Emergence of creative-like behavior in a developmental agent

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Abstract

This paper reports a model of a developmental agent. It simulates (some characteristics of) Piaget's sensorimotor stage. During this stage essential skills for creative thinking are developed. Our computational model attempts to shed some light about how these abilities arise and, in this way, contribute to the study of the developmental side of computational creativity.

Introduction

Creativity is an important characteristic of human beings. There are several approaches to its study. In this work we are interested in contributing to the understanding of the genesis of the creative behavior. Inspired by Piaget's ideas about children development, we are working on a computer model of a developmental agent. That is, an agent that initially is provided with basic knowledge structures and skills and that, through interaction with its environment, develops novel behaviors that allow it to adapt to its surroundings and to solve novel problems.

Piaget (1952) observed that children from birth to 24 months old are able to develop new behaviors of increasing complexity. He referred to this period as the sensorimotor stage of cognitive development, and is divided in six substages: 1) reflexes, where the child understands his environment through a set of inborn knowledge structures (that he called schemes) that correspond to reflexive behaviors, such as 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 schemes are replaced by new constructed schemes, and actions are repeated because they have pleasurable effects to the infant; 3) secondary circular reactions, in which the child intentionally repeats actions in order to trigger a response in the environment; 4) coordination of reactions, where the child begins exploring his environment and imitating the behavior of others, often combining different schemes 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; 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.

In this developmental stage, children's behaviors start to be goal oriented (where the goal is to reproduce and preserve an interesting result); this is the beginning of means-end differentiation, a basic skill to become capable of solving problems. In this way, children become able of developing new behaviors using known schemes in new situations. Children start using mental skills for depicting and solving a problem. In other words, they become able of learning from mental simulation instead of from actual experimentation. This is the beginning of problem solving.

Scandura (1977), defines problem solving as the generation and selection of discretionary actions to bring about a goal state. As mentioned before, in Piaget's view, infants develop their earliest abilities necessary to solve novel problems in the sensorimotor period. On the other hand, problem solving has been considered as a form of creativity (Runco 1994), so during this period, children's first manifestations of creative behavior arise. This work attempts to shed some light into the study of how these abilities appear.

Although they are clearly linked, it is hard to find computational models of creativity that include developmental characteristics and vice versa. Developmental systems like Drescher(1991), Chaput(2004), Stojanov and Kulakov(2003), Perotto and Alvares(2006) do not contemplate the creative aspect. On the other hand, works in computational creativity (e.g. Norton et al. 2010; Peinado et al. 2010; Pérez y Pérez 2007; Ritchie 2007) lack the developmental aspect. We expect that this work will contribute to both fields.

The developmental agent

Our agent lives in a 3D virtual world, as is shown in Fig. 1. It has physical, perceptual and cognitive characteristics: the agent can move his head up, down, left, and right, as well as its hands; it is able of seeing and touching its world; it has a memory and capacities like learning, and paying attention.

Agent Architecture

The architecture of the agent is inspired by the neo-piagetian work of Cohen et al (1998; 2002). According to this theory, infants are endowed with an innate information-processing system. This system enables them to learn about their environment and to develop a repertoire of knowledge of increasing complexity. They state that this learning system remains

(a) (b)

Figure 1: (a) Virtual world, (b) an example of the word viewed from the agent's point of view.

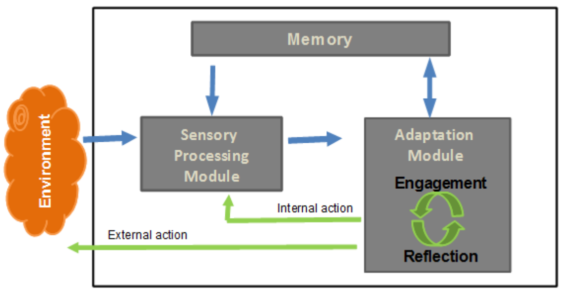

Figure 2: Agent's information-processing system.

the same throughout all development and across domains, and what changes is the complexity of the knowledge structures it manages.

Our agent is provided with the following elements which comprises its information-processing system (see Fig. 2).

- A memory.
- A sensory processing module.
- An adaptation mechanism called engagement-reflection.

Memory stores schemes. It is initialized with a set of predefined initial schemes which represent innate behaviors. The sensory processing module senses some parts of the virtual world (what the agent sees) and represents them in a structure called context. So, the context is an internal representation of what the agent senses. The agent's field of vision is divided in five sections: left, right, up, down, center. It is capable of determining in which section of its field of vision an object is located. Some elements in the environment are more prominent than others. By default, bright colored objects take the attention of the agent. As a result of paying attention, the agent eliminates from the context all information of any other item but the attended object. So, the context is exclusively devoted to register information of the focus of interest. The agent is programmed to simulate a pleasant reaction when an attended object is located in the center of its field of view.

