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Dev E-R: A computational model of early cognitive development as a creative process

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Abstract

This paper describes a computational model named *Dev E-R* (*Developmental Engagement-Reflection*) that, inspired by Piaget's theory, simulates the assimilation-accommodation adaptation process. It is implemented with a new extended version of the computational model of creativity known as *Engagement-Reflection*. That is, this model simulates adaptation as a creative activity. We introduce here the implementation of our model on an agent that is initialized with basic reflex conducts and that through the interaction with a 3D virtual world, it is able to build new behaviors autonomously. The new acquired skills, according to Piaget's theory, are typically observed in children that have reached the second substage of the sensorimotor period.

Keywords: Early cognitive development; Piaget's adaptation mechanism; Developmental agent; Computational creativity; *Engagement-Reflection* computational model

1. Introduction

Creativity is a fascinating characteristic of human being. It has been associated with other abilities and important behaviors such as innovation, imagination, intelligence, originality, problem solving, discovery and particularly with adaptation or adaptability. The ability to adapt to our environment has been seen traditionally (perhaps as of Darwin) as a necessary condition for really creative behavior (Gorney, 2007; Runco, 2007, p. 398). Cohen considers adaptation as the closest synonym to creativity (Cohen, 1989 cited in Runco, 2007, p. 44). She describes it as a series of adaptive behaviors in a continuum of seven levels of development: initially, creativity involves adaptation of the individual to the world; and at higher levels, it involves adaptation of the world to the individual.

The first level of development is called *Learning Something New: Universal Novelty*, which is similar to the *little c creativity* concept by Kozbelt, Beghetto, and Runco (2010, chap. 2) or as Beghetto and Kaufman (2007) suggest, *mini-c creativity*. This kind of creativity is that resulting in products or behaviors that are useful and new to the individual, but not strange or valuable to others (Runco & Pritzker, 1999, p. 9). Cohen considers it can be observed in babies and toddlers as a result of their need to start to adapt to the world. For Piaget, adaptation takes place by means of two processes he called *assimilation* and *accommodation*. The assimilation process allows children to face new situations by using their knowledge from past experiences. For instance, let us imagine that a baby is offered

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an unknown object and then he grabs and sucks it as he has done it previously with similar articles. We can interpret this behavior as that the infant learns that new items can be treated in the same way than old ones. However, what happens if the little one is given a very small toy that he cannot hold? In this case, he experiences a cognitive conflict because his information of the world does not fit reality. When such a cognitive conflict arises, the accommodation process allows children to deal with the new situation by progressively modifying their expertise (throughout the continuous interaction with their environment) in order to incorporate the results of their new experiences. Thus, the baby eventually learns that he can grip small objects if he uses his fingers as pliers. In this way, the creative-adaptive activity of Cohen's first level of development helps us to adjust to our world by, either modifying our perception of the environment so that it fits our current knowledge (adaptation by assimilation), or modifying and producing new knowledge when it does not match reality (adaptation by accommodation).

Piaget considers that when children interact with their environment by using their previously acquired experience, they are in a state called cognitive equilibrium. Whereas when the interaction with their environment causes a conflict between their information of the world and reality, they then experience a crisis moment called cognitive disequilibrium. He also suggests the change from equilibrium to disequilibrium and back to equilibrium (through accommodation) promotes children to evolve across four continuous qualitatively different stages, from birth to adulthood. The first of them is called sensorimotor stage, which starts at birth and finishes at around 2 years old (the interested reader can find a brief summary of his theory in Crain (2010, chapter 6)). For Piaget, this is the most creative period of life, since during this stage young children must begin to build their understandings of the world, and such construction requires creativity (Runco & Pritzker, 1999, p. 13). According to his theory, during the sensorimotor stage, infants progressively develop through six substages: (1) reflexes, where the child understands his environment through a set of inborn knowledge structures (that he called schemas) that correspond to reflex behaviors (e.g. closing the hand when an object makes contact with the palm); (2) primary circular reactions, where the child uses his reflexes to adapt to the environment, inborn schemas are replaced by new constructed schemas, and actions are repeated because they have pleasurable effects on the infant (e.g. when a baby sucks its thumb by accident, causing him a pleasurable sensation, so he repeats the action due to the pleasure he experiences); (3) secondary circular reactions, in which the child intentionally repeats actions in order to trigger a response in the environment (e.g. when a baby squeezes a rubber ducky by accident and it sounds "quack", the baby does it again because he considers the quack sound an interesting result); (4) coordination of reactions, where the child begins exploring his environment and imitating the behavior of others, often combining different schemas in acting to obtain a desired effect; (5) tertiary circular reactions, in which the child tries out trial and error experimentation to discover new methods of meeting challenges (e.g. when a baby steps on a toy and it makes a nice sound, then he tries to squeeze the toy to get a similar result); and (6) early representational thought that marks the beginning of the development of symbols representing objects or events, and the understanding of the child's world begins to be done through mental operations, and not merely through actions. Piaget calls the evolution through the different substages and stages *cognitive development*.

In this way, during the early childhood we use our creativity to construct our knowledge of the world, which is built by continuous adaptation to it, causing us to go from equilibrium states to disequilibrium states and back to equilibrium, which results in our cognitive development. Thus, creativity, adaptation and cognitive development are strongly related. This work presents a computational model that, based on Piaget's theory, simulates some of the aspects of cognitive development taking place during the sensorimotor period. Its core components simulate the assimilation-accommodation adaptation process by implementing it with a new extended version of the computational model of creativity known as *Engagement-Reflection* (Pérez y Pérez, 2007; Pérez y Pérez & Sharples, 2001, 2004). That is, this model simulates adaptation as a creative activity. We introduce here the implementation of our model on an agent that is initialized with basic reflex conducts, and that through the interaction with a 3D virtual world, it develops new behaviors autonomously. The new acquired skills, according to Piaget's theory, are typically observed in children that have reached the second substage of the sensorimotor period. Building this kind of systems helps the study of models from the developmental sciences, as Mareschal and Thomas (2006) suggest; it helps computer engineers and scientists to develop new methodologies for building better artificial systems that show more intelligence and autonomy; and it helps computer creativity researchers to better understand the creative process. One of the main motivations behind this kind of systems comes from the idea that it is easier to build an artificial agent that simulates a baby in order to let it learn until it gets an adult level than to implement all the complexity of the adult mind (see for example Guerin, 2011a; Turing, 1950). This is a motivation a community of artificial intelligence researchers share, particularly in what is called *Developmental Artificial Intelligence*, or *developmental approach to AI* (see for example Guerin, 2011a; Lungarella, Mettay, Pfeiferz, & Sandiniy, 2003; Weng et al., 2001).

The article is organized as follows. Section 2 presents a summary of related previous works. Sections 3 and 4 present a detailed description of our model, as well as the agent implementing it. In Section 5 we present the experiments and results. Finally, in Section 6 we present the conclusions and in Section 7 the future work.