## 7.2 Developing Independent Industrial Software and Upgrading Traditional Industries through Information Technology

### (I) Strategic requirements of industrial software

The process of industrialization has offered opportunities for the naissance of industrial software. The first wave of industrialization focused on mechanization, the second on electrification and the third on automation. With the invention and wide application of integrated circuits, industrialization has entered the fourth wave primarily characterized by digitalization, which is typically represented by CNC (Computer Numerical Control) machines and systems. Widespread applications of networks have promoted all phases of product life cycle, such as research and development, design, production, testing, supply and marketing, to a new level ready for a brand-new integration stage of informatization and industrialization. Clearly, industrialization is entering its fifth wave, where industrial software will play a special role in upgrading the operations and managements of various companies and enterprises.

Industrial software is the fusion of informatization and industrialization. It is the core technology allowing the production equipments to be featured with mechanization, electrification and automation and further featured with digital, networked and intelligent applications. It integrates product design, manufacturing, testing and management, and heavily uses simulation technology and multi-interdisciplinary technologies. If there were no industrial software, industrialization could only remain at the level of mechanization and electrification. If no breakthrough in industrial software, there would be no modern manufacturing industry as known today. Without digital, intelligent and network-based technologies, it would be impossible to eliminate the backward production capacity and revitalize the equipment manufacturing industry. According to the statistics in 2008, the gross value of Chinese software industry was about 757.3 billion Chinese Yuan Renminbi, of which embedded software accounts for about 111.8 billion Chinese Yuan Renminbi. In China, embedded software was mostly adopted by digital TVs, mobile phones, PDAs (Personal Digital Assistant) and other products, with quite few software adopted for industrial control. Those large-scale industrial software being adopted by Chinese aircraft and automobile manufacturing, petrochemical, construction design and other industries rely mostly on import. The price of a set of software varies from several million US dollars to as high as several ten million US dollars. In recent years, Western countries have begun to restrict the exports of key industrial software to China, such as oil exploration software. Compared to operating systems and common software, Chinese industrial software technology falls even further behind the west countries.

As the soul of the embedded computing systems, embedded software is an important part of industrial software. Thus the development of the embedded software industry becomes a breakthrough for the transformation of Chinese information industry from

“Made in China” to “Created in China.” It is also an important way for Chinese information industry to change from an extensive growth mode to an intensive one, and achieve sustainable development. R&D capabilities of embedded systems and their industrialization level have become an important symbol to measure a country’s economic development, science and technology progress and national defense power.

Industrial software is very complex, and its design is as difficult as the design of large-scale integrated circuits. The development of industrial software requires the interdisciplinary cooperation and the collective efforts of scientists, engineers and technical experts. The development of industrial software first requires mathematical modeling and algorithm design, rather than software programming. Therefore, we should devote major efforts to the development of modeling techniques, algorithm design and optimization techniques, as a good mathematical model and an ingenious optimization algorithm can often promote the development of a whole industry. In addition, the development of industrial software is not just the development of software products itself, it is more important to realize the services of industrial software.

According to the statistics from 1870 to 1980, the efficiency of the production process increased 20 folds, but the efficiency of enterprise management only increased 1.8-2.2 folds, and the efficiency of product design only increased 1.2 folds. It is thus evident that improving the efficiency of both product design and enterprise management will be the development focus of industrial software in the future. According to the historical experience in the U.S., physics-based industrial software triggered a revolution of high-tech manufacturing products, which was a major reason why the high-tech manufacturing products of USA became so competitive. This revolution will last several decades to complete. To create and promote an industrial software product, an interdisciplinary team with more than 20 experts will take five to ten years to focus on the work continuously before the software product can reach its mature level of massive production application. In addition, the failure rate of such software is around 25-50 percent. By 2050, China will need tens of thousands of such advanced industrial software. The development of the scientific industrial software is an important way to strengthen Chinese secondary industries, significantly improve Chinese industrial structure, expand high-tech industrial markets, and create more high-tech jobs.

The mid-short-term goals of Chinese industrial informatization include transforming manufacturing industry with informatization, promoting the informatization of product design, digital production equipment, intelligent production processes, networked management, and enterprise transformation, making full use of informatization to drive the transformation of those industries characterized by high energy consumption, high material consumption and high pollution, promoting Supply Chain Management (SCM), Customer Relationship Management (CRM), and vigorously support informatization of Small and medium enterprises (SME), making great efforts in the e-commerce development to reduce the costs of logistics and transaction costs, improving the informatization level of mechanical and electrical equipment to achieve more accurate and efficient production, promoting distributed control, field bus control, agile manufacturing and other technologies, and enhancing the on-line monitoring, early warning and control of the production processes.

