APPLYING KNOWLEDGE-BASED EXPERT SYSTEMS APPROACH FOR FENG SHUI DESIGN EVALUATION

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ABSTRACT

Feng Shui is a body of ancient Chinese knowledge that aims at creating a harmony between environment, buildings and people. Nowadays, as many advance countries seek to establish a deeper understandings of these relationships between the human and natural environments, architects begin to recognize that Feng Shui as a broad ecologically and architecturally connected paradigm. However, the development of Feng Shui principles and practices are complicated and there is little research into the application of Feng Shui knowledge to the built environment and architectural design. Knowledge-based expert systems approach is one of the artificial intelligent techniques possessing a high potential to deal with intuitive expertise which is appropriate to structure and represent the Feng Shui knowledge. This paper investigates the potential of this concept in establishing a knowledge-based Feng Shui expert systems for preliminary evaluation of architectural design.

KEY WORDS

artificial intelligence, knowledge-based expert systems, feng shui, design evaluation

INTRODUCTION

Feng Shui, which translates as “wind” and “water”, is the Chinese wisdom in knowledge and experience related to the built environment that has accumulated over more than three thousand years. It has been developing throughout the existence of Chinese history and civilization, and has evolved from Chinese philosophy. It is founded from the earliest and greatest philosophy document of Chinese, Yi Jing (The Book of Changes) that developed ca. 800 B.C. The primitive knowledge of Feng Shui was based on the observation from three sources: astronomical phenomena, natural phenomena and human behaviour (Feuchtwang, 1974). There are two main schools of thought and practice in Feng Shui: the Compass School and the Form School. The Form School approach has been well recognized and widely accepted by Feng Shui researchers as comprising the scientific bases in the analysis of built environment (He, 1990; Cheng and Kong, 1993). The principles and practices of Feng Shui aimed at creating a harmonised built environment for people to live in, and it represents a traditional Chinese architectural theory for selecting favourable sites as well as a theory for designing cities and buildings (Lee, 1986). Hwangbo (1999) recognized that the practice of

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Feng Shui is an intuitive matter that involving site selection and spatial organization, and it has strong parallels with the western concept of geometry in architecture.

Architectural design was recognized as a very complex and intuitive process. Although there were numerous studies tried to examine how architects learn and apply their knowledge to the design of buildings, the design process itself still cannot be explicitly identified (Gregory, 1966; Simon, 1969). As the way architectural design knowledge applied to building design cannot be formulated, the term "black box" was used to present an architect's design mechanism (Jones, 1970). Architects used their knowledge from past experiences to create spaces with desired experiential qualities. This design process required intuition and individual past experience to tackle every entirely new building design situation. Humphreys (1976) recognized that this mystical approach was remarkably similar to the Chinese philosophy.

Design evaluation is an integral part of the design process that contributes continuously during the design process. It is important for a design evaluation tool to have a mechanism that allows a designer to perform a rapid analysis on building design at preliminary design stages. However, problems arise when evaluating design alternatives. It is not easy to translate all attributes into a common unit of value and these factors are also difficult to measure. Most of the computer-based design evaluation systems have focused on individual engineering problems rather than experiential qualities of the integrated built environment. New directions of the total building performance concept (Hartkopf, Loftness and Mill, 1986) and integrated design evaluation systems (Augenbroe, 1992; D'Cruz and Vuong, 1994; Gann et al., 2003) were still in the theoretical stage. This new direction into the integrative evaluation of interdependency of building design is similar to the holistic view of the Feng Shui approach to built environment.

Artificial Intelligence (AI) is a branch of computer science that dealing with symbolic, non-algorithmic method of problems solving (Buchanan and Shortliffe, 1984). The development of AI aimed to understand the human reasoning process and to develop intelligent computer systems to supplement human brainpower. Since the preliminary design of a building involved activities and decisions that are primarily heuristic in nature and rely more on past experience and qualitative judgment than on quantitative computation, AI techniques can be used to develop solutions to design problems where conventional computer techniques have not proved suitable (Hardy and Danaher, 1994). It appears that the intuitive nature of Feng Shui knowledge and the interrelationship and complexity of Form School approach processing by the Feng Shui experts could be simulated and structured in AI techniques by using heuristic rules and conceptual networks rather than logically deductive structures of knowledge. The aim of this paper is to examining the appropriateness of applying Feng Shui knowledge to design evaluation using knowledge-based expert systems approach. Firstly, the principles and practices of Form School approach are explained and four fundamental concepts are derived. Secondly, three widely used AI techniques applied to solve design problems are compared for the suitability of Feng Shui knowledge. The benefits of applying knowledge-based expert systems approach to Feng Shui design evaluation are then explored. Finally, the conceptual framework of KBES for Feng Shui design evaluation is constructed based on the four fundamental concepts of the Form School approach.

