Criteria for Evaluating Early Creative Behavior in Computational Agents

Wendy Aguilar
Posgrado en Ciencia e Ingeniería de la Computación,
UNAM, México D.F.
weam@turing.iimas.unam.mx

Rafael Pérez y Pérez
Departamento de Tecnologías de la Información,
División de Ciencias de la Comunicación y Diseño
UAM Cuajimalpa, México D.F.
rperez@correo.cua.uam.mx

Abstract

Our research is focused on the study of the genesis of the creative process. With this purpose we have created a developmental computational agent, which allows us to watch the generation of the first behaviors we could consider as creative. It is very important to develop methodologies to evaluate the behaviors generated by this kind of agents. This paper represents our first effort towards that end. Here we propose five criteria for its evaluation, and we use them to test the behaviors created by our developmental agent.

Introduction

The construction of artificial systems which simulate the creative process is currently a topic of great interest among the artificial intelligence and cognitive sciences community. A great effort has been made to build methodologies that help us evaluate such systems (e.g. Ritchie, 2007; Colton, 2008; and Jordanous, 2012). Nevertheless, it has not been an easy task, and it is necessary to do more research. This article is intended to contribute to it. Our research is focused on the study of the genesis of the creative process, which takes place during the first years of our lives, as explained in the next section. With this purpose we have created a computational agent that simulates cognitive development (introduced in Aguilar and Pérez y Pérez, 2013), which allows us to watch the generation of the first behaviors we could consider as creative. In this article, we focus on proposing some criteria which may let us evaluate the behaviors generated by this kind of agents.

Concepts and Definitions

Creative Behavior

In the literature on the subject we can find a number of definitions for creative behavior. For example, from a behaviorist viewpoint, Razik (1976) defines creative behavior as a unique response or pattern of responses to an internal or external discriminative stimulus. Or, from the point of view of artificial systems, for example Maher, Merrick, and Saunders (2008) propose that the developing of creative behavior in artificial systems focuses on the automatic generation of sequences of actions that are novel and useful. This article is based on Cohen's point of view (1989), who describes creativity 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. For the context of this article, we will focus only on the first level, called "Learning Something New: Universal Novelty". This kind of creativity is that resulting in behaviors that are useful and new to the individual, but not strange or valuable to others. Cohen considered that it can be observed in babies and toddlers as a result of their need to start to adapt to the world.

Adaptation

For Piaget (see for example Piaget, 1952), adaptation takes place by means of two complementary processes he called assimilation and accommodation. The assimilation process allows children to face new situations by using their knowledge from past experiences. However, in some cases, the situations they face contradict its current knowledge of the world. In these cases of conflict, the accommodation process allows children to deal with new situations by progressively modifying their knowledge (throughout the continuous interaction with their environment) in order to include the results of their new experiences. In this way, Cohen's first level creative-adaptive activity helps us adapt to our world either modifying our perception of the environment so that it fits our knowledge acquired from past experiences (it is, adaptation by assimilation), or modifying and producing new knowledge when it does not match reality (it is, adaptation by accommodation).

Cognitive Development

Piaget considered that when children interact with their environment by using their previously acquired knowledge, they are in a stage called cognitive equilibrium. Whereas when the interaction with their environment causes a conflict between their knowledge and reality, they then experience a crisis moment called cognitive disequilibrium. He also suggested the change from equilibrium to disequilibrium and back to equilibrium (through accommodation) promotes children evolving across four continuous qualitatively different stages, from birth to adulthood (the interested reader can find a brief summary of his theory in Crain, 2010, chapter 6). The first of them is called sensorimotor stage, which starts at birth and finishes at around 2 years old (approximately the same age in which Cohen's first level adaptive creativity is observed). According to his theory, the sensorimotor stage is subdivided into six substages, each characterized by the emergence of new behaviors. For example, the second substage is characterized by the acquisition of behaviors centered on his body, such as learning how to follow any object visually or how to keep objects of interest grasped; whereas the third substage is characterized by the acquisition of behaviors involving consequences on external objects, such as learning how to squeeze a rubber duck in order to have it quack.

This first stage of development is quite interesting from the point of view of creativity. On the one hand because it is in this stage that the children's behaviors start to be goal oriented; this is the beginning of means-end differentiation, a basic skill to become capable of solving problems. And problem solving has been considered as a form of creativity (Runco 2007). On the other hand, because Piaget himself considered it as the most creative period of life, since it is during this stage that newborns must start to build their knowledge of the world, and such construction requires creativity (Runco and Pritzker 1999, p. 13). So, during this period, children's first manifestations of creative behavior arise.

