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Why Embodied Artificial Intelligence is not so Embodied?

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Abstract: In recent years, Artificial Intelligence (AI) has concentrated its research interest in the philosophical theories of embodied cognition (EC). Seeking a way out of the GOFAI's dead-end attempt to develop intelligent robots with the ability to perform complex tasks in unknown and changing environments, AI adopted basic principles of the EC, like the body's direct interactions with the world. This view inspired AI researchers to abort traditional "sense-plan-act" architectures in favor of bottom-up approaches that focused on the integration of action and perception. However, the embodied AI community, tried to integrate these concepts by encapsulating them into frameworks that relied heavily in fundamental assumptions and mechanisms, that violated core principles of EC, both ontologically and practically, as in the utilization of sensorimotor knowledge in the sense of information extraction -instead of using sensorimotor knowledge in the sense of a meaningful "know-how", the utilization of internal states and representations coupled with computational information processing based architectures, and the conceptualization of affordances grounded in categorization and internal representations. In this paper our objective is to identify and classify the fundamental principles and properties, by which embodied AI and EC differ, in a philosophical as well as in a technical context. In our view, grasping this fundamental ontological bounds, apart from being philosophically interesting, will contribute to the understanding of the limits of the capabilities of embodied AI, compared to the concept of embodied cognition.

Keywords: embodied cognition, embodied artificial intelligence, representations, affordances, meaning

One of the fundamental problems AI has to face - still the same way it had to face it from the era of its birth, is the problem of knowledge, i.e the possible ways by which an agent can acquire knowledge of its environment and make use of it. GOFAI as well as the current state of the art in the field, is based on the views of Descartes (1637) according to which knowledge and understanding of the world constitutes in

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the formulation and the use of the appropriate representations of the outer world in the mind of an intelligent entity. Latter, Kant added the idea of the existence of rules that governed these very elements, while Frege showed that these rules could be formalized and therein manipulated without the need of any interpretation. Adopting these views , researchers in AI still focus on finding efficient ways to define the particles - representations of the environment in which an agent is supposed to operate.

In order to overcome the problems that GOFAI faced when dealing with complex problems and environments, cognitive scientists shifted their research interest in the study of knowledge structures, other that the representational and descriptive ones, i.e knowledge structures that were based on the aspect of “know how”. In order for an agent to be defined as embodied it should: 1) Be part of the world and inside the world, i.e the world not just simply be constituted by a collection of representations inside the agent 2) Utilize at every instance the appropriate “set of information“ that the world has to offer 3) Identify various situations and facts of these situations as affordances, i.e. possible ways that give the opportunity to act in a way that these opportunities are not necessarily predefined in terms of representations. Consequently, the agent has to be able to give meaning to each particular situation and aspect of this situation - it has to understand, in a way that this understanding is not merely exhausted in terms of its content, and such that it will provide the agent the knowledge of what to do next. This is the basis on which we are going to compare embodied AI and EC in order to provide an answer to the question: Is embodied AI, really embodied after all?

[1] Representations: While GOFAI treated representations as amodal, in embodied AI the concept of modal representations was introduced in order for it to be consistent with the view of an embodied agent (Pezzulo, Barsalou, Cangelosi, Fischer, McRae, Spivey, 2011 • Hoffman, 2012) .

These representations may correspond to multiple modalities, i.e visual, sensory and motor modalities while their inclusion in the model depends on the specific embodiment of the agent. Different modalities can potentially contribute differently in action control while representations of different modalities are associated into patterns via connections or association areas.

However, despite the efforts of researchers in embodied AI to define the appropriate perceptual representations, the very use of representations remains deeply problematic for a world cannot be captured as a mere collection of context-free representations.

As Dreyfus (1992) suggests "the world is an organized body of objects, purposes skills and practices, in terms of which activities have meaning and make sense". Context free representations cannot provide the artificial agent the holistic view of it' s situation, the holistic view that would be necessary for him to directly perceive and interact with the environment, since by definition context free representations are detached and isolated from the situation within the agent is inside. A table can be described as a physical object that has four legs, it can be described in terms of the material it is constructed and it can be described by its shape, but no such

description is ever sufficient to define the function of a table in any given situation, for these descriptions are predefined outside of the situation and outside of the agent's own world.

