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Autor: Liu, Xila

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Development of Knowledge-Based Systems in Civil Engineering in China

Développement des systèmes experts pour le génie civil en Chine

Entwicklung von Expertensystemen für das Bauwesen in China

Xila LIU
Prof. of Civil Eng.
Tsinghua University,
Beijing, China

Xila Liu, born 1940, received his PhD at Purdue Univ. USA. He is a member of Board of Directors of China Civil Engineering Society, and Head of the Department of Civil Engineering at Tsinghua Univ. Beijing.

SUMMARY

The necessity to develop knowledge-based systems in civil engineering in general and the urgent need for China in particular are explained. A well organized project, which was supported by the National Natural Science Foundation of China (NSFC), is introduced. According to both the development of artificial intelligence technologies and the reals life applications in civil engineering, the possibility and some suggestions for further development are given.

RÉSUMÉ

Si le développement des systèmes experts pour le génie civil en général semble s'avérer nécessaire, cela est encore plus urgent pour la Chine. L'article expose un projet qui, sous l'impulsion de la Fondation nationale des sciences de Chine, fut bien organisé en vue de développer les technologies de l'intelligence artificielle et de les appliquer dans la pratique de la construction. L'auteur souligne les possibilités qui leur sont offertes et fournit quelques suggestions pour leur développement futur.

ZUSAMMENFASSUNG

Erscheint allgemein die Entwicklung von Expertensystemen für das Bauwesen geboten, so gilt das mit besonderer Dringlichkeit für China. Die Nationale Stiftung für Naturwissenschaften des Landes unterstützte ein wohlorganisiertes Projekt zur Entwicklung von Technologien der Künstlichen Intelligenz und ihre Anwendung in der Baupraxis. Der Beitrag behandelt ihre Möglichkeiten und einige Vorschläge für die weitere Entwicklung.

1. INTRODUCTION

Computer has been developed for over 40 years without stopping. There is no any industrial product which can compete with it. Since the great influence of computer development, the knowledge structures for many different disciplines have been changed. In any case, however, computer is still a calculation tool, even it is very powerful, the definition of "Calculation" has not been changed yet. Therefore, any over-estimating on computer's function may not be realistic. In the present paper, the necessity of development of knowledge-based systems in civil engineering in general and the urgent need for China in particular are discussed. A well organized project, which was supported by the National Natural Science Foundation of China (NSFC), and its contribution in China are briefly introduced. For further development of knowledge-based engineering in civil engineering, the possibility and some suggestion are also given.

2. CIVIL ENGINEERING AND KNOWLEDGE ENGINEERING

2.1 The distinguishing Features of Civil Engineering

In studying engineering systems, there are two categories of systems to be considered. The former is so-called continuous system and the latter is so-called discrete system. For the former, one usually starts with a continuous mathematical model which is obtained by considering some natural laws. For the latter, however, the behaviour of systems is described by some dynamic models with discrete mathematical structures. From the product point of view, the number of finished products can not be counted in the former system, and it is countable in the latter system. But the construction project, i.e. the product of civil engineering, is very individual. For example, the well-known project, Three Gorge Dam on the Yangtse River, has been planned for more than three decades. A great number of research works have been done just for this individual project. From the continuity point of view, the civil engineering is on the counter part as shown in Fig.1 .

		→	Continuity
Individual System Civil Engineering	**Discrete System** Auto Engineering	**Continuous System** Chemical Engineering	

Fig.1 Different Categories of Systems

It should also be mentioned that the decision making problems of civil engineering are synthetical. For example, the evaluation of the structural reliability does not only depend on the probabilities calculation, but also on psychology and social system. During planning and design of a high-rise building, besides architectural consideration and mechanical calculation, many environment and transportation problems must be considered. A new built highway may become a serious pollution source. Neglecting the durability of a highway bridge may cause heavy economic losses.

Unlike other engineering domains the individuality and multi-disciplines in civil engineering are very protrusive. In practice, during planning, design, construction and maintenance of a construction project, a great number of factors have to be involved. Usually, there are very strong interactions existing among these factors. Most of factors are uncertain and a great amount of incomplete information have to be treated. In addition, in many cases, it is difficult to do statistical survey. And it also seems that to build a comprehensive mathematical model is not so feasible. In fact, it is very often to solve a civil engineering problems only by experience or intuition of engineers.

