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AI Research in China: 50 Years down the Road

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Year 2006 marks the 50th anniversary of the birth of modern artificial intelligence research. Chinese researchers have been conducting AI research for more than four decades. Here, we sample some of the most promising

areas Chinese AI researchers are studying and predict related future activities.

Automatic geometrical theorem proving: Beyond mathematical mechanization

In 1997, Wen-Tsun Wu, a mathematics professor and an academician from the Chinese Academy of Sciences (CAS), won the Herbrand Award for Distinguished Contributions to Automated Reasoning, the highest recognition for researchers in that field. Other recipients of this award include pioneers such as Larry Wos, Woody Bledsoe, and Alan Robinson. Wu invented Wu's method in the 1970s, initiating the use of algebraic geometrical methods to obtain analytical solutions to complex mathematical problems.¹ As Deepak Kapur, editor in chief of the *Journal of Automated Reasoning*, pointed out, "Wu's work re-invigorated the field of Automated Geometrical Theorem Proving."²

The cornerstone of Wu's method is Wu-Ritt's zero decomposition algorithm, which Wu and others have used to develop a theoretical framework that scientists and engineers can apply to solve a range of problems, including algebraic-equation systems and differential-equation systems. Researchers have also applied Wu's method and related frameworks to areas such as intelligent CAD/CAM, computer vision, and robot design. In 1990, Wu founded the Center of Mathematical Mechanization Research at CAS to pursue this wide range of research directions and application innovations.

We predict that in the next 50 years, researchers will extend mathematical mechanization based on Wu's method, applying it in a much broader set of mathematical studies. In addition, Wu's method will likely play an important role in an increasing number of application areas. In particular, we expect wide use of the intelligent CAD/CAM platform based on Wu's framework, and we predict that its commer-

cialization will bring about a new generation of CAD/CAM technologies.

China is also investing intensively in robot research, so we wouldn't be surprised to see Wu's method applied to industrial, underwater, servant, or even lunar robots.

Intelligence science: Toward a molecular-level understanding

Intelligence science intersects with a range of fields, including brain science, cognitive science, neural science, psychology, molecular biology, biological physics, mathematical and physical sciences, computer science, and information science. The highly complex nature of human brain functions requires a cross-disciplinary approach to explore and understand the nature of intelligence and cognition at various levels, from molecules and cells to the entire brain and its functions. Clearly, research methodologies and results from intelligence science and AI can mutually benefit each other.

The Chinese National Basic Research Program (also called the 973 Program) has funded several major projects investigating brain-related research and intelligence science (see www.973.gov.cn/English/ReadItem.aspx?itemid=147; also see [itemid=247](#), [159](#), and [240](#)). Another recently completed project, headed by CAS academician Xiongli Yang, is "Fundamental Research on Brain Functions and Major Brain Diseases." This project studied cell and molecular mechanisms of basic neural activities and the mechanism underlying the formation of several important brain diseases. Another project, "Fundamental Research on Brain Development and Adaptation," headed by CAS academician Aike Guo, focused on neural nutrition factors regulating neural cell division, survival, migration, and growth, as well as the development and adaptation of perception, memory, and visual cognition. A third project, "Advanced Interdisciplinary Research on Intelligence Science," funded by CAS, led to interesting findings in selective attention and perception and resulted in new advances in brain-imaging technology. In yet another project, headed by CAS academician Chaoyi Li, researchers studied cats' brains and revealed a new low-level cognitive structure that consists of many small spher-

oids for processing complex images. This structure differs from all known brains' cognitive structures and has proven important in image processing.³

The recently published call for proposals from the Intelligent Information Processing unit of the 973 Program substantially emphasizes cognitive science and brain science. The goal is to further explore the nature of human brain functions and intelligence, develop the computational theories of cognitive science and intelligent systems, and investigate new theoretical and technological foundations enabling next-generation intelligence system design and development.

In the next 50 years, we expect China to make major advances in intelligence science research in the study of various types of brain activities such as consciousness, attention, learning, memory, language, thinking, reasoning, and even emotion. Some particularly promising research directions include

- how brains integrate and coordinate nerve cell cluster activities,
- how nerve cell clusters perceive, express, transmit, and reconstruct visual signals and awareness,
- how we can use experimental methods such as nuclear magnetic resonance to observe nerve cell cluster activities, and
- how we can develop and evaluate mathematical and computational methods to model and simulate nerve cell cluster activities.

Other relevant research areas include modeling the creative thinking process, studying the mapping of thoughts to language, and studying the coevolution of reasoning and language skills.

Large-scale knowledge processing: An open approach

In "Some Challenges and Grand Challenges for Computational Intelligence,"⁴ Edward Feigenbaum posed three major challenges to future computer science development:

- developing computers that can pass the Feigenbaum test, a restricted version of the Turing test in a given subject domain,
- developing computers that can read documents and automatically construct large-scale knowledge bases to significantly reduce the complexity of knowledge-engineering efforts, and

- developing computers that can comprehend Web contents and automatically construct related knowledge bases.

Researchers in China are tackling the last two challenges. Although both are essentially a massive knowledge-engineering challenge, the difference between the two is that the third challenge involves an open environment. Openness typically refers to

- a lack of standardization in knowledge representation and semantic understanding,
- the dynamic nature (that is, emergence and disappearance) of knowledge sources, and
- contradictions, ambiguities, noise, incompleteness, and nonmonotonicity in knowledge.

