Embodied/Situated Cognition and Evolutionary Devolopment as They Apply to Artificial Intelligence
CMSC828D Report 2

Cody Buntain
Department of Computer Science
University of Maryland

September 30, 2012

1 Introduction

Much of the work in artificial intelligence (AI), automated planning, machine learning, computer vision, and related fields focus primarily on the capabilities of formal logic, statistics, and other mathematical tools to emulate human cognitive capabilities. Though these areas have in fact seen significant success (e.g., spam detection, information retrieval, etc.), the much-sought goal of a human-level, strong AI has been firmly outside the reach of the field. In the past two decades, however, seekers of strong AI have gradually been waking up to a new paradigm: it may not be possible to replicate human-level cognitive capabilities divorced from the human physical experience of the real world. Restated, human-level reasoning cannot be achieved using the mechanics of formal logic, probability, and statistical inference *alone*; human-level cognition instead requires an approximation of human physical and social experience in which to learn.

This notion of the intrinsic roles of physical, social, and environmental interaction in cognition go by the terms "embodied cognition," situated cognition," and "evolutional developmental biology" (or evo-devo) respectively. In typical form, AI researchers have borrowed these concepts from fields like biology, sociology, philosophy, and other fields attempting to understand how complex systems and cognition evolve. Results of this cross-domain pollination have lead to a myriad of interesting projects and results that are strikingly different from previous mind-centric, formal approaches.

2 A Better Understanding of Understanding

To gain a better understanding of these new types of cognition and how they have impacted the AI field, it is worth a brief exploration of each topic in turn. It is easiest to begin this exploration with "embodied cognition" because it provides the most straightforward expansion of the typical AI approach. Traditional AI research focuses a great deal on logical and symbolic manipulation in what can be viewed as a "disembodied" model of the mind (such views were also held by many biologists studying the theory of mind as well, so this view was certainly reasonable). Embodied cognition, however, would say that this model is insufficient in that the cognitive experience transcends the strict confines of the brain and is equally influenced by the physical structure and capabilities of the body.

Examples of this embodied cognition are easy to find. In communication, body language and tone of voice convey a great deal of additional and *critical* information about meaning beyond just the spoken word (as anyone who has tried to detect sarcasm via text can attest). Similarly, understanding concepts is greatly facilitated by the visual sense. If asked to describe the necessary and sufficient conditions for an object to be a car, a human would have difficulty enumerating the special cases or would provide a very restrictive set

of rules (e.g., is a three-wheeled vehicle a "car"? what is the difference between a three-wheeled motorcycle and a three-wheeled car?). If shown a three-wheeled car versus a three-wheeled motorcycle, however, one could much more easily make the distinction. The conclusion is that logic, rules, and symbols without all of this supplemental information accessible via the physical world greatly impairs the cognitive abilities of "disembodied" systems in a fundamental way. As such, artificial systems can never be truly strong without expanding beyond the confines of the mechanical box and including a notion of the body and the perception it provides.

Situated and embodied cognition share many similarities and are at points difficult to distinguish (the literature will occasionally use the terms interchangeably), but the distinction, while subtle, is clear: situated cognition stems not just from the physical structure, i.e., embodiment, but from the interactions and practices of that structure in the real world and with those who inhabit it. In simple terms, situated cognition can be partially distilled to the saying: "learn by doing." That is, the social context and physical interactions with the real world are intrinsic parts of cognition and learning and to exclude them is to do neglect the very phenomena human-level AI researchers wish to mimic. To differentiate situated cognition from the auspices of traditional AI, one can return to the conventional Blocks World environment. Traditional AI would attempt to encode rules for block manipulation that describe constraints like how one must move a block A off of a block B before block B can itself be moved. Under situated cognition, the rule mechanism would be discarded in favor of allowing the system to practice moving the blocks in the real (or a suitably simulated) world, visually observe how a teacher would interact with the blocks, and potentially play with another entity to discover such constraints. This social model better mimics how humans learn, which should open the door for more realistic and more versatile AI systems.

Evo-devo in a way subsumes both the notions of embodied/situated cognition in its thesis: an organism's development and learning leverage simple mechanisms and are inseparably linked to its interactions with and, more importantly, the feedback from the environment. Translating to AI, for a system to exhibit true intelligent behavior, it can be composed of simple components that must be able to interact with the environment, observe feedback, and adapt to pressure the environment exerts back on the system. A concrete example of this area as applied to AI systems could be two robots, each composed of identical, interconnecting, movable segments in which robot A is placed into an environment filled with sand, and robot B is placed into an environment filled with water. Ideally, robot A would learn methods for locomotion on the sand through trial and error while robot B learns a completely different set of locomotive methods for movement in water even though both robots are initially equipped with the same tools. Cross-over between the traditional evo-devo biological field and AI is fairly recent and is a cutting edge research area in robotics, called evo-devo-robo, the state of the art of which will be discussed below.