2.2 The Knowledge Structure of Civil Engineers

The traditional knowledge structure for civil engineers is a two-apex structure, i.e. the practical experience and the theoretical basis. The practical experience should include the experimental skill, observation, and expertise. Due to the computer development the modern knowledge structure becomes a three-apex structure[1], i.e. the practical experience, the theoretical basis, and the computational training (Fig.2).

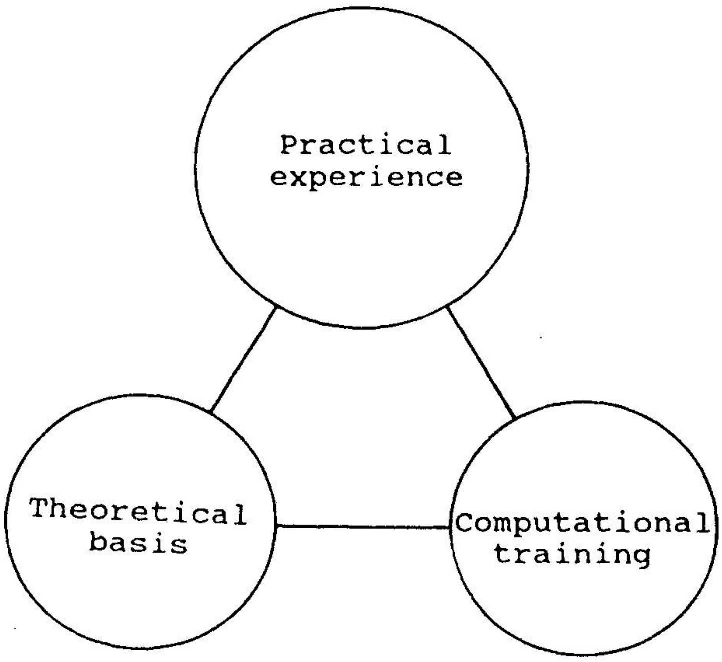

Fig.2 Modern Knowledge Structure of Civil Engineers

There is a more strong link between practice and theory. The computer makes the tests to be a real experimental science. Such as shaking tables and pseudo-dynamic tests are used to simulate the real earthquake. It is incredible to do these tests without computer. On the other side, however, the computer makes theory softer, which means that many uncertainties and incomplete information can be considered. Also, from the new development of knowledge engineering, it should be possible to code a great deal of experience in computer, which means the computer should make the experience harder[2]. It can be predicted that a civil engineer in the next century, who can handle the triangle knowledge structure, will be very active. Otherwise, he will be very passive.

2.3 The Education of Civil Engineers in The Next Century

Rethinking on the present education in civil engineering, there are two weak points existing. One is on systems engineering and another one is on practice.
It is very clear that the viewpoint of systems engineering has pushed the thinking mode of civil engineers forward. For example, the development tendency of structural engineering is to improve the pure analysis of individual elements to synthesis and control of the whole structure with its coupling systems, also to change the pure consideration of the structural service life to that of the whole structural life-cycle (construction, service life and maintenance). People have found that they made mistake such as on a Chinese steelyard shown in Fig.3, people used to be interested in refining the scale on the arm but forgot to check the sliding weight. But the problem is that, when they are dealing with a large scale system, a lot of uncertain factors and incomplete information have to be treated. People know quantitative calculation and analysis very well, but they are not so familiar with qualitative reasoning and syntheses.

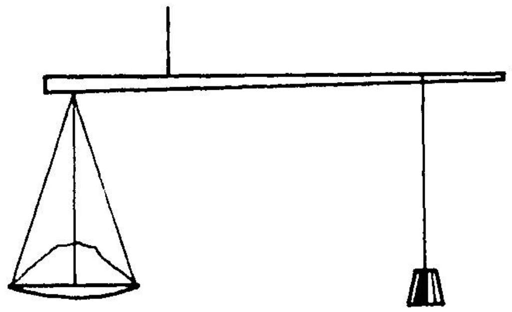

Fig.3 a Chinese Steelyard

The practical training probably is the most important part in civil engineering education, which is not only for future engineers but also for younger researchers. A man's knowledge consists only of two parts, that which comes from direct experience and that which comes from indirect experience. But it should be emphasised that direct experience is basic. Considered as a whole, knowledge of any kind is inseparable from direct experience. In order to have direct engineering feeling, for example, it is necessary to extend the practice training of students on construction site. But it is not the only way we can do. As one of the emerging technologies, knowledge engineering can help us to acquire, represent, and reuse indirect knowledge more efficiently. It is also possible to help senior engineers to code their own direct experience.

