Cognitive Modeling of a General- Purpose Creative System (Creagene Model)

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***Abstract*—Creagene is a multi– purpose, multi– agent creative model that has been designed after investigation of creative humans in science, engineering, management, art and scientific discovery. This model is able to solve problems creatively and generates and interprets figures and statements. In the proposed model, there are six intelligent agents (namely, preprocessor generator, explorer, domain processor, analyzer– examiner and postprocessor) as well as a memory and two libraries. First, the inputs from different domains are obtained, abstracted, and then processed iteratively by the generator and explorative agents. The obtained pre-inventive structures are sent to the domain processor to become particular structures in the desired domain. Next, the analyzer– examiner investigates the structures for novelty and value based on some criteria. If any structure is determined to be creative, it is output to the environment and placed into the library of creative products. Otherwise, it is retained in the usual library for future processing by the postprocessor. In this paper, various aspect of the Creagene model is discussed and three examples are presented.**

Keywords—cognitive modeling; creative systems; computational creativity; pre-inventive structures; generative agent; explorative agent

I. INTRODUCTION

Although creativity is a more recent scientific subject in artificial intelligence, it has long been a topic of study in cognitive psychology, philosophy, art and history of science. The importance of study and research in creativity was first presented by Gilford in 1950 [1]. In 1961, Rodes investigated different definitions and viewpoints of creativity and concluded that there are four basic domains of creativity: Person, Process, Product and Press. Theoretical ideas about creative thinking were noted by Feldhusen, Renzulli and Trefinger. Kirton (1976) showed that one of the most important cognitive theories for creativity i.e., the difference between learning and novelty, is a continuity. Writing creative programs began in 1958 and there are more recent successful programs. Evaluation criteria for creative products and theatrical activities about creative programs has been discussed by Ritchie [2], McCarthy [3] and Colton [4] et al [5-13]. There are sixty different creativity models gathered by Greene [14], none of which is similar to the model presented in this paper. The model is inspired from several papers in creativity [15-21].

II. THE BASIC STRUCTURE OF THE CREAGENE MODEL

The proposed model is shown in Fig. 1.

A. The Preprocessor Agent

This agent is the interface between the environment and the two main agents of the model namely the generator and the explorer. It receives its input knowledge from the environment as a collection from different domains. The main function of this agent is abstraction of the collected knowledge and production of some primitive pre-inventive structures. The obtained abstract data and rules are put in the working memory. There are six basic processes for the agent.

- Retrieval of knowledge from the library of usual products with the selection based on different properties of the knowledge and its degrees.
- Retrieval of relations that exist in the structures at hand.
- Retrieval of attributes and properties that exist in the structures and finding their degrees.
- Restructuring the primitive pre-inventive structures.
- Organizing the structures at hand.
- Purposeful selection of some pre-inventive structures among generated abstract structures needed for the next stages.

The output of preprocessor includes abstract structures that can freely enter the generator or the explorer. In both cases the output structures are put into the working memory.

B. The Generator Agent

This agent takes the primitive pre-inventive (abstract) structures from the preprocessor or explorative agent and performs the following nine operations on these structures.

- Decomposition of pre-inventive structures into simpler ones.
- Deformation of structures by change of size in simpler parts, as well as the displacement or rotation of the main structure or its parts.

