Proceedings of ICAD2000
First International Conference on Axiomatic Design
Cambridge, MA – June 21-23, 2000
ICAD004

"CREATIVE DESIGN ENGINE": A COMPUTER AIDED CREATION TO SUPPORT JAPANESE DESIGN ACTIVITY

Masayuki Nakao, Kiyoshi Matsumoto and Yotaro Hatamura

Email nakao@hnl.t.u-tokyo.ac.jp
Dept. of Engineering Synthesis, The University of Tokyo
7-3-1 Hongo Bunkyo-ku, Tokyo 113-8656 Japan
TEL +81-3-5841-6360
FAX +81-3-5800-6993

ABSTRACT

To support Japanese design activity, software of computer aided creation called "creative design engine" is proposed. It is composed of thinking operation engine, knowledge search engine, decision transfer CAD and design knowledge database. Especially, it assists functional analysis and mechanism selection in designer's thinking process.

Keywords: Design theory, Creative design, Function analysis, Knowledge database,• Search engine

1. INTRODUCTION OF CREATIVE DESIGN ENGINE

Now, Japanese manufacturing industries are suffering from two problems on design culture as explained in Fig. 1: (a) poor planning for new products and (b) poor transmission of design knowledge.

Fig. 2 is a diagram of thinking process of designing a new product[1]. Requirements for the product are analyzed and decomposed into functional elements. The functional elements are mapped to mechanism elements that meet the corresponding functions. The mechanism elements are developed and unified to a final structure. The first half process in Fig. 2 corresponds to the functional domain in the axiomatic design[1], the second half to the physical domain.

First, designing for a new product is an indispensable process for emerging industries such as information processing devices, communication devices or biochemical instruments. A senior planner or a chief designer is required to have a talent for methodology of this conceptual design process; he/she analyzes customer's requirements, decides functional business factors, decomposes a function into functional elements, checks their interferences with restraints, selects a mechanism for each functional element and tentatively assembles the mechanisms. The analysis is operated mainly in the first half of design process in Fig. 2. It is done in the designer's brain, so it is difficult for other design members to look, check or learn.

However, there are few people with this talent in Japan, because most of Japanese engineers have been copying mechanisms from foreign designs for these 100 years. Engineering students have been required design techniques such as understanding conventional mechanisms and drawing complicated structures. The techniques are useful for the second half of design process in Fig. 2. Now, we need to clarify designer's brain work, and to assist the analytical first half process.

Secondly, transmission of design knowledge is necessary for matured industries such as automobile, nuclear plant, wrist watch or metal making. Now we have many troubles because of lack of transmission of design knowledge. For example, a minor design change due to cost-down may induce a major design claim because the designer didn't learn failure histories. A new designer wants to know the reason why the predecessor decided the mechanism. Of course, the predecessor wanted to inform the reason to the successors, but he might be too busy. We need to build a useful education program/tool of transmission of design knowledge.

