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Impact of The Microelectronic Revolution on Future Industry [1])

By T. Kubo

1. The evolution of Japanese industry

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In ancient Japan, Wind and Lightning were believed to be gods as they were in some other cultures. In our oldest histories, it is written that the god of lightning exercised his supernatural power to uproot trees and send them flying as well as to pulverize huge boulders, and thereby defeated fleets of enemy ships. It is only a short one hundred years ago that electricity ceased to be a god, as Japan embarked on the road to the creation of a modern industry. Along with this industrialization, Japan's culture also became progressively more westernized. However, the traditional culture transmitted from our past has put down firm roots, and continues to flow as a strong undercurrent in our lives. The extent of the fusion of Nature with our literature, music, theatrical arts, painting, craftwork, and other aspects of the culture of our agricultural past, is particularly strong. The portion of this culture springing from our ancient imperial court and Buddhist temples is actually quite small in comparison with the overwhelming share that grew from ordinary people joining together in cooperation.

With the coming of the Industrial Age, the scale of companies expanded to include both small to large operations. However, the people working in such companies possessed a certain consciousness of cooperating in the running of the enterprise. In effect, they had a sense of a shared destiny. Fundamentally, this means that each individual feels that he has a responsibility, in his respective job, for the future of the company.

It is said that this phenomenon results from the fact that Japan is a homogeneous society composed of a single strain of people, without sharp differences in class or wealth. This is reinforced by the fact that there is a longstanding consciousness of sharing in a common culture. Accordingly, in Japanese companies, quality control is performed by all workers at every corporate level, accounting for the rapid and effective improvement in the quality of products. In the same way, productivity has also improved rapidly, and a system, without the disruption of large personnel turnover, has been realized. This pattern is widespread throughout the steel, chemical, machinery and all other major industries. There is every reason to believe it will continue in the future.

Japan joined the IEC in 1910. However, the manufacturing of electrical equipment had already been initiated as early as 1884. Nevertheless, until about 1930, imported equipment occupied a much greater market share than domestically manufactured products. In the field of industrial technology Japan made some contributions, for example, in the electrical material area with ferrite, and the invention of the Yagi antenna. However, here again the overwhelming share came from overseas.

After 1950, however, Japan's technology began to mark a rapid development. This sudden leap resulted from the nation's effort to make industry the main axis of its development, in addition to the fact that its industries continue to be based on the traditional cultural consciousness I referred to. Also contributing to the flourishing of Japan's electrical industry was the worldwide development of the philosophy of free trade.

Along with the increased demand for electricity, the number of hydroelectric, thermal, and nuclear power plants grew successively larger, and a wide and diversified variety of electrical appliances came to be used in almost all households. Additionally, the application of electronics, which began with communications, broadcasting, and computers, has come to permeate industry and society itself. Progress in electronics has come to be the motive force in the transformation of the industrial society into an information-based society. This electronics revolution has already become a reality throughout the world. Today I would like to describe my ideas about this present situation and what lies in store in the future.

2. An outlook to the year 2000

The computer communications system, which will form the basis for tomorrow's information-based society, will in the future have much higher-level functions than at present, and will also feature lower costs. As the range of public use of such systems expands throughout society, low-cost home-use computer terminals with performance equal to today's large computers will increasingly appear in ordinary households, and will be linked to large central processors and data bases. Figure 1 shows a few examples of the results of an extensive survey, conducted by the Japan Electronics Industry Development Association, to forecast what kind of systems will be developed and utilized in the future, and when we may expect them. Some of these have already been partially developed, and are now being utilized; some are now under intensive development, and their widespread utilization is predicted.