FORM SCHOOL APPROACH

There are two main schools of thought and practice in Feng Shui: the Compass School and the Form School. The Compass School is based on metaphysical speculations of cosmology, in particular, this school analyses the directional aspects in terms of the relationship between the Five Elements, Eight Trigrams, Heavenly Stems, Earthly Branches and constellations. Practice in the Compass School uses primarily the Luopan (Feng Shui compass) and the composed elements of time in space (Skinner, 1982; Chiou and Krishnamurti, 1997). The Form School is primarily based on the verification of the physical configuration of mountains and watercourses surrounding sites and buildings. Its theory was built upon an understanding of the landscape: the profiles of the land, the sources of rivers and the terrain. The practice of the Form School first observes the land formation and terrain, and then determines the location and orientation of buildings.

The development of the Form School was widely accepted by the upper class of the ancient Chinese society and attracted scholars and intellectuals to join its practice. The principles of the Form School were applied to design and construct castles, palaces and towns in China since ancient times (He and Luo, 1995). Lee (1986, p.367) suggested that the principles and practices of the Form School approach represent "a compendium of Chinese architectural theory".

Since the Ming Dynasty (1368-1644), these two schools of thought were not exclusively attached to their own methods for the practice of Feng Shui, but rather combined and integrated ideas from both Compass and Form schools (Lee, 1986). However, the Form School approach remained the primary consideration in Feng Shui practice (Xu, 1990; Too, 1996). Contemporarily, Form school approach has been recognized as comprising scientific basis in the analysis of the built environment (He, 1990; Wang, 1992; Cheng and Kong, 1993; Mak and Ng, 2005). For instance, one of the most important research investigations carried out by Xu (1990) has compared the Feng Shui concepts using the Form School approach and the Hendler model, a well-known western model of site analysis. The results indicated that Feng Shui is a more powerful tool in site analysis than the Hendler model.

According to Zang Shu (the Book of Burial), the first surviving important literature on Form School was written by Guo Pu (276-324), there are five main theories in terms of Form, namely Qi, Wind-water, Four Emblems, Form and Direction theories (He, 1990). The Form School approach considers mountain ridges, surrounding hills, watercourses, locations and orientations as the most important terrestrial and celestial elements for human dwellings because these elements represent both terrestrial and celestial Qi. These elements comprised the basic terms of the Form School approach and were known as the "Five Feng Shui Geographical Secrets", namely, dragon, sand, water, cave and direction (Lip, 1979):

(1) Dragon: means the mountain ridges to be traced, and represents the topography,
(2) Sand: means the enfolding hills and soil condition, and represents the surrounding environment,
(3) Water: means the flow of water through or by-passing the site,
(4) Cave: or "Feng Shui Spot" means the niche position, and represents the best location,
(5) Direction: means the facing direction of the site and building, and represents the orientation.

The five main theories of Form School approach together with these five Feng Shui Geographical Secrets are developed into four fundamental concepts of Form School approach (Mak, 2004):

(1) Concept of the Feng Shui model: The combination of these five Feng Shui geographical elements of the Form School approach produced a classic Feng Shui model. This model has been interpreted in diagrams of spatial organization of auspicious mountains and watercourses in most of the ancient Feng Shui literature. Many Feng Shui researchers have summarized these diagrams into a simplified sketch of a Feng Shui model as shown in Figure 1 (Shang, 1992; Cheng and Kong, 1993; Han, 1995; Yi et al., 1996; He, 1998).

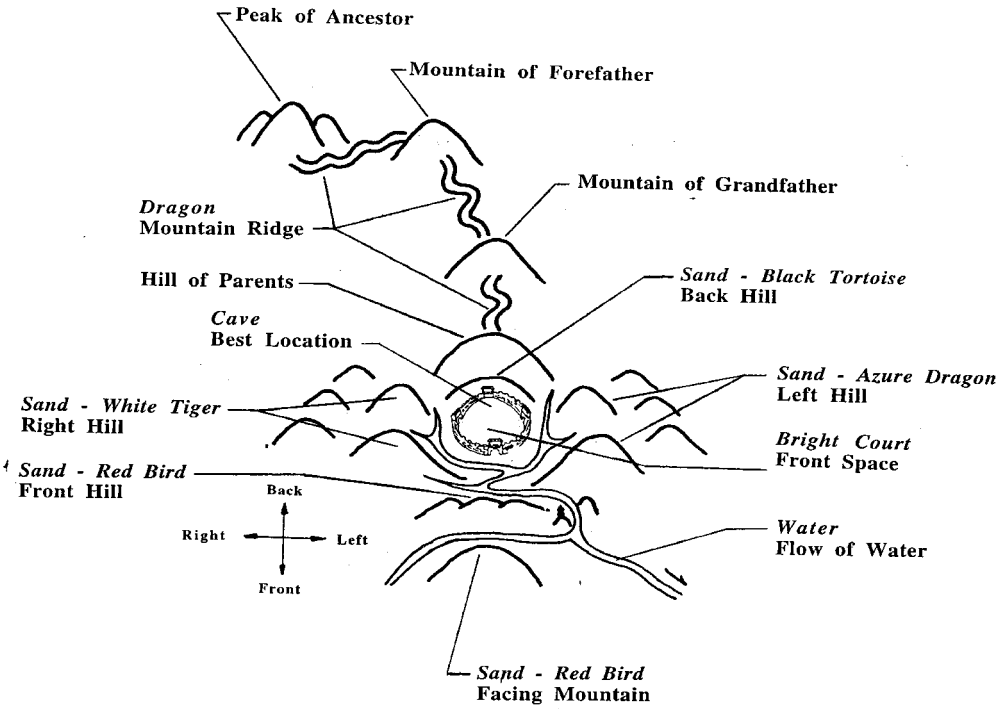

Figure 1: Feng Shui Model (Figure 3-1 in Yi et al., 1996)

