Striving to achieve "Human" information processing

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(1) When I completed my undergraduate degree and entered graduate school in 1959, Japan was witnessing the dawn of the computer age. In the second year of my Master's Program, computers had finally become accessible to students like myself, but at that time, programs were written in a language called "assembler language," and programs and data were input into the computers using paper tape. We had almost no academic journals from outside of Japan, and even when we did get them, they were usually more than six months old. At best, we had a vague impression that researchers were discussing about the incredible versatility of computers.

Ever since I was a child, I had been curious about the human mind and the workings of the brain, so I was very interested in the versatility of computers. I thought, if they were really so versatile, then perhaps we could teach them to do high-level human tasks, such as language translation or character recognition. At first, I began with Noam Chomsky's context-free grammar, but I soon realized that language could not be handled using this approach alone. I then incorporated the concept of "sememes" (the atomic meanings of words) using Roget's Thesaurus as a reference, and this made it possible to generate meaningful sentences from computer. I presented this research at the first International Conference on Computational Linguistics in New York in 1965, where it gained considerable attention.

The important element here is the role of the verb, which functions as the central component of the sentence. I studied a variety of grammars, and realized that the "Case Grammar" advocated by Charles J. Fillmore is the most appropriate grammar for computers. I also found that restrictions must be placed on the words that can be entered in the slots of the case frames of a verb, depending on the sememes.

For four years starting from 1982, with funding from the STA Program of the Science and Technology Agency, I conducted research and development targeting Japanese-English, English-Japanese translation systems for the abstracts of scientific and technical papers, incorporating the Case Grammar approach. The resulting system was later expanded with increased volumes of dictionary data, and an improved grammar. The system is still in use today.

(2) Even as I began this research, I was aware, to some extent, of the limitations of a system with this framework; for example, the fact that you have to write huge numbers of grammar rules to accommodate new expressions, and that no matter how many sememes you add, there are some subtle expressions that simply cannot be handled. I was thinking about how humans resolve these translation problems, and it occurred to me that generally, humans learn the translation for a given expression from someone else, and then translate similar expressions in the same way. I thus proposed a translation method which does "loan translation" — that is, preparing a translation dictionary comprised of English Japanese expression pairs corresponding to sentences or phrases of an appropriate length, and referencing that dictionary when similar expressions appeared. This method, which I called "translation by analogy," makes it possible to handle a variety of new expressions simply by increasing the content of the translation dictionary, and to eliminate the need for time-consuming processes such

as changing artificial frameworks like grammars and sememes. The greatest merit, however, is that it offers high-quality translation expressions. For this reason, it has come to be used widely not only in Japan, but throughout the world, under the name "Example-based Translation."

(3) When I examined the causes of failures in the analysis of sentences, I found that the most common reason was in long sentences, where several expressions were being used in parallel. Therefore the detection of which parts of the sentence have parallel structures is required, and I succeeded in this by introducing a dynamic programming method. Spurred on by this success, Dynamic Programming is now used extensively in resolving a variety of issues related to language processing.

(4) The thing that I learned through the course of our research in machine translation is that in this field of research, international collaboration is essential. From the end of the 1970s, I encouraged the Japan Electronics Industry Development Association and the Ministry of International Trade and Industry to dispatch teams several times to investigate the status of machine translation in Europe and the U.S. I hosted various international conferences almost every year since 1986, and in 1991 I established the International Association for Machine Translation, for which I was the first President. The IAMT holds international conferences every two years in Asia, Europe, and the U.S. on a rotating basis, to exchange information and present research results on various themes, including machine translation technologies and new applications for translation systems developed from the user's perspective. I also created the Association for Natural Language Processing in Japan, with the goal of contributing to the further development of this field.

(5) Image analysis and recognition is another aspect of "Human tasks undertaken by computers." I began conducting research in character recognition in the 1960s, and the results of this research were incorporated into a first postal code reader. Many other researchers began working in the field of character recognition, however, so I shifted the focus of my research to the analysis and recognition of photographs and other images, which at the time was a field that no one had yet explored. I started out by undertaking the world's first research in the analysis of human facial photographs, but simple analysis resulted in high percentage of failures, because there is such a diverse range of facial characteristics, and because eyeglasses and other accessories tend to throw the analysis off. I decided to set as the constraint conditions the relative positions of the facial features, such as the eyes, nose, mouth, and jaw. I wrote a program with feedback process in recognition; for example, if the system couldn't recognize the mouth correctly, it would go back to the position above the mouth, find the nose once more, and then use that as a reference to recognize the position of the mouth. In this way, I was able to dramatically increase the accuracy of face recognition.

The next stage of my research was in the analysis of aerial photographs. In order to recognize the objects in photographs — for example, roads, farmland, houses, and automobiles — we have to achieve recognition that satisfies a wide range of conditions as completely as possible, and with a minimum of contradictions among

these objects in a photograph. This recognition does not rely simply on color and shape, but also takes into account, for example, that a car is located on a road, or the way in which the shadow of a house or a grove of trees falls in a fixed direction depending on the conditions of the sunlight when the photo is taken. We achieved this by introducing a "Blackboard Model" which was developed in artificial intelligence research into the image recognition system. This feature of using a "human" process of trial and error, and of generating the most appropriate results from a comprehensive perspective, is what made my research works in image processing so completely unique.

(6) By the end of the 1980s, computers were capable of handling documents and images with considerable ease, and huge databases had become accessible as well, so I combined the research that I had conducted up until that time into a new theme: "Digital Libraries." In addition to search and retrieval by standard bibliographic information, we developed a highly accurate search method that effectively utilizes table of contents information, and also incorporated the concept of hypertext. Another feature I developed was a user interface equipped with machine translation and a variety of other convenient functions. I worked with companies to create a prototype system, and proved its effectiveness through a public demonstration in 1994. This system, one of the first to be developed anywhere in the world, had functions and features that made it truly unique. The framework of this digital library system is currently being used in many places.

I have conducted varieties of research while gaining hints from the human brain functions. I believe that the approach of human-like information processing will become increasingly important in resolving many diverse issues yet to be faced.