

Design Knowledge Systems: Artificial Intelligence for the Intelligent Architect; Architectural Domain Documentation and Analysis

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1. INTRODUCTION: ENDS AND MEANS

Design Knowledge Systems (D.K.S.) is a multidisciplinary group of researchers, led by Prof. Alexander Tzonis whose objective is to improve design methods and theory through joint investigations in design cognition and computation. The group was founded ten years ago in 1985. We present here a brief history of the group and an outline of our research philosophy and goals.

1.1 Research aims

The research aims of the D.K.S. group include:

- i Development of design knowledge through scientific research.
- ii Improvement of design methods applied by professionals through the development of design knowledge.

1.2 Research programs

The D.K.S. group pursues two programs of research: Theories in Use, and Reconstructed Theories. These two research directions are considered as closely interdependent and complementary and are pursued by the group in parallel.

1.2.1 Theories in use

The theories in use program takes the form of a series of studies documenting the design process and analyzing the conceptual framework and cognitive structures that constrain it. These comprise a program of empirical historical investigations under the name Architectural Domain Documentation and Analysis (A.D.D.A.).

1.2.2. Reconstructed theories

The reconstructed theories program engages in the reconstruction of models and methods in use by practitioners in the form of computational theories of design cognition. This program also includes projects for the development of normative knowledge-based, computer-based intelligent design systems. We call this: Artificial Intelligence for the Intelligent Architect (A.I.I.A.).

1.3 Dual approach

Why do we take this dual approach? What is the connection between the exploration of existing architectural practices, and the development of computational theories of design? These two tasks are, in effect, reflections of each other.

In attempting to improve the understanding of domain design knowledge, we seek to improve the understanding of domain design knowledge, and to express this knowledge in terms of design principles and design precedents. This is a prerequisite to the development of efficient and effective computer-based design methods.

Reciprocally, the development of computational design methods leads to better understanding, to more explicit and transparent design thinking. Both developments increase the control over the mental production of design, making it more reliable and robust.

1.4 Research resources

The research draws from several fields, both within and allied to architecture:

- i Design Theory and Design Methodology
- ii Cognitive Science
- iii Artificial Intelligence and Informatics
- iv Design History

1.5 Research foci

The research focuses on the following aspects of design:

- i Form of an artifact; the structure of a design solution
- ii Operation of an artifact; the behaviour contained in the solution when used
- iii Performance of an artifact; the function of a design solution in respect to accepted programmatic norms

The orientation of the research group towards computational theory of design and the view of the machine as a simulator of intelligent design thinking can offer insights about design creation, problem solving and the production of felicitous artifacts. The approach may also shed some light on broader questions of creative cognition.

To meet these multiple goals the group brings together, next to its regular members, a number of prominent specialists who advise on specific research areas related either to the domain studies of the group or to design system development.

1.6 Research products

The research leads to:

- i Scientific theories, models and support documentation offering more robust, rigorous descriptions and explanations of design intelligence, expanding frontiers in the understanding of design thinking and the opening of new perspectives in design practice.
- ii Design methods based on deeper and more general scientific theories of design result in better control of the design process. From the social contribution point of view these methods implemented in new thinking routines or in new computer programs lead to improvements in:
 - efficiency
 - effectiveness
 - reliability
 - reflective creativity and value learning

2. ARCHITECTURAL DOMAIN DOCUMENTATION AND ANALYSIS (A.D.D.A.)

The domain studies of the group investigate the knowledge—principles categories, rules, precedents, types of problems and heuristics—applied in design practice. Research activities are divided into:

2.1 Case studies

The A.D.D.A. program investigates case-studies of prototypical character to identify:

- i Conceptual frameworks; the product typologies and conventions accumulated through history inside design belief systems, theory and methodology (canons of spatial composition, product program stereotypes, design routines), through which intelligent designing is exercised.
- ii Cognitive constraints; the structures and properties of the mind through which design artifacts are recognised, compared, classified, memorized, conceived and evaluated. These include typologies of artifacts, spatial arrangements, and shape preference rule systems.

2.2 Architectural Archives

The group has been focusing on the creation of architectural archives the systematic cataloguing and publication of archives of conceptual design drawings, recording the creative thinking on a project. The project is carried out in collaboration with Garland Publishing, New York and major museum archives.

3. ARTIFICIAL INTELLIGENCE FOR THE INTELLIGENT ARCHITECT (A.I.I.A.)

The A.I.I.A. projects concentrate on the development of the Intelligent Architect (I.A.), an automated system for the production of new design solutions which satisfy programmatic requirements using previously acquired domain knowledge.

