelligence amplification. Selected works from Licklider, Ashby and Engelbart are discussed and compared to the conception of augmented reality arisen in the 1990s. In the author's point of view these two conceptions represent two different dimensions of enhancing human experience, the ontological and the cognitive. It is shown in the paper that these two perspectives are related very closely and can be considered as deeply integrated in the future.

KEYWORDS

Man-computer symbiosis, augmented reality, mixed reality, cyberspace, human cognitive enhancement, intelligence amplification, man-machine interface

1. INTRODUCTION

The purpose of the paper is to introduce the history of man-computer symbiosis conception which is closely related to the idea of human cognitive enhancement and human intelligence amplification. After a brief terminological clarification and several notes to the intelligence, I will focus on selected works from Licklider, Ashby and Engelbart from the 1960s in order to present the early visions of possible man-computer symbiosis. These are discussed and compared to the conception of augmented reality fully evolved in the 1990s together with so-called new taxonomy of reality. Augmented reality technology is developing very fast nowadays and it is merging progressively its mainly technological standpoint focused on ontological problems with the cognitive point of view. It is expectable that conver-

gence of these approaches will offer new practical ways of man-computer symbiosis.

2. WHAT IS IN THE TITLE?

I perceive the way we are using the word *symbiosis* for referring to a relationship between man and computer as kind of symptomatic, much like all the other scientific metaphors in the history.

It is a fact of common knowledge that the term *symbiosis* comes from biology in the meaning of two or more *organisms living* together.

Concerning computers – artefacts of human activity – we call them *computing machines* as well. A *machine* generally indicates some kind of an engine, artificial device; it is certainly not an organism, it is a *non-living mechanism*. In spite of this, the symbiosis was discussed already in the period when computers only have started to develop. Whereas we have never talked about symbiosis in case of e.g. steam engine or light bulb, which are also breakthrough technical devices. Why?

Obviously, we are obsessively bundled with technology guiding us through every day of our life. We create more and more intimate man-computer interfaces. Today, some people long for physical connection with computer technology; they want to interface computer on a neural basis, they want to become *cyborgs* (self-controlling man-machine systems). In fact, they want to *fuse* together with the computer; firstly, because computers do many things easier, faster and more precisely than solely human brain can ever do – computers therefore enhance human capabilities. Secondly, modern-day *computers* mean *online computer network systems* – they connect us in real time with other people, or rather let me say with other *man-computer systems* (because everyone using such connection needs a computer device) through the cyberspace and satisfy and even excite our social and cognitive needs.

Human enhancement is an expression well established among transhumanists, technocentrists and their opponents (bioconservatists and neo-Luddites). The verb *enhance* comes from the Latin word *inaltiare* (prefix *in*, *altus* – high), it originally meant *to make something physically higher*. As time went on, the figurative meaning (to make something better, to improve some quality or value) outweighed. Nick Bostrom (the founder of transhumanistic movement) defines human enhancement as "an interven-

tion that improves the functioning of some subsystem of an organism … or that creates an entirely new functioning or subsystem".[1]

I have to leave out the definition of *human being* in this case because we still do not have any universally accepted definition we could use. Nevertheless, we can stay with an intuitive understanding of the term, which is the most common definition used in such type of research anyway.

The word *cognitive* is used here just as the discourse of the contemporary cognitive science prescribes. Any improvement of our ability to learn, to remember, to get some knowledge, to recognize, to think and to process information is meant as a cognitive enhancement.

Moreover, what is also very interesting about the title is the latent assumption that man-computer symbiosis will lead to something positive. In principle, emphasising man-computer symbiosis as a tool for the immense rise of human intelligence is the core of that conception.

3. INTELLIGENCE

Intellect and *intelligence* are derived from the Latin verb *intellegere* meaning literally *to choose between the possibilities* (*inter* – between, among, *legere* – to choose, pick out). Such a definition completely corresponds with the psychological conception of measurable (quantifiable) intelligence. It has chimed in with the conceptions of artificial intelligence in the 1960s as well because computers have always understood only mathematics. Admittedly, computers manage tasks requiring this type of intelligence (especially the time-consuming and precision demanding ones) excellently and they actually go beyond human limits.

The trouble is that problems, which people usually have, are rarely solvable by checking the right answer in the questionnaire or by proceeding mathematical algorithm. Even more, as Joseph Weizenbaum mentioned, for most of our problems there is no solution at all.[2] A human being possesses intelligence belonging to a specific reference frame which (I believe) we are not able to express quantitatively; and therefore we are not able to implant it into a computer. The mentioned frame is human experience, an incredibly complicated and complex world of man.