From the perspective of medium to long-term development, industrial software will promote the transition of traditional industries from informatization to integrated and intelligent applications. The integrated application will promote the enterprise transition starting from internal full life cycles integration (including the design, production, sales and services) and all-round levels integration (including device control, manufacturing execution and enterprise management), to the whole industrial chain integration. The networked virtual manufacturing based on Internet platforms will gradually become the dominant mode. Intelligent application will promote enterprise from information integration and functional integration to knowledge integration and intelligence integration, and ultimately realize the integration of human-machine intelligence in the enterprise; namely, the organic combination and fully utilization of human intelligence and software intelligence.

**(II) Theoretical and technical system of industrial software**

**The theoretical system of industrial software mainly includes the following:**

1. Developing the innovative theory of product design

This is aiming at the improvement of product design efficiency and quality in order to meet the requirements on customization, humanization and green manufacturing. The main content includes: digitalization modeling, simulation evaluation theory and design specifications of product’s full life-cycle; design, planning and management techniques of rapid product innovation and development; theory and method of end-users’ design of their own product; theory and method for web-based collaborative design of complex products.

2 Integrated modeling and optimization theory for various kinds of flows

Enterprises involve various dynamic flows, such as material flow, energy flow, information flow, capital flow, value streams and so on. For example, process simulation is mainly concerned with the emulation of material flow and energy flow, which can be used for new process design, new equipment design, and optimization control of production equipment and processes, etc. Similarly, if we can grasp the operation laws of those flows themselves and the interaction laws among various flows, we can clearly understand the development and the change laws of the overall enterprise, and continuously enhance enterprise management efficiency and quality. The main research will focus on the integrated modeling theories, integrated optimization theories and a variety of core algorithms for various types of flows.

3 Innovation theory and parallel management theory of enterprise management

The goal is to continuously improve the enterprise’s management efficiency, promote the great-leap-forward development of the enterprise's operation and management, change the enterprise management mode to adapt to the development needs, speed up the integrated applications of informatization and industrialization into intelligent development processes. The primary research will include:

- Technologies and methods for the software realization of comprehensive enterprise innovative theory: Enterprise management based on globalization and integration will move from sole/partial innovation management to the comprehensive innovation management of the whole industrial chain. The main research will focus on technical innovation, product innovation, production innovation, service innovation, management innovation and strategy innovation, etc.
- Parallel control and parallel management theory: Using relevant theories and technologies to establish artificial systems for the "equivalent" description of actual complex dynamic enterprises, and to understand various change laws and interaction laws between elements of enterprise complexity and social complexity by means of computational experiments. On this basis, we can realize the parallel control of production device levels, parallel management of production and enterprise-level through artificial systems and actual systems (enterprise information systems), that artificial systems can enhance actual enterprise management levels, prevent the accidents under normal conditions, as well as improve the emergence processing speed and quality and reduce the loss under abnormal conditions. The main research will focus on the core theory, key technology and software development of artificial systems, computational experiments, parallel control and parallel management.

4. Enterprise intelligence theory

- The enterprise collaborative strategy theories and key technologies in the network environment. Both social and engineering factors at different levels, different aspects and different stages of enterprises internally and externally require organic integration. The Interaction laws between the enterprise elements are increasingly complex. The constraints and objectives needed by enterprises have become stricter and stricter. The main research will focus on the enterprise collaborative strategy theory with multi-agent, multi-constraint and multi-purpose in the dynamic network environment, and the integrated modeling, analysis and optimization theories.
- Intelligent control and management theory and technology. In order to improve the intelligence of industrial software, namely its "IQ" and "EQ", the main research will focus on data mining techniques, knowledge representation techniques, and intelligent analysis technologies to provide theoretical support for intelligent control, intelligent management, enterprise intelligence and business intelligence software, etc.
- Theory and technology of human-machine intelligence integration. The ultimate goal is to achieve the organic integration of human intelligence and software intelligence. The main research will focus on the theory and technology of

expression, processing, modeling, analysis and utilization in the areas such as human behaviors, languages, knowledge and wisdom (learning, analysis and decision-making); human-machine integration theory and technology based on the organic integration of artificial intelligence in industrial software and enterprise staffs' collective wisdom.