3.1 General research topics

The A.I.I.A. group is involved in studying the following problems:

- i How are cognitive constraining structures applied in design inference?
- ii How do design knowledge, conceptual structures and precedents control the design process?
- iii How does reasoning interrelating aspects of form, operation, and performance take place in creative design?

3.2 Research approaches

AIIA research exploits a number of approaches as the needs of specialized investigation demand:

3.2.1 Plan representation, recognition and typology

Development of methods to recognize and classify, pre-parametric artifact representations, spatial diagrams, sketches, and technical, production drawings.

3.2.2 Principles and precedents : Design Thesaurus

Analysis and storage of precedent plans in a Design Thesaurus, an organized intelligent memory whose structure reflects architectural knowledge constraints. Identification of design principles capturing large numbers of design rules, generalizing and organizing experience drawn from precedents concerning form/operation/performance relations.

3.2.3 Programmatic analysis

Development of methods to parse, analyze and structure normative statements from verbal discourses. Recasting values of such discourses into explicit design product programmatic constraints.

3.2.4 Analogy and creativity: automation based creative design

Analogy and metaphor as mechanisms of inference, are characteristic of learning and most intelligent creative thinking. Projects in this area contribute to the development of an analogical design inference system for Automation Based Creative Design (ABCD) using constraints of form - operation - performance.

3.2.5 Community and the mind

Development of multi-agent, collaborative, integrated, concurrent, or distributed design systems employing all the above (1-4) approaches. Such agents are either professional specialists who collaborate in the design process or users who also play a participatory role in decision making of the product.

4. COMPLETED PROJECTS

Most of the projects of the group are carried out in collaboration with outside domain experts.

4.1 A dialogical model for participatory design

Dr. Hoang-Ell Jeng (1995) has developed a computational model of participatory design dialogue. Since the mid-1960's there has been an important movement towards the participation of the public in determining their built environment. The present research is aimed at improving this process by providing a cognitive, computational methodology. The project draws from a case-study of the participatory design of Ho-Chu-Wei Park in Taiwan in which Jeng was involved. The goal of the research project is to generate a system reflecting the dialogical nature of participatory design thinking to aid the acquisition and tabulation of data during the process of debating and reasoning alternatives, and identify areas of agreement or dissent to support conflict resolution and collective design decisions. The work employs recently developed theories in cognitive science (discourse analysis of multiple communication), social psychology (conflict resolution, dialogical self), artificial intelligence (multi-agent problem solving) and design methodology (group decision-making and problem-solving process).

4.2 Rationalization, standardization and control in institutionalized design reasoning

Dr. P. Scriver (1994) studied the thinking processes that helped produce the distinctive architecture and settlement planning of British India in the 19th century. The work offers insights on the rationalization and institutionalization of design thinking, and the role of socially constructed conceptual systems in such processes. The project was undertaken with the collaboration of Prof. A.D. King.

The study examined the efforts of the Public Works Department of British India to rationalize the conception and execution of the wide range of civil and military buildings required by that colonial administration. This bureaucratically organized and regulated design system enabled a small number of engineers and subordinate technicians, widely distributed geographically, to generate a large volume of formally consistent and serviceable architectural solutions, with relative efficiency. A cognitive historical analysis of the relationships between this utilitarian architecture and the political and cultural intentionality of the colonial regime was pursued through a multi-faceted examination of the processes and patterns of reasoning of design the engineers concerned, on the basis of extensive empirical research in colonial government archives in India and England. The conceptual framework of knowledge in which Victorian engineers operated in British India was partially revealed through an analysis of certain well articulated "belief-systems" of which that framework was comprised, including the ideology of the engineering profession and the discriminatory beliefs of the colonial society concerning class and race.

In the cognitive analysis of the case, the systematic design methodology of the Public Works institution was interpreted as a prototypical rule-based system, offering a variety of generalizable observations of potential relevance to the cognitive modeling of professional reflection in action. These included the heuristics of design thinking in a narrowly circumscribed domain of expert knowledge; the role of architectural design theory and methodology such as canons of spatial composition, design routines, and architectural program stereotypes, as conceptual frameworks, in structuring and delimiting the design reasoning process; the codification of precedent knowledge in the form of design regulations and standard plans; the role of belief systems in controlling the way expert knowledge may be organized and employed institutionally.

4.3 A framework for comparing and controlling number-based design reasoning systems

Dr. Li Yu (1994) examined the role of Number in the representation of building design knowledge. His research investigated two culturally distinct systems for the prescription and categorization of architecture, employing theories of number: a traditional Chinese system employed in the classic Chinese house-builder's manual,

Zhai Pu Zhi Yoa (1741); and the system developed for universal use by contemporary architectural professionals, Le Corbusier's Le Modulor. This comparative case-study explores the possible commensurability of these systems at the level of pre-parametric design-thinking, with particular regard to the association of numbers with formal and performance criteria in cognitive categories. The results of the study were used to develop a general computational system of representation capable of handling cross-cultural design thinking. The system, when applied, will extend present capabilities of object oriented programming into new domains. The study was carried out in collaboration with Dr. K. Ruitenbeek.

