Extending the Knowledge Level of General Cognitive Architectures with Conceptual Spaces

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Cognitive architectures (CA) have been historically introduced i) "to capture, at the computational level, the invariant mechanisms of human cognition, including those underlying the functions of control, learning, memory, adaptivity, perception and action" (Oltramari and Lebiere, 2012) and ii) to reach human level intelligence, also called AGI (Artificial General Intelligence), by means of the realization of artificial artifacts built upon them. During the last decades, many cognitive architectures have been realized - such as ACT-R (Andersson et al. 2004), SOAR (Laird 2008) etc. - and have been widely tested in several cognitive tasks involving learning, reasoning, selective attention, recognition etc.

One of the open problems of such computational artefacts regards, however, the fact that they are general structures without a corresponding "general" content, able to cover the different types of knowledge available to humans and used by them in decision making processes. In other terms: the type of knowledge represented and manipulated by such CAs is homogeneous in nature. It mainly covers, in fact, only the so called "classical" part of conceptual information (that one representing concepts in terms of necessary and sufficient information, see Frixione and Lieto, 2012 on these aspects). On the other hand, the so called "common-sense" conceptual components of our knowledge (i.e. those that, based on the notions developed in the experimental and theoretical cognitive sciences, allow to characterize concepts in terms of "prototypes", "exemplars" or "theories") is largely absent in such computational frameworks. Common sense conceptual representation and reasoning, in fact, is only partially allowed by the symbolic-based formalisms and structures of the "chunks" adopted by the most common general CAs (e.g. ACT-R and SOAR), or by alternative hybrid solutions adopted by CAs such as CLARION (Sun, 2006).

This aspect represents both a technological and an epistemological problem: the lack of the common-sense representational and reasoning level, in fact, affects not only the performance of artificial agents (embodied or not) based on such CAs, but also the explanatory power of the heuristics adopted within the CAs compared to the human decision making strategies (Lieto 2015).

Conceptual Spaces (Gärdenfors, 2014) have been proposed as a general framework for representing knowledge and have been widely adopted in many applications and cognitive systems solving specific problems, ranging from vision to human-robot interaction (see Zenker & Gärdenfors, 2015 for a recent overview).

In particular, they have been applied both - under a unified representational perspective - as an intermediate representational level allowing to ground both symbolic and sub symbolic representations (Chella, Frixione and Gaglio, 1997; Chella, Frixione and Gaglio, 2000) and, more recently - in a heterogeneous representational perspective (Lieto 2014; Lieto et al 2015a) - as a unified framework for peculiarly representing and reasoning on common sense information (i.e. prototypes and exemplars-based) associated to a given concept. Such heterogeneous representational perspective has been provided to be integrable in Cognitive Architectures (and with their structural mechanisms of memory retrieval and storage of conceptual information) by adopting the framework of "*heterogeneous proxytypes*" (Lieto 2014).

The *heterogeneos proxytypes* approach is a revision of the Prinz's proxytype theory (Prinz 2002), inspired by the work of Barsalou (Barsalou 1999), considering concepts as temporary constructs of a given category, activated ("going proxy") in working memory as a result of conceptual processing activities, such as concept identification, recognition and retrieval. In the revised view of this theory the availability of a wider range of conceptual representation types, corresponding to the kinds of representations hypothesized to co-exists by the *heterogeneous approach* is assumed (e.g. "prototypes", "exemplars" and so on, for a review see Machery 2010)[1].

In this perspective, *proxytypes* are *heterogeneous* in nature (i.e., they are composed by heterogeneous networks of conceptual representations and not only by a monolithic one) and act as 'semantic pointers' towards the same reference concept. In this framework, each body of knowledge provides specific types of information and specific access and reasoning procedures to the concept they refer to.

As showed in (Lieto et al. 2015b), in this approach, Conceptual Spaces can be very powerful in representing and reasoning on common sense information, and can be additionally integrated with the processes and the representations of the knowledge level of different CAs. I will present the rationale adopted (and under adoption) for the integration of the Conceptual Spaces framework in different CAs (ACT-R, CLARION and LIDA) making different assumptions about the underlying representational and reasoning structures of our cognition. Finally I will present some results obtained in categorization tasks with such Extended-CAs showing the benefits of the proposed integration with the Conceptual Spaces.

[1] The characterization in terms of "heterogeneous proxytypes" also allows to deal with the problem of the "contextual activation" of a given information based on the external stimulus being considered. The general idea is that, when we categorize a percept, we do not activate the whole network of knowledge related to its assigned category. Conversely, we only activate the knowledge that is "contextually relevant" in its respect. In other terms, we only proxyfy the type of representation that minimizes the distance w.r.t. the percept (see Lieto 2014, for further details).

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