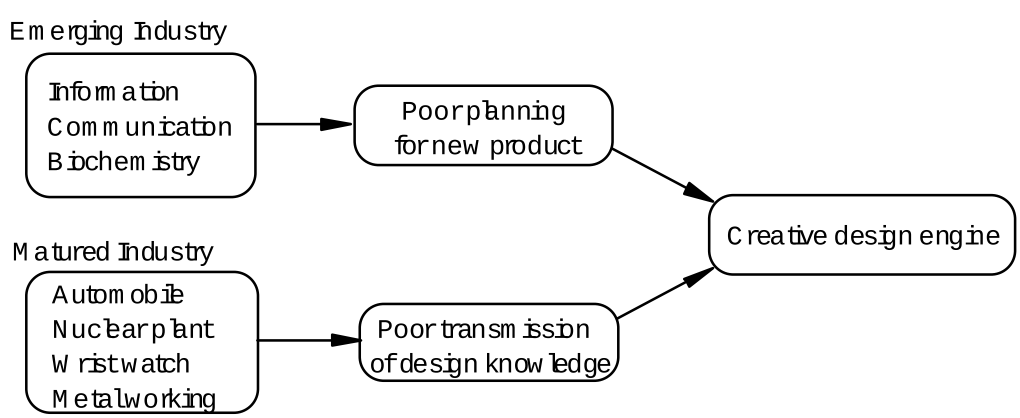

Fig. 1 Necessity of creative design engine

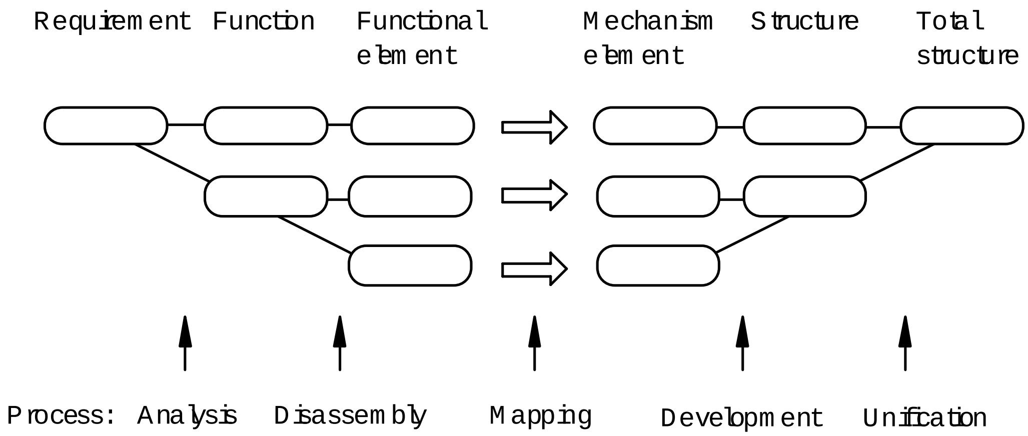

Fig.2 Design thinking process diagram

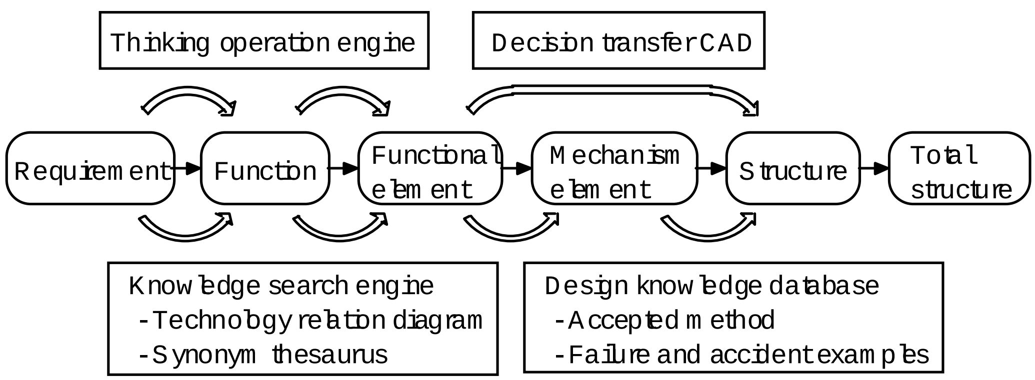

Fig. 3 Relation between design thinking process and units of creative design engine

Consequently, to solve the problems and to keep Japanese design activity, the authors are developing software for computer aided creation, called "creative design engine". The creative design engine has following four parts: (1) thinking operation engine, (2) knowledge search engine, (3) decision transfer CAD and (4) design knowledge database. Fig. 3 illustrates relation between the parts and the above thinking process. We will introduce them in the following chapters.

2. DESIGN OF CREATIVE DESIGN ENGINE

2. 1 THINKING OPERATION ENGINE

The thinking operation engine supports the first half process. It helps to analyze the functions and to decompose them into the functional elements. It sets several symbols as shown in Fig. 4, which represent requirements, functional elements, restraints and mechanisms. It also checks disadvantageous relations, conflicts or interference on a thinking operation plane of a design space. It also suggests some thinking operation methods for solution of the conflicts or interference. Fig.5 shows an example of the thinking operations. These operations are presented to the designer when he wants to develop and decompose the functions.