4.4 A computational representation of the spatial organization of residential buildings

Dr. ir. M. van Leusen (1994) has developed an automated design support system for the design of residential buildings. The system provides information interrelating spatial form types with operational and performance requirements. The project was undertaken in collaboration with Prof. K. Rijnboutt and Dr. Ph. Steadman.

At the early stages of the design process, fundamental decisions are made with respect to the spatial organization of a project concerning overall shape, size, and internal organization. Such pre-parametric decisions, particularly concerning the building's spatial organization, may have serious consequences for various aspects of the design product's performance. The study aimed at supporting decisions at the early stages of the design process by developing a typology of pre-parametric possible design solutions. Many architectural handbooks—particularly those in the domain of housing—discuss building typologies in which types are described by means of diagrams and illustrated with one or more precedents. The effectiveness of such books as design supporting tools is limited by the fact, among others, that type descriptions are not based upon a rigorous representational system for spatial organization. This leads to unreliability and ineffectiveness. The study explores the possibilities of overcoming these weaknesses.

In addition to a review of existing work in the area of housing typology, the study develops: (1) a type-representation of basic arrangements of dwellings which retains only the most general characteristics of spatial organization; (2) a demonstration of the potential of this representation in relation to design.

While the study itself is pre-computational, the idea of a computerized typology of basic spatial arrangements of buildings is a constant preoccupation. Challenging issues are the automatic recognition of type descriptions from precedents, and precedent retrieval on the basis of (incomplete) type descriptions entered by the user.

4.5 Meaning of the site

The development of a system for classifying and analyzing building sites, taking into consideration multiple points of view and cultural belief systems, was the topic of the doctoral research of Dr. Xiaodong Li (1993). His study compares an archaic with a contemporary case; a traditional Chinese theory of architecture from a 15th century text, Xian Puo Ji, and the theories of Kevin Lynch. The cases are compared in terms of the systems of graphic spatial representations and categories they employ and their respective value structures. Out of this comparison an attempt is made to generate a more holistic, multi-view method for advising designers on problems of site organization and arrangement. The project was undertaken in collaboration with Prof. Schmid and Dr. Ruitenbeek.

4.6 Automation Based Creative Design

The importance of using precedent design products in the design process has often been pointed out by architectural theorists, educators and by practicing architects themselves. But it is only recently that the role that precedents can play as design knowledge for design thinking and inference, has begun to receive widespread attention in design computation research with an eye to improve design practice. How far and in what manner precedents can be integrated in a computational design practice is a highly debatable subject while most computer-based architectural techniques tend to suppress the importance of precedent. In collaboration with I. White, A. Tzonis edited a special issue of *Construction Automation* (1993) and a book, *Automation Based Creative Design* (1993), devoted to this topic.

4.7 A knowledge-based computational approach to architectural precedent analysis

Nan Fang in his *Architectural Precedent Analysis* (1993) developed a computational methodological framework for the use of precedents. The research drew from the analysis of a case-study of urban renewal in the ancient residential quarter of Beijing was carried out by the prominent Chinese architect and planner Prof. L. Wu, whose work relied heavily on the use of traditional precedents. Prof. Wu was also an advisor in this research. The case study was used heuristically to provide criteria for reviewing critically the available analytical systems for architectural space representation. This indicated normative criteria for a representation system to employ precedents in the design process. In addition to these pragmatic criteria the new system developed ARPRAN, relying on recent developments in cognitive theory, spatial semantics and artificial intelligence. Among current methodologies in computer science, Machine Learning was used as a best-match tool to help reconstruct the design thinking implicit in the case study and, finally, to shape the new system.

4.8 The structure of architectural theory

Dr. C.J. Baljon (1993) developed a method to analyze conceptual systems contained in architectural discourses. He used texts by Ruskin, Semper, and Viollet-le-Duc as cases. The project was undertaken in collaboration with Prof. D. van Zanten.

4.9 Global

A computer-based system for urban design, GLOBAL, which identifies zones of land use on given sites using reasoning from first principles and constraint propagation, was developed by N. Harkes (1993). GLOBAL identifies, formulates and draws plans on the basis of a small data base. Monitoring and conflict resolution capabilities are aspects of the system.

