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ABOUT COEVOLUTION OF HUMANS AND INTELLIGENT MACHINES: PRELIMINARY NOTES

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ABSTRACT: Cooperation is something worthy to be explored from a social, economic, biological and even genetic point of view. This paper deals with human cooperation and focuses specifically on how humans interact with intelligent machines, which are considered as entities that, along with others (humans and non-human animals), populate the same ecological niche. The discourse is based on two theoretical pillars: the hypothesis of self-domestication of humans and the niche construction theory. Then, the movement of intelligent machines from isolation to direct cooperation is shown as the factual technological change which raises the problem of how cooperation between humans and intelligent machines works and with what effects. A presentation of the two main visions about the future of human-machine relations is offered and the different possibilities of development of self-control between humans and intelligent machines are discussed. According to the Author, machines will not destroy humanity. Humans will co-evolve with the machines they create which they will control through social, ethical, and legal rules. In addition, humans, integrated with mechanical or electronic devices, will continue their evolution by developing their self-control as cyborgs. A final note is reserved for how our ecological niche is changing.

KEY-WORDS: human cooperation; intelligent machines; robot; ecological niche; technological change

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1. The point

This paper deals with human cooperation and focuses specifically on how humans interact with intelligent machines, which are considered as entities that, along with others (humans and non-human animals), populate the same ecological niche.

The idea of this topic came from some conversations I had with Monika Gruter Cheney and Oliver Goodenough, November 2019 in Stanford-Palo Alto. They were thinking about "cooperation" as the issue of the 2020 Gruter Institute annual meeting. The question that came

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to my mind was: if cooperation is something worthy to be explored from a social, economic, biological and even genetic point of view, why not to extend this exploration also to the cooperation between humans and intelligent machines?

Finally, the 2020 round of Gruter Institute annual meeting was (for the first time remotely) held in October 15-17 and focused on *The evolution of cooperation* and on how cooperation works:

> Darwin is often said to have left cooperation "unexplained." Subsequent evolutionary biologists such as W.D. Hamilton have spent decades seeking to understand it. It is particularly important for humans. Cooperative groups allow the division of labor, the specialization of abilities, and productive trade. […] When you apply this approach across entire countries or even the globe, the productive power of groups of humans is huge. And the advantages are not just on the production side. Sharing of resources across groups provides important insurance against short term failure by any given member[1].

In the *Topic Précis* of the meeting the organizers outline specific aspects of cooperation, such as the case of some kind of insurance contracts in our contemporary markets, which are exactly scaled up applications of the cooperation and distribution of risks, and, also, the extraordinary power of human exchange and law, as one of the most important domains of institutional design and creation. The talk I gave on *Humans, cooperation and artificial entities* is the basis of this paper.

It seems to me that the cooperation among humans is an extremely interesting issue, something worthy to be explored in its various ramifications, e.g., under biological and even genetic point of view. Epigenetics offers an insight for such broadening of the scope of cooperation. Indeed, epigenetics implies a shift of focus from the individual genetic makeup to the environment and its retroaction on the human genetic dowry.

In this paper I try to go a little bit forward and laterally, and to outline a reply to the broader question of how we, human beings, change our ecological niche and how it retroacts on human beings. I say *forward* because the exploration seems to be worth to be extended beyond interactions among humans and to include also human-nonhuman animals interactions[2], and *laterally* because the cooperation between humans and intelligent machines (namely humans-machines interactions) is, in my view, the challenging point of the next future. In this paper I'll

[1] Gruter Institute for Law and Behavioral Research, *Topic Précis, The Evolution of Cooperation, Virtual Squaw Valley Conference*, October 15-17 2020. Organizers: Monika Gruter Cheney, Oliver Goodenough, Andrew Torrance, Isabel Behncke.

[2] A session in the meeting was dedicated to non-human primates, with the participation of Isabel Behncke, Cognitive and Evolutionary Anthropologist at Oxford University.

focus on this lateral side of the issue, referring for the theme of relations between humans and non-human animals in ethical and legal studies to a previous research of mine[3].

In paragraph 2., the two theoretical pillars on which the discourse is based are briefly presented, i.e. the hypothesis of self-domestication of humans and the niche construction theory; then, in par. 3., the movement of intelligent machines from isolation to direct cooperation is shown as the factual technological change which raises the problem of how cooperation between humans and intelligent machines works and with what effects; in par. 4., premised on a clarification of the terms used (robot, autonomous system and intelligent machine), the two main visions about the future of human-machine relations are presented and the different possibilities of development of self-control between humans and intelligent machines are discussed. In par. 5. a final note is reserved for how our ecological niche is changing.