We are now in a great new era of technical revolution. There are so many advanced technologies which need to be handled. In reality, however, we only can handle a part of them, which may be very significant for developing our particular discipline. For some of them, the ebb tide may come very early or may be very low(Fig.4). How to make the choice? Here, the prediction on the ebb tide is very important. As discussed previously, it can be seen that the development tendency of knowledge engineering is going up and getting more and more important in general(Fig.4). Consequently, in the next century, knowledge engineering may become a fundamental technology for civil engineers.

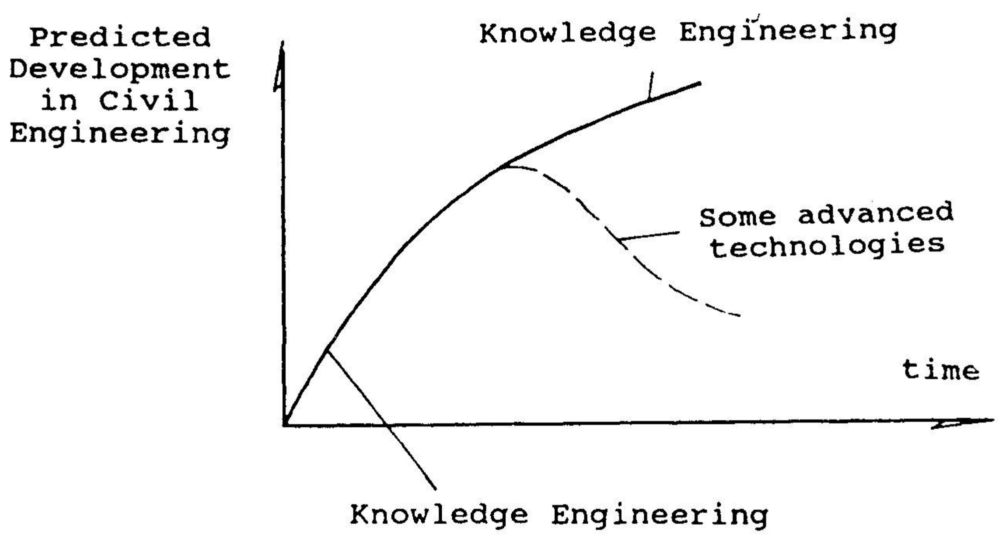

Fig.4 Prediction on Knowledge Engineering in Civil Engineering

3. KNOWLEDGE BASED SYSTEMS RESEARCH IN CHINA

3.1 Background

China is a developing country. The citification is an irrecusable tendency. At present, the ratio of city population is around 26%. By the end of this century, the ratio may increase to 33%. At that time, the economics of our country will develop by leaps and bounds. By prediction, in 2020, we will have 1100 cities and the ratio of city population may increase to 50%. It is true that our country is just shortly before the economic development at full speed.

In China, there are more that 20 million people working in construction companies. During the past 40 years, almost 40 million big construction projects and 1.64 billion meter square apartments have been completed. We rebuilt or expended 200 cities and more than 1000 towns. The living condition and environment of 400 million people have been improved. As predicted by experts, during the next 20 to 30 years, the hot regions of economic development in the world will be moved to the west coast of the Pacific Ocean. Probably, China will be the hot point in these regions.

Although the construction background in China is really beneficial to the academical development of civil engineering, some short-comings should still be noted. Such as the safety criteria of design codes are lower than the average level in the world, the quality control of construction is not so satisfactory, the structural maintenance and durability have been neglected for long time. In this case, by the end of this century, almost 50% of existing buildings in our country (i.e. 2.34 billion meter square) need to be repaired. The most serious problem is that after the cultural revolution, almost one generation of educated engineers has been lost. China is really short of senior civil engineers. Many experienced engineers are going to be retired. In order to save their expertise, it is worth to explore the new field - knowledge engineering.

