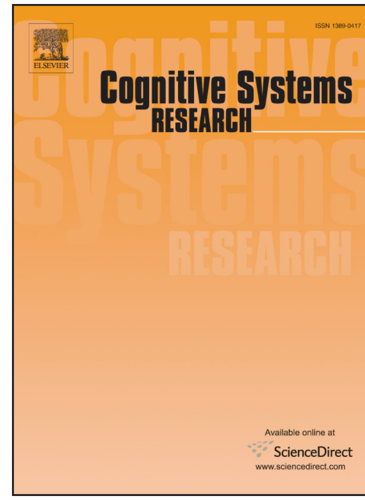

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From Human to Artificial Cognition and Back: New Perspectives on Cognitively Inspired AI Systems

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Abstract

We overview the main historical and technological elements characterising the rise, the fall and the recent renaissance of the cognitive approaches to Artificial Intelligence and provide some insights and suggestions about the future directions and challenges that, in our opinion, this discipline needs to face in the next years.

Keywords: Cognitive Systems, Artificial Intelligence, Computational Models of Cognition, Epistemology of the Artificial.

The scientific vision of the early Artificial Intelligence (AI) can be successfully synthesized by the words of Pat Langley: "AI aimed at understanding and reproducing in computational systems the full range of intelligent behaviour observed by humans" (Langley, 2012). This approach, known as the 'cognitivist' approach to AI according to the terminological distinction provided by Vernon (Vernon, 2014), borrowed its original inspiration –from a historical perspective– from the methodological approach developed by scholars in Cybernetics (Cordeschi, 1991). In this perspective, the computational simulation of biological processes was assumed to play a central *epistemological* role in the development and refinement of theories about the elements characterizing the nature of intelligent behaviour in natural and artificial systems. As a consequence, it was also crucial for the development of artificial solutions inspired by human processes and heuristics (Gigerenzer & Todd, 1999).

Likewise, thanks to the computational approach to Cognitive Science, intelligent systems based on computational models and architectures of cognition have been also proposed with the aim at providing a deeper understanding of human thinking, as originally suggested in the manifesto of the *Information Processing Psychology* (IPP) (Newell & Simon, 1972).

After the first decades of pioneering collaborations, however, starting from the mid 80's of the last Century, Artificial Intelligence and Cognitive Science have started to produce several sub-fields, each with its own goals, methods and evaluation criteria. On the one hand this fragmentation led AI to reach remarkable results in a variety of specific fields by focussing on quantitative results and metrics of performance, and on a machine-oriented approach to the intelligent behaviour (i.e., without taking into account human-inspired heuristics). On the other hand, however, it has significantly inhibited the cross-field collaborations and the research efforts targeted at investigating a more general picture of what natural and artificial intelligence is, and how intelligent artifacts can be designed by taking into account the insights coming from human cognition. Nowadays, in fact, artificial systems endowed with human-like and human-level intelligence (McCarthy, 2007) are still far from being achieved. Given this state of affairs, in the last few years the cognitive approach to AI gained a renewed consideration, both from academia and industry, in wide research areas such as Knowledge Representation and Reasoning, Robotics, Machine Learning, Bio-Inspired Cognitive Computing, Computational Creativity and further research fields that aspire to Human Level Intelligence (also called AGI, Artificial General Intelligence) in designing computational artifacts.

The AIC workshop series on Artificial Intelligence and Cognition[1] (most works in the current Special Issue are selected and extended versions of the papers presented therein), played, in this perspective, a recognized role of promotion and development of this movement, at least in Europe (Lieto & Cruciani, 2013; Lieto et al., 2014; Lieto & Cruciani, 2015; Lieto & Radicioni, 2015).

This sort of 'cognitive renaissance' of AI, essentially, still considers the "cog-

[1] `http://dblp.uni-trier.de/db/conf/aic/`

nition in the loop" approach as a useful one to detect and unveil novel and hidden aspects of the cognitive theories by building properly designed computational models of cognition useful to progress towards a deeper understanding of the foundational roots of intelligence (both in natural and artificial systems). An important methodological aspect to consider within this framework regards the explanatory role played by such artificial models (and systems) with respect to the target natural cognitive systems they take as source of inspiration. In particular, models and systems based on the methodological approach known as *functionalism*[2] and, therefore, purely based on a weak equivalence (i.e. the equivalence in terms of functional organization) between cognitive processes and AI procedures are not good candidates for providing advances in the science of cognitive AI (and this is the case, for example, of technologies like IBM Watson. In this case, in fact, the adoption of the expression "cognitive system" represents a misuse). On the other hand, since it is currently not possible to reproduce a realistic strong equivalence between a computational model/system and a target natural system (such as human cognition),[3] the only way to make progress is based on the development of plausible structural models of our cognition based on a more constrained equivalence between AI procedures and their corresponding cognitive processes. Only models and systems based on the design constraints proposed by the "structural" approach[4] can be considered good