2. Two theoretical pillars: self-domestication and niche construction

Cooperation between humans and intelligent machines can be properly framed by relying on two lines of research that exist in the literature and can be considered the premises of this paper: the self-domestication hypothesis and the niche construction theory.

According to the self-domestication hypothesis, humans have gone through a process of selection against aggression, a process that was self-induced. In his book on *The Goodness Paradox*, Richard W. Wrangham notes as some human extraordinary abilities of present times, such as heart surgery, space travel, and comic opera, all depend «from an evolutionary point of view […] on capacities for a quite exceptional ability to work together, including tolerance, trust, and understanding. Those are some of the qualities that cause our species to be thought of as exceptionally "good"»[4].

The fact that man's relative docility and tolerance is a rare phenomenon in wild animals justifies the idea that man is a domesticated species. So, the question turns into «who could have domesticated us?» A possible reply is we might have self-domesticated, as bonobos did. Similar to humans, bonobos «show many of the features of a domesticated species» and, excluding humans having domesticated them, the conclusion might be «the process happened in nature» (thus, they «must have self-domesticated»).

[3] A. SANTOSUOSSO, *The human rights of nonhuman artificial entities: an oxymoron?*, in *Yearbook of Science and Ethics/Jahrbuch für Wissenschaft und Ethik*, 2015.
[4] R.W. WRANGHAM, *The Goodness Paradox*, 4.

However, the question of *how* self-domestication happened stands and is still open, even though some suggestions seem to come from the «way that aggressive individuals are prevented from dominating others» or the creation of «despotic» hierarchical social institutions, which cannot be found in other species. In addition, the same *why* self-domestication happened is still open, as the parallel with bonobos evolution does not explain «why bonobo aggression was reduced» (*ivi*, 103) and why it was reduced in humans as well.

The paradox of virtue and violence, both so prominent in human life, is a topic of Wrangham reconstruction:

> We have evolved in both directions simultaneously. Both our tolerance and our violence are adaptive tendencies that have played vital roles in bringing us to our present state. The idea that human nature is at the same time both virtuous and wicked is challenging, since presumably we would all wish for simplicity. (*ivi*, 12)[5].

According to Wrangham, Jean-Jacques Rousseau and Thomas Hobbes are classic icons for the alternatives. Rousseau has come to stand for humanity's being instinctively nice, Hobbes for humanity's being naturally wicked. However, «both positions have some merit. There is plenty of evidence that humans have innate tendencies for kindness, just as there is for our having spontaneously selfish feelings that can lead to aggression. No one has found a way to say that one kind of tendency is more biologically meaningful or evolutionarily influential than the other»[6].

As intriguing as it is, the idea of some sort of immutable balance between aggression and kindness in humans seems to be contradicted by the lowering of violent crimes around the world reported in criminology[7]. Of course, less violence does not equal to less evil behavior, but also the opposite is not true, as violence cannot be said to be morally insensitive.

In a recent study, Dor Shilton et al. criticize the concept of self-domestication and maintain «the social evolution of humans is better explained in terms of selection for pro-social motivation and self-control, which are guided by symbolic communication and representation rather than as

[5] "For centuries, people have simplified their understanding of a confusing world by adopting one or the other of these opposed views".

[6] R.W. WRANGHAM, *The Goodness Paradox*, 5-6. See also Id., *Two types of aggression in human evolution*, in *Proc. Natl. Acad. Sci.*, U.S.A, 115, 2018, 245–253. doi: 10.1073/pnas.1713611115.

[7] M.R. SANTOS, A. TESTA, *Homicide is declining around the world because we're getting old*, in *Quartz*, November 11, 2019, https://qz.com/1743595/why-global-homicide-rates-are-declining/#:~:text=A

a process of self-domestication»[8]. In this view a special role was played by the emergence of mimetic communication, the beginnings of musical engagement, and mimesis-related cognition, and, in a second stage, the emergence of language and imagination, which facilitated emotional control and emotional plasticity.

The authors highlight the ambiguity of the theory of domestication, which was popular in the literature about social hierarchies in civility (more civilized humans who domesticated inferior humans) and later racist and eugenic political movements. This well-known problem (stressed also by Wrangham) is the result of the intrinsic ambiguity of the concept of domestication when used in explaining human evolutionary processes. At the end, the authors «do not find the notion of human self-domestication useful and believe that the partial analogy with domesticates focuses too much on the reduction of reactive aggression and too little on social organization».

