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Computer Software Policy and Development in the People's Republic of China*

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One of the important effects of the opening of the People's Republic of China (hereinafter: China) to the international community and market in the 1980s has been the rapid introduction of new information technology. In addition to imports of a number of major computer systems as the COCOM regulations were gradually relaxed during the decade, the country experienced a virtual boom in the diffusion of microcomputers in the early 1980s. A substantial amount of these microcomputers are now produced indigenously, and there has been a growing exports of personal computers manufactured in China.

In the process of diffusion of computers, it has become ever more apparent that the lack of adequate software is posing a serious barrier to the effective use of computing power in China. Therefore the government has placed increasing emphasis on the promotion of software development, both for the domestic and the international market. This paper examines the describes the software sector in China and the software policies adopted during the last decade; in addition, it looks at Chinese software exports. Final-

ly, the specific problems posed by a lack of legal protection for software in China, the difficulties of processing the Chinese script, and the weak professional and technical infrastructure is discussed.

China's Software Sector

In the mid-1980s there were 216 enterprises engaged in computer information processing services. Approximately one-third of these enterprises were providing only information processing services, while the majority were in other lines of business as well, such as marketing computers and software or delivering training. In fact, the income from technical service constituted only 12 per cent of total turnover in the sector. The companies employed more than 4,000 software technicians.

The sector is dominated by four large corporations, all based in Beijing but with a wide network of subsidiary companies in other regions of China. They are:

* China Computer Technology Service Corporation (Zhongguo jisuan jishu fuwu gongsi). This Corporation was established in 1980 for the purpose of providing maintenance service, systems design, installation, and training for domestic and foreign computers. By 1986 the Corporation had established 42 subsidiaries and 14 training centres, earning 135 million RMB yuan (36 million US dollars) annually.

* Stone Corporation (Sitong jituan gongsi), an entrepreneurial firm set up in 1984 by scientists from the Chinese Academy of Sciences. Through the marketing of microcomputers, peripheral equipment and specialized software, this corporation quickly managed to become one of the largest and most pro-

fitable firms in the emerging high-tech business of China, earning 106 million RMB yuan (28 million US dollars) in 1986.

* China Software Technology Corporation (Zhongguo ruanjian jishu gongsi). Established in 1982, this corporation includes 32 subsidiaries and achieved a turnover of almost 20 million RMB yuan (5,33 million US dollars) in 1986. The Corporation is targeting both the domestic and the international market for new software and services, and apparently was the largest state-run software company in China in 1989.

* China Computer Systems Engineering Corporation (Zhongguo jisuanji xitong gongcheng gongsi). This Corporation created by the Ministry of Electronics in 1984 on the basis of a large number of research institutes and factories in China, primarily undertakes systems engineering projects for large enterprises and public organizations. Approximately a third of the units participating in this corporation are research institutes, less than a quarter are enterprises, while the rest are regional branch units. Altogether these units are said to represent a staff of 60,000 people, a third of which are scientists and technicians.

With the exception of the Stone Corporation, these firms are still heavily influenced by the state authorities, in spite of their formal status as semi-private ventures. For this reason, they tend to lack entrepreneurial and commercial incentives, often becoming what the Chinese term "portfolio" companies. This has left the rapidly expanding market for hardware, software and training services open to more business-oriented firms like the Stone Corporation and other start-up companies in high-tech areas such as the "Electronics Street" in the Zhongguancun area in Beijing.

A major problem is that although these new entrepreneurs have targeted the large information technology market with considerable success in recent years, they tend to lack the technological resources available to the somewhat lethargic state-supported corporations. A similar weakness characterizes data processing services. At the end of the 1970s, it was decided to establish a range of computer services centers at the provincial and municipal level. It is generally recognized, however, that these computer centers have failed to provide services to users beyond a limited community of scientists.

The Chinese software sector thus tends to be dominated by state-run research institutes and their technology development companies[1]. In contrast to the West, where large private firms are supplying both computer systems and applications software, Chinese users will usually look in vain for such packages from domestic computer manufacturers. Some manufacturers even regard the diversification into computer services, maintenance, training, etc. as a burden on their "normal" business (Chen Liwei, 1985, p. 59).