At present, there is a large-scale movement to mechanize the tasks formerly performed by manual labor. In addition, office work is also being automated. This may eventually lead to the performing of tasks through computer terminals installed in homes, doing away with the necessity of commuting to a workplace. Commuting to work will thus be limited to

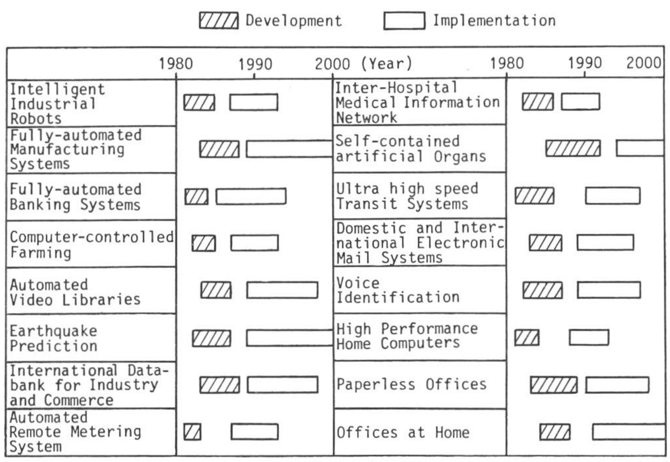

Fig. 1 Example of future Electronic System Forecast (Jeida)

[1]) This lecture was given on the occasion of the celebration of the 75th anniversary of IEC on June 19th 1981 at Montreux. The subheadings have been added by the editor.

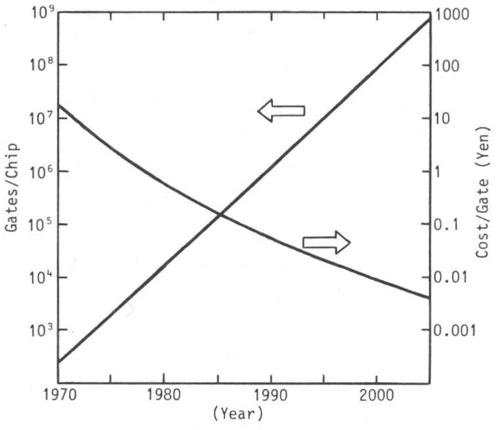

Fig. 2 Forecast of Integration Density and Cost per Gate for Logic LSI

occasions when especially creative work must be done or important decisions made.

Furthermore the intellectual work behind the design and manufacture of hardware and software for complicated and sophisticated systems will gradually be taken over by machines, and productivity further improved.

In recent years, the daily lives of people in their homes have been made enormously more efficient through the use of electrical appliances. In the coming electronic revolution, daily shopping, the selection of clothing, adult education, physical examinations, medicine, private interests, recreation, and a countless number of other social activities will be shifted to the home itself.

It is my fond expectation that, in the future, man will overcome the limitations of time and space, make his life richer, conserve more energy and easily fit into the society's move towards the goal of becoming information-based. Accomplishing this, I believe that in the future we will be able to lead satisfying lives in harmonious and peaceful societies.

3. The role of semiconductor technology

The support of science and technology is needed to advance the electronic revolution along a smooth course. One good example of this is the appearance of the microprocessor. The rapid progress of semiconductor science and technology, which no one had foreseen, formed the basis for the development of the microprocessor. Although microprocessors became available for practical applications only five years ago, they have already been put to work in nearly every field. Today, home appliances, office machines, automobiles, EDP systems, communications equipment, measuring instruments, and medical equipment are included among the vast array of machines and equipment that utilize the electronic wizardry of microprocessors. As of the end of 1980 it was estimated that 250 million microprocessors were being used throughout the world. It has also been forecast that the microprocessor business will continue to show a high annual growth rate of around 30% in the years to come.

Through the advances made in semiconductor technology, the cost per unit function for Large Scale Integration (LSI) has dropped over the past ten years at the rate of 30% a year. In the same period, there has been a two-order-of-magnitude improvement in the power-delay product. Furthermore, in the years to come we will see the day when the number of logic gates integrated on one small chip will reach 10^7–10^8.