(2) Concept of parallelism: Most Feng Shui scholars (Skinner, 1982; Lee, 1986; Xu, 1990) recognized that the theories and practices of Feng Shui work in macrocosm and microcosm. This relationship is recognized as the concept of parallelism in Feng Shui (Lee, 1986). The concept of a Feng Shui model not only applied to landscape and site selection, but it can also be applied to the interior layout of buildings. Therefore, whether it is dealing with physical or topographical elements, or housing structure, or the proportional relationships of the interior of a house, the same principles and relationships of the Feng Shui model are still applied.

(3) Concept of four design modules: When describing the site conditions and the design of dwellings, most of the Feng Shui texts, such as Yang Zhai Shi Shu (Ten Books on Dwellings of Living) categorized these aspects into Outer Form and Inner Form. According

to Lee (1986), the Outer Form can be identified as the location of the site, conditions that surround the site, topographical conditions of the site and the shape of the site. The Inner Form can be identified as the layout of the building, elevations of the building, and elements of building. Feng Shui scholars, Cheng and Kong (1993) explained the application of the Form School approach to the design of dwellings and proposed a further classification into four design modules: surrounding environment, external layout, internal layout and interior arrangement.

(4) Concept of Feng Shui criteria: Most contemporary Feng Shui scholars (Lip, 1979, 1986; Rossbach, 1984, 1987; Lee, 1986; Xu, 1990; Han, 1995; and Choy, 1999) have set up their own criteria for Feng Shui evaluation. For instance, Lee (1986) outlined three-basic-criteria for architectural design; Xu (1990) derived a four-step landscape model to deal with land formations; Han (1995) used 24-major criteria for selection of the best location; Lip (1979, 1986) listed a set of standard rules of thumb for assessment of architectural design; Choy (1999) suggested a ten-point design criteria checklist for property selection; and Rossbach (1984, 1987) provided a set of interior design diagrams for furniture placement. Although these criteria derived from various contemporary Feng Shui scholars were presented in different formats, they all follow the principles and practice of the Form School approach. Based on these contemporary practices for Feng Shui evaluation, 24 key criteria are identified (Mak, 2004) and grouped according to the four design modules as shown in Table 1 (Mak et al., 2005).

Table 1: Feng Shui Criteria Grouped in Four Design Modules (Table 1 in Mak et al., 2005)

Surrounding Environment	External Layout	Internal Layout	Interior Arrangement
♦ Topography	♦ Shape of Site	♦ Layout	♦ Door Openings
♦ Front of Site	♦ Entrance	♦ Doors	♦ Bedroom
♦ Rear of Site	♦ Shape of Building	♦ Windows	♦ Kitchen
♦ Sides of Site	♦ Orientation	♦ Shape of Rooms	♦ Living Room
♦ Street Location	♦ Trees	♦ Staircase	♦ Bathroom
♦ Water View	♦ Pond	♦ Ceiling	
♦ Wind Direction			

These four fundamental concepts of Form School approach will become the base to construct the conceptual framework and hierarchical structure of Feng Shui knowledge for the development of the knowledge-based expert systems (Mak et al., 2005).

KNOWLEDGE-BASED EXPERT SYSTEMS FOR FENG SHUI KNOWLEDGE

In the early 1980s, Lansdown (1982) and Wager (1984) analyzed the applicability of AI and more specifically expert systems to the construction industry, and concluded that some domains such as design, consultation, interpretation, or planning appeared to be worthy of significant consideration. Various AI techniques have been used to develop solutions to design problems where conventional computer techniques have not proved suitable. Ballal (1999) identified that there are three widely used AI techniques applied to solve design problems: Case-Based Reasoning (CBR), Artificial Neural Networks (ANN) and

Knowledge-Based Expert System (KBES). These three AI techniques have been considered (e.g., Maher et al., 1988; Maher and Balachandran, 1994; Medsker and Liebowitz, 1994; Tasso, 1998) and their strengths and weaknesses (e.g., Riesbeck and Schank, 1989; Schmitt, 1993; Vob, 1994; Brown and Wensley, 1995; Mukherjee and Deshpande, 1995; Rawicz and Girling, 1995; Maher and Garza, 1996; Tarassenko, 1998; Feng and Xu, 1999; Liebowitz, 2001;) are compared in Table 2.