It has been estimated that for the rest of this century, the Chinese computer information service industry could grow by 20 per cent annually. With this growth rate, it is projected that the ratio between the production value of the information service industry and the computer industry will be 1:5-8 in 1990 and reach 1:2-3 by the year 2000 (Gong Bingzhen, 1988)[2]. At the same time, the sector is expected to undergo a structural transformation from the current emphasis on marketing, training and installation service to an increasing share of software and information services, as indicated in Table 1.

Table 1: Projected Annual Turnover and Structure of China's Computer Information Sector, 1990-2000 (Million US dollars)

	1990	1995	2000
Computer Industry	1.200	3.000	8..000
Information Service Industry	200	750	2.600
of which:			
- Information Service	10%	15%	20%
- Software Service	10-15%	20%	25%
- Specialized Service	45-50%	35-40%	30%
- Systems Service	25-30%	30%	25%

Source: Adapted from Gong Bingzhen (1988), p. 211. Estimated turnover in US dollars represent mean values of Gong Bingzhen's projections, using the exchange rate 100 dollars = 375 yuan.

This growth and structural transformation would, in Gong Bingzhen's view, require the Chinese government to increase investment in the sector, for instance by linking the allocation of funds for development of the sector to investment in computer manufacturing. Gong Bingzhen suggests that one-fifth or more of the investment in the national computer industry should be reserved for the development of software and services. Moreover, he suggests that there should be introduced such measures as tax relief and special funds for the development of the sector. Finally, the government should set new prices for the products delivered by the information service firms.

More concrete projections referring specifically to the software sector Jia Yaoling (1989). He suggests that China could have as many as 100 firms specializing in software development and production by 1995. Their combined annual turnover would amount to 1 billion RMB yuan (266 million US dollars), earning 50 million US dollars on exports -- a ten-fold increase in export value over a five-year period. This scenario would also require continued official support, in particular the promulgation of regulations providing legal protection.

The Software Market: Diffusion of Computers and Applications

An accurate picture of the diffusion of computers in various sectors in China is difficult to establish since available statistics are often contradictory. Table 2, based on national surveys conducted by the Chinese Association of Computer Users, indicates an important change that has taken place since the early 1980s. In 1982 almost 60 per cent of China's computer stock was installed at research institutes, universities and colleges. In 1986, these institutions accounted for 43.9 per cent, while public administration had raised its share to more than 30 per cent.

It is noteworthy that industrial enterprises apparently still accounted for less than a third of computer installations in 1986. Most likely these installations were also rather small systems (mini- or micrrocomputer systems), since most enterprises in China cannot afford to purchase large systems. There are regional disparities, however, and statistics from major industrial centres such as Shanghai city and Liaoning province indicate that the industrial sector raised its share from 15 to 36 per cent of the total installed base during the same period.

Table 2: Sectoral Shares of Computer Installations in China, 1982 and 1986 (in per cent)

Sector	1982	1986
Research Institutes	39.7	31.5
Industrial Enterprises	28.5	25.7
Administration	13.2	30.4
Universities and Colleges	18.6	12.4

Source: China Electronics Yearbook (in Chinese) 1986, p. III-72.

A report from 1988 indicates that the trend has been somewhat reversed, so that "of the total number of computers in China, 30 per cent are used for industrial operation control" ("Computer Industry ...", 1988). Nevertheless, major computer resources continue to be concentrated within sectors of research, higher education and state administration. The relatively low rate of diffusion of computers in the industrial sector may pose a long-term structural problem.

One aspect which must be considered in connection with these figures concerning diffusion of computers in China is the low rate of utilization that is a distinctive feature of Chinese computer installations. The rate has been estimated at 20-30 per cent, and it appears extremely difficult to raise this figure[3]. This under-utilization of equipment implies that an investment worth 25 billion RMB yuan (6.6 billion US dollars) has been wasted ("Computer Industry ...", 1988).

In the mid-1980s the emphasis on software production generated a rapid growth in production of new items. The results of the process can be gleaned from Table 3 which shows that - at least in quantitative terms - a larger selection of software became available during 1985-86.

Table 3: Production of Applications and Integrated Systems, 1984-86 (No. of Items)

	1984	1985	1986
Applications Software	290	2,878	11,066
Integrated Systems	26	221	38

Note: Network systems increased and CAD systems declined in the category of integrated systems.