Of course, I make no claim to resolve the open questions in each of these two theories and, therefore, refer to both in the later part of this paper.

The second pillar of this paper is the niche construction theory. According to this vision of evolution, organisms are not passive entities, malleable at will by selection. The metabolic and behavioral activities of biological populations change the ecological niches, thus influencing the environmental resources and the selective pressures that in turn retroact on organisms themselves. This phenomenon, called "niche construction", is essential in evolution. Organisms actively change their environment and the environments selectively change organisms[9].

The idea at the basis of niche construction theory is interesting as it is able to encompass the relation humans-machines in the wider concept of human evolution simultaneously with the larger environment and also the products of human activity, from machines till to social institutions as laws and regulations.

[8] D. SHILTON, M. BRESKI, D. DOR, E. JABLONKA, *Human Social Evolution: Self-Domestication or Self-Control?*, in *Front. Psychol.*, 11:134, 2020, doi: 10.3389/fpsyg.2020.00134.

[9] T. PIEVANI, *How to Rethink Evolutionary Theory: A Plurality of Evolutionary Patterns*, in *Evol Biol*, 2015, DOI 10.1007/s11692-015-9338-3; K. LALAND, B. MATTHEWS, M.W. FELDMAN, *An introduction to niche construction theory*, in *Evol Ecol.*, 30, 2016, 191-202.

3. Intelligent machines: from isolation to cooperation

The case of robots in industry is meaningful. In past decades robots were kept in isolation. Now the main concept is to boost a closer interaction and cooperation between human workers and robots. In this light, robots enable humans to enhance their performance.

In the last ten years, some important changes happened in the relationship between society and Artificial Intelligence, robotics and advanced technologies. If, for example, we think of robots in industry, up to a certain point the prevailing idea was that they were potentially dangerous entities to be kept in confined places and departments, so that they would not harm humans. Since then, the idea has changed and progressively they started to be accepted as entities facilitating human work and replacing mainly the simplest and most repetitive tasks. And, what is most interesting, they started being considered as entities with which you could work together side by side. This was the result of several factors such as the development in safety devices and measures, and also in Artificial Intelligence increasingly embedded in tools, machines and systems.

In this new environment the driving idea has become that of cooperation. Some have given this new horizon the name of intelligent automation continuum, others have spoken of a new «Age of With»[10]. Where the idea of *with* is understood as the co-presence and interaction between different technologies, such as character recognition systems (ICR and OCR), natural language processing (NLP) and natural language generation (NLG), and more[11].

It is against this current (and predictable) backdrop that the question of cooperation in human evolution must be posed today, and the question of what shape niche construction might take.

The development of powerful and intelligent machines impacts the ecological niche in several ways. One is the environmental one, considering for example the huge amount of electricity those technologies consume (such as for example mining in blockchain or 5G[12]), but the one I wish to focus on is the interaction between humans and intelligent machines, in the light of the

[10] On *intelligent automation continuum* see S. KAPOOR, *IDC Perspective: Six Capabilities from Leading RPA Service Providers That Advance Financial Services Institutions Toward Intelligent Automation*, 2020, in: https://www.capgemini.com/wp-content/uploads/2020/04/An-IDC-perspective-on-Intelligent-Process-Automation.pdf (visited November 20, 2020). On the *Age of With* see the 2019 Deloitte Report, significantly titled *Automation with intelligence*, https://bit.ly/3lJOY1h(visited November 20, 2020).

[11] S. OVERBY, *How Robotic Process Automation (RPA) and digital transformation work together*, August 11, 2020, https://enterprisersproject.com/article/2020/8/how-rpa-robotic-process-automation-and-digital-transformation-work (visited November 20, 2020).

[12] Although it could be said that it is not enough to be a new selective pressure, rather having effects only on the social niche.

theory of self-domestication or self-control, as determining forces in the construction of the ecological niche. Indeed, the above outlined scenario can be considered a description of our ecological niche.

At a first schematic level the dilemma can be formulated as follows: should we domesticate intelligent machines? Or will intelligent machines self-domesticate or develop their own self-control?

The first horn of the dilemma is consistent with the traditional reassuring idea that machines are a mere tool to be used at will by humans and underestimate how the presence of those intelligent machines retroactively affects the way humans think and act. The second horn of the dilemma takes for granted the development of higher forms of artificial intelligence that can have human-like evolutions.

The question requires more in-depth considerations, which are carried out in the next paragraph.