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[1] Bostrom, N. 2007, Dignity and Enhancement, http://www.nickbostrom.com/ethics/dignity-enhancement.pdf, [Accessed Oct 10 2010].

[2] Weizenbaum, J. 2002, Mýtus počítače: Počítačový pohled na svět. Ed. Fiala, J. Moraviapress, Praha.

Nowadays we can read about computers endowed with artificial intelligence coping not only with simple mathematical operations, as the former computing machines did, but also about those that have started challenging complex adaptive systems. Anyway, an average man is able to deal with tens of such systems every day: from anticipation of his partner's mood or driving a car in heavy traffic, to righteous adjudication of children's argument. We do not need to do routine and mechanical tasks because we have programmed computers to help us, to make things easier. For example, my generation cannot imagine how it could be possible to write a diploma thesis using a mere mechanical typewriter, with no Internet sources, hypertext and email communication. Due to computers and mainly computer networks (cyberspace) we do not need to reload information from our own memory; we simply command an electronic memory. We do not need to bounce along for precious literature kept by far-away library because we use electronic databases and scanned books in portable document format. Not only is it safer to convey various issues such as calculating, storage, analyzing, simulating or searching to a computer, but often it is the only way how to get a result. I consider as plausible enough that computers really *enhance* possibilities of human intellectual capacity in this sense. However, I certainly hesitate to adopt a conception of purely artificially created autonomous intelligence that would replace the human one. Behind all of these expectations or apprehensions, there is an opinion that quality emerges from quantity (if the latter reaches an adequate level of complexity), or more radical theory that the qualitative level of human intelligence is nothing but the delusion and hence there is no need to try to achieve this level in case of computers as well.

In my opinion, the only true human intelligence is wisdom, which apparently does not require augmented memory, faster processor or automatic information searching, but just the specific human experience, including digestion of our own stupidity, errors, suffering, helplessness and ultimately the social experience of existence of other people, other selves. In this moment, no computer can obtain such experience. And the reason for this is that computers do not have access to such specific human experience on principle. Together with Weinzenbaum I would like to accentuate that we must not imagine that computers *could* be able to solve *human* problems. And we must not imagine at all that they s*hould* do so.

4. MAN-COMPUTER SYMBIOSIS CONCEPTIONS IN THE 1960S

In this paper, I focus on conceptions of so-called *intelligence amplification* which point to man and computer technology mergence, supporting and enhancing current cognitive function of human organism and further preserving actual human experience. In contrast to the strong program of artificial intelligence, I consider the concept of intelligence amplification as a viable perspective.[3] We could trace prognoses of man-machine symbiosis participating on preparing present AI discourse at least back to the 1920s.[4] However, I want to enter the historical excursus upon the time when the second generation of computers arrived on the scene,[5] when transistors replaced vacuum tubes and computers were equipped similarly to modern-day computers. From this period of computer history it is harder to trace back to a single name of an inventor responsible for a new gadget, device or progress in computer technology. Nevertheless, we still know about propellers of that time. In this paper, I notice Ross Ashby – the pioneer of cybernetics, and Joseph Licklider – one of the most important people in the history of computer. Licklider worked for United States Department of Defence Advanced Research Projects Agency (ARPA) and was the first to formulate the vision of the network of computers, which led to ARPANET and later to our Internet. Finally, there is Douglas Carl Engelbart, well known for his invention of computer mouse. There were many other even more popular and important names in computer sciences, but hardly anybody is related as closely to the idea of man-computer symbiosis as these men.

4.1 ROSS ASHBY: INTELLIGENCE AMPLIFICATION

In his book An Introduction to Cybernetics, from 1957, Ross Ashby titled one chapter as Amplifying Regulation. According to Ashby, genes are the first regulators of a human organism. They regulate the organism directly and give rise to another more sophisticated regulation device – the human

[3] I use the term *artificial intelligence* at firstly for referring to a large interdisciplinary scientific field, and secondly for a computer technology. The term *intelligence amplification* is used in my paper in a similar way – as a scientific concept belonging under the more general artificial intelligence discipline, and as a concrete computer technology implementing the theoretical concept.

[4] See for example Haldane, J. B. S. 1924, Daedalus; or Science and the Future, London. Bernal, J. D. 1929, The Worlds, the Flesh & the Devil. An Enquiry into the Future of the Three Enemies of the Rationaly Soul, Indiana University Press, Bloomington.

