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Fundamental Laws of Dynamics for Computational Creativity

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Abstract

Dynamics for computational creativity forms a promising unified theoretical framework for cognitive science broadly construed. This paper discusses its some fundamental laws that can be employed to understand the mechanism of the mind, to find the solid theoretical foundation for and to practically support the implementation of creativity support systems. These laws include curved manifold law, completeness law, normal distribution law, boundary law, and asymmetric law. Finally, a prototype of creativity support system based on these laws is also illustrated.

1 Introduction

Creativity is a fundamental trait of intelligence and one of the most remarkable characteristics of the human mind[Sumit 2003]. Currently two primary approaches to study them are used: cognitive and systematic[Sugimoto1998,Maimon1999]. Brainstorming techniques can be categoried as the former. The latter includes symbolic, connectionist, and dynamical approaches[Randall2000], where dynamical approach with symbolic and connectionist approaches differ markedly in the theoretical vocabulary and style of explanation that each brings to bear on cognitive phenomena. It is also contributing to a more general broadening of cognitive science from its historically narrow focus on disembodied, language-like reasoning to embodied, situated action. However, in both approaches, many theories are universally used with the implication that there are significant differences among them, but they are rarely defined precisely and difficult to be used to construct application systems. Actually both approaches seem to be complementary rather than contradictory. For example, to solve a problem in an innovative way requires organizing transfer of knowledge from one engineer domain to another, thus creative reminding needs to be simulated. Therefore, we integrate them together to develop the dynamics for computational creativity embedded in a suitable multidisciplinary framework, which intends to provide a unified way to address development and implementation issues of creativity support system [Wen2001, 2004,2005]. This paper discusses its some fundamental laws.

2 Dynamics for Computational Creativity

It is discovered that creativity such as happened in all engineering systems evolves according to the same regularities, independently of the domains which they belong to, where these regularities can be studied and used for efficient problem creative solving, as well as forecasting the further evolution of any engineering systems. After analyzing a large number of patents taken from different areas of engineering, investigating lots of inventive techniques, and integrating with studies in multidiscipline, we puts forward two basic principles and field reasoning model.

H_1. *Contradiction Principle*: *Any creative system consists of a group of contradiction equations.*

Engineering systems, like social systems, evolve through elimination of various kinds of conflicts. For example, logic of contradiction has been employed to support provoking creativity[Livingstone2002], and most creativity support tools such as TRIZ have been exploited to solve the engineering problems.

H_2. *Invariance Principle*: *Any creative system must keep some properties unchanged when evolving.*

Any inventive system that comes from the solution of the group of conflicts must keep some intrinsic properties of the original system. For example, they should at least keep the same category.

H_3. *Field Reasoning Model*

Like most psychological theories such as Gestalt theory and topology psychology, dynamics for computational creativity also takes the field model as its primary reasoning model.

Based on above hypotheses, framework of dynamics for computational creativity has been structured hierarchically in the manner that separates different groups of small component theories into a dependent sequence, shown as Fig.1, which can lead to some significant conclusions that coincide with our conscious experiences.

Clearly there are many interactions between component theories at each level, but a strong claim of proposed dynamics is that it bridges the gap between human creativity and computational models, which have several important functions:

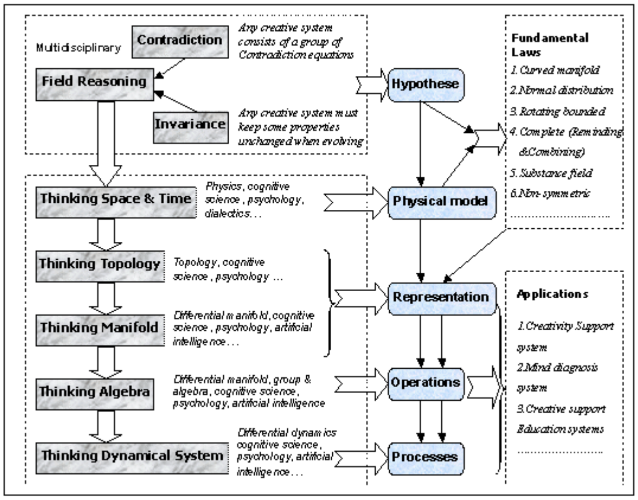


Fig.1 Framework of Dynamics for Computational Creativity

- It extends well beyond representing concrete creative methods alone, and can in a unified way to improve the existing creative methods and to develop new creative methods, including explaining, predicting and controlling the thinking processes.
- It provides an underlying structure that enables formally the main focus of conceptualisation to be directed towards theorising about the thinking activities, the knowledge needed, the tools used, the information available, and the specifications of new ideas being developed.
- It highlights some issues that should be addressed in an orderly manner during the development process of complicated creative systems.
- It identifies ongoing research directions to implement creative systems as well as to do research on the psychology and cognitive science independently as they are needed.

3 Fundamental Laws of Dynamics

From the framework of dynamics for computational creativity, several fundamental laws can be induced and applied to construct creativity support systems. These laws illustrate that creativity is not fundamentally mysterious, or beyond scientific understanding.

A. *Curved Manifold Law: Creativity occurs on the curved manifold, whose generating process can be described by dynamics on the curved manifold.*
Our conscious experience demonstrates that mental time corresponding to the internal scale of a mental information process need not coincide with physical time. Periods of the mental evolution that are quite extended in the physical time scales can be extremely short in the mental scales. Dynamics of computational creativity considers that these two kinds of events happen in different regions of the mental space, where they have their own special time scale and thinking laws. In general there is not an order structure for mental times as it can be that some instances can be incompatible. For instance, the engineer is often strongly limited to his single professional domain, which makes him inapplicable for problem solving in different domains that follow different laws. If he wants to solve a problem in an innovative way, he requires organizing transfer of laws from one domain to another. Thus creativity happens on the curved manifold.
According to curved manifold law, metrics previously defined in Euclidean space should be extended to manifold. For example, Euclidean distance should be replaced by geodesic distance. The difference between them can be illustrated in Fig.2, where the spiral is embedded in a two-dimensional space. According to Euclidean distance, B is nearer to A than C. But in terms of geodesic distance on the manifold, C is nearer to A than B. This difference will bring about the distinguished influence on some applications. For example, the spiral cannot be unrolled onto a straight line if utilizing the Euclidean distances to determine the neighborhood. But geodesic can be employed to attack this problem.

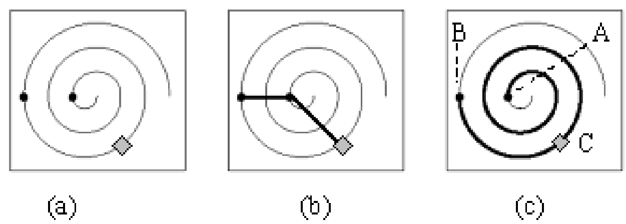


Fig.2 (a) Three points in space (b) Euclidean distance between two points (c) Geodesic distance between two points

B. *Completeness Law: Any creativity can be acquired through reminding and combining*
This law illustrates that creativity support system can generate novel ideas by just modeling reminding and combining [Wen1999a,1999b,1999c,2000a,2000b,2001]. People of a scientific cast of mind, anxious to avoid romanticism and obscurantism, generally define creativity in terms of novel combinations of familiar ideas. For instance, the appeal of Heath-Robinson machines lies in the unexpected uses of everyday objects; and poets often delight us by juxtaposing seemingly unrelated concepts. Among combined ideas, the most fruitful are often those that are formed of elements borrowed from widely separated domains[Santanen2004]. Thus creativity depends on whether remote or subtle connections between items that are correlated but not necessarily causally related can be reminded. Many psychometric tests designed to measure creativity also work on this principle.