4. Intelligent machines, humans and augmented humans: whose self-control?

In this paragraph, premised on a clarification of the terms used, and presented the two main visions about the future of human-machine relations, the different possibilities of development of self-control between humans and intelligent machines are discussed.

4.1. Robots, autonomous systems, intelligent machines

A preliminary clarification is necessary about wording: robot, autonomous system, intelligent system/machine express different concepts and refer to different entities.

According to its etymology, *robot* refers to a mechanical entity (a machine) which does an even cognitively poor work instead of humans[13], while *autonomous system* stresses the specific feature of a machine which is able to act (at a certain degree) without human input or with a non-direct intervention/suggestion by a human[14]. Finally, an *intelligent system/machine* is an

[13] The word "robot" is first known to be found in the sci-fi drama R.U.R. (1920), by Czech writer Karel Čapek, set in Rossum's Universal Robots (R.U.R.) industry, which used human replicants (called robots, in fact) as labor slaves for humanity. The Czech neologism "robot" is derived from the word "robota" meaning "work".

[14] G. SARTOR, A. OMICINI, *The autonomy of technological systems and respon-sibilities for their use*, in N. BHUTA, S. BECK, R. GEISS, C. KRESS, H.Y. LIU (eds.), *Autonomous Weapons Systems: Law, Ethics, Policy*, Cambridge, 2016, 39-74. See also, RockEU Robotics Coordination Action for Europe, *ELS issues in robotics and steps to consider them Part 2: Robotics and Regulations*. The deliverable was coauthored by B. BOTTALICO, A. SANTOSUOSSO, O.

entity which, having a variable balance between its mechanical components and software or AI components, is able to work intelligently, within the limits of and according to its AI components and devices[15].

Needless to say, it is the third one that is the most controversial reality, and for several reasons. The main is that intelligent machines can be considered a wider concept which encompasses both mechanical aspects of traditional robots (and thus the ability to provoke changes in the surrounding physical environment) and a high degree of autonomy. In addition, AI is the driving force of development of machines having cognitive and decision-making capacities.

For these reasons, in this paper, I use the concept of intelligent machines, namely because of its strength and its challenging feature.

4.2. Two competing visions on humans and intelligent machines

Two competing visions (and scenarios) face each other in the current debate about future coexistence of humans and intelligent machines. Within the vast literature on the issue, it seems to me that the most significant and authoritative positions are the following two.

According to the first one *Superintelligent AI* might be the last event in human history**.** The Center for Human-Compatible AI (at Berkeley University) presents its mission in a scenario that is anything but reassuring:

> to develop the conceptual and technical wherewithal to reorient the general thrust of AI research towards provably beneficial systems […] The long-term outcome of AI research seems likely to include machines that are more capable than humans across a wide range of objectives and environments. This raises a problem of control: given that the solutions developed by such systems are intrinsically unpredictable by humans, it may occur that some such solutions result in negative and perhaps irreversible outcomes for humans. CHAI's goal is to ensure that this eventuality cannot arise, by refocusing AI away from the

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GOODENOUGH, R. DE BRUIN, C. HOLDER, C. GÔME, Y. DE FRANCE, C. NIEL-AUBIN, N. BENDER, C. LEROUX and delivered on June 2016, available at https://www.eu-robotics.net/cms/upload/downloads/Rockeu1/2016-08-16_RockEU_deliverable_D3.4.1-part2.pdf .

[15] A. SANTOSUOSSO, B. BOTTALICO, *Autonomous Systems and the Law: Why Intelligence Matters*, in E. HILGENDORF, U. SEIDEL (eds.), *Robotics, Autonomics, and the Law: Legal issues arising from the Autonomics for Industry 4.0 Technology Programme of the German Federal Ministry for Economic Affairs and Energy*, January 2017, doi: 10.5771/9783845284651-27.

> capability to achieve arbitrary objectives and towards the ability to generate provably beneficial behavior[16].

Main promoter is Stuart Russell, a very well-known computer scientist who has coauthored with Peter Norvig the authoritative book *Artificial Intelligence: A Modern Approach*. Other important people sharing similar views are Stephen Hawking, Max Tegmark, & Frank Wilczek[17], who in a commentary article on the movie *Transcendence* (Johnny Depp protagonist) evoke singularity:

> Looking further ahead, there are no fundamental limits to what can be achieved: there is no physical law precluding particles from being organized in ways that perform even more advanced computations than the arrangements of particles in human brains. An explosive transition is possible, although it may play out differently than in the movie: as Irving Good realized in 1965, machines with superhuman intelligence could repeatedly improve their design even further, triggering what Vernor Vinge called a "singularity" and Johnny Depp's movie character calls "transcendence." One can imagine such technology outsmarting financial markets, out-inventing human researchers, out-manipulating human leaders, and developing weapons we cannot even understand. Whereas the short-term impact of AI depends on who controls it, the long-term impact depends on whether it can be controlled at all[18].