Table 2: Comparison of Three AI Techniques for Design Problems (Table 4.1 in Mak, 2004)

	Strengths	**Weaknesses**
Case-Based Reasoning (CBR)	♦ Learn from old problems ♦ Existing cases-memory stored in a library ♦ Solution of new problems stored to improve knowledge of the system	♦ Several hundred cases required for database ♦ Information does not express reasons ♦ Solutions only limited to known situations
Artificial Neural Networks (ANN)	♦ Learning process capability ♦ Training of the system without human interaction ♦ Weighting and fuzzy logic allowed	♦ "Black box" approach ♦ Large number of cases required for training ♦ Relies on complex mathematical calculations ♦ No explanation facilities ♦ Lack of interpretability
Knowledge-Based Expert Systems (KBES)	♦ Domain-specific knowledge ♦ Humanistic approach ♦ Logic and heuristic rules allowed ♦ Easy trace of logic ♦ Explanation facilities provided	♦ Too many rules in complex problems ♦ Expression of logic is long ♦ No learning capabilities ♦ No generalized rules

Taking into consideration the above comparison of three commonly used AI techniques for solving design problems, there are a number of advantages in investigating the potential of the KBES for the development of knowledge structure. They are summarized as follows:

(a) The KBES approach to the behaviour of composite and complex systems results in an explicit representation of both the knowledge base and the heuristic rule bases utilized to apply this knowledge to a given problem. Unlike ANN, users are not faced with having to interpret a "black box" solution to problems, as all of the assumptions, parameters, models and data may be accessed, reviewed and modified at any time (Kesik, 1992).

(b) Although the ability to learn from existing cases and training processes have made both CBR and ANN especially good at dealing with complex situations or solving new kinds of problems, their major constraints are that these techniques require a large number of cases for their database while these cases are not always available (Vob, 1994).

(c) The humanistic approach of KBES uses logic and heuristic rules which can be easily traced to review reasoning and explanations. Li and Love (1999) pointed out that this explanation capacity not only expresses the logic reference of the system, but, more importantly, it increases the user's acceptance of the output. The explanation facility of expert systems is a primary advantage of KBES over CBR and ANN.

(d) As uncertainty can be allowed for in KBES, gaps, discontinuities, or errors in the knowledge base or heuristics may be readily identified and investigated. Users may be

made aware that a higher level of risk is involved where knowledge is lacking or insufficient. This makes it possible to explicitly assign the certainty of a given fact or heuristic employed (Kesik, 1992).

(e) Although KBES approaches require many rules to be expressed in complex problem environments and the chain of reasoning is lengthy (Riesbeck and Schank, 1989), this is not a primary concern as this study is mainly focused on the knowledge structure of a specific domain area at a conceptual framework and research prototype level.

Feng and Xu (1999) recommended KBES as being excellent in handling logic, heuristics and domain knowledge, and Kesik (1992) recognized that KBES is an effective tool to structure and represent knowledge. Based on these potential benefits of KBES, this paper investigates the use of Knowledge-Based Expert Systems to structure and represent Feng Shui knowledge. There are five main reasons that explain why this study adopted the KBES approach:

(1) Domain-Specific Knowledge: KBES emphasized domain-specific knowledge rather than general problem-solving strategies (Feigenbaum, 1977). The principles of Feng Shui knowledge mainly concern architectural design and the built environment, and its practices are applied specifically to site selection and building design. Therefore, the application of Feng Shui knowledge to design evaluation fits the nature of a domain-specific knowledge base.

(2) Human Experts: KBES are computer programs that perform sophisticated tasks once thought possible only by human experts (Benfer et al., 1991). The fundamental function of KBES is to transform the knowledge of "human experts" into a structured domain-specific knowledge base. Like a human expert, a KBES gives advice by drawing upon its own store of knowledge, and by requesting information specific to the problem at hand. The intelligence of the KBES is the mechanism that combines this knowledge and information to make decisions. While the principles and practices of Feng Shui are very complex, Feng Shui Masters have always been respected as "experts" even though they obtain no formal training or recognized qualifications.

(3) Heuristic Approach: A KBES is an 'intelligent' interactive computer program that can play the role of a human expert by using heuristic knowledge or rules of thumb (Adeli, 1988). A KBES involves the creation of sophisticated computer programs that emulate the complex human problem solving capabilities by exploiting explicit representations of specific domain knowledge and by means of sophisticated reasoning algorithms (Tasso, 1998). The principles and practices of Feng Shui are too complex to express through a fixed set of rules, and the inference engine of heuristic rules of thumb therefore provides a better analytical base.

