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A SIMULATED BRAIN MODEL FOR PRODUCTS' CREATIVE DESIGN

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1. Introduction

In today's highly competitive market, enterprises are obliged to fulfil the customer's varied demands. They have to consider not only products' physical functions but also mental functions. Therefore, designers come to take computer aided industrial design system (CAID), which including ergonomics, aesthetics, and humanism factors, to a very important place.

However, current computer aided industrial design software does not work effectively. We can conclude that there are some disjointedness between products designed methods and computer systems; between CAID software and customer's preference; between engineer and designer in design process.

The reasons lies in the difficulties to manager and organize design knowledge in the computer system, because industrial design is a subject involved many other subjects like aesthetics, art, and literature; and the work pattern of human in information-processing is different from computer system. In a process full of fuzzy, uncertain, dynamic and changing information, traditional computer aided methods can not work well.

As we study the human brain's information-processing pattern, we find it may be an effective road that simulates brain's information-processing pattern to transplant design knowledge to computer system. Therefore, the paper build a simulated brain model by building a memory model of three layers structure used semantics networks and artificial neural networks(ANN). And based on the memory structure, some control mechanisms like self-balancing, self-learning, self-organizing, are built for brain to react to extern stimulus. Here we emphasis that the system get information from Internet and carried out data digging to attain useful knowledge.

Simulating brain's work pattern to manage, organize and utilize design knowledge, it is not only an exploration to develop creative design system, but also a road to systematically transplant design knowledge to software.

2. Architecture of brain model

In the view of cognitive psychology [1], see figure 1, the human brain has a structure including Preceptor, Effecter, Memory and Control Unit to carry out information processing.

In these four parts of human information processing system, preceptors are equipments to attain information; effecters are equipments to output actions, and memory is an equipment to save information. Control unit is the control equipment to supervise the whole process by generating aims, and planning serials actions to realize these aims. Based on memory and controlled by control unit, information inputted, saved, accessed and outputted. These four parts affect mutually and organise to compose one united system.

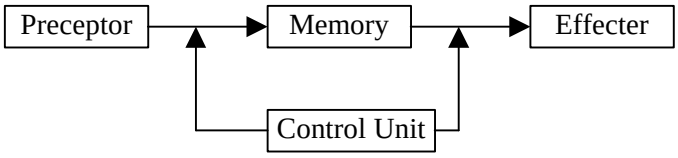

Figure 1. Basic structure of brain in view of cognitive psychology

In macroscopic, brain has some functions like associate, image, compare, judge, abstract, generalize, dream, language, problem-solving etc. In view of extern environment, the whole process of brain is just stimulus (external information inputted)-react (actions outputted). In microcosmic, the information processing process can be think as following: external information inputted be transferred into nerve impulses by different kinds of preceptors, when nerve impulses been conducted into brain cortex, relations of nerve cells replace the nerve impulses of expressing information inputted, and then on the base of these relations of nerve cells, information processing are carried out. In generally, it is also stimulus-reaction mechanism that every nerve cell is excited or suppressed when get impulses from other nerve cells. The basic function of brain is stimulus-reaction, only when a great deal nerve cells get information and enrich its' knowledge, brain can associate, image, compare, judge, abstract, generalize, dream, language, problem-solving in practice life.

Therefore, we build a brain-style information-processing model on the base of stimulus-reaction mechanism. Figure2 show the computational model of stimulated brain.