3.2 Organization on Research Projects

Although the research funds and the total number of intellectuals are very limited in our country, China has enough foresight and sagacity to pay great attention to fundamental research, even on many engineering fields. We have already been adjusting the whole economic system in our country, but as far as the National Natural Science Foundation of China concerned the annual research funds are still increasing. For instance, in 1992, it has increased by 28% over 1991. After abundant proving and consulting by a large circle of experts, a priority joint project on intelligent decision support systems in civil engineering was organized by NSFC and seven ministries (such as construction, transportation, environment, and education et al.). Almost 25 universities and research institutes, 220 researchers including about 90 professors or senior engineers, some of them are very famous in our country, were involved. There were 10 aspects and 30 subprojects including: urban planning, seismic risk prediction, railway construction, highway and water transportation design, evaluation of ecological-environment qualities, preliminary design of structures, construction management and cost prediction, damage assessment of existing buildings, intelligent CAD and simulation, and treatment of uncertain information in civil engineering.

The predicted objectives of the mentioned project were: to build a group of relatively complete knowledge bases, to provide a great number of advanced papers or books, to complete a number of applicable softwares, and to train and bring up large numbers of qualified younger researchers for the next century. The administration system was very strict. Each subproject had to be re-evaluated by an advisory group once a year. The annual research fund of each subproject in the next year entirely depended on the contribution in the present year.

3.3 Recent Development

The mentioned priority joint project started in 1987 and has been checked and accepted item by item by the National Natural Science Foundation of China (NSFC) in December of 1992. In the five years, 45 research achievements have been appraised by NSFC, ministries, or different units, respectively. Among them, 9 projects have won research awards or prizes. 49 softwares have been provide to different users and 48 users reports on their qualification have been received. More than 480 papers have been published in various technical journals, conference proceedings, symposium volumes and technical report series. Four proceedings (914 papers in total)[4] and 16 professional books have been or will be published. During the past five years, we have trained a great number of graduate students by the joint project and 17 doctoral degrees and 120 master degrees were conferred. According to excellent personal contributions, 16 young researchers have been promoted to associate professors or full professors. As shown in Fig.5, the earliest knowledge-based systems in civil engineering in China were developed from 1985 to 1986, which were later than those developed in other domains for several years. But now, researches on knowledge based systems in civil engineering have become a very active field in China. It is very significant not only for the discipline development but also for the education of the next century. In the following five years, the National Natural Science Foundation of China will continuously support the same project (1993-1998) especially on the integration techniques and fundamental researches of structural design and construction control.

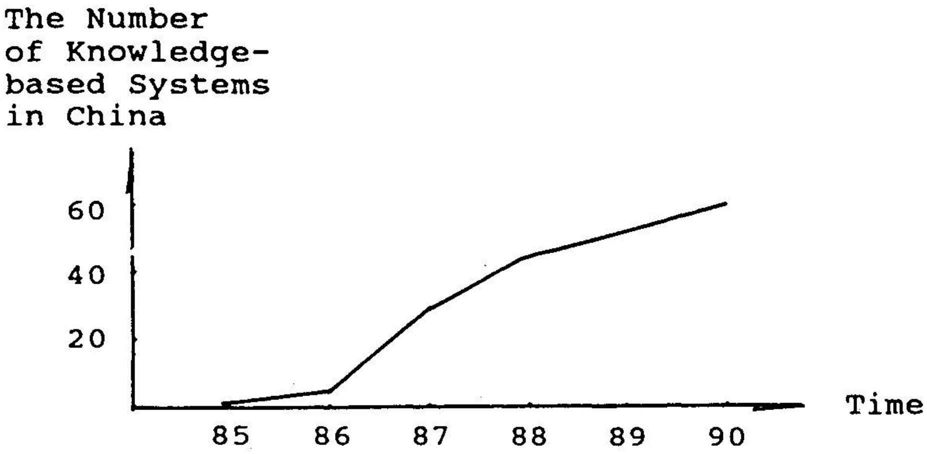

Fig.5 Development of Knowledge-based Systems in Civil Engineering

3.4 Some Remarkable Systems

PDSMSMB-1 and **PDKSCB-1** : Knowledge-based Systems for Prediction of Earthquake Damage to Urban Buildings (Institute of Engineering Mechanics of the State Seismological Bureau)

Based on a vast amount of collected data and facts, such as those from Xing Tai earthquake in 1966 and Tang Shan earthquake in 1976, both systems have been developed for damage prediction of masonry buildings. **PDSMSMB-1** is particularly for individual multistory masonry apartments and **PDKSCB-1** is for clusters of masonry buildings in a particular district, which includes predictions on damage degrees, casualties, economic loss, and some countermeasures. Both systems have been used in many cities, such as Tai Yuan (population of 1.5 million), Xia Men (0.3 million), Zhan Jiang (0.3 million) et al. Since systems have very solid knowledge-bases, the Ministry of Construction of China has decided to spread them in every seismic region of China in 1993.