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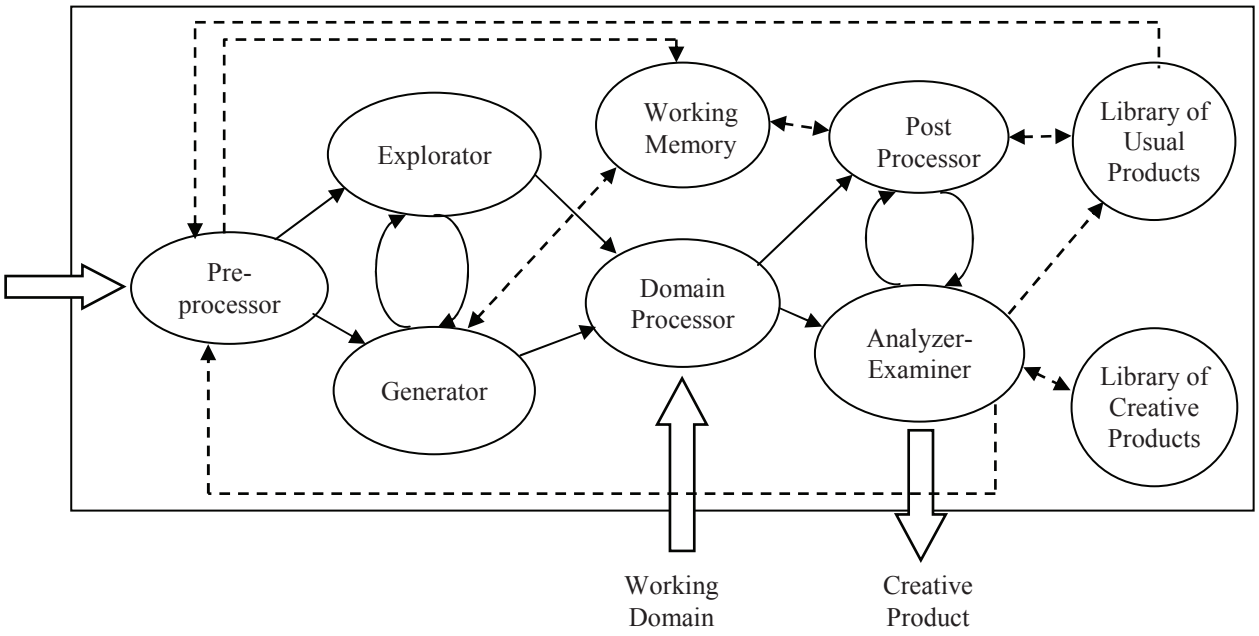

Fig. 1. Creagene model

- Composition of a string of symbols or conceptual structures.
- Classification of structures based on different criteria.
- Retrieval of new formats for structures.
- Analogical transfer of structures from one abstract space to another.
- Retrieval of abstract knowledge from the working memory of the model.
- Selection of a suitable subset of obtained structures at hand.

The outputs of this agent are pre-inventive structures that can freely enter the explorative agent or the domain processor. In either case they are placed into the working memory.

C. The Explorative Agent

This agent takes primitive pre-inventive structures from the preprocessor or the generator agent and applies the following seven processes on them.

- Finding similarities and harmonies in structures (unification of structures).
- Extracting features and special attributes and determining their degrees.
- Finding relations, connections and association properties.
- Obtaining functional structures.
- Testing of new hypotheses.
- Conceptual interpretation of structures.
- Searching for limits and boundary conditions.

The output of this agent is pre-inventive structures that can freely enter the generative agent or the domain processor and in both cases they are also sent to the working memory.

D. The Domain Processor Agent

This agent takes the generated or explored pre-inventive structures and changes the abstract structures to the structures in the desired working domain related to the final goal. These processes are done with respect to the special features of the goal domain. The output of this agent can freely enter either the analyzer- examiner or the postprocessor agents.

E. The Postprocessor Agent

This agent prepares the generated or explored structures for expert confirmation from the point of view of novelty and value. The three important processes of the postprocessor agent are:

- Reformatting of the existing structures.
- Making some of the relations in the structures more prominent than others.
- Making some attributes in the discussing structures more prominent than others.

These three processes are done on the basis of the desired poles of the experts or society. The output of this agent can enter to the analyzer- examiner agent.

F. The Analyzer- Examiner Agent

This agent performs very important and basic functions such as judgment about creativity of the structures at hand. It does the two following processes based on suitable criteria.

- Testing of novelty and originality for the structures at hand in the desired working domain.

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- Testing of valuability and degree of interest in the structures from different important point of view in the expert domain.

The analyzer– examiner agent decides whether or not the structures are new (non-typical) and interesting (valuable). In case a structure is determined to be creative, it is output to the environment and is also put into the library of creative products. Otherwise, it is put into the library of usual products and is forwarded to the postprocessor or preprocessor agents.