3 Contrasting Models of Cognition

The overarching theme of embodied/situated cognition and evo-devo should be clear: for an artificial system to exhibit a truly human-level intelligence, it must have some physical presence with which it can interact, observe, and adapt to the environment. As mentioned, this learning paradigm differs significantly from traditional, more formal AI research. For instance, the logicist view of AI would say that logic provides the foundation of cognition, and without it, one could not communicate rigorous arguments or proofs. That is, a set of logical rules provides the frame through which cognition is achieved. Perhaps the more embodied/situated approach would respond and say that logic grew out of the social interactions necessary to communicate ideas in a rigorous manner and is therefore a product of the situated view.

Similar to logicism, Cycorp's Cyc knowledge server attempts to provide the foundation for a human-level reasoning system by constructing a vast knowledge base of inference rules and facts of so-called "common knowledge." The idea behind Cyc is to code into a program the tools necessary to *understand* most assertions and rules the system could encounter. Of course, as with logicism, one could argue that, through societal interactions, situated cognition would suggest a human-level AI system could be *taught* many of these common-knowledge facts and rules in a manner not requiring such a significant hard-coding effort.

4 Existing Work and the State of the Cognitive Art

A considerably large amount of work has been performed in these new areas. In fact, Dr. Antonio Chella of the University of Palermo just recently gave a presentation as part of the University of Maryland's Metacognition Seminar entitled "Toward Robot Consciousness" in which he made the case for the necessity of human-level perception in robot cognition as well as reviewing a decade's worth of work in the area. Cicerobot, a robotic and interactive museum guide, is an example Chella's work into integrating perception and situated cognition into an automated system capable of adapting its tours to the preferences of the audience on the fly.

Another more local example of embodied cognition at work can be found in MIT's Cog project by Brooks. In this project, MIT's Human Robotics Group built a robotic, humanoid torso capable of learning from societal interactions with humans. Through extended interaction with humans and self-exploration, the Cog project was able to learn kinesthetic methods for limb, spine, and head locomotion along with limited human-like facial expression.

Beyond these works, however, cutting edge research is now exploring a fuller spectrum of the evo-devo concept through evo-devo-robo. In fact, in the 2012 GECCO conference, a special workshop was dedicated specifically to this topic and how it is being applied to robotics. Some of the novel research presented includes expanding a robot's adaptations from purely neurological to include morphological; that is, developing robots who can alter physical form in response to environmental stimuli. Another such topic concerns robotic systems that employ situationally cognitive learning methods such as self-guided exploration of its environment as a means for autonomous learning. Such learning could include peer interaction, teaching, or other tenets of the situated cognitive theory.

For further reading on embodied/situated cognition and evo-devo as they apply to AI, artificial life, and robotics, the reader is encouraged to explore the following resources: [1, 2, 3, 6, 5, 7, 8, 9, 10, 11, 4]

References

[1] J. M. Brille. Situated cognition. In *Emerging Prospectives on Learning, Teaching, and Technology*. The University of Georgia, http://projects.coe.uga.edu/epltt/index.php?title=Situated_Cognition, 2012.

[2] R. A. Brooks, C. Breazeal, M. Marjanovic, B. Scassellati, and M. M. Williamson. The cog project: Building a humanoid robot. *Computation for Metaphors, Analogy, and Agents*, pages 52–87, 1999.

[3] A. Chella and I. Macaluso. The perception loop in cicerobot, a museum guide robot. *Neurocomput.*, 72(4-6):760–766, Jan. 2009.

[4] S. Doncieux, Y. Jin, and J.-B. Mouret, editors. *Evo-Devo-Robo: Evolutionary Robotics and Developmental Robotics*, http://pages.isir.upmc.fr/evodevorobo/, September 2012. GECCO 2012.

[5] S. Doncieux, Y. Jin, and J.-B. Mouret. Evo-devo-robo workshop program. In *Evo-Devo-Robo: Evolutionary Robotics and Developmental Robotics*, July 2012.

[6] F. A. e Costa and L. Rocha. Embodied and situated cognition. In *Artificial Life*, volume 11, pages 5–11. http://informatics.indiana.edu/rocha/embrob/, 2005.

[7] Y. Jin and Y. Meng. Morphogenetic robotics: An emerging new field in developmental robotics. *IEEE Transactions on Systems, Man, and Cybernetics, Part C*, 41(2):145–160, 2011.

[8] B. Scassellati. Cog. Website, MIT Artificial Intelligence Lab, http://www.ai.mit.edu/projects/humanoid-robotics-group/cog/, September 2012.

[9] Wikipedia. Embodied cognition – artificial intelligence and robotics. In *Wikipedia.org*, http://en.wikipedia.org/wiki/Embodied_cognition#Artificial_intelligence_and_robotics, September 2012.

[10] B. G. Wilson and K. M. Myers. Situated cognition in theoretical and practical context. In *Theoretical Foundations of Learning Environments*. University of Colorado at Denver, http://carbon.ucdenver.edu/~bwilson/SitCog.html, March 1999.

[11] R. A. Wilson and L. Foglia. Embodied cognition. In E. N. Zalta, editor, *The Stanford Encyclopedia of Philosophy*. http://plato.stanford.edu/archives/fall2011/entries/embodied-cognition/, fall 2011 edition, 2011.