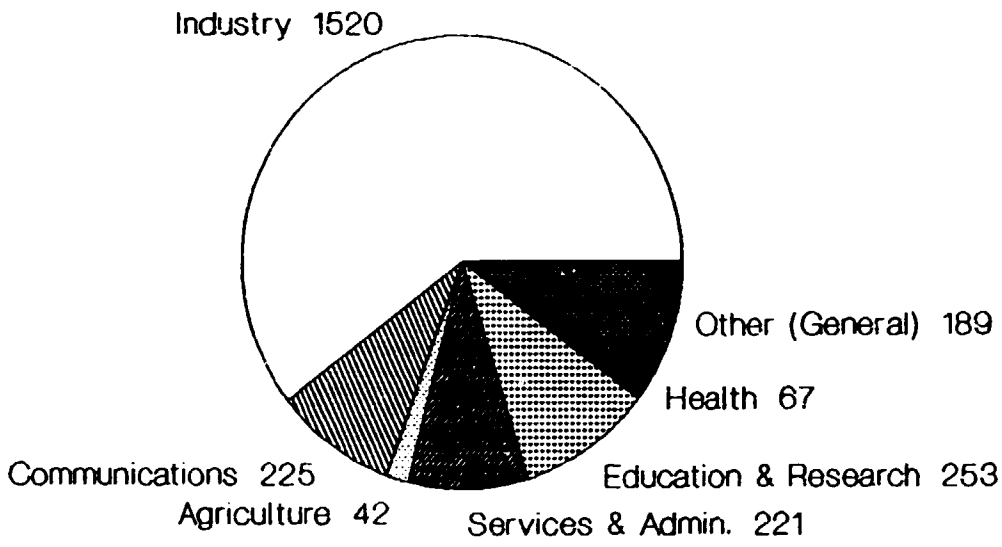
Source: China Electronics Yearbook (in Chinese) 1986, p. III-61 and 72.

By 1986 the authorities made a survey which apparently resulted in the registration of more than 20,000 items of software applications. A few thousand were selected for the first National Exhibition of Computer Application Results, held in Beijing in June 1986.

The diagram in Figure 1, prepared on the basis of the exhibition catalogue, indicates the importance of applications developed for industrial sectors[4]. Generally such software is developed by organizations subordinate to an industrial ministry. A relatively limited amount of general applications packages are developed for service and administration, although items listed under industry occasionally cover management information systems (accounting,

etc.) developed for a specific line of business. Thus, in spite of the substantial share of computer installations in administrative departments, as indicated in table 2 above, there appears to be a lack of applications software for this sector.

Figure 1: Computer Software: Main Application Areas



Source: National Exhibition Catalogue 1986

The domestic market for computer software is thus composed of two major parts. On the one hand, there is a core demand for major systems designed around large computers, the development of which is usually commissioned on non-commercial terms. Whatever "market" there exists for such systems is highly monopolistic. On the other hand, the rapid diffusion of microcomputers in China has led to a large potential demand for general purpose software and standard applications[5]. This market is highly competitive and constrained by poor quality of products, lack of commercial marketing outlets,

and the weak protection offered by the legal system. In spite of the apparent concern of policy-makers for increased commercialization of software in China, little progress seems to have been made so far.

For example, the Chinese market for computer networks is seen by some commentators as a particularly promising area. There is a substantial market for microcomputer networks (of the LAN-type) at the large and medium-sized enterprises which have already installed many microcomputers. Only during the last five years have some software companies offered services in this important market. The domestic computer manufacturing companies have largely ignored the potential market for networking packages ("An analysis of...", 1989).

For several years the formulation of large plans for the establishment of specialized information systems have been fashionable in China. Major cities -- like Shanghai -- have already drawn up programmes for the development of specialized systems, while Beijing and Tianjin cities are planning to introduce similar systems within the municipal area. It is envisaged that such systems will develop towards inter-city links. The weak telecommunications infrastructure in China has been -- and continue to be -- a major constraint for the development of such integration at the inter-city level or at the national level. Shanghai has taken steps to introduce advanced digital communications in the city, but the high cost of such systems have held back large investments in this area. The development of software for networks and large information systems is usually undertaken on a contract basis by the major, state-operated corporations or directly by research institutions. Although the government has increasingly invited tenders for such projects, this use of market forces has hardly managed to bring about the commercial exchange of software that has been a priority lately.