**The technical system of industrial software mainly includes the followings:**

1. High-performance computing platforms and technologies of industrial software

Industrial software is becoming increasingly large, complex and intelligent, which means that data, knowledge and intelligence will need a rapid increase in storage capacity, computing processing capacity as well as networked hardware platforms. The main research will focus on industrial applications of high-performance computing platforms and technologies; technologies of transforming enterprise data center and information center into knowledge center and even wisdom center; high-performance universal parallel computing technology, dedicated parallel computing technology, cloud computing technology, and grid computing technology of industrial software.

2 The interconnection and integration technologies and standards for industrial software

The main research will focus on the network technology to provide more and more powerful wired/wireless sensing, to connect information sources from enterprise internally and externally as an organic whole in real time, and on the interconnection and integration technologies and standards of various kinds of information systems on network, hardware and software layers.

3 The architecture and platform technologies and standards for industrial software

Industrial software has become increasingly large and complex. Its new progression and success depend largely upon its safety, usability and reliability. Therefore, the main research will focus on the architecture and platform technologies as well as the standards for industrial software. They mainly include: SOA (service-oriented architecture) for large-scale industries; SAAS (software as a service) framework to meet SME's requirements by using "long tail theory"; Web 2.0 and Web 3.0 to Web n.0 technologies to meet service trend of industrial software development; industrial software platform technologies and standards to realize information integration, functional integration, process integration, knowledge integration, wisdom integration and human-computer intelligence integration.

4 Languages and tools of industrial software development and configuration

Both the formation of an advanced industrial software industry and the development of efficient and high quality industrial software require studying advanced industrial software languages, development tools, configuration tools, testing maintenance tools, infrastructure components, middleware and visualization tools, etc.

## 8.5 Promoting Social Computing as an Important Field in the Studies of Social Sciences

### (I) Strategic Requirements of Social Computing

Social computing is the emerging field of research and development in computational theories and methods for social activities, processes, organizations, functions, and applications. Based on a combination of cognitive science, intelligence science and complexity science, social computing research and applications have become an urgent agenda for ensuring national security and for building a harmonious society. The current needs and challenges of social computing are as follows:

- Social behaviors and emerging social patterns

The rapid development of new Internet technologies has made the entire community realize that these new technologies will profoundly affect the structure, organization and activity patterns of the future society. Although we are unable to know exactly what form the society will take on in the future, yet it is still clear that, as opposed to traditional social patterns, its dynamic changes are faster and more difficult to predict, and its organization forms are even broader and more unfathomable. These factors have made social computing a new and important area for further research.

With the advances of science and technology, especially those in network communication technology, the social networking trend has become increasingly evident. The network includes not only physical communication networks and the Internet, but also social networks emphasizing human-to-human interaction. Facing these highly networked realities, we need new computational theories and tools to understand everything around and social computing meet people's needs in this aspect.

- Scientific analysis and decision support of complex problems

China is on the historical phase of fully achieving a well-off society, promoting the process of state modernization and building a socialist harmonious society. The spectrum of the social development sequence corresponds exactly to the "non-steady-state" development phase. In response to a series of major issues concerning national economy and people's livelihood, especially in the face of natural disasters and social emergencies, we urgently need a scientific method which provides strong support to the analysis and decision-making in these situations. Research and applications of social computing will provide such a solution to this quandary.

- Knowledge-based industrial engines and enabling technology

For enterprises in the highly information-oriented and competition-oriented society today, how to obtain accurate information is not only a driving force for development, but also a key factor in determining a company's survival. Knowledge-based industrial engines provided by social computing provide enterprises with effective information retrieval tools, and the popular enabling technology offers a highly efficient operation system that facilitates the operations and managements of those enterprises. All these technologies have become the driving force for the enterprises' rapid development.