(4) Humanistic Approach: Smith (2000) described expert systems as the closest approximation to human reason which has yet been devised in the field of Artificial Intelligence. KBES development is very humanistic whereby frequent human interaction is critical to the success of an expert system (Liebowitz, 2001). Knowledge acquisition is usually a labor-intensive activity, involving interviewing domain experts and eliciting their knowledge. The knowledge engineering life cycle process is an iterative one, incorporating prototyping approaches that require the constant feedback from the users, knowledge engineers, and domain experts. The rules and logic flow can be easily traced in order to see

how the KBES is reasoning and handling explanations. Expert system testing and evaluation requires frequent human interaction and dialogue. The user interface of an expert system is designed on very frequent discussions and iterative displays with the intended users. Human interaction is the fundamental approach of the KBES. These characteristics of KBES correspond to the humanistic and intuitive approaches of Feng Shui practice.

(5) Explanation Facility: The primary strength of expert systems is based on the capacity to provide explicit explanation for outputs. This explanation capacity enables users to understand the logic reference of why and how the output is reached and increases users' acceptance of such outputs (Li and Love, 1999). While most designers have little understanding of the Feng Shui knowledge and practice of Form School approach, the explanation facilities of KBES are able to explain the system's conclusions and its reasoning. Such explanation facilities will allow auditable analyses and more importantly, increase designers' acceptance of the system's output.

The major advantages of KBES over other AI techniques, as discussed previously, are that KBES provide a clear structure of knowledge and provide users with explanations (Brown and Wensley, 1995). This nature of KBES is the primary reason why this study selected KBES for the structuring of Feng Shui knowledge.

CONCEPTUAL FRAMEWORK OF KBES FOR FENG SHUI DESIGN EVALUATION

The most common structure of KBES involves knowledge acquisition, representation, encoding and evaluation (Liebowitz, 1995). A number of useful KBES applications have been developed according to this paradigm where the knowledge base has been coupled to the heuristics (rules of thumb) of one or more experts in a particular field to produce useful problem solving applications, such as MYCIN (Shortliffe, 1976), ELSIE (Brandon et al., 1988), and BREDAMP (Allwood et al., 1988). In most cases, the areas investigated have been highly focused, well defined and self-contained, as the primary aim of the application is to solve problems within a human expert's domain of specialization (Liebowitz, 1995).

However, the KBES for Feng Shui design evaluation is more difficult than conventional design problems. The knowledge acquisition process for Feng Shui knowledge is a very complex and difficult task, because the languages used in the classical Feng Shui texts may have ambiguous linguistic meanings and difficult to interrupt. Knowledge representation in Feng Shui is the mostly complicated task because Feng Shui knowledge has never been organized into a schematic and consistent format, and the rules in classical Feng Shui texts may be ill-defined, incomplete and inconsistent.

Since the knowledge acquisition is a complex process to obtain, organize and analyze knowledge, Scott et al. (1991) recognized that detail investigation is required to develop a conceptual framework at the knowledge acquisition stage. A conceptual framework creates the full scope of a KBES and it consists of high-level descriptions of the tasks the KBES will perform and provides a classification of the characteristics of the system. The procedures of developing the conceptual framework of Feng Shui knowledge are as follows:

- Review and summarize relevant concepts from the Feng Shui knowledge.
- Develop an appropriate framework for analysis.
- Review trends, patterns and issues in Feng Shui principles and theories.

- Review and summarize methods and findings in the main streams of design evaluation research.
- Reinterpret and develop knowledge hierarchy from the Feng Shui perspective in related to design evaluation research.
- Integrate the conceptual framework development.

Based on the fundamental concepts of Form School approach of Feng Shui knowledge, a conceptual framework for Feng Shui design evaluation is constructed to demonstrate the interrelationships between these four fundamental concepts as shown in Figure 2. This conceptual framework enables the conceptualization of what activities are occurring to accomplish the task of Feng Shui design evaluation without committing to the details of how these activities are to be performed (Mak, 2004).

