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INFORMATICS AND MODERN SOCIETY*

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Ladies and gentlemen, we have entered into a decade which offers mankind huge opportunities and ever greater challenge. The decade of the 70s will see the Republic of China achieve enormous increase in Gross Nation Product and reach historical record-breaking prosperity.

The major area in which our society would face a critical challenge in the 1970s is the explosion of knowledge which would continue at an accelerated pace. In order to insure our economic survival, we can no longer afford to ignore the development of the most important national assets: scientific information.

In 1830, there were about 300 technical and scientific journals in circulation. Today, there are over 60,000 journals and 2.5 million articles per year throughout the world in over 50 languages. Each year approximately 80,000 new book titles are published throughout the world. Every year approximately 20 billion checks pass through the banks, with each check being handled 4 to 5 times. The U. S. Post Office is facing a severe mail problem-today it handles 82 billion pieces of mail per year; this figure will reach 116 billion by 1980. The U. S. federal offices currently maintain files for more than 200 million fingerprints, 150 million social security accounts, and 100 million tax returns. Other leading nations in the world will sooner or later face similar problems.

I cite these astronomical figures to give you some idea of what lies ahead for America, the Republic of China, as well as the whole world and to set the stage for my discussion this morning of the impact of informatics upon our modern society.

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The word informatics is coined from information and mathematics. It is a new field of scientific endeavor which is concerned with the computer and information problems. It is commonly referred to as computer and information science.

The conception of informatics arises basically from the use of modern computers and information processing technology to extend man's intellect, to handle automatically some of the man's higher mental tasks, and to solve the severe problem created by information explosion. It is the computer industry which holds the key to our success or failure.

I want to discuss with you today the scope of informatics and its impact upon our modern society. This field of scientific study is inter-disciplinary in nature and encompasses a very broad spectrum.

Ten years ago, realizing the importance of informatics, I organized the first International Symposium on Computer and Information Science (COINS Symposium)under the auspices of the United States Department of the Navy to stimulate research, development and applications in this field. Three years later, the second COINS Symposium was held. Last year we conducted the third COINS Symposium emphasizing software engineering. The first two COINS Symposia stimulated a great deal of interest. In 1967, the U. S. Congress authorized the National Science Foundation to establish the Office of Computing Activities for promoting, sponsoring and coordinating research efforts in this area. Now informatics is becoming the most important subject in the United States. I foresee that within a short period informatics will also become the most demanding subject in the Republic of China.

The invention of the steam engine in the late eighteenth century made it possible to replace the muscle power of men and animals by the motive power of machinery. The development of the stored-program digital computer following World War II made it possible to replace many of man's menial tasks, such as arithmetic computation, data storage, and record keeping, by electronic operations in machines. We are now entering the stage where it is reasonable to contemplate replacing some of man's higher mental tasks by machines. This includes the ability to recognize patterns, to read pictures, to process languages, to retrieve information, and to make intelligent decisions. We lack the "steam engine" or "digital machine" which will provide the necessary technology for pattern recognition, picture reading, language processing, information retrieval, and decision making. However we may cope with these problems by making use of the principles of informatics.

Major activities in engineering have headed in several directions. In one direction, the engineering discipline has been engaged in three stages of active development. In the first stage, it was primarily concerned with conversion, transmission, distribution, and utilization of energy. Electricity was used as a convenient carrier for energy. Major emphasis was concentrated upon the conversion of thermal, hydraulic, and mechanical energy into electric energy and its transmission and distribution. Electromagnetic interactions, electric circuits, applied mechanics, and heat transfer were the principal subjects of study. The primary interests were concerned with the design of power plants, steam turbines, heat exchangers, turbogenerators, motors and transformers, transmission systems, and distribution networks. This stage of development may be referred to as the energy conversion stage which had enjoyed its significant glory for more than a quarter of a century. The pioneering work of engineers in this period created the multi-billion dollar electric power industry and electromechanical manufacturing industry, and formed the cornerstone for the advancement of science and technology of our times.