2.2 KNOWLEDGE SEARCH ENGINE

To express the functions is difficult for design beginners. Most of the engineers memorize his knowledge as images of mechanisms or structures, not as words. They conceptually design a mechanism with the images in the brain; they have no experience to analyze functions with language.

To support his language domain, we prepare two dictionaries using technical nouns and verbs, which is called "synonym thesaurus" and "technology relation diagram" in the knowledge search engine. The synonym thesaurus is used when he searches a well-defined, engineering, normalized word from a vague word. The technology relation diagram is used when he searches related technical words like an association chain. Fig. 6 shows an example of the technology relation diagram.

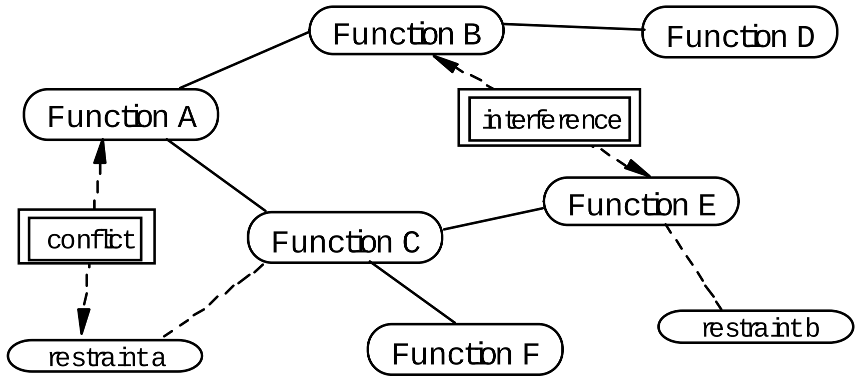

Fig. 4 Decomposition of functions using thinking operation engine

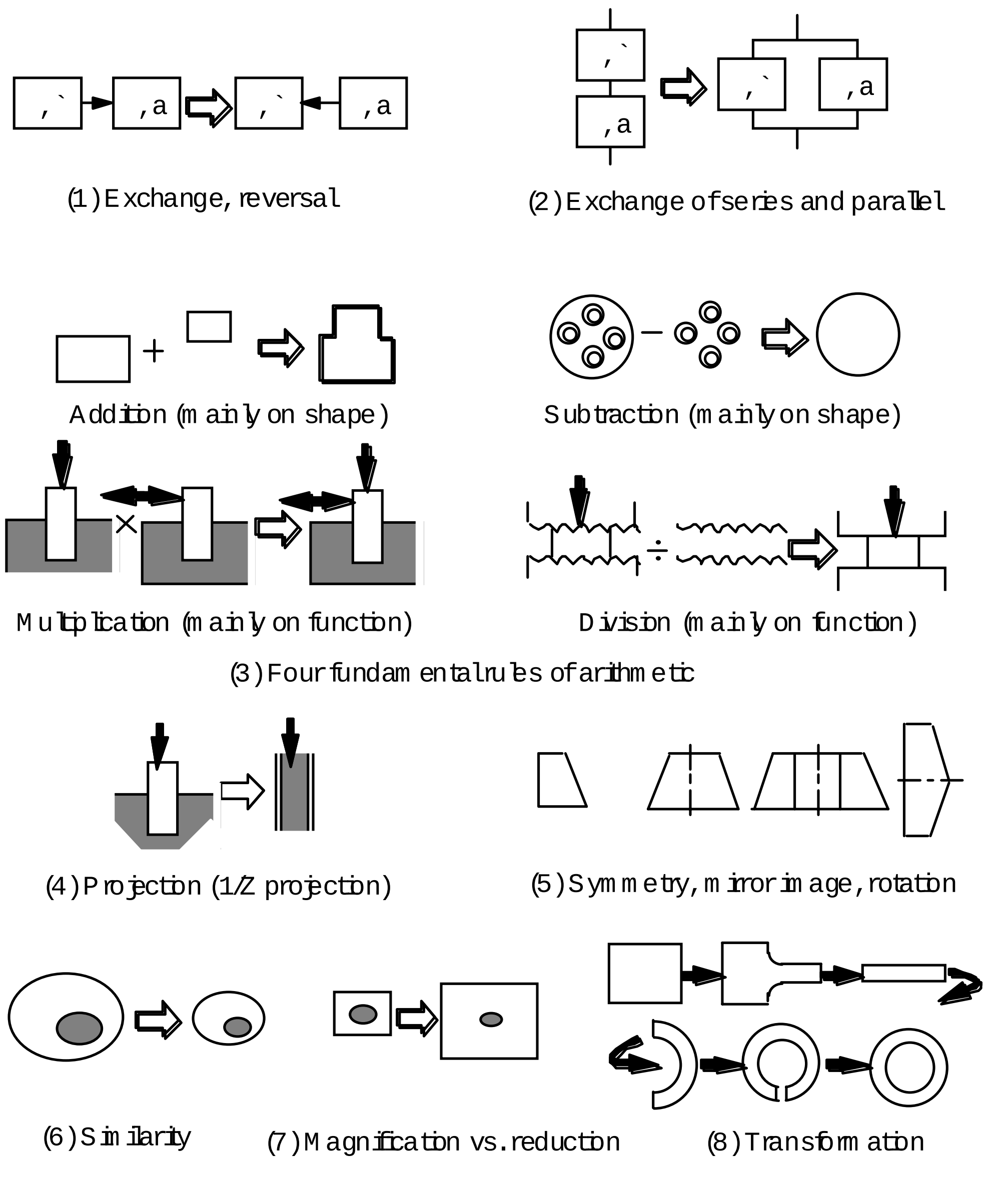

Fig.5 Thinking operations for expanding ideas

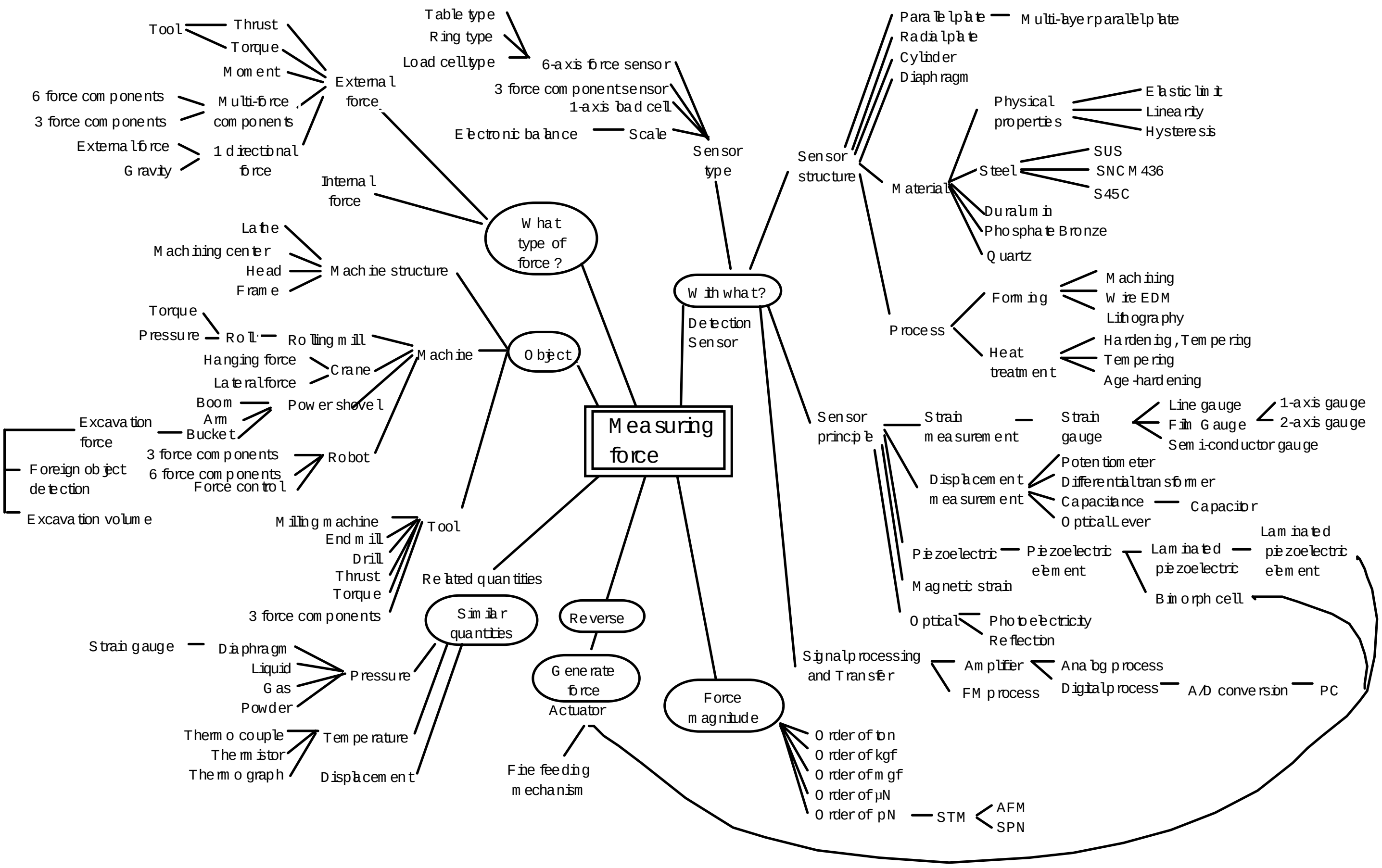

Fig.6 Example of technology relation diagram

2.3 DECISION TRANSFER CAD