C. *Normal Distribution Law: Probability of that object A can be reminded or combined from target object B follows normal distribution in a variate x with mean μ and variance σ, where x is the geodesic distance between A and B.*

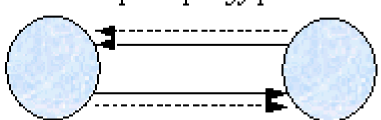
$$f(x) = \frac{1}{\sqrt{2\pi\sigma}} e^{-(x-u)^2/2\sigma^2}$$

This law means that if A is too close to B, A is much similar to B so that novelty cannot be satisfied, and on the contrary, B is difficult to be materialized and accepted by society if it is far away from A too much. This law explicitly points out how to choose objects with valuable creativity. Actually, many psychological and educational variables are distributed approximately normally. Measures of reading ability, introversion, job satisfaction, and memory are among the many psychological variables approximately normally distributed. Particularly, these models work very well even if the distribution is only approximately normally distributed.

D. *Substance Field Law: Force F1 and reverse force F2 does exist at the same time between any objects in technical systems that can be analyzed through substance field, where every force acts in contradiction.*

TRIZ has applied this law successfully to many engineering systems. It is a powerful tool for problem solving, technology forecasting, and business development for the emerging knowledge era. The strength of TRIZ as a method for developing creative solutions to problems is the removal of contradictions, rather than the conventional approach of accepting compromises or making tradeoffs. Examples and case studies illustrate strategies emerging from the TRIZ methods of ideality, the use of resources, trends of evolution and TRIZ-derived Inventive.

$$F_1 = x_1 + jy_1$$



$$F_2 = x_2 + jy_2$$

Fig.3 Interaction Forces between objects

E. *Boundary Law: Human being tends to keep on doing what they're doing, thus thinking boundary is formed, creativity occurs when breaking through boundary*

When facing large and complex problems, people tend to think within a bounded, familiar, and narrow subset of the potential solution space. But most ideal solutions may lie outside the boundary. Therefore psychological inertia sets up many barriers to personal creativity and problem-solving ability. Creative solutions occur when boundary are broken.

The nine-dot puzzle involves graphic manipulations on a sheet of paper based on the regular spacing of nine-dots on it (Fig.4 (a)). The goal is to draw four straight lines so that each dot has a line going through it (Fig.4(b)). Furthermore, the lines must be connected end point to end point so that no more than two end points are unconnected to another line.

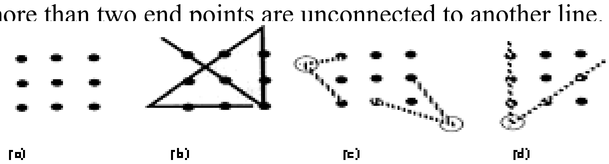


Fig. 4 the nine-dot puzzle

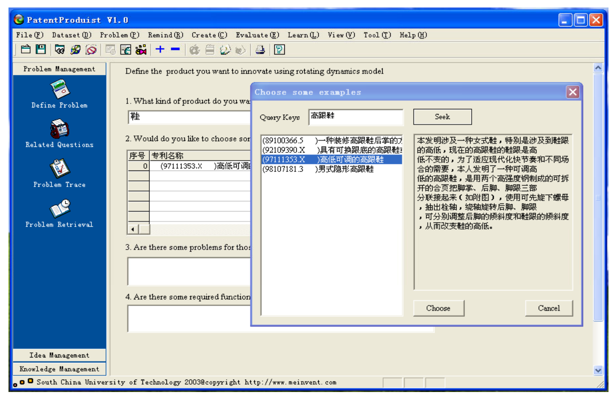
In our organized experiments, most subjects tend to restrict themselves to the inside boundary(box). This usually makes the creative solution impossible to attain. Typically, the key to solve the problem is to identify and break through the thinking boundary that is often determined implicitly. When discovering and then breaking through the boundaries takes place "naturally", it leads to the solution rapidly without any need for external assistance. For example, when presented a hint to the subjects in the form of a statement: "you may place additional dots on the page if it aids you in finding the solution", like Fig.4(c, d), most subjects solved the problem with no difficulty.