According to embodied cognition, sensorimotor knowledge constitutes our ability to perceive and act, but this kind of knowledge does not correspond to simple factual knowledge about an entity or a domain, ie, visual representations of a red apple, but it corresponds to the relationship of an agent with its environment. Perceiving something as a table, means that we perceive it as something upon we can exercise a particular skill .On the other hand, knowledge of tables does not merely correspond to an understanding that a table can afford a place to eat or to read, but further understanding of how the agent's relation to a table will change according to various actions that are context-dependent. What matters is not the intrinsic character of an agent's sensations or the information it gathers while listening to or looking at its environment, but the implicit understanding of the structure of its own sensations (Morse, Harrera, Cleeves, Monteballi, Ziemke, 2011• Noë, 2004) and the ways this structure changes and reconfigures its architecture in the context of various actions. In that sense, modal representations might account as embodied in the strict sense, but they cannot enable the artificial agent to truly interact with its own environment. Furthermore, the architecture of their structure inside the agent, for instance the existence of a single association area or multiple hierarchical association areas is predefined and even if a designer allows its reconfiguration - this reconfiguration should have to cope with the world's changing dynamics and the specific situation of the agent.

[2] Frame Problem: But the world's dynamics and the given situation put forth another equally important problem that Wheeler (2005) describes as the frame problem: “[G]iven a dynamically changing world, how is a nonmagical system... to take account of those state changes in that world ... that matter, and those unchanged states in that world that matter, while ignoring those that do not? And how is that system to retrieve and (if necessary) to revise, out of all the beliefs that it possesses, just those beliefs that are relevant in some particular context of action?”

In other words, how can it be possible for an agent to retrieve the relevant facts of the situation he is into and leave out all the irrelevant information? In order to retrieve the relevant facts, an agent should have to categorize the situation and search through all facts that could be relevant with this situation. However, under this approach, the more rules and the more facts the agent takes into account and represents, the more longer it would take to find the relevant ones. Clearly this solution might work well in predetermined situations or controllable environments, but it would fail to scale up in more complex scenarios. One possible solution would be to gather statistics of the various facts that seem to affect the actions of the agent and declare the relevant facts on the basis of the current statistics. However, particular facts might be relevant only when combined with other facts of the environment which in turn implies that one should keep track of the combinations of all facts as well. On the other hand relevance of a fact is not a property of the domain but a property of the particular situation the agent is into.

In general, the frame problem as is called, can be viewed as a metaphysical, a logical or an epistemological problem (Zambak, 2013). The metaphysical aspect of the frame problem is concerned with finding and implementing general rules that govern our experience in the world. For instance Janlert (1988), views the frame problem as the problem of the form and internal working of the representations. According to the logical aspect, the frame problem is a part of commonsense reasoning and logic. For instance, according to Freeman (1992), the frame problem is a question of finding a reasoning procedure in a dynamic process. Finally according to Dennett (1978) the frame problem "is an abstract epistemological problem that was in effect discovered by AI through experimentation". But the frame problem still largely unresolved-should no longer be treated as a problem arising from the use of representations. Appropriate knowledge mechanisms and structures should be designed such, that take into account the situatedness and the embodiment of the agent, and such that the traditional view according to which an agent constitutes a separate system from its environment is aborted (Gounaris, 2012).

[3] Affordances: By exploiting the relationship between an agent and its wolrd, researchers can concentrate their efforts in designing mechanisms and procedures that will allow the detection of opportunities for action. These opportunities for action, formally addressed as affordances were introduced by Gibson in 1977. According to McGrenere and Ho (2000), affordances have the following three fundamental properties i) affordances exist relative to the capabilities of a particular agent ii) affordances are independent of an agent's ability to perceive them and iii) affordances do not change as the goals of an agent’s change. In AI, affordances are treated as internal functional representations or as internal relations between external objects and the agent's own interactions (Horton, Chakrabortry, Amant, 2013). Consequently the affordances the artificial agents can discover depend not only on their perceptual abilities, but also on the types of exploratory behaviors with which they have been preprogrammed (Stoytchev, 2005). Clearly the view that AI has adopted contradicts Gibson's own ideas and makes direct perception infeasible.

Designing artificial agents that are truly embodied and situated is not an easy task. Nor is the reexamination of the knowledge structures that will allow the artificial agent to directly interact with its own environment. Furthermore when researchers choose the building blocks and the models that are going to be used to the design of an artificial agent, several physical and practical limitations should be taken into account. However designers should keep in mind the limitations the fundamental principles and assumptions they adopt, pose on the performance of the system and the on the feasibility of the goals they pose. Most importantly, they should keep in mind that the most important limitations of the current embodied AI, are not simply technical or practical. Instead, these limitations, arise as a consequence of the ontological foundations on which AI is rooted. Consequently, no positive answer seems to suit the question of whether a truly embodied agent could be constructed, at least not as long as the fundamental principles and assumptions of AI fail to seamlessly be attuned to the fundamental principles of embodiment.

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