The decision transfer CAD is shown in Fig. 7. It connects the first half process with the second half process as illustrated in Fig. 3. The 3D-CAD links the above-mentioned software and embeds them on the final scheme drawing. It looks like a production data management (PDM), but the related data are directly embedded in a individual shape, chamfer, fillet and so on, or a individual comments of dimension, surface roughness, fabrication method, material, heat treatment and so on. It presents the drawing in many ways using the embedded information. Furthermore, the reason of the decision or selection, "how it was decided", can be presented on the drawing. It makes it easy to transfer the knowledge.

The predecessor may decide only several design parameters per one drawing with considerable reasons, logical analysis or correct calculation, but decided the remainder with insignificant reasons such as rounding the number, copy from the conventional product or just intuition. We can focus only the former.

To transfer the knowledge, we should reduce or eliminate input time of the knowledge. Otherwise, nobody will use the software. Without any CAD, we could have transferred the knowledge; even hand-written comments on the drawing works well. But the engineers tend to be too busy to write down their experiences. Our new CAD automatically saves the used knowledge and memorandum as well as possible.

2.4 DESIGN KNOWLEDGE DATABASE

The design knowledge database presents accepted methods of a certain technical subject or failure examples of the subject. Fig. 8 is an example of a failure presented by the database. The example shows breakage of a shaft caused by swarf generation, and shows similar accidents that may happen. We plan to collect about 1,000 data within these 2 years from our collaborating industrial companies or our published design textbooks. We add "knowledge keywords" besides the text and figures. It is useful for the designer who wants to utilize the same knowledge.

3. APPLICATION TO DESIGN OF IMPLANT ELECTRODE

We applied the creative design engine to design of a plane-type multi-electrode for implantation. This electrode is fixed on a rat brain for stimulation and signal pick-up. Fig. 9(a)(b) show the electrode and its tip which our student designed, and Fig. 9(c) shows its implantation surgery.