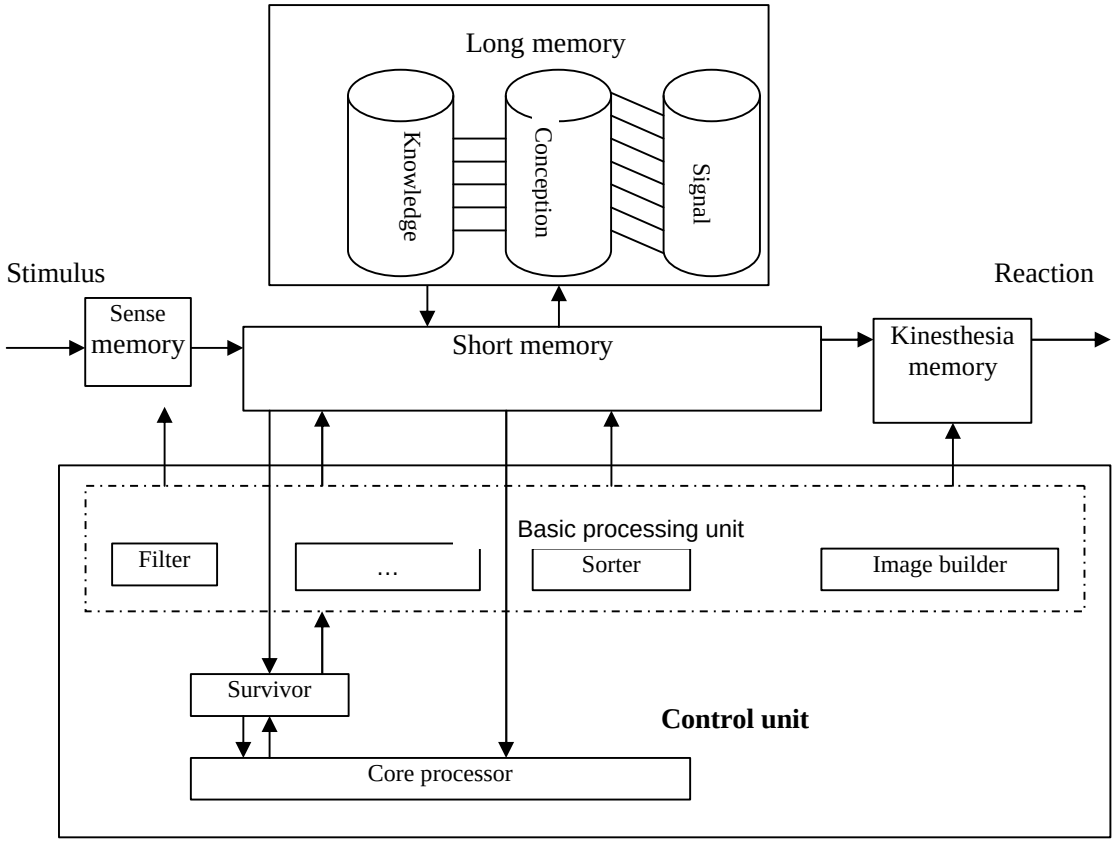

Figure 2. The computational model of stimulated brain

We can describe the working process of model as: external things input stimulus by preceptor, after filtering by attention, these have strong strength or needed is save in sense memory. Then some semantic fragments is build in work memory, then, brain begin to search and match these fragments in long memory to get some need data, information, knowledge. At last, results are put to kinaesthesia memory, and based on these kinaesthesia memory, some action is arrange to react to external things.

3. Memory of brain model

Memory is the place brain saved information. Generally speaking, memory consist of three kinds of memory, they are temporary memory, long memory and work memory.

Temporary memory: including sense memory and kinaesthesia memory, it last shortly, and keep temporary information related to preceptors or effecters.

Long memory: keep some memory last long time, it consist of all kinds of information like knowledge, rules, procedure etc. Most of nerve cells saved information are in relatively rest state, only a few nerve cells can because active and enter into work memory.

Work memory: it is the workstation that brain process information, generally speaking, work memory consist of some work memory and some special procedures.

Here, we build a stimulated model to represent knowledge and information in computer. It has a three layers structure of signal layer, conception layer and knowledge layer.

3.1 Signal layer

Signal layer is related to stimulus directly, one nerve cell save a signal or a stimulus. The signal layer consist of four basic processing procedures as signal accepting, signal saving, signal accessing, nerve cell reaction.

With the aim to save data in database of computer, signal is build by a three factors array.

$$\text{Signal} = f(\text{Object}, \text{Relation}, \text{Value}) \quad (1)$$

In (1), object is key factor. Relation consist of “kind”, ”case”, ”property”, Therefore, signal can represent some fact like” dog is a kind of animal”(kind relation), “Toni is a dog”(case relation), “dog bay”(property). Value can be number, fuzzy value, or be noun, adjective, verb and so on. Here, we must point out that signals can repeat in the layer. If there are many repeat signals in layer, the information of signal is easy to access, that is, can remember easily.