RAISE-4 : Expert System for Reliability Assessment and Countermeasures of Reinforced Concrete Mills (Tsinghua University of Beijing)

In the present system, the moduli on the reliability assessment, the diagnosis of structural damages and the strengthening methods are integrated. Some algorithms on structural remained safety, reliability assessment specifications, and the strengthening code are also included. A great number of factors that affect the structural reliability are synthesized by a new fuzzy measurement method. Also, an advanced association model is proposed to obtain the most possible damage causes among all damage causes. By prediction, there is a very good market for the present system in China. The newest investigation shows that the annual income only on damage assessment and strengthening design of existing industrial buildings is around 172 million Yuan. Many research centres on structural diagnosis and strengthening in different provinces hope to buy the software RISE-4.

CARB : Expert System on Condition Assessment for Railway Bridges (Southwest Jiaotong University)

The special contribution of the present system is the technique for integrating an expert system with a dynamic database. The following measurements are taken, such as keeping the consistency of items of damage data with premises of assessment rules, auto-collecting of damage data, and auto-generating of damage data. Besides, two kinds of heuristic knowledge, i.e. the synthetical criterion of assessment and the current specification method, are used. Also, unauthenticity reasoning, unsuitability reasoning, and default reasoning are performed. This system is very useful for monitoring railway bridges. The similar system has also been used in highway bridge monitoring system in Guang Dong province.

UENC : Intelligent Decision Support System on Urban Environmental Noise Control (Tongji University)

The present system is a typical integration system including knowledge base, data base, models base, and algorithms. Its functions involve noise prediction, evaluation, and noise precaution. The traffic noise, industry noise, construction noise and area noise all can be controlled by the present system. Many practical noise data and calculation modules are provided for users inquiry, and the graphical interface is very friendly. A number of users reports with satisfactorily comments have been received. Also, after examining by a group of experts in December of 1992, it is recommended that this advanced integration system can be widely spread not only for noise precaution and control but also for management of noise information.

4. SOME COMMENTS ON DEVELOPMENT OF KNOWLEDGE-BASED SYSTEMS

4.1 Cognition Process is Primary and Its Conceptualization is Secondary

Since 1980s, although some fundamental researches on knowledge representation, inference of common knowledge, machine learning and the distributed knowledge artificial intelligence et al. have been developed gratifyingly, it seems that there is no considerable breakthrough in the artificial intelligence field. It is worth to rethink some basic questions[5] as: How much have we already known on cognition process? Is there really a single architecture underlying virtually all cognition? Actually, in the endless flow of absolute truth, each particular contribution in this field is heartening but only a relative truth, there may be a long way to go to reach the absolute truth. In this case, any over-optimistical or over-pessimistical viewpoint may not be appropriate.

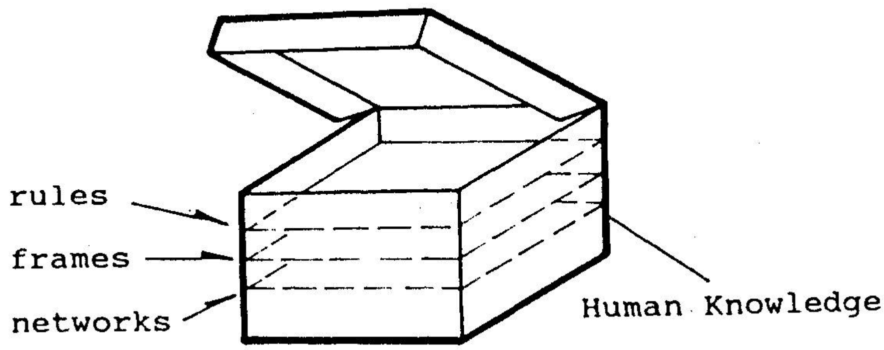

Fig.6 The Box of Human Knowledge

Until now, how much do we really know about the human brain? As shown in Fig.6, the three most popular ways of representing knowledge are rules, frames and semantic nets. Rule-based representation is a shallow representation on the first layer of the box of human knowledge, whereas schemes using frames and semantic nets are deeper representations on the second or the third layer. What about the next layers? It should be understood that the ways of representing human knowledge are very limited. We are not so familiar with human association (between different domains), human inspiration, knowledge distillation, the leap of cognition process et al. Even it is very hard to handle the human ability on searching and simplifying.