This trend towards ever larger integration is shown in figure 2. Integration on such a large scale will be made possible through the super-miniaturization of devices, further reductions in power dissipation, refinements in packaging techniques, and improvements in circuit as well as device configurations.

4. Compunication Systems

The future system for the information-based society will be made up of a mammoth Central Computer Station as its brain, distributed processors and terminals as its hands and feet, and a Communication Network as the nervous system that links everything. Several years ago, I called such a system a Compunication System as a general term embracing all the components. Interestingly, without any connection with me, it seems that this term has also come to be used in other countries.

A schematic diagram of a Compunication System is shown in figure 3. The Compunication Age will have a higher level of internationalism than what exists at present. However, there are several large problems that stand as obstacles in the path to the future development of the system.

Figure 3 shows only the system hardware. The cost of developing the software needed to construct the system, as well as the cost of software maintenance, will increase sharply as shown in figure 4. In the years ahead, software-related costs will probably account for more than 90% of the total cost.

At present software is at a much lower level of productivity than hardware. The reason for this is that most software is produced through human labor. As figure 4 shows, the large increase in the proportion of the total cost accounted for by software is due to the personnel costs involved in software production.

When we consider that there will be a great expansion in the number of systems in the future, and that each system will be on a colossal scale, it is no exaggeration to say that it will be impossible to develop and maintain all the necessary software. Therefore, the need to increase our software productivity is one of the most urgent tasks confronting us.

Another important problem related to software is its lack of application on an international scale. At the present time,

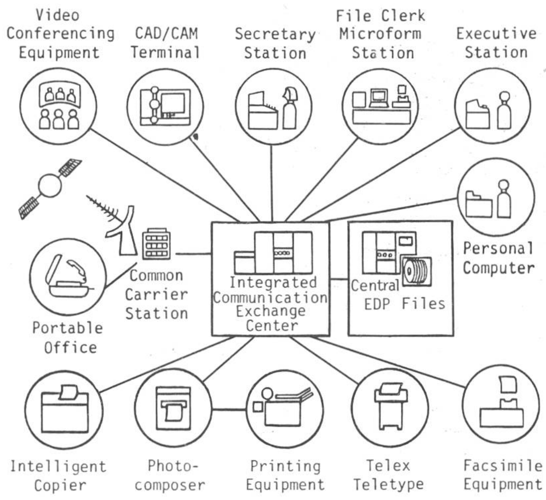

Fig. 3 The Prototypical Office in the Future

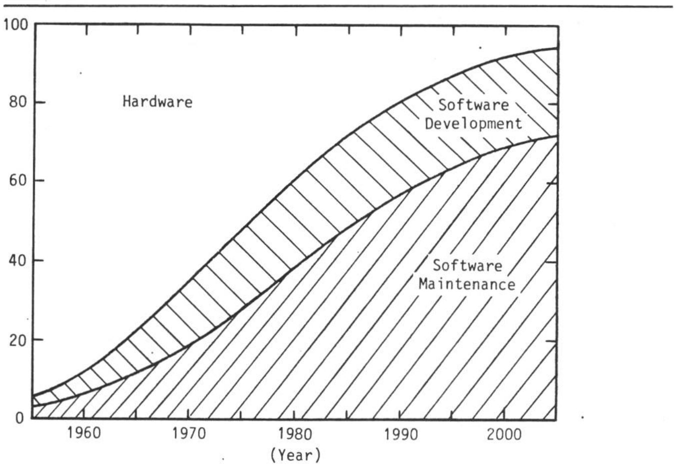

Fig. 4 Software Cost as an increasing Percentage of total Computer System Cost

only a very limited number of people are enjoying the benefits of the microelectronic revolution. Moreover, the number of people having access to computers, which represent the driving force behind the revolution, is even further restricted. Thus, spreading the benefits of the microelectronic revolution to all the peoples of the world is yet another technological task that we must grapple with.