Here show an example of database fragment saved signals, see Table 1.

Table 1. An example of database fragments saved signals

Key signal Name	Signal relations	Value
lumber	Kind	material
mental	Strength Property	hard
plastic	Kind	material
lumber	Texture Property	rustic
yellow	Case	sunlight
circle	Kind	shape
plastic	Sense Property	lively
...	...	...

Following are four basic processing procedures of signal layer:

(1) signal accepting:
Extern information is divided into some independent signals because computational brain used to percept independent property. And after some process like filtering, judgment and so on, signal can be accepted and saved in signal layer.

(2) signal saving:
We save signals according to distance rules. That is, refer to functional axis of brain, we divide signal layer into some data areas. Then we save signals in data area near sense, and signals of closer relations to existing signal are saved firstly.

(3) signal accessing:
Signal accessing is according to rule of activation limitation, when nerve cell get impulse from near cell, if something alike, the nerve cell get to a certain activation limitation and excited, and the signal saved in it can be accessed. Otherwise, the signal cannot be accessed.

(4) reaction of never cell:

Only two kind of reaction a nerve cell can show when get impulse from other never cell, that is excited or suppressed.

3.2 Conception layer

On the base of signal layer, conception layer is build. Generally speaking, as figure 3 shows, conception can represent as “kind”, ”case”, ”property”. Therefore, when signals have more and more relations, some conceptions can be built.

We apply spreading activation model ([2][3]) of Collins and Loftus in conception layer. See figure 4 we organize conceptions according to semantics relations. A network node represent conception, link line between two nodes represent relations of two nodes. Shorter line, closer relation is, that show two nodes have more property alike, for example, “apple” has a closer relation with ”pear”, but has a far relation with “red”.

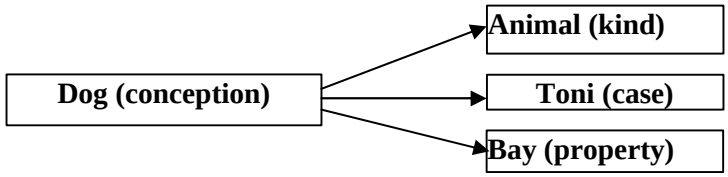

Figure 3. The semantics representation of conception

Used spreading activation model, we can stimulate brain associating. When a network node of conception get impulse, the node is excited, then it produce and send impulse to near nodes, and the impulse will spread. The spreading strength of conception will stepwise weaken. When some node get impulse from different source add up to a active limitation, node will evaluate the active network passage, get a result of like or dislike so that to change the spreading strength, that is, make more excited or suppressed.

Therefore, the spreading strength relevant to the link strength, and the link strength relevant to used frequency of link passage. So, link has two property, one is length, one is strength, length represent closer or far relation, strength represent easy or hard when transfer impulse. Based on these definitions, associate, analogy functions of conception can be stimulated, and these two functions will do a deal for brain to think and work.

3.3 Knowledge layer

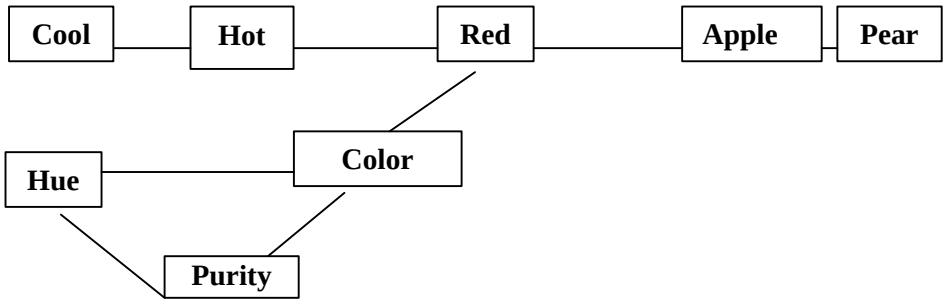

Figure 4. spreading activation model

Knowledge layer is design to represent two kind of knowledge: description knowledge and procedure knowledge. In traditional AI system, proposition and rules are usually used to represent two kinds of knowledge. Here we can safely build knowledge refer to AI system.