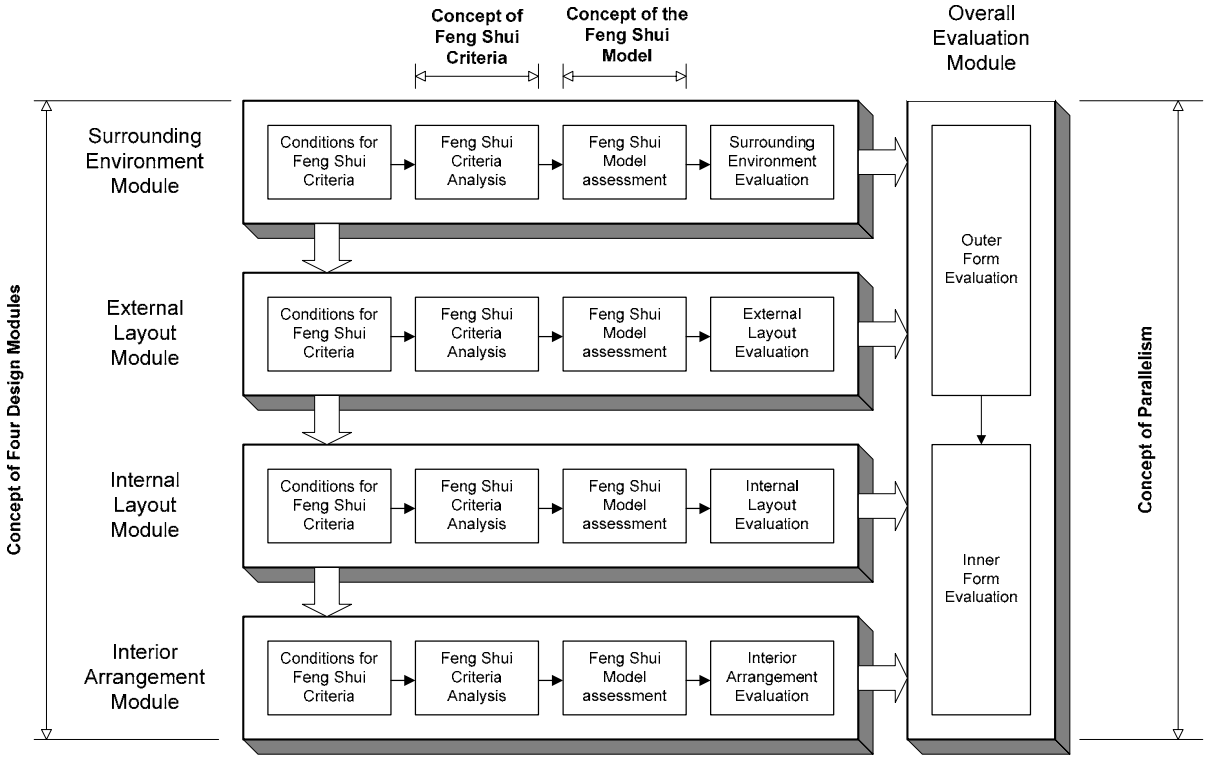

Figure 2 Conceptual Framework of KBES for Feng Shui Design Evaluation
(Fig 6.8 in Mak, 2004)

Primarily, the conceptual framework comprised of five integrated modules, and the concept of four design modules forms the skeletal structure of the conceptual framework (Mak, 2005). The first four modules are determined according to the concept of the four design modules; they are surrounding environment, external layout, internal layout, and interior arrangement modules.

In each of these four design modules, the conditions for Feng Shui criteria are first identified and assessed. Each of these conditions was linked to the corresponding Feng Shui

criteria, and each of these criteria was represented an integrative part of the Feng Shui model according to the concept of Feng Shui criteria as shown in Table 1. Each design module is evaluated based on the assessment of the Feng Shui model in that particular design module. An overall evaluation module is provided to process the integrated evaluation from all these four design modules. There were two parts in the overall evaluation module: the Outer Form and Inner Form as the concept of parallelism implies that the concept of Feng Shui model applied to macrocosm as well as microcosm. The surrounding environment and external layout modules are contributed to the Outer Form evaluation, while the internal layout and interior arrangement modules are contributed to the Inner Form evaluation.

A questionnaire survey of architects in Sydney and Hong Kong was used to evaluate the fundamental concepts of Form School approach and the developed structure of the conceptual framework. The results of the survey demonstrated that the fundamental concepts and the conceptual framework are accepted by architects (Mak, 2004; Mak and Ng, 2005). Overall, there was very strong correlation between both groups of architects in Sydney and Hong Kong notwithstanding the fact that they have very different cultural, educational and geographical backgrounds.

CONCLUSION

Architectural design was recognized as a very complex and intuitive process. Architects used their knowledge accumulated from intuition and past experiences to make heuristic design decisions. These characteristics are similar to the eastern philosophy of direct insight into the nature and the principles and practices of Feng Shui as applied in Chinese architecture. Design evaluation is an integral part of the design process that contributed continuously during the design process. It is important for a design evaluation tool to have a mechanism that allows a designer to perform a rapid analysis on building design at preliminary design stages. Feng Shui is a traditional Chinese architectural theory for selecting a favourable site for dwellings as well as a theory for designing a domestic building. It is suggested that interpreting Feng Shui knowledge would enable the development of a design evaluation tool from this Chinese architectural discipline. In particular, the Form School provided a holistic approach that allows integrated components and elements to be considered for the built environment. Based on the Form School approach, four fundamental concepts were derived from its principles and practices.

The development of Artificial Intelligence aimed to understand the human reasoning process and to develop intelligent computer systems to supplement human brainpower. It appears that the interrelationship and complexity of Feng Shui knowledge and the intuitive aspect of Form school practices processing by the human experts could be structured and simulated in AI techniques by using heuristic rules and conceptual networks. Based on five main reasons, Knowledge-Based Expert Systems (KBES) is the most appropriate approach for structuring and representing Feng Shui knowledge for design evaluation.

A conceptual framework comprised of five integrated modules is constructed based on the four fundamental concepts of the Form School approach. This conceptual framework of KBES for Feng Shui design evaluation will be evaluated by two groups of architects. The refined conceptual framework will be developed into a prototype model and tested by verification and validation process.

REFERENCES

Adeli, H. (1987) Software Review: INSIGHT 2+. *Micro-computers in Civil Engineering*, 2 (2), pp.173-184.