III. Creativity Criteria in the Analyzer- Examiner Agent

These criteria are defined based on the following definitions:

Def 1: Assuming a set *B* of Pre-inventive structures, a properties' degree schema for *B* is a sorted $<f_1, f_2, \dots, f_n>$ of functions each of which are defined from *B* to [0, 1].

In fact each f_i shows a property with degree for every pre-inventive structure in *B* i.e. each f_i is fuzzy set on *B*.

Def 2a: Novelty or typical pre-inventive structure is defined as follows:

$$\forall x \in \mathrm{B}, typical(x) \in [0,1] \quad (1)$$

Typical (x) = 1, means *x* is quite usual and common, while *Typical (x)* = 0, means *x* is quite unusual and uncommon.

Def 2b: Valuability of a pre-inventive structure is defined as follows:

$$\forall y \in \mathrm{B}, valuable(y) \in [0,1] \quad (2)$$

Valuable (y) = 1, means the structure y is interesting, while *Valuable (y)* = 0, means the structure y is not interesting.

Def 3: A value– based class of pre-inventive structures of a set *B* is a sorted triple $c \equiv < B, T_{0,1}(B), V_{0,1}(B) >$ such that:

$$\forall 0 \le \alpha \le \beta \le 1, T_{\alpha,\beta}(\mathrm{B}) \stackrel{\text{def}}{\equiv} \{x | x \in \mathrm{B}, \alpha \le typical(x) \le \beta\} \quad (3)$$

$$V_{\alpha,\beta}(\mathrm{B}) \stackrel{\text{def}}{=} \{y | y \in \mathrm{B}, \alpha \le valuable(x) \le \beta\} \quad (4)$$

Def 4: The first criterion of merit in the Creagene model with suitable α, β, θ, all between 0 and 1 is defined as follows:

$$\text{Criterion I: } \frac{|T_{0,\alpha}(\mathrm{B}) \cap V_{\mathrm{B},1}(\mathrm{B})|}{|\mathrm{B}|} > \theta \quad (5)$$

Def 5: The second criterion of merit in The Creagene model with suitable α, β, θ' such That $\theta' > \theta$, all between 0 and 1 is defined as follows:

$$\text{Criterion II: } \frac{|T_{0,\alpha}(\mathrm{B}) \cap V_{\mathrm{B},1}(\mathrm{B})|}{|T_{0,\alpha}|} > \theta' \quad (6)$$

IV. Three Examples for Creagene Model

A. Mutilated Checkerboard Problem

For creative problem solving, the following puzzle is presented. A checkerboard size $4n \times 4n$ without two of its corners, $(0, 0)$ and $(4n - 1, 4n - 1)$, is represented in Fig. 2. The rows and columns of the array are black and white alternately. Is it possible to place dominoes of size 2×1 to cover all the squares?

1) The preprocessor agent:

$n = 4k$
Board= $Z_n \times Z_n$
Attributes and properties of the problem
Color: 2, white and black
Total no of squares: $n^2 - 2$
No of black squares: $\frac{n^2}{2}$
No of white squares: $\frac{n^2}{2} - 2$

2) The generator agent: Generated hypothesis: Does the Domino cover the board completely or not?

3) The exploratory agent: Test of hypothesis: for covering of the board by Domino, there is a paradox.

$$\begin{aligned} partial\ covering\ (\mathcal{Z}) &\rightarrow card(\{u \in \cup\, \mathcal{Z} | color(u) = 0\}) \\ &= card(\{\mathcal{V} \in \cup\, \mathcal{Z} | color(\mathcal{V}) = 1\}) \\ &= \neg(\exists \mathcal{Z} | partial\ covering\ (\mathcal{Z}) \\ &\wedge multitated\ Board = \cup\, \mathcal{Z}) \end{aligned}$$

4) The domain processor agent: For the above problem

$n = 4$
$Z_n \times Z_n = \{(0,0), (n-1, n-1)\}$
$\rightarrow Z_4 \times Z_4 = \{(0,0), (3,3)\}$
White color = 0, black color = 1

$$card(\{u | color(u) = 0\}) = 6$$
$$card(\{\mathcal{V} | color(\mathcal{V}) = 1\}) = 8$$
$$card(\{u | color(u) = 0\}) \neq card(\{\mathcal{V} | color(\mathcal{V}) = 1\})$$