The second stage of active development began with the invention of electronic devices and the introduction of radio and television. In this period, the center of activities was shifted from the generation of electric energy to the filtering of signals and process optimization and control. Engineering curricula were decorated with courses on network theory, filter design, waveshaping circuits, noise studies, quantum mechanics, electromagnetic theory, communication systems, estimation theory, operations research, and automatic controls. The major problems which engineers had attempted to solve during this period were the optimum filtering and processing of signals. Consequently, the second stage may be called the signalfiltering stage. Intensive study in the second stage has led to the development of modern radar, sophisticated telecommunications, color television, space navigation, guidance and control systems which have played an important role in the landing of men on the moon. The significant developments in the second stage have created the gigantic communications industry and electronics industry which formed the stimulant for the rapid growth of modern technology.

With the advent of powerful, sophisticated digital computers, engineering is earnestly entering the third stage of active development. Engineers are now confronted with a task of much greater magnitude than they had faced in the past. The major problem is no longer the signal-filtering problem; it is the problem of processing information. Thus, the third stage may be referred to as the information processing stage. No matter whether he deals with microelectronics, lasers, fluidics, bioengineering, mathematical logic, communication theory, computer organization, programming theory, information systems, or software engineering, his ultimate goal is perhaps to find some solutions for certain problems in information processing. In the materials area, research workers endeavor to discover new materials for exploitation in processing information. In the physical electronics area, engineers and scientists strive for developing new devices for information handling. We have reasons to believe that informatics in general, and software engineering in particular, will play a role of utmost importance in our modern society for the next two decades. Research efforts in this direction will accelerate the development of the new multi-billion dollar information industry and computer utility industry. In his banquet speech at the third International Symposium on Computer and Information Science, U. S. Congressman Roman C. Pucinski regarded information systems as a basic

American industry in the 1970s along with steel, building construction, and transportation.

The basic tool for processing information is the digital computer. Early computing machines may be regarded as "consumer products." Examples of such machines are the abacus, desk calculators, and first-generation digital computers. These machines are relatively simple to operate. The users can quickly learn the straightforward algorithms and programs. Some help from a customer engineer was usually sufficient. However, modern computing systems are no longer consumer products. These modern computers are so sophisticated and so general that when delivered they are ready for use on nothing, but they can be made useful on anything. Under these circumstances, the help of customer engineers is definitely inadequate. The users need the professional services of a specialist-the software engineer. Software engineering is one of the most important branches of informatics.

Now, let us take a closer look at the ingredients of the informatics discipline. Major activities in information processing systems may be broken down into hardware, firmware, and software, which deal with the design of information processing machinery, systems programming, and information-system processors. The primary tasks in the hardware aspects are the design of computer building blocks by making use of available circuits, chips, and devices. The design parameters normally include speed, size, weight, reliability, interface requirements, etc. The design of firmware is concerned with computer architecture and organization. Word size, order codes, instruction format, register types, pipeline structures, addressing schemes, memory hierarchies, micro-programming, storage requirements, and I/O interface are among the important design parameters. The software aspects deal primarily with systems programming and the design of information-system processors. Among the design considerations for systems programming are programming languages, compilation and assembly processes, operating systems, symbol manipulation, etc. The design of information-system processors is concerned with the development of software for information systems in various applications, such as information retrieval, computer-aided instruction, pattern recognition, picture processing, process control. management information systems.

The hardware technology has been extensively studied by the engineers for decades. We can say that it is now in good shape. For instance, we have faster circuits, larger memories, wider channels, efficient error detection devices, accurate error correction schemes. All these accomplishments came from the fact that the hardware technology has a firm foundation. With regard to machine organization, programming, and information systems (in other words, informatics and software engineering), we have not gained complete mastery of these subjects. We will get into a lot of trouble with computer architecture, operating systems, compilers, assemblers. We need to lay the groundwork for the development of a firm theoretical base for this discipline of informatics.

Digital computer today bears a resemblance to steam engine in the nineteenth century. The steam engine was widely in use long before thermodynamics and statistical mechanics were developed. The steam engine permitted the tremendous expansion of the railroad industry before we had a science of thermodynamics and statistical mechanics. However, the theoretical bases have enabled us to design more efficient steam engines and other energy conversion machines, and have stimulated the invention of the internal combustion engine, the diesel engine, the steam turbine, the gas turbine, and even the jet engine, which differ from the steam engine. If we did not have the theoretical bases, we would still remain in the stage which was not too far from the steam engine age.