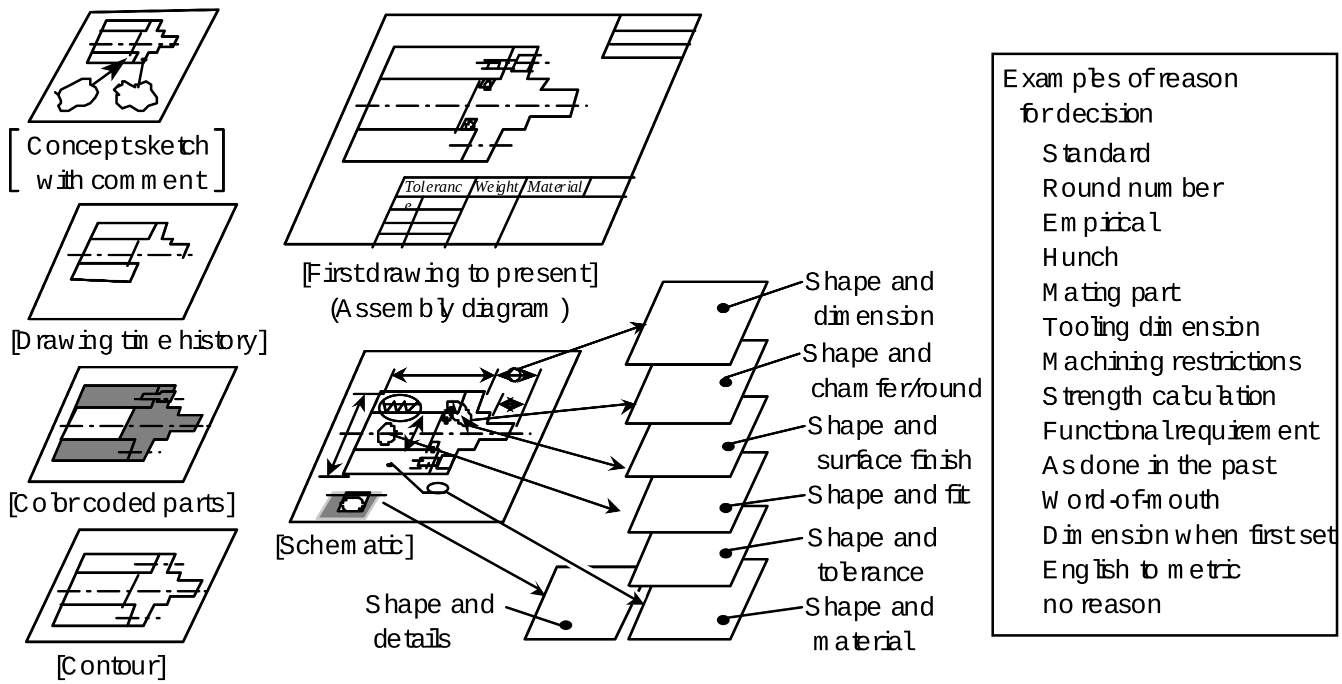

Fig. 7 Decision transfer CAD systems

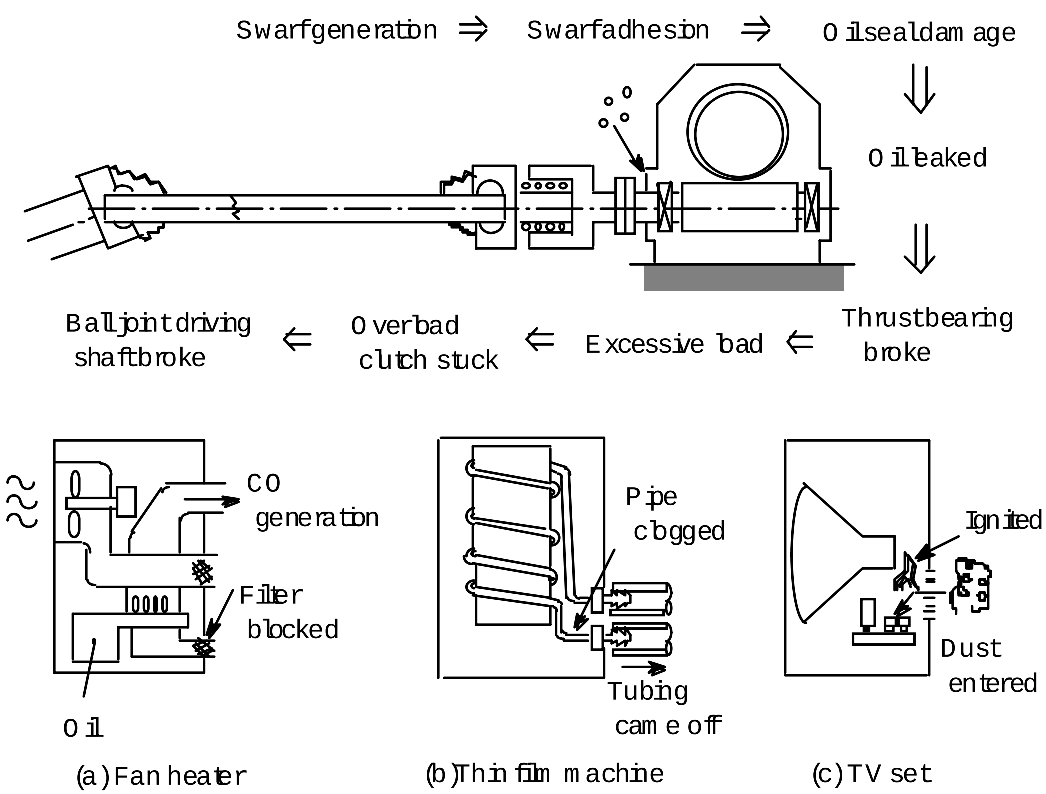

Fig.8 Example of design knowledge database

At first, requirements for the electrode is analyzed and decomposed to functional elements with a help of thinking operation engine. To visualize this conceptual process with language, the designer is asked to fill up the thinking process development diagram. For example, the designer write down the following words in the blanks: "to stimulate a brain", "to fix an electrode", "a quick-hardening surgery glue tentatively and a nerve growing permanently" and "scleroproteins of fibrin and collagen".

After the decomposition, some mechanisms are presented. For example, "to fix" the electrode to surface of a brain is one of major functional elements. By the word "to fix", some mechanisms to fix the electrode are presented : a surface force of brain liquid, a glue with a brain, a wound-string with a skull, a spring against a skull, etc. The mechanisms are searched by a key word like " to fix".

In some cases it is difficult for the designer to decompose the requirements. In the electrode design, we first consider the word of a "penetrated pin" because we have an image of a conventional pin-type electrode. To enlarge his design options, we have to climb to the functions of "to fix", "to keep good contact" or "to insert/remove" from the mechanism of the "penetrated pin". Using the technology relation diagram, we get an association chain such as "pin, connector, insert, fix, friction, contact, resistance and so on". Then we can select "to fix". From the word "to fix", the knowledge search engine presents general fixing mechanisms such as screwing, welding, soldering, adhering, sticking and so on. Then we can select "adhering".

The design knowledge database presents some information when a functional element is mapped to a mechanism. For example, a failure fact that "a glue becomes brittle under low temperature" is useful for a designer who wants to fix parts with glue.