When we are talking about artificial intelligence in design, we have to clear the definition on design first. Actually, in most cases, "design" means a kind of innovation based on existing cases and knowledge, which is similar to the interpolation in numerical method. No matter what kind of cognition model is used, mostly, people have to make a closed domain (may use users interface) to obtain the final scheme. Strictly speaking, for the time being, basic knowledge coded in a knowledge base comes from human being, it is not automatically generated from another knowledge base. In this case, the computer creation is very limited.

On the other side, in general, domain knowledge is incomplete, intractable, incorrect and inconsistent. It is very hard to be generalized. The tunnel between widely generalized knowledge representation and unified inference process is still troublesome. From this point, a new generation of development environment of knowledge-based systems is not a easy task.

But there is no reason to be pessimistical. At present, we could not develop a knowledge-based system instead of domain experts, but it is possible to build a system to provide best advice when we have no domain expert. It is very difficult to develop an intelligent computer aided design system to create some newest schemes, but it is possible to develop a knowledge-based design system to ensure the generated scheme is not worse than the average design level, which is also very useful in application.

From Nilsson's strict logicism to Hewitt's open information systems semantics, from Lenat-Feigenbaum's thresholds of knowledge and Newell's SOAR in chunk to Brooks' intelligence without representation many contributions have been done from a particular aspect, but none of them is the absolute truth. In the endless flow it may be hardly to reach the end, but anyway, each contribution makes us to be closer to the absolute truth.

4.2 Practice is Primary and Knowledge is Secondary

Where does man's knowledge come from? It comes from his activity in material production, through which he comes gradually to understand the phenomena, the properties, the laws of nature, and the relations between himself and nature[3]. None of this knowledge can be acquired apart from practice. When human activity develops step by step from a lower to a higher level, consequently, man's knowledge also develops step by step from the shallower to the deeper level. It is true that, for artificial intelligence development the considerable breakthrough on theoretical research is needed, but successful application is more important.

The truth of any knowledge or theory is determined not by subjective feeling, but by objective results in social practice. Only social practice can be the criterion of truth. For a successful knowledge-based system, it is not enough to show some experts how to finish some particular examples, the real application during a certain period is necessary.

In China, the research group for each related subproject has to be "three in one", which means that three kinds of experts, such as the civil engineer, the knowledge engineer, and the software engineer, have to be involved. The head of each research group should be a real civil engineer. Furthermore, the civil engineer in the group is encouraged to learn some general concepts on knowledge engineering, meanwhile the knowledge engineer is suggested to know some basic ideas on civil engineering. In practice, the former seems more efficient.