Piaget called the evolution through the different substages and stages *cognitive development*.

Evaluation Criteria

Inspired by Maher, Merrick, and Saunders's paper (2008), we propose that an artificial agent that simulates cognitive development (e.g. Stojanov 2001; and Aguilar and Pérez y Pérez 2013) generates creative behaviors if they comply with the following characteristics:

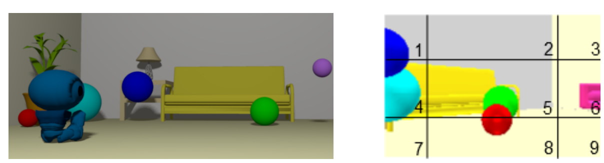
- **Novelty**. A behavior is considered novel if it did not exist explicitly on the agent's initial knowledge base.
- **Usefulness.** A behavior is considered useful if it serves as a basis for the construction of new knowledge that eventually leads the agent to acquire new skills that are characteristic of its next developmental stage. For example, those driving it from behaviors characteristic of the second substage of the sensorimotor period (behaviors based on the body) to behaviors characteristic of the third substage (behaviors involving consequences on external objects).
- **Emergence**. Based on Steels's (2014) definition, we propose to consider a behavior as emerging if its origin cannot be directly traced back to the system's components, but if it originates as a result of the way such components interact.
- **Motivations.** Amabile (1983, 1999) distinguished between two types of creativity: intrinsically and extrinsically motivated creativity. Intrinsic motivation refers to a behavior that is driven by internal rewards, while extrinsic motivation is focused on external reward, recognition or punishment avoidance. In this article we propose that a behaviour that an agent develops should be considered creative only if it resulted from an intrinsic and/or extrinsic motivation.
- **Adaptation to the environment.** The ability to adapt to our environment has been seen traditionally (perhaps as of Darwin) as a necessary condition for really creative behavior (Runco 2007, p. 398). We therefore propose that a behavior that an agent develops should be considered creative only if it resulted from an agent's adaptive process to its environment.

Case Study

In order to illustrate the application of the evaluation criteria we propose, we assessed the agent presented in (Aguilar and Pérez y Pérez 2013).

Brief description of the agent

The agent lives in a 3D virtual environment with which it interacts. It can lift its head, move it down and turn left and right; as well as open and close its hand. It has a visual and a tactile sensor. The visual sensor is implemented as a virtual camera with a field of vision of 60 degrees. Its field of vision is divided into the nine areas shown in Figure 1b. It implements five main cognitive capabilities: 1) it can see and touch its world; 2) it simulates an attention process; 3) it simulates affective responses of pleasure and displeasure (represented by variables with values -1 for displeasure and +1 or +2 for two intensities of pleasure), emotional states of interest, surprise and boredom, and an intrinsic motivation of cognitive curiosity (represented by boolean variables with value "true" when the agent shows such state or motivation); 4) it has a memory where it stores its knowledge on how to interact with its world, and it does so in structures called schemas of which there are two types: *basic schemas* representing default or "innate" behaviors (defined as two-part structures consisting of a context and an action), and *developed schemas* representing behaviors created by the agent as it interacts with its world (defined as three-part structures consisting of a context, an action, and a set of expectations); and 5) it simulates an adaptation process which is inspired by Piaget's theory.



(a) The agent in its virtual world

(b) The division of the agent's field of vision

Figure 1: The agent and its virtual world

The agent interacts with its environment: 1) by sensing its world, 2) by choosing one of the sensed objects as its center of attention, 3) by choosing what action to carry out, and 4) by executing the chosen action. Steps 1 to 4 are called *perception-action cycle*.

Its central component is its adaptation module called *Dev E-R* (*Developmental Engagement-Reflection*). It is imple-

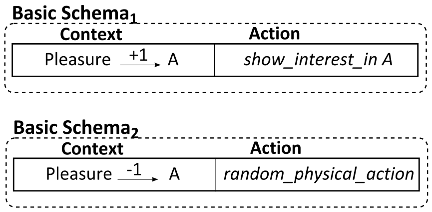


Figure 2: Initial basic schemas. They represent the initial behaviors the agent knows for interacting with its world. $Basic\ Schema_1$ represents the tendency to preserve a pleasant stimulus, and $Basic\ Schema_2$ represents the tendency to perform a groping to get a pleasant stimulus back when it disappears.