4. EVALUATION OF PROTOTYPE OF CREATIVE DESIGN ENGINE

We made a prototype of the creative design engine, and evaluated. We gave our students some design requirements, and asked them to design a mechanism with a mechanism chart.

We found the following results; most of the students could not express the functions; they directly selected mechanisms using an image drawing, without any functional analysis; the strategy of "function first, mechanism second" as a thinking process didn't work well, synonym thesaurus and technology relation diagram of about 2,000 words each were not enough to express the functions; the offered company data are too specialized, detailed and technical to be generalized; a "knowledge manager" were necessary, who navigates design beginners to express the function.

From these results, we are improving the software; the strategy of "mechanism first, function second" is still preserved, but the software allows navigation of the functional analysis from mechanisms that are selected tentatively; the images of mechanisms should be linked with language in the technology relation diagram; the two dictionaries should be expanded to at least 20,000 words each.

5. CONCLUSION

To solve the Japanese design problems of poor planning for new products and poor transmission of design knowledge, the authors are developing software of computer aided creation, the "creative design engine". This paper introduced the design concept and the prototype. We are still making an early-stage prototype, but evaluate the promising results.

ACKNOWLEDGMENTS

We thank Prof. T. Yoneyama, Prof. Y. Yamamoto and Prof. H. Kinukawa for useful suggestion; The Mechanical Social Systems Foundation for research fund; Mr. H. Mase and Hitachi, Ltd. for detail design of the software; Hitachi, Toshiba, Toyota, Nippon Steel, Seiko Epson, Asahi Glass, Konica, Komatsu, Nissan, Furukawa Electric for offer of the knowledge data.

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Fig.9 Electrodes for brainstem implantation