The opposite view outlines a very different scenario where the same idea of «Superintelligence» is criticized as a flawed concept**.**

Melanie Mitchell, a professor of computer science at Portland State University, maintains «the problem with such forecasts is that they underestimate the complexity of general, human-level intelligence. Human intelligence is a strongly integrated system, one whose many attributes — including emotions, desires, and a strong sense of selfhood and autonomy — can't easily be separated. […] the notion of superintelligence without humanlike limitations may be a myth»[19].

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[16] See https://humancompatible.ai/about and http://bit.ly/3r7am1L.

[17] S. HAWKING, R. STUART, M. TEGMARK, F. WILCZEK, *Transcending Complacency on Superintelligent Machines*, in *The Huffington Post*, 2014, available at http://bit.ly/3dd0fUf. Recently published: S. RUSSELL, *Human Compatible*, Viking, 2019.

[18] THE BLOG 04/19/2014 09:14 am ET Updated Jun 19, 2014; S. HAWKING, R. STUART, M. TEGMARK, F. WILCZEK, *Transcending Complacency on Superintelligent Machines*, cit.

[19] M. MITCHELL, *We Shouldn't be Scared by Superintelligent A.I.. "Superintelligence" is a flawed concept and shouldn't inform our policy decisions*, in *NYT*, Oct. 31, 2019, http://nyti.ms/3cWx4nZ.

Roger Penrose, professor of mathematics, Nobel Prize in Physics 2020 «for the discovery that black hole formation is a robust prediction of the general theory of relativity»[20] and friend of his colleague Stephen Hawking, is even sharper and, in an interview given in May 2018, in the occasion of *AI For Good 2018 Global Summit* (Geneva, Switzerland), says that the real risk are people who think that Superintelligent AI might be the last event in human history, rather than AI per se[21].

4.3. Intelligent machines and self-control

Hereinafter I pose the issue of self-control in this discussion context, calling *Scenario 1* that of singularity and *Scenario 2* that of flawed concept.

The question is whether the development of something like self-control (or self-domestication) is conceivable in intelligent machines.

According to *Scenario 2* this is unconceivable, because of the lack (in machines) of *emotions, desires, and a strong sense of selfhood and autonomy*. At the opposite end of the spectrum, the ideas of the proponents of *Scenario 1* would seem to leave room for this possibility. However, even to follow this idea, some important questions would arise. Self-domestication is a hypothesis for explaining the reduction of aggression in the evolution of humans: should we exclude the possibility of a reduction of their aggression?

In *Scenario 2* there is room for the opposing hypothesis of humans domesticating Intelligent machines. This might be the case of regulations of AI and AI equipped machines with the aim of preventing damages to humans and environment and increasing the level of safety. This attempt is connected with the today mainstream idea to keep humans in the loop of decision making and focusing AI on human needs and values[22]. We don't know if this is just an aspiration or a realistic guide for practical decisions. Either way, it is a worthy attempt to address the problems that intelligent machines present.

[20] The prize was divided, one half awarded to Roger Penrose, the other half jointly to Reinhard Genzel and Andrea Ghez «for the discovery of a supermassive compact object at the centre of our galaxy»: https://www.nobelprize.org/prizes/physics/2020/summary/.

[21] See https://www.youtube.com/watch?reload=9&v=dpSpwzyO0vU.

[22] e.g. *Stanford Institute for Human-Centered Artificial Intelligence*, http://stanford.io/317ttOv: led by the well-known computer scientist Fei Fei Lin.

4.4. Augmented human intelligence

However, there is also another way of framing the issue. We might consider what is happening today in the human-machine relationship as a new twist in the evolution of "our" self-control.

A basic idea of Scenario 1 is that intelligent machines can evolve completely independently of humans. In my opinion this is not a correct assumption. Things seem to me to be in a different way. Machines, more or less intelligent, are part of a wider human-machine scenario populated by many things unified in an essential logic of bringing technologies closer to humans, towards a progressive integration. Indeed, we have entered a phase in which technologies become closer to and interpenetrate with the human body: examples start with tech *on* our bodies (e.g. wearable devices), to tech integrated *with* our bodies, to augmented humanity (senses, cognition, motion), to invisible neural signals interface up to direct neural interfaces.