**(II) Scientific issues and key technologies of social computing**

The overall goals of social computing research are to form an advanced new computational theory based on the information and knowledge society, to develop advanced information processing technology to deal with social problems and to realize universal applications. To accomplish the above goals, following five major tasks need to be completed in succession:

1. Real-time access to comprehensive information. Computing, analysis and processing are based on the access to information. Surrounded by diverse social information, how to carry out effective real-time information collection is the most urgent task at present.
2. Content computing and understanding. After having collected the information, we need to calculate and understand the content, extract the required data and provide data support for further modeling and simulation.
3. Build up parallel social systems. Simultaneously emphasize artificial systems and actual system. In other words, compose parallel social systems, with the simultaneous running of the two systems focusing on the constitution of parallel execution. The main purposes of constructing parallel social systems are to compare and analyze the behaviors of the actual and artificial systems based on their mutual connections, complete the "study" and "estimates" of their individual future states, correspondingly adjust their respective management and control system and implement effective solutions to complex social problems.
4. Computational social experiments and decision support. In the computational experiment method, traditional computer simulation has become a "pilot" process in the "computational laboratory", as well as a way to "foster" all kinds of complex systems. However, the actual system is only one possible outcome of the computational experiments. Through parallelism and the reference of artificial and actual events in the parallel system, a particular computational social experiment can be carried out to achieve effective control and management of the actual system, so all relevant actions and policies can be experimented on and evaluated.
5. Decision-making execution and feedback system of complex system management. Use the parallel system approach to manage and control the complex system. The parallel systems change the conventional passive simulation to an active parallel artificial systems, also change its role from passive to active, static to dynamic, offline to online, and finally from a subordinate position to an equal status. By doing so, the artificial system fully plays its role in management and control of the actual system. It also enhances the feedback from the actual system on

decision-making information, achieves automatic adjustments and controls, and increases the accuracy of the computing social experiments as well.

**Three layers of social computing framework**

The main research areas of social computing are to design, implement, evaluate and promote a variety of information technologies of people-to-people communications, coordination and cooperation in society on the basis of advanced computing technology, focusing on people and activities as well as interdisciplinary collaborative research. The major scientific issues and key technologies of social computing can be divided into the following three layers:

1 The technology layer, which includes some basic techniques supporting social computing. Technologies currently involved include data acquisition and organization technology, machine learning and data description, content understanding and opinion mining, Web science, dynamic visualization techniques, computational psychology and computational sociology, etc.

2 The model layer, which contains those methods of model construction for specific social issues and social phenomena supported by basic technologies. It mainly includes cognition and behavior modeling, uncertainty in complex networks and complex systems, comprehensive seminar and human-computer integration, and so on.

3 The decision-making layer, which means artificial society and parallel management. Built on a wide range of complex models, it can strongly support the final decision by providing accurate simulations and simulation results.

We have divided the research of and development strategy for social computing into four phases. Each phase has its corresponding focus and research contents, and is comprised of the desired research results and specific applications.

The goal of the first phase is to realize typical applications in basic social computing theory and major issues, and to reach an advanced international level. Typical applications include social monitoring and public opinion analysis of normalization and non-normalization, especially the monitoring and coverage for emergencies; advanced intelligent control of urban transportation and chemical processes; research of e-commerce mechanisms and e-commerce computational experiments. The expected theoretical result of this phase is a system of socio-physical methods.

The objective of the second phase is to improve social computing theory and technological framework, to achieve the wide range of applications in important areas and to form major decision-making platforms and software with completely independent intellectual property rights. On the basis of the first-stage applications, this phase has been expanded and consolidated, with the main applications including: (1) based on public opinion monitoring, we have built an integrated social information system and improved the emergency management mechanisms for social security affairs; (2) based on the intelligent control of urban transportation, we have implemented intelligent management controls for other public facilities and the environment; (3) extended chemical process controls to the area of complex production process control; (4) based on e-commerce mechanisms research and computational experiments, we have built an intelligence analysis and decision-making system for business. Theoretical research of this stage will focus on computational psychology, which will in turn guide specific applications.

The goal of the third phase is to promote more scientific government and enterprise decision-making ability and implement the concept of scientific development based on wider applications of social computing. Focusing on the further integration of the former system-level applications, this phase has achieved the digitization of various social functions including digital government, digital economy and digital enterprise, etc. At the same time, social computing has become an integrated discipline featuring theoretical framework and technical support based on continuous improvement.

In the fourth phase, based on the promotion of a wide range of applications and the popularization of social computing in education, normalization and socialization of social computing concepts and methods will be realized. We will have expanded and integrated social functions of the aforementioned digital applications, eventually resulting in a complete digital society and constituting an engine of knowledgeable economy. At the same time, on the basis of the discipline of social computing, we will have developed social macro-informatics; and thus far, our understanding of society will have reached a new level.