Allwood, R.J., Shaw, M.R., Smith, J.L., Stewart, D.J. and Trimble, E.G. (1988) *Building Dampness: Diagnosing the Causes*. Building Research and Practice, 16, No. 1, pp.37-42.

Augenbroe, G. (1992) Integrated Building Performance Evaluation in the Early Design Stages. *Building and Environment*, Vol. 27, No. 2, pp.149-161.

Ballal, T.M.A. (1999) *The Use of Artificial Neural Networks for Modelling Buildability in Preliminary Structural Design*. PhD Thesis, University of Loughborough.

Benfer, R., Brent, E. and Furbee, L. (1991) *Expert Systems*. Newbury Park, California, SAGE.

Brandon, P.S., Basden, A., Stockley, J. and Hamilton, I. (1988) *Expert Systems – The Strategic Planning of Construction Projects*. London, Surveyors Publications, RICS.

Brown, C.E. and Wensley, A. (1995) Expert Systems – One Set of Views of the State of the Art. *Expert Systems with Applications*, Vol. 9, No. 4, pp.433-439.

Buchanan, B.G. and Shortliffe, E.H. (1984) *Rule-Based Expert Systems: The MYCIN Experiments of the Stanford Heuristic Programming Project*. Reading, Addison-Wesley.

Cheng, Jianjun and Kong, Shangpo (1993) *Feng Shui and Architecture*. Nanchang, Jiangxi Science and Technology Press [Chinese].

Chiou, S-C and Krishnamurti, R. (1997) Unraveling Feng Shui. *Environment and Planning B: Planning and Design*, Vol. 24, pp.549-572.

Choy, H. (1999) Go with the Flow. IN: Property Council of Australia, *Residential Property Investors Guide*, p.19.

D'Cruz, N. and Vuong, M. (1994) An Integrated Design and Appraisal System. IN: *Building Simulation'93: Proceedings of 3rd International IBPSA Conference*. Belgium, International Building Performance Simulation Association, pp.169-175.

Feigenbaum, E. A. (1977) *The Art of Artificial Intelligence: Themes and Case Studies of Knowledge Engineering*. IJCAI 5, pp.1014-1029.

Feng, S. and Xu, L. (1999) An Intelligent Decision Support System for Fuzzy Comprehensive Evaluation of Urban Development. *Expert Systems with Applications*, v (16), pp.21-32.

Feuchtwang, S.D.R. (1974). *An Anthropological Analysis of Chinese Geomancy*. Vientiane, Laos, Vithagna.

Gann, D.M., Salter, A.J. and Whyte, J.K. (2003) Design Quality Indicator as a Tool for Thinking. *Building Research and Information*, Vol. 31, No.5, pp.318-333.

Gregory, S.A. (ed.) (1966) *The Design Method*. London, Butterworth.

Han, Ke-Tsung (1995) *Basic Theory of Landscape Feng Shui*. Taipei, Lamper Enterprises [Chinese].

Hardy, N. and Danaher, M. (1994) A Knowledge-Based Approach to Preliminary Design of Buildings. *Proceedings of the Institution of Civil Engineers: Structures and Buildings*, v (104), pp.135-144.

Hartkopf, V., Loftness, V. and Mill, P. (1986) The Concept of Total Building Performance and Building Diagnostics. IN: G. Davis (ed.), *Building Performance : Function, Preservation, and Rehabilitation*, ASTM STP901. American Society for testing and materials, Philadelphia, pp5-22.

He, Xiaoxin (1990) *The Source of Feng Shui*. Nanjing, Southeast University Press [Chinese].

He, Xiaoxin (1998) *Feng Shui: Chinese Tradition in a Manchester Context*. PhD Thesis, University of Manchester.

He, Xiaoxin and Luo, Jun (1995) *History of Chinese Feng Shui*. Shanghai, Shanghai Arts and Literature Press [Chinese].

Humphreys, C. (1976) *Zen Buddhism*. London, Allen & Unwin.

Hwangbo, A. B. (1999) *In Search of Alternative Traditions in Architecture: a Cross-Cultural Interdisciplinary Study*. PhD Thesis in Architecture, University of Sheffield.

Jones, J.C. (1970) *Design Methods*. John Wiley and Sons.

Kesik, T.J. (1992). *A Knowledge Based Expert Systems Approach to the Assessment of Basement Performance*. PhD Thesis, University of Toronto.

Lansdown, J. (1982) *Expert Systems: Their Impact on the Construction Industry*. London, RIBA.

Lee**,** Sang-Hae (1986) *Feng Shui: Its Context and Meaning*. PhD Thesis, Cornell University.

Li, H. and Love, P.E.D. (1999) Combining Rule-Based Expert Systems and Artificial Neural Networks for Mark-up Estimation. *Construction Management and Economics*, 17, pp.169-176.

Liebowitz, J. (1995) Expert Systems: A Short Introduction. *Engineering Fracture Mechanics*, Vol. 50, No. 5/6, pp.601-607.