mented with a new extended version of the computational model of the creative process *Engagement-Reflection* (Pérez y Pérez and Sharples 2001). Dev E-R simulates the assimilation process by searching in the memory for schemas representing similar contexts to the current perceived situation (which is defined in terms of the current agent's affective responses, emotional states and motivations). On the other hand, Dev E-R models the accommodation process by creating new schemas and/or modifying the existing ones as a result of dealing with new situations in the world. The creation and modification of the schemas takes place by means of one of the two following methods: generalization or differentiation. This way, the agent interacts with its virtual world, assimilating and accommodating its knowledge, until it manages to reach a cognitive equilibrium state. It is, until it does not need to modify its schemas during the last NC cycles, since they allow it to interact with its environment satisfactorily. When the agent reaches a cognitive equilibrium state, it is able to face new situations by partially using its knowledge from past experiences. This may cause new schemas to be built, having the agent enter a cognitive disequilibrium state again. It is this way that the agent goes from equilibrium states to disequilibrium states frequently, until it stops its development because it keeps equilibrium for a certain number of cycles. It is then that its execution ends.

Testing

In Aguilar and Pérez y Pérez (2013) it was reported that the agent interacted with the environment shown in Figure 1a, for 9000 cycles. In this world there were balls in different colors and sizes, moving from the left to the right and downwards, independently. Nevertheless, they never made contact with the agent's hand. It was also reported that the agent was initialized with two basic schemas representing behaviors characteristic of the first substage of the sensorimotor period (shown in Figure 2).

Novelty At the beginning of the agent's execution, it constantly lose the objects of its interest. This was due to the fact that it could only use its basic predefined behaviors to interact with its world. When this happened, the behavior it showed was a random movement of its head (resulting from the use of its $Basic\ Schema_2$). Nevertheless, after letting the agent interact with its environment for 9,000 cycles, it built 13 new schemas that did not exist in its initial knowledge base. The seven first, called *schemas type 1*, represented behaviors meant to recover the objects of interest it had lost in different positions of its field of vision. For example, if it lost an object on its right, then its schema indicated to turn its head right, generating the expectation of recovery. The six next schemas, called *schemas type 2*, represented behaviors meant to keep the objects of interest within its field of vision, causing the number of objects it lost to progressively decrease and even reach zero. The 13 schemas the agent built are different in structure and contents; and, more important, they represent different behaviors to those it was initialized with. Although it is also important to note that the seven schemas of the first type are very similar among themselves, since all of them represent behaviors of recovery for lost objects of interest. Similarly, the six schemas of the second type are very similar among themselves, since all of them represent how to keep the objects of its interest within its field of vision. We can therefore conclude the agent built 2 groups of schemas, schemas type 1 and schemas type 2, that represent totally novel behaviors to the agent (recover and keep objects of interest). It also built 7 and 6 schemas within such groups, representing behaviors less novel among themselves.

Usefulness In order to evaluate the usefulness of the behaviors the agent developed, lets remember it was initialized with behaviors characteristic of the first substage of the sensorimotor period. From there, throughout the interaction with its environment, it built its first seven schemas related to recovering the objects of interest (schemas type 1). These were later used as a base, on partially using them in the new situations it faced, in order to build the following six schemas related to keeping objects of interest (schemas type 2). The use of these 13 schemas together caused the agent to show the new behaviors of following the objects of interest visually (by moving its head), and of keeping them centered within its field of vision most of the times. These two new abilities that the agent acquired were described by Piaget as two of the main abilities related to vision which children develop during the second substage of the sensorimotor period. Therefore, the schemas the agent developed are considered useful since they allowed it to go from predefined or "innate" behaviors (typical of the first substage of the sensorimotor period) to behaviors based on its body (typical of the second substage of the sensorimotor period).

Emergence The construction of the different behaviors the agent develops depends on various factors, among them: 1) the characteristics of its environment, 2) its physical characteristics, and 3) its current knowledge. For example, regarding the first point, if the agent lived in a world in which it always had to lift its head in order to recover the objects, it would build schemas representing that particular characteristic of its environment. Similarily, if the agent were enabled with the ability to touch but not to see its world (it means, if it were blind), it would develop different behaviors to those it developed with vision (using exactly the same adaptation processes in both cases). Except that now, the new abilities would be related to touching. For example, it would learn how to keep the object of its interest grasped. Also, regarding the third point, the behaviors the agent develops depend on its current knowledge. For example, schemas type 2 require the construction of schemas type 1 first, since it is not until they exist and are stable that those type 2 can originate. This is because the agent uses its knowledge on how to recover objects of interest in the different positions in order to learn how to keep them within its field of vision. We can therefore conclude that the behaviors created by the agent emerged as a result of the way the different components of the system interacted among themselves, since the new behaviors were not set up by default, and also because they are contextual. It is, because they depend on its interaction with the environment, on its sensory abilities and on its current knowledge.

