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Author
Liu, Hsi-wen

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Language-Like Representation in Embodied and Situated Cognition: A Case Study of a Situated Robot's Planning

Hsi-wen Liu (hwliu@pu.edu.tw)
Division of Humanities, Providence University
200 Chung-Chi Rd, Shalu, Taichung County 433, Taiwan

Interests in embodiedness and situatedness have increased in all disciplines of cognitive science (Clark, 1999). Such interests generally concern the complex interplay between robotic (or neural) systems and their local environments. A number of theorists and philosophers with such interests cast strong doubt on the need of a rule-based search and even the need of overall *internal* representations (Brooks, 1991; Beer, 1995; Keijzer, 1998).

Also with those interests, Andy Clark and some co-authors raise significant reasons for reconsideration regarding the above doubt (Clark, 1997ab, 1999; Clark and Grush, 1999; and others). The gist in general is that in the above systems internal representations can exist, by playing a two-fold role. On the one hand, the internal representations in the systems constitute descriptions of the world, and on the other, these representations serve as *internal* representations/codes to *control* those systems' tight coupling agent-environment interactions. With such a two-fold role, those internal representations are named *action-oriented representations* (Clark, 1997ab, 1999). This two-fold role has been exemplified by a number of robotic architectures with on-line control of situated activities (e.g., see Mataric's TOTO discussed in Clark (1997ab, 1999)). A question with the above theory of action-oriented representations is whether some of those representations can be characterised in language-like codes. If the answer is yes, it would constitute a link between the situated-and-embodied approach and traditional cognitive science.

Conforming to the above theory of action-oriented representations, this work contends that the answer is indeed yes. That is, language-like codes can play the above two-fold role in the control of tight coupling agent-environment interactions. This claim is exemplified by the robot arm designed by Maes (1990).

The robot activities, as Maes (1990) sees, lead (though not in terms of abstract thoughts) to the *planning* of various actions in support of a goal—catching an appropriate tool to paste sand on a board. The architecture of that robot arm is hybrid. It consists of several *action modules*, which perform certain motor actions. The architecture of each action module includes *both* symbolic codes (i.e. language-like codes) which describe environmental conditions (or arm states) *and* the control over the (numerical) energy flowing across those action modules. When the robot system observes, or initiates an action, those modules change their inherent energy and their condition lists of the environment (or the arm states). An action module initiates its action, when the energy flowing in the module goes beyond a certain threshold. Yet, the energy flowing in a certain module may go below its threshold and hence need a fine-tuning of the energy flowing among certain relevant modules, and even a fine-tuning of the threshold itself.

The present work argues that the language-like codes in the architecture of Maes' (1990) robot arm play the aforementioned two-fold role of action-oriented representations. The steps of argument are as follows.

1. The architecture of the robot arm clearly adopts certain language-like codes, which describe certain conditions.
2. There is a limited degree of searching among those language-like codes, which serve as initiating conditions of the action to be carried out by an action module.
3. The activities of the robot arm are situated, because of the tight coupling agent (arm)-environment interactions.
4. The computation for the control of the above interactions is embodied, because the energy spreading among the relevant action modules (and even a threshold itself) is sensitively fine-tuned in response to the recurrent re-try of initiating a single module's action.

As the above argument shows, the language-like codes in the architecture of Maes' (1990) robot arm play the two-fold role of action-oriented representations, in support of the robot's situated and embodied activities. This constitutes a link between situated-and-embodied approach and traditional cognitive science.

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