Therefore, based on conception layer, we build more complex knowledge in two ways. One, simple conception can apply adjunction, conjugation, disjunction and so on to build complex conception; Other, we build event context by use action as centre conception, and add others conception like people, condition, object, tool, place, time etc. Use basic event representation, some descriptive knowledge and procedure knowledge can be saved in knowledge layer. See Table 2,We can build a whole event description in the memory.

Table 2. Parts description of a whole event

action	In event, verb is usually used to represented action.
people	People who act
condition	Condition that event happened
tool	Thing has evoke or complete this event
place	Place event happened, generally, two places are involved.
object	Object affected by action
receiver	People affected by action
Time	When, the event happened
Reliability	Mainly use to express false state

Used three layers, the long memory structure can be built. Much complex, vivid domain knowledge are saved and organized in the memory structure. Based on these knowledge representations, brain could think and do complex work.

4. Control Mechanism

Essentially, behaviours of brain model are some information processing processes in control of some mechanisms. The basic control mechanism is stimulus-reaction outsider brain, and excited – suppressed insider brain. Here we build brain thinking state by BDI (belief-desire-intention) theory, and generate motive to control brain's behaviour so that to carry out information processing.

4.1 Self-balancing Mechanism

Brain is self-balance system. Nerve cells have to obey two control rules to keep this balance.
(1) prevalence principle:
There is a conclusion in physiologic, when very important stimulus act on man, a certain stabilized, centralized excited centre will form in brain. That is prevalence excited centre. The forming of prevalence excited centre will affect other nerve axis and make nerve cells in these areas suppressed. In such case, other nerve axis is difficult to active and attends to information processing process. It is the basic principle that nerve cells have to obey.
(2) excited conservation principle:
Nerve cells insider brain has only two states: excited or suppressed. But according to excited conservation principle, Nerve cells in one axis can not always excite or suppress. These Nerve cells will tire and suppressed after a period of excited time.
Nerve cells in brain are control by both prevalence principle and excited conservation principle. Then, brain is a self-balancing system.

4.2 Mental State of Brain Model

We use belief-desire-intention to descript thinking state of brain. In computer, we build belief-desire-intention so as to divide control mechanism to many levels and let them work in different time. Belief can be predefined in brain so as to make sure such prevalence, for example, different predefined belief of esthetician and musician make them grow in different ways. Of course, we must consider satisfaction of an intention very seriously. Otherwise, it is a disaster if intention generated can not be terminated. In [4] [5][6],some useful model are provided, we can safely apply these in our research.
In view of microcosmic, the generation of an intention is also result of nerve cells excited, here list three ways generate intention:

(1) Unbalance of some parts insider brain, for example, consciously learning;
(2) External stimulus transfer to brain axis;
(3) Nerve cells in some area automatically excited after a long suppressing time.

Generally, brain is a self-balance system, it drive directly by inner state, extern stimulus just change some balance to drive it indirectly.

4.3 Growth Mechanism

It is very important for brain model growing to enhance its knowledge or intelligent. Brain's growth can divide into three stages as accept stimulus, enrich memory and build thought. The growth process

is a stepwise process, and these three stages have no clear border.

(1) Accepting stimulus: Brain begins to accept and save signal, many independent, dispersive signals got from extern environment are saved in brain.
(2) Enriching memory: When the number of signals get to a certain quantity, relations between signals begin rich to build some simple conceptions according to “case”, ”property”, ”kind” relations. In computer, some sorters are used to so these works. And the relations of simple conception stepwise build a network.
(3) Building thought: Then, based on many conception and data in the conception layer, the useful knowledge can be attained. Simple conception build complex conception and the work use event description to organize knowledge. When the description knowledge combined with operating knowledge, brain build its thought.

5. Conclusion

The paper build a simulated brain model by building a memory model of three layer structure used semantics networks and artificial neural networks, and some control mechanisms like self-balancing, self-learning, self- organizing is built to react to extern stimulus. Now, we build a prototype model and have got some preliminary results. A computer aesthetics evaluation system with the idea has been developed and used in practice design-effect evaluation. And a web data digging system is also developed to supporting market analysis process of product design. We are certain that building brain-style system is a hopeful road to manage, organize and utilize design knowledge.

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