Modeling Human Infant Learning in Embodied Artificial Entities to Produce Grounded Concepts

Eric Berkowitz
Roosevelt University
1400 N. Roosevelt Blvd.
Schaumburg, IL 60173
eric@cs.roosevelt.edu

Abstract

I present a system for concept development in an artificial entity. The concept development is designed around the foundations of human cognition while at the same time remaining grounded in the agent or robot's own perception of its world.

1. Introduction

I present here ASPARC, as a system that, utilizing a unique concept acquisition system, can develop concepts that are both grounded in its existence and modeled after human reasoning.

2. PHYSIOLOGY

ASPARC has a complete simulated body. In order to distinguish one type of movement from another, such as stepping forward or stepping sideways, the system was given controllable knee and hip joints. ASPARC steps forward by first stretching out a leg and then pulling the rest of its body forward in a manner very similar to a human step. As it does this it receives feedback from all of its systems and parts. The feedback is used to build memories, to activate existing memories (reminding) and to activate higher level patterns (words and concepts).

3. META-SPATIAL PERCEPTION

ASPARC's initial perception is meta-spatial. As in earlier systems (Berkowitz, 2000, Berkowitz, 2001), the theory that human perception is spatially grounded was modeled, but it was determined that for this perception to frame the most basic memories it must be by nature and not nurture. Spatial perception is part of how our minds are designed or have evolved, not learned behavior. For ASPARC, basic physical motion in reality is not the underlying foundation for perception; rather, it too is perceived in terms of a meta-spatial mapping into an instinctive meta-spatial perception that is an evolved systemic manifestation of a system with physical existence in its world. ASPARC does not first learn of movement and then decide to use it as the underpinning for its reasoning and symbolic representation of its world. From its very first moments it perceives everything it experiences in terms of itself. Without this foundation there is no perception.

4. INITIAL LEARNING

Each possible action ASPARC is capable of performing is tried. The actions are sorted into two groups, those that change the relationship to the goal in the meta-space and those that do not. The system then tries every pairwise combination the act that singularly did not affect the goal to see if, when performed as a temporally set, they do meet this criterion. ASPARC acquires the knowledge that within its set of possible actions.

ASPARC's training is designed around a new foundation which is devoid of subsumed levels of abstraction; the concept of infinity. This is not an understanding of the meaning of infinity; rather, it is a mode of thinking.

5. CREATING THE BASE CONCEPTS

Infinity based perception gives a definition of walk that does not suffer from any of the problems described above. It has no hidden levels of abstraction, and does not rely on any higher level mathematical concepts. Further, this definition allows ASPARC to recognize a "walk" of any length and to create plans for walking without needing any *a priori* knowledge. Being five locations from the goal does not require a five step solution in any explicit way. Being away from the goal by any, even indeterminate number of locations, requires a single generalized solution of walk. ASPARC's basic understanding, being infinity based, divides the possible relationships with the goal into only two: the unitary *at* and the infinite *away*. The single infinite set of *away* problem-states are all addressed by the single infinite solution "walk". Discrete measures of distance are actually a level of abstraction built above this perception. Distance can only be defined after walk, as the finite number of steps in a given walk. Thus the concept of a finite set is added to the concept of unitary

and infinite in a natural grounded way.

6. RELATION TO THE HUMAN MODEL

In a human child's development also, its first mathematical concepts are nominal. Numbers are unique tokens or names. The child can distinguish 2 from not-2 just like he/she can distinguish mommy from not-mommy and me from not-me. There is an implicit but not conscious awareness of finite versus infinite that is only formalized much later in the child's study of mathematics (Elkind, 2001, Mix et al., 2002, Spelke and Tsivlin, 2001). Children learn distinctions between concepts, particularly quantitative ones, before they develop formal, distinct definitions for them (Walkerdine, 1988, Piaget, 1952).

7. NEW CONCEPTS, NEW MEANING THROUGH NEW MEMORIES

During its training, ASPARC develops a new complex concept with the following sequence of sub-concepts:A memory "away", a memory of ($step^+$, a memory of ($step^+ \Rightarrow failure$, an a memory of ASPARC "at" the goal.

ASPARC builds grounded a concept of "do-something" as described in Greene and Chien (1993), a concept which as shown Berkowitz and Greene (2001) can be used to to form the foundation for spatial reasoning. Further, the do-something concept is completely defined in terms of introspective primitives and as such can be re-enacted by the system as well as used for reasoning. Whereas before ASPARC was limited to concepts defining its basic actions and the meta-concept "go," it now has, through the use of this new memory, a term for performing a specific act.

8. DISCUSSION

ASPARC's predecessor worked with built-in atoms designed by its developers. It was believed at the time that these atoms were the most basic representations possible for the system's base concepts. However, when given the ability to develop its own atoms in a completely empty memory, ASPARC's definitions are very different and demonstrates many of the hidden concepts which, rather than constituting atoms, are actually built upon them. Examples are the concept of path and objects. In the earlier systems, *path* was placed in the memory as an ordered collection of *objects* upon which all concepts of *doing* could be built. It was believed that this represented base concepts. ASPARC's autonomous ability to develop its own atoms demonstrates that this was incorrect and reveals the levels of hidden concepts in this original definition. ASPARC builds the concept of a path out of two locations without higher level concepts such as ordinality. Also, the concept of a step is represented in ASPARC's memory as a movement between locations not objects. ASPARC's grounded definition for step revealed the hidden higher level concepts subsumed in earlier attempts at priming the mem-

ory, such as the implied concepts of objects, order, and contiguity. ASPARC's concept of a path involves two locations, not object. The path is defined in terms of moving between these locations and the steps, defined earlier as objects, are now to ASPARC, the act of stepping, that is, the smallest episodic concept that changes its location. ASPARC's definition is truly grounded in introspective atoms requiring no prior definition of objects, order, contiguousness or other concepts. It forms a far more natural foundation for the mapping of actions.

9. CONCLUSION

ASPARC, using its goal orientation, infinity-based perception, and grounded concept development mechanism, develops grounded concepts appropriate for thought and reasoning based on a system that organizes its own memories based on atomic concepts emanating from its perception of its own existence.

References

Berkowitz, E. G. (2000). *Metaphor-Based Reasoning for Software Agents and Heterogeneous Robots Using Body-Based Feeling Sequences*. PhD thesis, Department of Computer Science Illinois Institute of Technology, Chicago, IL.

Berkowitz, E. G. (2001). Body based reasoning using a feeling-based lexicon, mental imagery and an object-oriented metaphor hierarchy. In *Proceedings of the 14th Biennial Conference of the Canadian Society for Computational Studies of Intelligence, AI 2001*, pages 47 – 56, Ottawa, Canada.

Elkind, D. (2001). Early childhood education developmental or academic. *Education Next*.

Greene, P. H. and Chien, G. H. (1993). Feeling-based schemas, neuralarchitectures, and distributed ai: From schema assemblage to neural networks. In *Proceedings of the 1993 Workshop On Neural Architecture and AI*, pages 112 – 115, Los Angeles, CA. University of Southern California.

Mix, K. S., Huttenlocher, J., and Levin, S. C. (2002). *Quantitative Development in Infancy and Early Childhood*. Oxford University Press, New York, NY.

Piaget, J. (1952). *The Child's Conception of Numbers*. P J International, Great Britian.

Spelke, E. S. and Tsivlin, S. (2001). Initial knowledge and conceptual change: space and number.

Walkerdine, V. (1988). *The Mastery of Reason*. Mackays of Chatham, Great Britian.