5. An overall International Computer Language

In conjunction with the development of larger and faster computers, the languages needed to communicate instructions and commands to them have gradually progressed from the basic machine code to high level programming languages. Among the languages devised to date, there are high level languages such as PASCAL and ADA which are very easy to use, as well as various types of POL, that is problem-oriented languages.

Development has also been started to produce specific hardware that will be oriented towards these languages. In other words, instead of making software bear all the complexities of the language processing program, if both software and hardware share this burden, the overall development process can be greatly simplified. However, even if this approach is adopted, there will still be large gaps between the natural languages, i.e. our mother tongues that we use for everyday communication with other people, and the languages used to communicate with computers. Consequently, one large problem remaining to be solved is how to bring computer languages closer to our natural languages.

The pursuit of a simple, easy-to-understand language has led researchers to consider the use of natural languages or speech, as well as graphs and symbols, as a medium for programming and effecting communication with computers. At present, research is under way in many advanced countries to develop computers that will be able to understand natural languages.

I think it is quite safe to predict that in twenty-five years some countries will have achieved the art of using natural speech in programming. It is my sincere hope that this future vision will encompass as many nations of the world as possible. To make this dream come true, I would like to propose the establishment of an international computer language, which I will call IL for short. IL should be easily translatable into advanced programming languages and should afford complete notation in terms of both grammar and logic. Figure 5 shows how an interface between the language of each country and a computer can be achieved by using IL. The expected results of adopting IL can be summarized as follows:

1. By simply producing a system for translating between its own language and IL, every country in the world will be able to utilize the software assets contained in each section of IL. This would greatly reduce the amount of software that will have to be produced in future years as more systems come into use.
2. IL itself will be strictly a logical language. As such, it will not permit the free expression that natural languages are capable of. However, there will be no problem in spreading the application of IL, because it will be designed for use by certain specialists around the world rather than by ordinary laymen.
3. Every country will produce programs in IL notation for translating its language into IL and vice versa. These translation programs will make up an international exchange system. Moreover, in international communications all data can be transmitted in IL notation. Thus every nation will have common access to this machine translated data.
4. The use of IL will not only be advantageous for the Western bloc countries, but will also achieve a more rapid diffusion of the benefits of Compunication to many nations throughout the world. In this sense, it will help to build a foundation for maintaining world peace.

I am convinced that setting up IL as an international computer language should be an important task for both ISO and IEC in the coming years. I would also like to add that much more effort should be put into the research and development of artificial intelligence. There is a definite need to further advance the work now being done on artificial intelligence in such areas as natural language comprehension, information base systems, speech recognition, and pattern recognition.

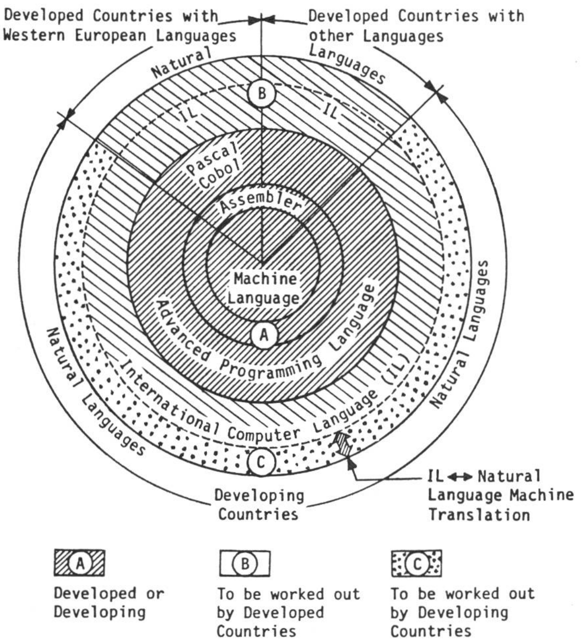

Fig. 5 Role of an International Computer Language

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