Computer Software Policy in the 1980s

During the period from the 1950s, when China initiated indigenous development and production of electronic computers, to the end of the 1970s, when equipment ranging from mini computers to super-computers was manufactured in China, very little effort was spent on the development of new software. The emphasis was placed instead on production of computer hardware. Chinese computer manufacturers developed the most essential operating systems software and adopted a few language compilers for languages such as FORTRAN, PL/I, and APL. Applications programs were predominately developed by scientists and stressed numerical and scientific problems.

The early 1980s witnessed a significant shift in policy as the leadership turned its attention from the production of mainframes and mini computers to the diffusion of microcomputers. Available statistics suggest that in 1980 there were onlu 600 microcomputers and some 2900 larger computers installed in China. In 1985 the relative shares had changed considerably, so that official figures listed 130,000 micro-computers and 7000 larger installations. More recent figures from 1987 indicate that the installed computer base comprises 8824 mainframe and mini computers plus 275,000 microcomputers.

The vast majority of these microcomputers were imported from the United States, Japan and Europe, or assembled in China on the basis of imported kits. Nevertheless, official figures suggest that an increasing number of microcomputers are designed by Chinese manufacturers and include a significant number of components produced in China. There are 150 computer manufacturers in China at present, producing 396 mainframe and mini computers and 59,000

microcomputers annually. The output value of this industry exceeded 2 billion RMB yuan (533 million US dollars) [6] in 1987 ("Computer Industry ..." 1989, p. 5).

A number of other important changes in policy took place simultaneously with the shift in emphasis from large computers to microcomputers. First, peripherals and complete computer systems - rather than exclusively the central processor - were identified as a crucial link in production of new systems. Secondly, the emphasis on hardware was supplanted with a stronger support to software and applications. Thirdly, the policy guidelines stressed that the expansion of computer services might play a leading role in the diffusion of computers (Chen Liwei 1985, p. 60)

A turning-point came when a new emphasis on software development was included in the Sixth Five-year Plan (1980-85)[7]. In this plan a key national project with the topic "Research and Development of Computer Software" was allocated a budget of 8 million RMB yuan (2.13 billion US dollars) (China Electronic Yearbook 1986, p. III-67). In 1982 the establishment of a national computer software sector was endorsed by Premier Zhao Ziyang in an official policy statement, thus providing instrumental support to the sector. Subsequently 47 research and development projects was completed under the plan. In addition, thousands of applications were alledgedly created during this period. These results fostered a wider recognition of the importance of software by national policy makers (Zhong Xichang 1986).

The policy change was further reinforced by the establishment of the "State Council Leading Group for the Invigoration of the Electronics Industry" headed by Li Peng (Simon and Rehn, 1986)[8]. Established officially in 1984, this organization has been concerned with setting the priorities for the development of the electronics industry across departments. One of the subgroups

created has been exclusively concerned with applications and software. After providing an initial impetus to the development of the sector, however, the group experienced serious difficulties in coordinating the activities of different departments. Nevertheless, the group appears to have been able to influence the priorities of the State Planning Commission so that several software development projects were included under the Seventh Five Year Plan (1986-90).

The most important policy-making institution in this sector continues to be the Ministry of Machine-Building and Electronics Industry[9]. The priorities in the software sector formulated by this organization in the mid-1980s have been to improve the diffusion and application of fourth generation languages, and to introduce standard software packages for several fields of activities. In addition, training of software engineers has been given high priority[10].

During the last five years there has been a broadening of the conceptual framework of China's policy, as the information sector and information technology have become the center of attention. The introduction of these new concepts is significant inasmuch as it signals an effort to integrate policies regarding the development of computers, software and telecommunications. There is a mutual interrelationship between these sub-sectors which has been largely ignored until now. It is significant, however, that Chinese observers now express concern that the lack of adequate software is inhibiting to the diffusion of computers ("Computer Industry ..." 1988), or that the weakness of telecommunications infrastructure tends to hold back the introduction of office automation systems (Xie Xiren et al. 1989, p. 39).