5) The postprocessor agent: There is no activity

6) The analyzer– examiner agent: For a creative solution of the above problem, the number of squares in the mutilated checkerboard while covered by Domino is:

$$n = 4 \times 4 = 16 \rightarrow n^2 - 2 = 14 \rightarrow \frac{n^2 - 2}{2} = 7$$

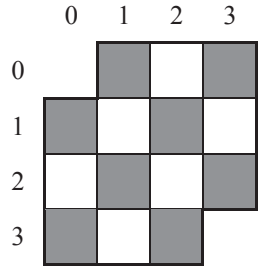

Fig. 2. Mutilated checkerboard

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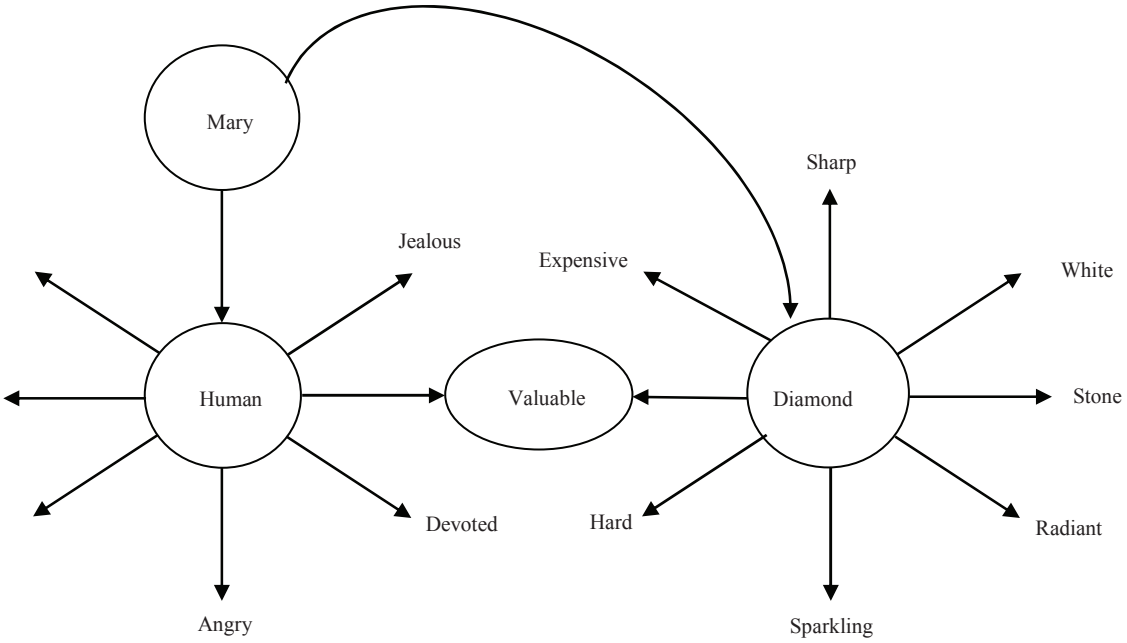

Fig. 3. The word's semantic network for the metaphor

White = black = 7

The count of black and white squares of the mutilated board is:

8 blacks $\neq$ 6 whites

B. The Interpretation of a Metaphor

In the interpretation of metaphors for combination of words, the following example is presented:

Mary is like a diamond (a metaphor)

The semantic networks related to the example's words are seen in Fig. 3.

1) The preprocessor agent:
A ≡ Mary, B ≡ Diamond → A is B
2) The generator agent: The network related to the words A and B is generated as 2 trees like Fig. 4.
3) The exploratory agent: The trees generated for the words A and B are expanded until they reach a common word.
A is B & A is α_i & B is $\beta_j \rightarrow \alpha_i \equiv \beta_j$

4) The domain processor agent:
A ≡ Mary, B ≡ Diamond, $\alpha_i \equiv \beta_j \equiv$ Valuable

Mary is Diamond and Diamond is Valuable so Mary is Valuable.