Liebowitz, J. (2001) If You are a Dog Lover, Build Expert Systems; If You are a Cat Lover, Build Neural Networks. *Expert Systems with Applications*, v 21, p.63.

Lip, E. (1979) *Chinese Geomancy*. Singapore, Times Books International.

Lip, E. (1986) *Feng Shui for the Home*. Singapore, Heian International.

Maher, M. and Balachandran, B. (1994) Multimedia Approach to Case-Based Structural Design. *Journal of Computing in Civil Engineering*, v (8), no. (3), pp.42-52.

Maher, M. and Garza, A. (1996) Developing Case-Based Reasoning for Structural Design. *IEE Expert: Intelligent Systems and Their Applications*, v (11), no. (3), pp. 42-52.

Maher, M., Fenves, S.J., and Garrett, J.H. (1988) Expert Systems for Structural Design. IN: Adeli, H. (ed.) *Expert Systems in Construction and Structural Engineering*, Chapman and Hall, pp.85-120.

Mak, M.Y. (2004) *Application of Feng Shui Knowledge to Preliminary Design Evaluation using Knowledge-Based Expert Systems Approach*. PhD Thesis, University of Newcastle, Australia.

Mak, M.Y. (2005) A Conceptual Framework of Feng Shui Knowledge Structure. IN: *Proceedings of International Symposium on Scientific Feng Shui and Built Environment*, City University of Hong Kong, pp.17-26.

Mak, M.Y. and Ng, S.T. (2005) The Art and Science of Feng Shui – A Study on Architects' Perception. *Building and Environment*, 40, pp.427-434.

Mak, M.Y., Ng, S.T. and Chen, S.E. (2005) Formulating a hierarchical structure of Feng Shui knowledge. IN: Loforte, F. et al. (Ed.) *Information and Knowledge Management in a Global Economy*. Instituto Superior Técnico, Lisbon, Portugal, pp.395-404.

Medsker, L. and Liebowitz, J. (1994) *Design and Development of Expert Systems and Neural Networks*. Macmillan.

Mukherjee, A. and Deshpande, J. (1995) Modelling Applications of Neural Networks in Construction. *Canadian Journal of Civil Engineers*, v (19), pp. 521-529.

Rawicz, A. H. and Girling, D. (1995) Application of Expert Systems to Systems Reliability Evaluation. *Microelectronic Reliability*, Vol. 35, Nos 9-10, pp.1309-1320.

Riesbeck, C.K. and Schank, R.C. (1989). *Inside Case-Based Reasoning*. Lawrence Erlbaum Associates, Hove and London.

Rossbach, S. (1984) *Feng Shui*. London, Rider.

Rossbach, S. (1987) *Interior Design with Feng Shui*. London, Rider.

Schmitt, G. (1993). Case-Based Reasoning in an Integrated Design and Construction System. *Construction Information Technology*, v (1), no. (3), pp.39-51.

Scott, A.C., Clayton, J.E. and Gibson, E.L. (1991). *A Practical Guide to Knowledge Acquisition*. New York, Addison-Wesley.

Shang, Kuo (1992) China's Pattern of Feng Shui: Its Formation, Relationship to Environment and Landscaping. IN: Wang, Qiheng (ed.) *Research of Feng Shui Theory*. Tianjin, Tianjin University Press, pp.26-32 [Chinese].

Shortliffe, E. H. (1976) *Computer-Based Medical Consultations: MYCIN*. New York, Elsevier/North Holland.

Simon, H.A. (1969) *The Sciences of the Artificial*. Cambridge, The MIT Press.

Skinner, S. (1982) *The Living Earth Manual of Feng Shui Chinese Geomancy*. London, Arkana.

Smith, J.C. (2000) *Can Machines be Made to Think Like Lawyers?* [Internet] Available from: <http://www.flair.law.ubc.ca/jcsmith/logos/noos/machine.html> [Accessed 19 Nov 2000].

Tarassenko, L. (1998). *A Guide to Neural Computing Applications*. London, Arnold.

Tasso, C. (ed.) (1998) *Development of Knowledge-based Systems for Engineering*. New York, Springer Wien.

Too, L. (1996) *The Complete Illustrated Guide to Feng Shui*. London, Element.

Vob, A. (1994) Case-Based Reasoning in Building Design: Problems of Case Elicitation and Retrieval. *The International Journal of Construction Information Technology*, c v (2), no. (4), pp. 49-62.

Wager, D.M. (1984) *Expert Systems and the Construction Industry*. Cambridge, Construction Industry Computing Association.

Wang, Qiheng (ed.) (1992) *Research of Feng Shui Theory*. Tianjin, Tianjin University Press [Chinese].

Xu, Ping (1990) *Feng Shui: A model for Landscape Analysis*. DrDes Thesis, Harvard University.

Yi, Ding, Yu, Lu and Hong, Yong (1996) *Geomancy and the Selection of Architecture Placement in Ancient China*. Shi Jia Zhuang, Hebei Science and Technology Press [Chinese].