The current policy for the development of the software sector

includes the following components (see Guidelines on ... 1989, Appendix III, pp. 75-79):

- Establish a full-fledged software industry in two stages:
  * the first stage should emphasize the commercialization of software products and the introduction of "industrialized" methods of software production;
  * the second stage should concentrate on the creation of a comprehensive, integrated software industry with modern business management, offering service to the whole society.
- Develop both the domestic and foreign markets for Chinese software, stressing applications in major sectors of the Chinese economy and international competitiveness abroad.
- Make a rational selection of products and technologies for a concentrated effort on key breakthrough projects, e.g.:
  * Applications software for microcomputers and for large national information systems.
  * Chinese language processing, networks, graphics, and database management systems.
  * Systems software for micro- and minicomputers (operating systems, high-level languages).
  * Software engineering: development tools, standards, software management, and quality assurance technology.
- Promote research and technological innovation.
- Strengthen the management of the industry and introduce an appropriate legal framework.
- Adopt special measures for the promotion of the software industry, such as tax reliefs, full retention of export earnings, special funds for development, and easier conditions for travel abroad.
- Speed up manpower training.

The overview presented above indicates that the Chinese software sector has achieved a substantial expansion under a period of

increasing official support in the 1980s. The structure of the industry is rather weak, however, and its resources are inhibited by barriers of both a technical and a human nature. In my view, one of the main issues to be faced in the immediate future is how to develop the international marketing for Chinese software so that the industry's products will be commercialized, and so that the industry does not have to continue to rely on large projects allocated in the various five-year plans. Other issues include solving the problem of Chinese language input and processing and the introduction of more advanced software engineering and systems analysis techniques.

Exports of Chinese Software

Chinese software producers have, in the past, adopted a strategy of technical and economic cooperation to facilitate exports of software and services. One example of this was the announcement in 1988 of a joint venture with a total investment of four million yuan, the Shanghai Venus Software Company Ltd. The venture incolves three Chinese organizations and eight Japanese companies, and appears to be aimed at developing products for the Japanese market ("Software Company", 1988). This year it was announced that the China Computer technical Service Company has entered into a contract with the Japan Electric Co. to export Chinese software to Japan, where the market is expanding rapidly ("Japan Imports ..., 1989).

Other computer software exports announced include more specific systems, for example a package with a five-stroke Chinese character input technology which was apparently purchased by Digital Electronic Corporation (US). A microcomputer-based typesetting system for simplified Chinese characters has been offered at the East Asian markets by the China Printing Science and Technology

Research Institute, By mid-1987, this system had reportedly been sold in the domestic market for an amount of 1 million yuan, while sales agreements totalling US$ 100,000 had been concluded ("Chinese Software ..." 1987).

During the period 1982-86, the income from software exports alledgedly amounted to more than 5 million US dollars. Qinghua University, one of the leading centres of software research, developed software for both firms in the US and in Japan. The export of such services provided badly needed foreign currency earnings of a total 1.8 million US dollars (Cheng Jun, 1987). In addition, Qinghua was able to get an additional income of 1 million US dollars on the exports of software services during the first five months of 1986. Shanghai city, another centre of computer development in China was apparently also able to earn more than 1 million US dollars through software exports before 1986.

A study of software exports from the Beijing region revealed that as much as 80 per cent of the software products were sold on a commission basis (Yin and Yu, 1988). This implied a loss of potential revenue by at least half of what could have been earned through direct sales. Nevertheless, supplying software to international customers was an extremely lucrative business. The study indicated that an imcome of 2.5 million US dollars had been generated from software which amounted to 11 per cent of items sold domestically, for which an income of mere 250.000 RMB yuan had been generated. In other words, for each man-year involved 7,630 US dollars was generated in foreign currency, while the necessary investments had been a neglible 550 RMB yuan per man year.

An important component of the Chinese policy to create an internationally competitive software industry has been to send personnel to work in foreign firms. The Chinese have also considered this an

aspect of exports, since the hiring out of Chinese personnel, more than 1000 programmers in recent years, has generated other sources of foreign currency revenue. In spite of the apparent shortage of software engineers in China, many organizations have been eager to offer qualified staff at a low cost to foreign software houses.