5) The analyzer– examiner agent: The relational degree of Mary (human) and Diamond (stone) is too small to produce congruence between discordant and unrelated things (very low relational degree results in a creative product). The more perfect interpretation in a context is done with respect to the subjective relation of the desired sentence with other sentences of the context.

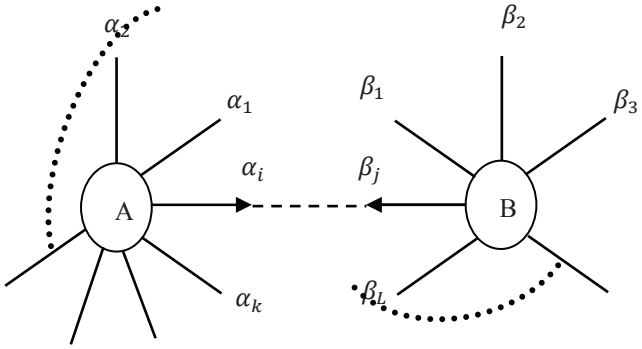

Fig. 4. Generating new words for the words of the metaphor

C. Tangram: Seven Piece Puzzle

In generating figures and interpreting them, the famous Chinese game of tangram is presented.

1) The preprocessor agent: Seven pieces are at hand. In the abstract case, there are n pieces of different or similar geometric figures.
2) The generator agent: The arrangement of n piece starts from an arbitrary or random chosen piece. For continuation of arrangement the choice of next piece among remained pieces is done randomly. Placing the edges of two pieces along each other can be perfectly or partly. A vertex can be set on part of an edge or intersects it. The needed operations are as follows:

a) Rotation of a structure
b) Classifying the obtained structures.
c) Combination of structures using different ways.
d) Suitable selection of a subset of obtained structures.

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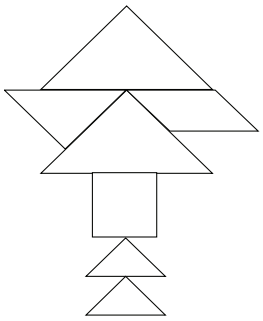

Fig. 5. The structure generated with the tangram seven piece puzzle

An example of an obtained structure is shown in Fig. 5.

3) The exploratory agent:

a) Extraction of features and special attributes and finding their degree.

b) Finding the relation between the parts of the figure's structure.

c) Functional effect of structures.

The examination of the tangram example shows that the length of the structure is more than its width and the top part of the structure is wider than its lower part. The structure can have different applications like foods, war missiles, etc.

4) The domain processor agent: Using different working domains for the last stage shows that Fig. 5 can be an ice cream, a tree or a rocket.

5) The analyzer– examiner agent: The structure generated in Fig. 5 can have various interpretations. Ambiguity and multifold in interpretation represents degree of interest and valuability of the desired structure. In fact the number of different interpretation for a structure is one of the parameters for valuability and interest level for that structure.

V. CONCLUSIONS

Creagene is a creative model with six intelligent agents: preprocessor, generator, explorer, domain processor, analyzer–examiner and postprocessor. The function of this model is to process the input knowledge from different domains and retrieve knowledge from the library of usual products to produce primitive pre-inventive structures. Pre-inventive structures are generated after performing different processes (sometimes repeatedly), within the generator and explorative agents, turning operations between them. These structures are then forwarded to the goal working domain processor. After that, analyzing and examining the structures for creativity is performed and there may be probable formatting of structures. As a result, these structures are accepted or failed. In case of failure of all generated structures, the operation of the Creagene is repeated from the beginning or from the postprocessor agent. Although the Creagene model is designed to be all- purpose, but it may not be in some applications. It may not need all of the agents (i.e. some agents such as preprocessor and analyzer– examiner and postprocessor can be human agent).

The Creagene model has the ability to be implemented in different engineering applications, art, creative problem solving and management, and it is solely designed based upon creative cognition of how a product with interesting innovation has been produced.

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