[5] Period from 1958 to 1965. Compare Naumann, F. 2009, Dějiny informatiky. Od Abaku k internetu, Academia, Praha, p. 197.

brain, which executes highly complex psychological processes (e. g. learning, thinking, recognizing) serving to a successful environment adaptation. We count these processes as intelligence. Ashby's definition of intelligence is in accordance with measurable intelligence conceptions mentioned above and in his time it was strongly supported by behaviourism. He affirms that "… it is not impossible that … 'intellectual power' may be equivalent to 'power of appropriate selection'"[6] and the selection, as he discusses previously in his book[7], can be amplified. Ashby insists that creation of intelligence amplifier, heading to an overcoming of human intellectual capacities and efficient regulation of society, is feasible and desirable as well. It would help people to understand and handle their mental life and social world which are for pure human cognition intangible due to their complexness. Nature regulates mankind by genes. Genes regulate an individual human being by providing brain development. Brain and actual mental operations regulate environmental adaptation. We regard this process as natural.

According to Ashby, in the half of the 20th century we were facing an unprecedented opportunity to extend this process synthetically, artificially and consciously by creating artificial intelligence – amplified intelligence capable of more effective regulation. Following An Introduction to Cybernetics we are not able to disclose a concrete vision of Ashby's amplified intelligence. Two basic realizations can be suggested. The first way of the realization is creation of independent artificial intelligence; the second way is artificial enhancement of human intelligence by means of man-computer symbiosis. The conclusion of Ashby's book could prone to both interpretations. I assume that although Ashby's term has been borrowed by later authors mostly in the second meaning, he sympathized rather with the first scenario. His behavioural conception of intelligence achievable in any medium indicates such way.[8]

From this perspective his vision of artificial intelligence regulating human society sounds very provocative and it anticipated futurological movement of singularitarianism[9]. Singularitarianism on its own reflects the bifurcation of the greater-than-human intelligence conception, and elaborates

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6 Ashby, R. 1957, An Introduction to Cybernetics, Chapman & Hall Ltd, London, p. 272.

7 Ibid., pp. 258-259.

8 Ibid., p. 272.

9 See for example Kurzweil, R. 2005, *The Singularity Is Near: When Humans Transcend Biology*, Viking, New York.

on traditional artificial intelligence as well as on human intelligence amplification.[10]

4.2 JOSEPH CARL ROBNETT LICKLIDER: MAN-COMPUTER SYMBIOSIS

Joseph Carl Licklider published his famous paper Man-computer Symbiosis in 1960.[11] He believed that in the near future "human brains and computing machines will be coupled together very tightly, and that the resulting partnership will think as no human brain has ever thought and process data in a way not approached by the information-handling machines we know today [in 1960, noted by E. Ž.]".[12]

Licklider defines man-computer symbiosis as a kind of a *man-machine system.* A traditional man-machine system of the past was a *mechanically extended man*[13]always defining *what* to do and *how* to do things. Mechanical parts of the system are only extensions of a human being (of his eyes or hands). Licklider does not refer to such a system as to symbiotic system; he calls it simply *semi-automatic system*. There is also the case of *humanly extended machines* which employ humans only in specific situations.[14]

Licklider is focused on such relationship between man and computer that will increase efficiency on both sides. As mentioned above, and as we have known from the beginning of the computer era, there are tasks that computers manage with surprising ascendency over man, and conversely, man handle problems non-solvable by computers. For Licklider, these are the reasons to define diverse competence domain for each other within their symbiotic relationship: "Man will set the goals, formulate the hypotheses, determine the criteria, and perform the evaluations. Computing machines will do the routinizable work that must be done to prepare the way for insights and decisions in technical and scientific thinking."[15]

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[10] See Vinge, V. 1993, 'The Coming Technological Singularity', Whole Earth Review, Winter issue.

[11] Licklider, J. C. R. 1960, 'Man-Computer Symbiosis', IRE Transaction on Human in Electronics, volume HFE-1, pp. 4 – 11.

[12] Licklider, J. C. R. 1960, 'Man-Computer Symbiosis', *In Memoriam: J.C.R. Licklider: 1915-1990*, ed. Taylor, R.W., Digital Systems Research Center Reports 61, Palo Alto, CA, 1990. Available at www.kmdi.utoronto.ca/rmb/papers/B15.pdf, p. 2.

[13] Ibid., p. 2. Licklider uses term *mechanically extended man* in accordance with J. D. North (The rational behavior of mechanically extended man, Boulton Paul Aircraft Ltd., Wolverhampton, Eng., September, 1954.). He refers to him explicitly.