To use the jargon of one of the largest economic analysis and technology information company, one would have to say that we are already in the era of augmented humanity, where technology merges with biology to extend the physical and mental capabilities of the human body[23].

On the academic side the Stanford University (USA) is on a similar wavelength, dedicating its Spring 2021 conference to *Intelligence Augmentation*, which is described as the way to make Artificial Intelligence not replace humans but augment their capabilities. The conference is announced with these words:

> Artificial intelligence is poised to change every sector of the economy. How do we ensure that this technology will augment, not replace, humans? During HAI's spring conference, scholars and industry professionals in the fields of healthcare, education, art, and others will discuss how AI technology can best support humans as they approach critical global challenges[24].

If this is the case, the question becomes *who* will be the subject of self-control/self-domestication: machines alone?[25] It does not seem to be probable, as there is too much

[23] IDC is a leading global provider of market intelligence, consulting services and events for the information technology, telecommunications and general technology markets: see https://www.idc.com/ (visited November 20, 2020). For the vision byIBM, see Rucas, *The Fourth Platform Revolution of IBM: From Hybrid Cloud to AI*, May 26, 2020, https://www.rucashk.com/the-fourth-platform-revolution-of-ibm-from-hybrid-cloud-to-ai/ (visited November 20, 2020). See also C. WONG, *Get ready for the 'fourth platform'*, November 14, 2016, https://blog.allstream.com/get-ready-for-the-fourth-platform/ (visited November 20, 2020).

[24] See at http://stanford.io/3vQA7H6.

[25] E. FOSCH-VILLARONGA, C. LUTZ, A. TAMÒ-LARRIEUX, *Gathering Expert Opinions for Social Robots' Ethical, Legal, and Societal Concerns: Findings from Four International Workshops*, in *International Journal of Social*

interpenetration for saying that intelligent machines will develop autonomously. Humans alone? Again, an antihistorical uncontaminated (by technology) humanity simply has never existed. Humans in their present situation and experience, rather resemble to persons «whose physiological functioning is aided by or dependent upon a mechanical or electronic device», which is the Oxford dictionary definition for cyborg.

In this realistic perspective, machines will not destroy humanity. Humans will co-evolve with the machines they create, which they will, one way or another, control through social, ethical, and legal rules. In addition, humans, integrated with mechanical or electronic devices, will continue their evolution by developing their self-control as cyborgs[26].

5. Coevolution of humans-machines and our ecological niche

Machines are part of the game of action-retroaction which happens in the ecological niche, with other entities populating it such as humans (with their development of institutions as law, economic activity and exchange) and non-human animals and more.

The vision of the ecological niche allows us to have a more complex and richer vision of our future: we are not solitary agents, even if we bear higher responsibilities that are related to our development of a rich system of communication and self-control based on language and neuro-awareness (a system which does not exclude aggression might amplify in some social conditions).

How this will all work and along what specific dynamics is an agenda for a further research project. For example, under the self-control/self-domestication hypothesis, the enhancement of humans+machines should not (necessarily) serve their aggression, which might continue to decline. However, one must consider that an increase in power usually generates control problems: what could drive the evolution towards self-control or aggression? Also, to have an effective niche-building process, concrete feedback from selective pressures is needed, such as

Robotics, https://doi.org/10.1007/s12369-019-00605-z; A.P. VARGAS, E.A. DI PAOLO, I. HARVEY, P. HUSBANDS (eds), *The Horizons of Evolutionary Robotics*, Cambridge MA, 2014. The idea of a machine able to alter its own instructions is well rooted in Alan Turing ideas: see J. COPELAND, *The Modern History of Computing*, in *The Stanford Encyclopedia of Philosophy*, 2017.

[26] On co-evolution, see P.J. RICHERSONA, R. BOYD, AND J. HENRICH, *Gene-culture coevolution in the age of genomics*, in *PNAS*, 107, 2, May 11, 2010, 8985-8992, https://doi.org/10.1073/pnas.0914631107; O.R. GOODENOUGH, *Mind viruses: culture, evolution and the puzzle of altruism*, *Social Science Information*, 34, 2, 1995, 287.

chips in the brain, more fitness for cyborgs, and more[27].

[27] I am in debt with Telmo Pievani and Oliver Goodenough for their extremely kind and helpful suggestions and remarks. Of course, the final responsibility for the article is entirely mine.