The agent's adaptation mechanism is inspired by Piaget's ideas about children's adaptation to its environment. According to Piaget, adaptation is comprised by two processes: assimilation and accommodation. Assimilation is about interacting with the world employing all the available schemes in memory; while accommodation is about the modification or creation of new schemes as a result of dealing with unknown situations in the world. Piaget states that when children employ their schemes to interact with the world, they are in a situation known as a state of equilibrium. However, sometimes they face unknown situations (which are not represented in their schemes) producing a state of disequilibrium. Piaget suggests that the movement from equilibrium to disequilibrium and back again to equilibrium promotes childrens development. In this work, we extend and adapt the Engagement-Reflection model (Pérez y Pérez and Sharples 2001) to implement some of the Piaget's ideas about the children's adaptation mechanism.

Engagement works as follows. The agent senses his environment and internally represents it in a structure known as context. The context is employed as cue to probe memory in order to match a scheme representing a similar context or situation. If the process fails, the system modifies the context and tries again to match a scheme in memory. In Piaget's terminology, engagement tries to assimilate the current situation to its actual knowledge. All schemes in memory have associated logical actions to perform. When a structure is matched, the agent selects and performs one of the associated actions. All actions modify either the environment or the perception that the agent has of its environment (e.g. when the agent executes the action of moving its head towards the right, its world's perception changes). When the system detects that the repeatedly execution of an action always produces the same outcome, the agent registers this situation in a structure called expectation that is linked to the action. The agent senses again its world, updates the context, and the cycle continues. Engagement ends in two situations: 1) when the agent cannot associate any scheme in memory (an impasse is declared) and therefore it does not know how to act, and 2) when the agent executes an action with associated expectations that are not fulfilled. In these cases, the agent switches to reflection. During reflection the agent attempts to analyze the current situation and, with the help of some predefined heuristics, attempts to deal with the unknown situation either modifying schemes or creating new ones. Thus, conflict (dealing with unknown situations) triggers the necessity of building new schemes. The creation of novel structures is one of the core components in our model.

Thus, engagement represents an automatic behavior while reflection represents an analytical thoughtful behavior.

Summarizing, the complete process works as follows:

1. The system is initialized with a set of predefined schemes, which represent innate behaviors.
2. The agent starts.
3. The agent senses its environment and updates the context.
4. Engagement uses the current context to try to retrieve from memory an action to be performed.
5. The selected action is executed, and the system goes back to step 3.

If during step 4 the system cannot retrieve any action from memory, or if the agent executes an action with associated expectations which are not fulfilled, then the system switches to Reflection. During reflection, the system employs a set of predefined heuristics, to attempt to deal with the unknown situation either modifying current schemes or creating new ones.

To illustrate this process, consider the following example that describes the creation of a new scheme:

1. The agent starts.

2. For this example we suppose that there are no schemes in memory. Let us imagine that the agent is paying attention to a bright object that is located on the right side of its visual field. Then, it executes at random the action of moving its head towards the right (because there are no schemes, the action to be performed by the agent is chosen at random). As a result of this action, the object of attention is now located at the center of its visual field. This automatically triggers a simulated pleasurable effect, which is registered in the agent's context. So, the context records that the agent is sensing a pleasurable object located at the center. Now, the agent tries to match in memory a scheme similar to the current context. However it fails (the memory lacks any scheme representing a similar situation) and the system switches to reflection.

   During reflection the system analyses that it has discovered a pleasurable new situation:

   1) The agent was attending a bright object that was on the right side of its field of view
   2) The agent executed the action of moving its head towards its right,
   3) As a result of this action the object is now located at the center of its field of vision triggering a pleasing effect. So, the agent creates a new scheme that records the following information: when a bright object is located on the right side of my vision field, a logical action to perform is to turn my head towards the right. This action has associated the expectation of generating a pleasurable situation.

Discussion and Conclusions

This work describes a computational model of a developmental agent that represents some aspects of Piaget's sensorimotor stage. The agent has limited interactive functions with stimuli. It has an architecture that accounts for piagetian equilibrium processes (assimilation, accommodation) representative of this period. As a core characteristic, the agent constructs new knowledge from its interactions with the environment and uses this knowledge to his own adaptation process. Given Scandura's (1977) definition of problem solving as the generation and selection of discretionary actions to bring about a goal state, and taking into account that sensorimotor stage includes the initial goal-oriented intentional actions, we consider helpful a model describing these initial forms of goal orientation and problem solving, because it would shed light to these processes. Thus, this work attempts to contribute to the study of an essential characteristic of the creative process: the capacity for problem formulation and problem solving.

In the same way, according to Pérez y Pérez and Sharples 2004 "A computer model might be considered as representing a creative process if it generates knowledge that does not explicitly exist in the original knowledge-base of the system and which is relevant to (i.e. is an important element of) the produced output". As mentioned earlier, one of the core characteristics of our model is the generation of new knowledge, an essential component of the developmental process that allows the agent to face and solve novel situations. We hope this work encourages researchers to study the developmental aspect of computational creativity.

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