[14] Ibid., p. 2.

[15] Ibid., p. 1.

Computers were on much lower level in the half of the 20th century than today. A path towards computer *hardware* running any *software* was only being searched. At that time, computers did not have separated internal and external memory, often could not fit in a single room, they were too slow and too expensive. Although Licklider believed that it is only a matter of time when man will "think in interaction with a computer in the same way that you think with a colleague whose competence supplements your own".[16]

The only difference will be that computers "will accept clearly secondary status" in this cooperation.[17]

Licklider realized impediments to completion of man-computer symbiosis. Among other things (as memory organization for example), communication between man and computer was a fundamental problem. Computer languages have always been (and still they are) based on syntax. On the other hand, people are using languages containing the semantic level. For example, people define a *goal* when they want someone to do something (e. g. 'Take your mother to the shopping centre.'). However, when we want a computer to do the same thing we have to formulate the *operation* step by step (e. g. 'Turn left, lift your arm, open the door, go straight along the street, turn right at the crossroad etc.'), thereto in a programming language. Another issue described by Licklider was related to the communication interface. A computer needs to understand the inputs and a man has to be able to understand the outputs. Today in 2011, we commonly use such computer languages and interfaces. We have already learned how to communicate with computers but as Howard Rheingold says "the future limits of this technology are not in the hardware but in our minds"[18].

Licklider's conception of man-computer symbiosis was later revitalized and it is still developing as the conception of *human cognitive enhancement* (or *human augmentation*).

4.3. DOUGLAS CARL ENGELBART: H-LAM/T SYSTEM

Ross Ashby's *amplified intelligence* was presented in his book only as a fuzzy picture of the future. Few years later, Douglas Carl Engelbart published the

[16] Ibid., p. 4.

[17] Ibid., p. 7.

[18] Rheingold, H. 2000, Tools for Thought: The History and Future of Mind-Expanding Technology, http://www.rheingold.com/texts/tft/, [Accessed Jan 01 2011].

summary report Augmenting Human Intellect: A Conceptional Framework[19] in which he presented concrete frame of further research and prepared basis for practical realization. Similarly to Ashby, Engelbart regards human intellect augmenting as an evolutionary process that we can observe since the culture was born.[20]

He differentiates four basic categories of *augmentation means*: 1. artefacts; 2. language (for portioning world into the notions); 3. methodology (to proceed problem solving) and 4. training (in 1. – 3.).[21] These amplifiers are highly organized, and according to Engelbart, it synergistically creates functioning structure.[22] From his explicitly engineering point of view, it is evident that if we change (enhance) a part of the structure (containing 1. – 4.) we can enhance the whole interconnected structure.

A human organism together with this augmenting tools constitutes the so-called H-LAM/T system; "Human using Language, Artefacts, Methodology, in which he is Trained".[23] This system, a *synergistic superstructure*, helps a human to survive, to be evolutionary successful. Language evolution is the most fundamental because it enables conceptual grasp of reality and symbolic representation (necessary for thinking). The computers fit in the H-LAM/T system as artefacts helping us manipulate with symbols on a higher level. This type of manipulation goes beyond human abilities.[24]

According to Engelbart, "the explicit nature of future improved systems would be highly affected by expected changes in our technology or in our understanding of the human being".[25]

5. AUGMENTED REALITY

The introduced conceptions of man-computer symbiosis were developing and proliferating in the outlined way till the 1990s, when Internet spread out and communication technology progressed. In this time, fifteen years ago, new strange terms have started to be used in laboratories of communication technologies (*mixed reality*, *augmented reality* and *simulated reality)*. It

[19] Engelbart, D. C. 1962, Augmenting Human Intellect: A Conceptional Framework, prepared for: Director of Information sciences Air force office of scientific research, Washington 25, D.C.

[20] Ibid, p. 19.

[21] Ibid., p. 9.

[22] Ibid., p. 31.

[23] Ibid., p. 11.

[24] Ibid., p. 25.