Motivations One of the core components of the agent is that it simulates affective responses, emotional states and an intrinsic motivation of cognitive curiosity that push it to act. Particularly, regarding the development of new schemas, they are created, modified or eliminated as a result of the triggering of: 1) an emotional state of surprise (for example, caused by the unexpected recovery of an object of interest), or 2) a cognitive curiosity motivation (that is generated when dealing with unknown situations that contradict its current knowledge of the world). So, in this model, the emotional state of surprise and the intrinsic motivation of cognitive curiosity trigger the necessity of modifying and building new schemas.

Adaptation to the environment The schemas the agent developed originated as a consequence of its facing new unknown situations, to which it reacted whether assimilating the new situation into its acquired knowledge (by means of the process of searching a schema representing a similar situation to that of its current context in memory) or accommodating its knowledge so that it fitted the new experience (by creating a new schema or by differentiating, generalizing or deleting an existing one). Therefore, the construction of new schemas took place as a result of a complementary assimilation and accommodation process. In other words, they originated from an adaptation process of the agent to its world.

Conclusions

In this article we propose five criteria to evaluate if the behaviors created by agents that simulate having cognitive development can be considered creative. The criteria we propose are: novelty, usefulness and emergence. Additionally, it is requested that such behaviors had originated as a result of intrinsic and/or extrinsic motivations, as well as of the adaptation to its environment. The results of the evaluation of the agent of the case study showed that, under these criteria, the first behaviors it develops (learning how to follow objects of its interest visually and how to keep them centered within its field of vision) are considered creative. These results represent our first approach to the evaluation of this kind of agents. There is still much more research to do on this matter.

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References

Aguilar, W., and Pérez y Pérez, R. 2013. A computer model of a developmental agent to support creative-like behavior. In *AAAI Spring Symposium: Creativity and (Early) Cognitive Development*, 8–13.

Amabile, T. M. 1983. *The social psychology of creativity*. Springer-Verlag, New York.

Amabile, T. M. 1999. *Motivation and creativity. In: R.J. Sternberg (Editor), Handbook of creativity*. Cambridge University Press, Cambridge.

Cohen, L. 1989. A continuum of adaptive creative behaviors. *Creativity Research Journal* 3.

Colton, S. 2008. Creativity versus the perception of creativity in. In *Proceedings of AAAI symposium on creative systems*, 1420.

Crain, W. 2010. *Theories of Development: Concepts and Applications*. Pearson.

Jordanous, A. 2012. A standardised procedure for evaluating creative systems: Computational creativity evaluation based on what it is to be creative. *Cognitive Computation* 4:246–279.

Maher, M. L.; Merrick, K.; and Saunders, R. 2008. Achieving creative behavior using curious learning agents. In *AAAI Spring Symposium on Creative Intelligent Systems*.

Pérez y Pérez, R., and Sharples, M. 2001. Mexica: A computer model of a cognitive account of creative writing. *Journal of Experimental and Theoretical Artificial Intelligence* 13:2:119–139.

Piaget, J. 1952. *The Origins of Intelligence in Children*. London: Routledge and Kegan Paul, 1936 (French version published in 1936, translation by Margaret Cook published 1952).

Razik, T. 1976. Programming creative behaviour. *British Journal of Education Technology* 3:5–21.

Ritchie, G. 2007. Some empirical criteria for attributing creativity. *Minds and Machines* 17:67–99.

Runco, M., and Pritzker, S. 1999. *Encyclopedia of Creativity*. Academic Press.

Runco, M. 2007. *Creativity Theories and Themes: Research, Development,*. Academic Press in an imprint of Elsevier.

Steels, L. 2014. Towards a theory of emergent functionality, from animals to animats. In *First International Conference on Simulation of Adaptive Behaviour*, 451–461. Bradford Books (MIT Press).

Stojanov, G. 2001. Petitagé: A case study in developmental robotics. In *C. Balkenius, J. Zlatev,H. Kozima, K. Dautenhahn, and C. Breazeal, editors, Proceedings of Epigenetic Robotics 1*.