Although these exports indicate the new capabilities of the Chinese software industry, most software packages sold abroad relate to the processing of Chinese script, which is a rather specialized market. The survey mentioned above also indicated that 70 per cent of the software programs exported had a size of fewer than 20,000 code lines, while at least 80 per cent took less than four man years to develop (Yin and Yu, 1988). In other words, most of the work which the Chinese undertake for foreign firms on a commissioned basis remain small adaptations or modules. The capability to develop and sell larger software packages abroad have not been promoted significantly through this effort. Subcontracting services and the "export" of manpower is also a somewhat limited market, although it is clearly an important entry point for the internationalization of Chinese software. A major drawback is the requirements of marketing, documentation, and after-sales service at the international market, which may prevent Chinese software producers from capturing a significant share of important markets in database management packages, graphics, or network design.

It has been argued, however, that China may have a comparative advantage in exports of systems software, since rather large groups of programmers were collected in the past efforts to equip the indigenous Chinese computer systems with basic software (Jiang et al., 1988). The Joint Design Group for the development of systems software for two major Chinese computer series (the 16-bit minicomputers known as DJS 100 and the 32-bit medium-sized

computers of series DJS 200) collectively represent important qualifications, which could be utilized in exports under the right conditions.

Legal Protection for Software: An Inadequate Framework

A frequent complaint from Chinese and foreign observers is the lack of legal protection for software in China. A recent analysis (Fakes 1989) has shown that Chinese laws and regulations concerning foreign trade and licenses currently provide inadequate protection of foreign software in China. The Chinese strategy has been to provide contractual protection on licenses of software for a limited period of time, and to simultaneously pursue a policy of software technology assimilation, i.e., the copying and widespread diffusion of software without permission[11]. Arthur Fakes concludes his analysis with the following words:

> China has yet to learn that seizing the property of foreigners does not encourage them to offer help. China is only now beginning to learn that its political actions can decrease trade and the variety and number of technology acquisitions. In respect to software, China could encourage foreign help in reaching its goal by enacting legal protections against (1) the unauthorized reproduction and distribution of software, and (2) the misappropriation of software trade secrets by any party.(Fakes, p. 292)

In order to expedite the enactment of the Chinese Copyright Law, it was decided to exclude protection of software author's rights (Gao Hang, 1988). It is envisaged that separate legislation will be drawn up concerning the protection of software. There has also been a long debate whether Chinese computer software should be

provided protection under the Patent Law, but most people agree that this law is not a suitable framework[12].

Meanwhile the copying of computer software in inside China is at least as serious a problem as the approach to international software markets that draws the severe criticism of Arthur Fakes and most foreign firms. A lack of legal protection for domestic producers of software have virtually removed the incentives to engage in the development and commercial marketing of software. This state of affairs have characterized both microcomputer software and packages developed on larger systems. Many research units have experienced that only a few dozen copies of new software packages will be sold, even if several hundred copies are known to be used[13].

Consequently, the income from software and systems development in China is generally low by domestic and international standards. Standard microcomputer software packages are sold within a price range of 50 to 250 RMB yuan. Dedicated applications software developed for large mainframe computer systems, such as a management information system for enterprises, are produced under contract for a sum in the range of 50-100.000 RMB yuan. This price is barely sufficient for recovering the cost of a team of qualified technicians and use of computer facilities. These conditions reinforce the reluctance of computer manufacturers to engage in software development. For example the Keli High Technology Corporation, a profitable computer production and marketing firm in Beijing, has consciously avoided undertaking software development and sales, alledgedly because they cannot afford to make losses[14].

The Chinese Language

The difficulties of processing the Chinese script on computers have continued to be a major stumbling-block for the diffusion of

computers and software, particularly in the administrative sector. After a few years of experimentation in the late 1970s a series of national standards was promulgated for the coding of Chinese characters (Dai Zhaokang 1989, p 7). Research and development projects in the early 19890s produced a Chinese version of the MS-DOS operating system (CC-DOS) and of the UNIX operating systems kernel, which are now able to process Chinese characters. In addition, new versions of a few general application packages for wordprocessing, database management and spreadsheets have been developed to cope with Chinese characters. Other research and development projects are in the process of providing reasonably functional protocols for data communication involving Chinese characters, and the technical problems of producing output has also been largely solved.