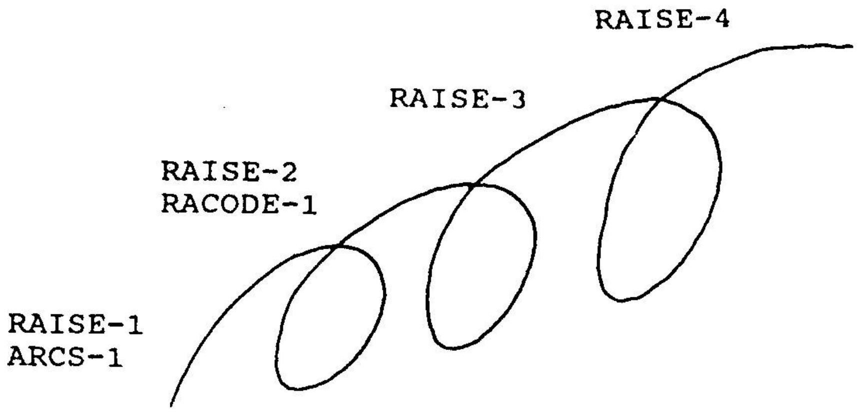

Fig.7 Development of RAISE Series

Usually, the life cycle of a software includes: planning, requirement analysis, software, design, programming, testing, running, and maintenance. It is so-called the falls model. But most of knowledge-based systems in China are following the fountain model shown in Fig.7. Following users requirement, we keep improving the previous prototype in each cycle. With each cycle the function of the software rises to a higher level. For example, during developing the RAISE series, we started from two original prototypes, i.e. RAISE-1, an expert system for damage assessment of single-storied reinforced concrete frame, and ARCS-1, also an expert system for damage assessment of reinforced concrete elements in industrial workshops. In the second cycle, we expanded the function of RAISE-1 to cover various single-storied workshops and also built another prototype RACODE-1 to store a new specification on structural reliability assessment. In the third cycle, we added a calculation program of safety factors on RAISE-2 and performed the new version RAISE-3 on personal computers. The Chinese version of RAISE-3 is called RAISE-4, which can be directly used by Chinese technicians. It is very clear that the engine to push the RAISE series forward is practice, is the application. Practice always produces some new requirement. After improving the previous version the prototype and knowledge has risen to a higher level. It is true that practice, knowledge, again practice, and again knowledge. This form repeats itself in endless cycles, and with each cycle the content of practice and knowledge rises to a higher level[3]. We believe that discover the truth of cognition process through practice, and again though practice verify and develop the truth.

4.3 Individual Character is Primary and General Character is Secondary

Cognition process always moves from the particular to the general, and then from the general to the particular; each cycle makes it more and more profound[3]. For example, the well known expert system MYCIN was built first and then the generalized EMYCIN was developed, afterwards EMYCIN has been used to develop several systems, such as PUFF and SACON. On a lower level, the inductive method can be used to extract some general rules from particular examples. But the scientific abstraction on a higher level may be based on some intuition which is very hard to be explained by existing knowledge. At present, we may not be able to find the architecture underlying virtually all cognition in a short time, but more particular systems or examples may give us more solid foundation for the creative inspiration. We belive that the individual character is the most abundant. The general character is contained in every individual character; it should not be converse (Fig.8). The considerable breakthrough in artificial intelligence seems not so easy. When we are wandering about the next knowledge distillation, why we do not pay more attention to individual systems? Without individual character, there can be no general character[3].

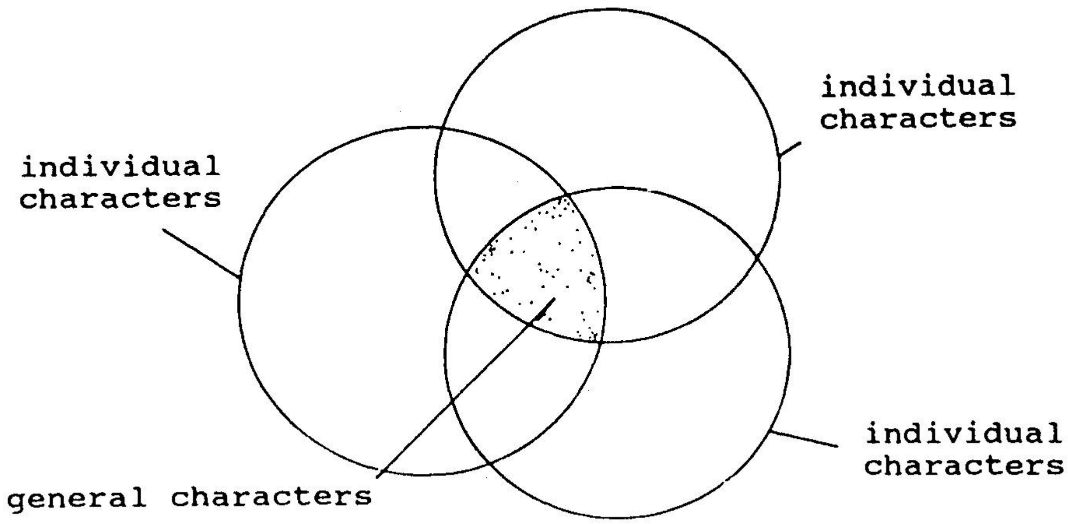

Fig.8 General Character vs. Individual Character

5. CONCLUSIONS

The necessity to develop knowledge-based systems in civil engineering not only comes from the individuality and multi-disciplines in civil engineering but also comes from the education for younger civil engineers in the next century.

Considering the financial and education background of China to organize a prior joint project to involve a large circle of related experts is a efficient way, especially in some advanced fields.

We are looking for some considerable breakthrough in artificial intelligence. But it is worth to emphasize that, at any time, the objective world and practice are primary.

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