[25] Ibid., p. 7.

happened because in these laboratories they needed new words for discussing what they were working on. A new taxonomy of reality was necessary. In 1994 Paul Milgram and Fumio Kishino published their concept of *reality-virtuality continuum* in the paper A Taxonomy of Mixed Reality Visual Displays.[26]

Reality-virtuality continuum is the term referring to all cases in which real and virtual objects are presented together in one single environment through any display technique. There is a r*eal environment* at one end of the continuum and *virtual environment* at the opposite side. *Augmented reality* lying between these extremes is the most interesting and essential. Sometimes it is called *mixed reality*. There is also *augmented virtuality* lying closer to the right end of the virtual continuum, but the only difference (irrelevant for us) is the proportion of real and virtual. In any case they are both mixed. According to Azuma, augmented reality includes all systems which combine real and virtual objects, which are interactive in real time and which are displayed in a three-dimensional format.[27]Azuma also refers to a special case of using AR technologies which "remove real objects from the perceived environment". This is called "*mediated* or *diminished* reality".[28] Thereby the taxonomy of realities is multiplied all the more.

Technologies are nowadays far more sophisticated than in the nineties, hence Milgram's and Kishino's taxonomy cannot involve all multifarious cases of contemporary augmentations of reality. Famous examples of augmented reality technologies application (available commonly) are EyePet, Zugara´s AR Dressing Room, USPS Priority Mail Virtual Box Simulator (for PC), Metro Paris Subway iPhone and iPod Touch Application, Layar (for mobile devices), ARQuake, EyeTap or Tinmith (wearable AR). From the beginning, AR technology has aspired to be implemented as a wearable technology. For this purpose the head mounted displays have been used to provide audio-visual information, sometimes special gloves for manipulation with virtual objects are engaged as well. However, the wearable AR technologies (closely related to the general idea of wearable computers), as for example EyeTap or some kind of eye-wear device, are desired because

[26] Milgram, P., Kishino, F. 1994, 'A Taxonomy of Mixed Reality Virtual Displays', IEICE Transactions on Information and Systems E77-D, 9, pp. 1321–1329.

[27] Azuma, T. R. 1997, 'A Survey of Augmented Reality', Presence: Teleoperators and Virtual Environments 6, 4, pp. 355-385.

[28] Azuma, T. R. et al. 2001,'Recent Advances in Augmented Reality', Computer Graphics and Applications, IEEE, Volume 21, Issue 6, p. 34.

of their "hands-free nature" and "walk-up and ready-to-use aspect", which allow the user to "receive the information just by looking at the desired artefact."[29] Such applications are not available to a common user yet, because serious technological and user interface limitations persist. In addition to the traditional tools for generating augmented reality, the brain-machine interfaces (BMI) are considered to be the way of reality extension.

The frontier between AR technology and brain-machine interface used to be the frontier between the conceptions of augmented reality and augmented intelligence. AR technology has been for the most part a domain of computer scientists and their point of view has been directed at changes in the ontological sphere (*reality*). On the other hand, brain-machine interfaces have been a hot topic for neuroscientists, who have focused on cognitive changes and the noetic sphere (*intelligence*). We can consider a brain implant serving for faster calculation or providing access to external data storage both as a cognitive enhancement and a reality augmentation, because the first one sets a new perspective for perceiving a richer field of reality, new entities with (unexplored) ontological status. Nonetheless, the rapprochement of the ontological and the cognitive dimension can be seen for example in so-called *augmented reality-brain-machine interface*, which use EEG-based BMI system (it means non-invasive technique) and the traditional AR technology.[30] Kenji and his team demonstrated in their study that a human is able to reach a cognitive enhancement by the new capability to manipulate with a robot just by thoughts, and moreover can (in the same way – by thoughts) manipulate virtual objects (and by their means another distant real objects as well) sensed by that robot in external environment.[31]

6. CONCLUSION

Something has changed in comparison with the 1960s. In the 1990s the conception of immersive virtual reality prevailed. However, today we tend to use technologies that allow staying in full touch with the *primary reality*[32] and keep us in connection with cyberspace in the same time. As soon as we settled in every day every minute living together with computer techno-

[29] Thomas, B. H, Sandor, Ch. 2009, 'What Wearable Augmented Reality Can Do for You', Pervasive Computing, IEEE, April 2009, p. 8, 11.

[30] Kenji, K. et al. 2010, 'My Thoughts through A Robot's Eyes: An Augmented Reality-Brain-Machine Interface', Neuroscience Research, 66, pp. 219-222.

[31] Ibid.

[32] I use term *primary reality* in the meaning of common physical reality, counterpart of virtual reality.

logy, we woke up in a *new mixed reality*. Augmented reality is a logical consequence of an augmented human. We have always been fascinated by a possibility to overcome the human nature and now we are again amazed and overwhelmed by inventing and entering a new reality. At present, the conception of augmented reality and conception of augmented (enhanced) human intelligence are converging into the united perspective and I take future even deeper integration of these conceptions for granted.

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