The key outstanding problem is to find a convenient and fast method of input. Hundreds of different input methods emphasizing various modes of entry (keyboard, pen, etc), various components of the Chinese characters or their pronounciation have been developed over the years. Some have been filed for patents and others have become accepted as "standard" input methods for popular operating systems such as the CC-DOS. Nevertheless so far no method has achieved the versatility and relative convenience of the the ASCII keyboard.

Zhou Zhinong of the China Software Technology Corporation has distinguished between four generations of Chinese character processing software. The first generation is based on entering a single character. The second generation of software will be able to quickly enter Chinese words, which are mostly composed of multiple characters. The third generation is based on intelligent voice recognition and will be able to enter text on the basis of sentences. The fourth generation would use artificial intelligence and enter text based on its meaning (Zhou Zhinong, 1989, p.13).

The vast majority of character input software available in China today belong to the first generation. A few systems -- including the "Natural Number Chinese Character Input System (Ziran ma hanzi shuru xitong)" developed by Zhou Zhinong himself -- belong to the second generation, while there is now a considerable amount of research in the area of voice recognition and artificial intelligence in order to develop third and fourth generation systems. It may take a decade before third and fourth generation systems become generally available in China. But even the transition to second generation systems will mean a major advance since the number of entry mistakes will be reduced significantly.

Professional and Technical Infrastructure

According to an official from the Computer Bureau, Ministry of Electronic Industry, by 1984 only 10,000 of the 80,000 employees of the computer industry were engaged in services (Chen Liwei, 1985, p. 59). These people were working in about 60 computer service units in China. In many Chinese articles, these figures were used to argue that China had a ratio of 1:7 among software and hardware personnel in the computer sector, while the US was seen to have a ratio of 4:1 among these groups.

More recent reports have estimated that between 30,000 and 40,000 people are engaged in software development in China[15]. Approximately one-third of this corps of software personnel were based in Beijing. These new figures provide a ratio of 1:2 among software and hardware personnel in the Chinese computer industry-proportions which are still far from the US pattern.

Moreover, statistics compiled by the China Computer Society have indicated an annual capacity for training 18,000 people at educational and research institutions. A delegation of international

computer professionals which visited China in May 1987 offered the following conclusion:

> Computer science education has progressed rapidly in the past several years in China's top universities and research institutes. This progress must be attributed in part to the official recognition of computer science as a scientific discipline with the formation of the Chinese Computer Federation in the mid-1980s, and the subsequent expansion of government support for new educational programs, facilities and research. (Wilson et al. 1988, p. 963)

The delegation noted, however, that the growth in computer education and research continues to be hindered by the absence of adequate hardware and reliable software. In addition, the need to master English in order to use textbooks and practice programming skills was seen as a major problem for the students, while the isolation from the international research community constituted a significant impediment to faculty.

Several methods have been applied to ensure widespread training of software professionals. Apart from the university sector, it has been estimated that an additional an annual contingent of 80,000 people could be trained in computer applications by the industrial ministries (Cheng Jun, 1987). China is also sending many software engineers abroad for employment or training in Western computer or software companies, hoping that they may learn more advanced methods. However, the general feeling in China is that there is a fundamental gap between the number of people trained in information technology and services and the actual requirements. It has been estimated that from a base of 15,000 professional staff in the information service industry in 1985, the contingent need to be raised to 100,000 in 1990, to 250,000

in 1995 and finally reach 500,000 people in the year 2000 (Gong Bingzhen, 1988, p.211).

These software professionals would also need access to an infrastructure of modern hardware and productivity tools. The access to hardware has been gradually upgraded during the 1980s, in particular due to the equipment installed in key universities as part of a World Bank project. In addition, substantial efforts have have been spent on the inidgenous development of advanced software engineering tools. 1987 China announced its first experimental automatic software production system. This system was a key national project under the Seventh Five Year Plan and was developed by a group of Ph.D. students at the Computer Department of Nanjing University under the supervision of Prof. Xu Jiafu, a well-known computer expert. After two years of theoretical research and practical development work this group had completed a system which was able to automatically write programs from conceptual diagrams, provide automatic validation and testing procedures, etc. ("China's First ..." 1987). A recent announcement of the development of a system for automatic design of algorithms (NDADAS) for a Sun workstation by this group indicates that technical capabilities have also been created.