F. *Asymmetric Law: Human and computer are asymmetric in evaluation and generation of creativity.*

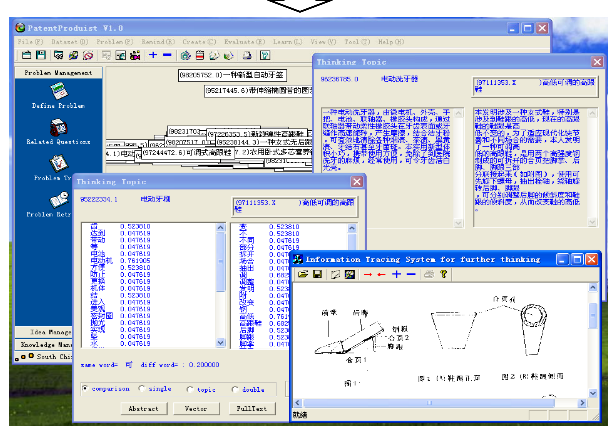
This law demands creativity support system should be human-computer interactive system. Computer emphasizes the generation of creativity, whereas human focuses on evaluation of those generated ideas.

4 Applications to Creativity Support System

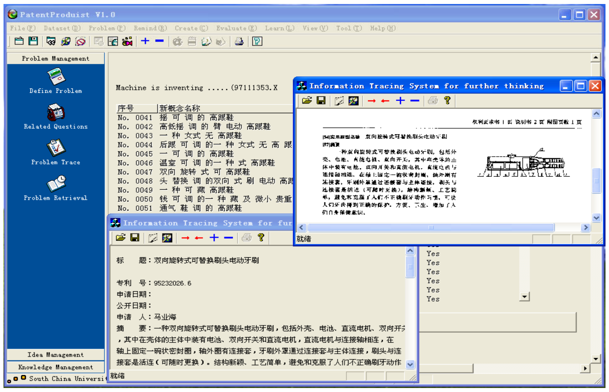
Dynamics for computational creativity and its laws are very effective for constructing creativity support system by providing the systematic, step-by-step procedure. Based on it,



) **Define Problem**: A user inputs the problem that he wants to olve into the *PatentProducist* system. He performs an examination f the problem and clarifies what to solve. He can also push the search" button to choose some examples from patent base.



) **System Reminding**: System automatically reminds patent jects related to the problem defined as step 1 by simulating reative associative. They are all based on completeness law, rmal distribution law and asymmetric law, while visualization tracing to see reminding process are also provided.



(3) System Creating: *PatentProducist* automatically generates new ideas by combination of reminded objects through genetics algorithm framework on text vectors for patents, while visualization and tracing to see reminding process are also provided.

Fig.5 Three working steps of Creativity Support System

We implemented a prototype of creativity support system called *PatentProducist* with the Visual C++ on Microsoft Windows 2000. Based on asymmetric law, this system is built in interactive way, thus it can perceive user's emotion or preference in the working process. System is primarily composed of definition of problem, reminding and creating, shown as Fig.5, where Chinese patents have been taken as knowledge sources and natural language processing techniques are utilized.

5 Conclusion

Dynamics for computational creativity has been outlined to provide a rigorous framework for mathematically integrating the various aspects of creativity that are commonly omitted or treated haphazardly by existing methodologies. Its fundamental laws influences the phenomena that are considered to be cognitive, the questions asked about these phenomena, the experiments performed, and the ways in which the results of these experiments are interpreted. However, these fundamental laws are only a preliminary step towards the development of generic theory that is responsive to the needs of building creativity support systems. Many crucial issues need to be further investigated in the future.

Acknowledgments

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