The invention of the steam engine and the development of thermodynamics and statistical mechanics have given us a historical precedent. The theoretical bases were developed almost 75 years after the steam engine was invented. The digital computer is only 25 years old. We may expect some breakthrough in the field before this century passes into history, if we can develop a firm theoretical base for software engineering. It is informatics which holds the key to our success or failure.

History has told us that exploitation of machinery power following the first industrial revolution created the western superiority. Now, we have entered the computer age which may be described by the future historian as the period for the second industrial revolution. By the same token, in order to achieve world leadership, we need to make good use of computer power. It seems that we have no other alternative. Computer power will serve as a yardstick to measure the strength and prosperity of a nation.

Software engineering today bears some resemblance to electric power engineering at the turn of this century. Let us make a comparative study of these two fields. Electric power engineering deals with the generation, transmission, distribution, and utilization of electric energy; while software engineering is concerned with the storage, retrieval, analysis, transformation, and display of information. The electric power engineer is responsible for the design, operation, and maintenance of electric power plants and systems. The software engineer is responsible for the design, operation, and maintenance of information processing plants and systems, which include computer manufacturers, computing centers, and information system centers for various industries and applications. The design elements for electric power engineering are schematic diagrams, circuit diagrams, layouts, etc. By contrast, the design elements for software engineering are programs, flow charts, languages, compilers, algorithms, etc. During the early part of this century, the demand for electric power was so great that the utility companies launched an accelerated expansion program and as a result an acute shortage of electric power engineers arose. This happens to software engineering today. In addition to the need of computer manufacturers and software firms, all major industries, research laboratories, and educational institutions have established computing centers and information system plants. The mushrooming of such establishments has created a shortage of software engineers and information scientists, which is far more severe than the shortage of electric power engineers at the turn of this century. The situation is aggregated by the fact that information processing is far more sophisticated than electric energy conversion and utilization.

The use of computer is widespread. Many of its applications were never dreamed of by the human mind. It is the key to banking automation. It is used to make hotel and airline reservations and to examine every income tax return. It is used to operate libraries, hospitals, department stores, transportation systems, industrial processes, and educational institutions. It is used to analyze pictures, to recognize speech, to predict weather, to prepare menus, and to execute transactions in the stock market. It is used as an aid in instructing pupils, in plotting drawings, in composing music, in translating languages, in performing medical diagnosis, in making management decisions, in designing military and tactic plans. It is used to plan urban centers, to improve transportation, to streamline government, to monitor air pollution, to give better health care, and to conserve and optimize natural resources. We have named only a few.

We can confidently state without any fear of contradiction that it was the advent of the computer that opened up opportunities for man's plunge into ever-increasing heights of achievements in every one of his endeavors. The computer provides us the intellectual tool that will enable us to deal more successfully with the growing complexity of daily life. In fact, we have found no other branch of scientific study which has penetrated so many areas of human activity in such a short period of time. It is safe to predict that the computer will become a tool no one can live without, knowing how to use a computer will become as important as reading and writing, and informatics will become a fundamental discipline of our times. Informatics holds the master key not only to problem solving in science and technology, but it holds the power to mold a new society, unique in all history of mankind.

My five-week sojourn in Taiwan has convinced me that computerization will play a key role in meeting the rapid growth of industry and commerce of the Republic of China. However, this necessitates national emphasis upon training, education, and research in informatics. It is my judgement that the Republic of China has great potential to become a leader in this field and will be able to provide software engineering expertise to the western world, if she will spare no effort to develop informatics education and research. A number of our countrymen have already made significant contributions in informatics in the United States. Some of them have gained international reputation. I am sure that they are more than to help their motherland to achieve leadership in informatics.

To conclude my discussion this morning, let me just say that to build a meaningful world community, we need men of vision and courage, not doom and doubt; dedication and understanding, not skepticism and selfishness. I understand that we have such men, who have made Taiwan a peaceful country to live, a secure place to work, a land of opportunities, and a home for democracy. I believe, by making good use of modern computer technology, the Republic of China will quickly get on her way to economic excellence, great prosperity, and world leadership.