International collaboration constitutes another important component of the strategy to improve computer software engineering methods. For example, a national project entitled "Integrated Software Engineering Environment (ISEE)", led by the China Software Technology Development Center jointly with ten universities and academic research institutes, included a major effort by US researchers to introduce software engineering techniques in China. This project was initiated in 1984, and results were presented at a conference in Beijing 1986 (see Zhong Xichang et al 1986).

Another important initiative undertaken to introduce and develop software engineering methods is the proposed International Institute for Software Technology, which is envisaged to be set up as a United Nations University Research and Training Center in Macao. This center is expected to become engaged in the development of application software development tools, project management methods, distributed system software, and applications in selected fields.

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Notes:

*. This paper is a revised version of an article entitled "China's Software Industry" which is forthcoming in Information Technology for Development. I am grateful to Robert Sware, Richard Conroy, and Liu Suying for providing me with important background material.

1. The Joint Institute of Information High Technology established in Spring 1989 by the computer departments at 7 universities and 3 civilian and military institutes from nearly all regions of China is a typical manifestation of this point. This new institute is collectively owned and features 350 technical personnel, which are involved in a broad range of applications systems engineering. See "Information High-Technology ..." (1989).

2. Gong Bingzhen is employed at the Computer Systems Engineering Institute of the Ministry of Machine-Building and Electronics Industry. When interviewed in Beijing in 1986, he was also Vice-Director of the China Systems Engineering Corporation, so one can assume that his projections are optimistic.

3. The most recent figure, 20-30 per cent, is provided in "Computer Industry ..." 1988. The Chinese sources have never bothered to explain how they arrived at this figure, nor tried to define what it stands for: is 75 per cent of computer installations in China out of order at any given time, or is the installed base only utilized 25 per cent of the time?

4. The diagram does not include items which were developed for defense-related applications (including space and aerospace), for which a separate catalogue was published. It is, of course, very difficult to get a clear picture of the production of, and demand for, software in these important sectors.

5. The high rate of diffusion of microcomputers in the mid-1980s led to an installed base of almost 300,000 microcomputers in China. However, this market has stagnated during the last couple of years. A study of 26 major computer producers showed that the income of the industry had gone up 25,64 per cent from 1987 to 1988, but profits dropped by 7 per cent. The reasons appear to be competition from imported equipment and higher costs of production and marketing ("The Computer Information ... ", 1989).

6. Dollar equivalent calculated according to a 1989 exchange rate of approximately 100 US dollars = 375 RMB yuan, which will be applied throughout this paper.

7. The crucial significance of this event was stressed by Hao Chunmin, Deputy Director of the China Software Technology Development Center, in an interview in Beijing in the Autumn 1986.

8. Li Peng has apparently become even more influential since the recent political conflicts in China, occupying the important administrative post of Premier. Together with the newly elected General Secretary of the Chinese Communist Party, Jiang Zemin, who has been a key figure in Shanghai's high-tech modernization during the 1980s, he appears to ensure the continued priority of computer and software development.

9. This ministry was formed by merging the Ministry of Electronics Industry and the State Machine-Building Industry Commission in March 1988. The purpose was to promote the integration of electronic and mechanical engineering. Bureaucratic inertia may, however, impede this process; see Simon 1988.

10. Interview with an official of the Computer Industry Bureau at the Ministry of Electronics Industry, Autumn 1986.

11. Arthur Fawkes (1989) discusses the potential protection offered under four relevant legal documents that have become effective since 1985: the United Nations Convention on Contracts for the International Sale of Goods, the Foreign Economic Contract Law, the Regulations on Administration of Technology Import Contracts, and the General Principles of Civil Law.

12. To my knowledge, there have been few concrete initiatives to protect software, in spite of the urgency of the matter. Foreign firms have also been concerned with the problem, and a conference was recently convened in the United States to propose new measures.

13. Interview with a researcher at the Computing Centre of the Chinese Academy of Sciences in Beijing, Spring 1987.

14. Interview in Beijing, Spring 1987.

15. Within a span of a two years, various sources have provided widely different estimates. The figure 30,000 is cited in "Computer applications..." (1988), while "Software firms ..." (1989) indicates that "China has around 35,000 people involved in software development." Yin Zhihe et al. (1988) claims that 40.000 people are working on software. To add to the confusion, no source provides a more detailed breakdown of this aggregate figure.