Answering these challenges calls for new methodological and technological innovations. One ongoing project in China addresses this issue. In 1995, Cungen Cao proposed building a National Knowledge Infrastructure; in 2000, the Chinese NKI project officially started.⁵ The CNKI's early effort, inspired by the Cyc project,⁶ had focused on developing a nationwide network-based knowledge-service system, serving scientific education, research, and social services needs. This system has three components:

- an internal platform providing the core usable services and software libraries,
- external applications developed by partnering organizations in various application domains, and
- a module interfacing with the outside world (including the Web and Semantic Web).

The CNKI's knowledge base has approximately 3 million knowledge records; when completed, it will contain approximately 100 million records. CNKI aims to provide knowledge to anyone who needs it at any time, anywhere, and to support community knowledge, communications, and coordination needs.

The Internet has become an indispensable source of knowledge for people around the globe. According to recent surveys,⁷ China has over 100 million Internet users, and the number is still growing rapidly. Closely related to Feigenbaum's third challenge, despite the Internet and Web's extensive use and development in the past decade,

many critical and pressing challenges remain in Web-based information management.

First, the effectiveness of Web-based information retrieval measured by recall and precision is still low. Second, knowledge management on the Web is still based on semistructured Web pages as opposed to semantics-driven knowledge items. Third, current Web technology supports access to raw information but not to processed, refined, customized knowledge. For instance, after you enter one or more keywords into a search engine such as Google, the search presents you with hundreds of thousands of potentially relevant Web pages. Clearly, we need more advanced knowledge-driven online search and browsing technology to address these challenges.

Such new technology should demonstrate both high recall and precision and support online knowledge processing and mining. It should have adequate natural language processing capabilities to process and integrate potentially conflicting, uncertain, and ambiguous knowledge. In addition, it should be able to organize, edit, refine, and mine data and knowledge and facilitate the transition from information to knowledge. Fudan University computer scientists are developing elements of this technology. They plan to provide a generic online knowledge acquisition and management tool to users as part of their Web environment.

Computer-facilitated art and animation: From research to industry

The Chinese animation industry is experiencing significant growth. Approximately 3,600 television channels nationwide broadcast cartoon programs, and another 50 channels dedicated specifically to cartoons are expected in the near future (see www.Chinanim.com/dh1 (in Chinese)). According to a recent estimate from www.Chinanim.com, the total air time of cartoon programs exceeds one million minutes annually in China. Such a huge demand is creating a serious shortage of professional animators (the current gap is approximately 150,000). Nationally, more than 200 colleges and universities offer majors related to cartoon art and production.

Computers are playing an increasingly important role in the animation industry. In particular, computer-facilitated animation is becoming a necessity. The CAS Academy of Mathematics and Systems Science

has been conducting research in this area since 1989 and is cooperating with the Beijing University of Technology to commercialize its research results.⁸

In the next 50 years, computer-facilitated art and animation will find more extensive and wider applications in the real world. For example, a computer will be able to automatically translate 80 percent of a natural language script into animation. It will be able to

1. analyze the natural language script,
2. understand the story's plot,
3. decompose the script into a detailed scene-by-scene script, and
4. plan and execute animation production according to the movie director's interpretation, including scenarios, roles, actions, cameras, color, and light planning.

Obviously, each of these steps confronts many AI challenges, and many relate to image reasoning and common-sense reasoning. Research in these areas could possibly benefit other applications as well.

Knowledge as a commodity: From software to knowware

Although knowledge-based software engineering has become a widely accepted R&D area, knowledge is still largely embedded in software products. Recent research suggests that isolating knowledge from software and treating the two as independent entities for both research and system development will bring about many advantages.⁹ This might also address many of the difficulties that current software and intelligent system development efforts face.

For example, following this isolation principle, complicated software might be developed jointly by two teams: the software engineering team and the knowledge engineering team. Software engineers don't need to learn new domain knowledge when they switch from one application domain to another, and domain experts can play a more active role in software development by contributing their knowledge directly to system development. Following this emerging framework, *knowware* is an independent, standards-compliant, and executable knowledge module. An early example of knowware was the Promis object, where domain models (preliminary forms of knowware) are dealt with independently from the information management systems.¹⁰

In the next 50 years, we expect the IT industry to comprise three parts: hardware, software, and knowware. Knowware development will exploit AI and software engineering research. Similar to the establishment of software engineering as a field, we expect knowware engineering to emerge as a study of scientific principles, engineering guidance, and best practices for managing knowware development. In effect, knowware engineering will be the large-scale-production form of knowledge engineering. It will have its own model of knowware development life cycles, practical guidelines on industry-strength knowledge acquisition, and suggestions for efficiently maintaining and updating knowledge and for resolving conflicts, ambiguities, noise, redundancies, and incompleteness.

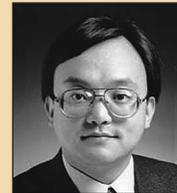
We don't have space here to cover all the important AI topics that Chinese researchers are actively studying (including machine learning, pattern recognition, and emerging social computing and informatics). For a comprehensive picture of Chinese AI research, please refer to related Chinese journals, such as the *Journal of Pattern Recognition and Artificial Intelligence* (in Chinese), the *Journal of Computer Science and Technology* (in English), the *Journal of Software* (in Chinese), and the *Journal of Computer* (in Chinese). ■

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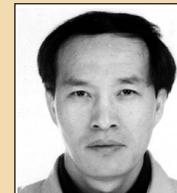
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