[2]Functionalism was introduced in the philosophy of mind by Putnam in his seminal article entitled *Minds and Machines* (Putnam, 1960). In its more radical formulation it postulates the sufficiency, from an epistemological perspective, of a weak equivalence between cognitive processes and AI procedures and propose that, from an explanatory point of view, the relation between "natural mind" and "artificial software" can be based purely on a macroscopic equivalence of the functional organization of the two systems. This position has been widely criticized in the literature in the last decades (also by Putnam himself).

[3]This phenomenon is known as the "Wiener paradox", and can be summarized through Wiener's own words about the fact that "the best material model of a cat is another or possibly the same cat" (Rosenblueth & Wiener, 1945). In short, this "paradox" advocates for the need of the realization of proxy-models, not *replicas*, of a given natural system by pointing out the difficulty of such challenge.

[4]Differently from the *functionalism*, the structural approach claims for the epistemological

"proxyies" of a the target cognitive system taken as inspiration, and can play an explanatory role about it (Cordeschi, 2002; Miłkowski, 2013).

According to such approach, these kinds of models and systems can be useful both to advance the science of AI in terms of technological achievements (e.g. in tasks that are easily solvable for humans but very hard to solve for machines, such as - for example - in common sense reasoning) and to play the role of "computational experiments", able to provide insights and results useful in refining or rethinking theoretical aspects concerning the target biological system used as source of inspiration. This perspective –along with the many challenges it forces us to accept– represents the pillar of this Special Issue and, at different levels of granularity, the papers selected in this issue illustrate systems that can be ascribed to this approach of cognitive AI.

Under a historical perspective, this Special Issue also appears in a very important occasion since in 2016 falls the 60th anniversary of the Dartmouth Conference, the event which actually inaugurated the history of Artificial Intelligence (AI) and Cognitive Systems research. As mentioned, many of the pioneers who settled AI as a research discipline shared the dream of (re-)creating high-level intelligence through computational means, i.e., achieving human-level AI by taking inspiration from the heuristics of the human cognition. This goal is still being pursued (although with varied interpretations) by many researchers all around the world, and it still represents one of the main challenges for the AIC community.

In the following we provide a quick tour on the works appearing in the Special Issue. The article *What is 'Wrong' in a Neural Model* by Alessio Plebe presents a biologically plausible neurocomputational model of moral behaviour; such a model is implemented in a neural network that combines reinforcement and Hebbian learning. The model is used to simulate the interaction of the sensorial system with emotional and decision making systems in situations involving

need of artificial models whose "functions" are designed and implemented by considering the same "structures" (i.e. the same biological and cognitive "constraints") of human cognition.

moral judgments. The article *Object Replacement and Object Composition in a Creative Cognitive System. Towards a Computational Solver of the Alternative Uses Test* by Ana-Maria Olteteanu & Zoe Falomir proposes a creative approach to problem solving defined through a cognitive architecture where a goal can be reached by replacing a missing object with another one with similar affordance; alternatively, a suitable object can be composed with other ones that are present in the environment. The work *Hierarchies of Self-Organizing Maps for Action Recognition* by Haris Dindo, Miriam Buonamente and Magnus Johnsson presents a hierarchical neural architecture, based on Self-Organizing Maps (SOMs), designed to recognize observed human actions. The article *Image Schemas in Computational Conceptual Blending* by Maria M. Hedblom, Oliver Kutz and Fabian Neuhaus is an investigation on the role of image schemas in the concept creation process; it also shows how this approach has led to the development of a library of formalized image schemas that provide heuristics for the computational blending of concepts. The work *Multilayer Cognitive Architecture for UAV Control* by Stanislav Emel'yanov, Dmitry Makarov, Aleksandr I. Panov and Konstantin Yakovlev presents an architecture designed for dealing with control problems in the field of unmanned aerial vehicles. The proposed architecture includes a three-layered structure, including a strategic level (accounting for high-level cognitive tasks, such as planning, prioritizing tasks), a tactical level (concerned with navigation activities) and a reactive level (intended to generate various sorts of control signals).

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