4.10 Topgene: an artificial intelligence approach to a design process

Dr. A. Zandi-Nia (1992) has developed TOPGENE, a computer-based system for generating pre-parametric spatial arrangements of buildings. The system employs deep models of expertise which can (1) generate (2) evaluate (3) analyze and (4) give diagnosis of malfunction with respect to multiple social performance norms. The system uses Q-analysis to organize circulation operation data, an iterative bottom-up approach in conjunction with hill-climbing and heuristic techniques, to arrive at a design. The research included analysis of the computational complexity of architectural design, the role of domain heuristics reducing such complexity and means for diagnosing the structural complexity of systems having a topological property representable as a graph, as is the case of designing buildings in relation to social performance norms. A new theorem for keeping track of distances in incrementally growing graphs was developed. The study also produced topological indices useful for quick diagnosis of alternative design solutions.

TOPGENE can generate various design types depending on the programmatic requirements. It uses rules of thumb to relate and code relations between form, operation and social performance norms in buildings combined with numerical data structures and computations. The system uses hill climbing to generate designs from a single point of view in conjunction with negotiation based problem solving. It employs an agenda mechanism to automate resolution of conflicts between the various programmatic social norms.

Dr. Zandi-Nia carried out several experiments to test the system using realistic data. The results demonstrated the efficiency and the effectiveness of TOPGENE. In collaboration with Dr. Kerckhoff he also compared the system with a neural network model borrowed from the Hopfield model. The superiority of TOPGENE was shown. TOPGENE has limitations as a totally automated system, parts of its methodology and special techniques can already be easily integrated in practice, in particular in fast pre-parametric evaluation of alternative building types.

H.S. Roozenbeek worked towards visualization of the output of the Zandi-Nia system.

4.11 Aspects of Arab islamic architectural discourse

The identification of the conceptual system contained in the early Arabic discourse on architecture was the topic of investigation of Dr. B. Al-Abed (1992). The research also involved an extensive documentation of Arabic texts on architecture from the early Jahiliyya (pre-Islamic) period to the 18th century when foreign influences begin to be evident in the Arabic culture. The study discussed al-Jahiliyya verse, and religious, literary, scientific, geographical and historical texts, involving issues of building typology, urban planning principles, and descriptions of construction techniques, buildings and the belief systems with which they were built. Prof. I.R.T.M. Peters collaborated in the study.

4.12 Development of a computerized handbook of architectural plans

A framework for automated recognition of metric properties of architectural plans has been developed by Dr. A. Koutamanis (1990). Recognition includes identification of spa-tial primitives, grouping of primitives/subdivision of the plan and investigation of well-formedness. Image understanding and well-formed-ness concepts employed derived from the classical canon domain study researched by L. Lefaivre and A. Tzonis (1986). The research is seen as a step towards the development of the module for inputting architectural precedent solutions in the Design Thesaurus, an automated intelligent data-base of precedents. Koutamanis has also worked on a theory of perception and understanding of the built environment and its graphic representations based on cognitive mechanisms. (Koutamanis, 1990a, 1991, 1992).

4.13 Morphology and building performance

Under a contract from the Rijksgebouwen Dienst of the Ministry of Housing and Planning J.S. de Boer and V. Mitossi prepared a typological study of morphological aspects of buildings related to performance criteria of flexibility and multifunctionality. The products of the study are: (1) an analysis of factors which determine flexibility and multifunctionality and their interrelationships; (2) a practical tool for the analytical description and evaluation of these factors by field

researchers of the Rijksgebouwen Dienst and methods of correlation to be used by the decision-makers of the Rijksgebouwen Dienst for the interpretation of data supplied by field researchers.

4.14 Management of the urban environment through image-processing

Methods and techniques for the management of the urban environment by means of image-processing using the computer and CAD systems was the research topic of Ronald Stenvert. The project included a systematic comparison of the prescriptions of the Classical orders given by twenty one treatises and a group of late sixteenth and seventeenth century Dutch buildings. The project was undertaken mainly in the University of Utrecht with Prof. dr. J. van der Berg.

4.15 Fitting old buildings to new programmatic demands

M.W. Ludema has worked on developing a framework for an expert system for identifying buildings fitting new programmatic demands on operation and performance out of a large stock of unused buildings in the possession of the Rijksgebouwen Dienst. of the Dutch Government. The system is based on knowledge collected from extensive interviews with experts of that agency.

4.16 Analogy in architectural invention

Prof. A. Tzonis worked on computational representation of the case (1990). He also researched the case of inference by analogy in the invention of the bastion by L. Da Vinci and the role of representation conventions in the solution of the problem (1989).

4.17 Roomfinding

During the initial phase of the Intelligent Architect project (1985-1987) Robert Seidl worked on a 'roomfinder' algorithm for the representation of buildings as graphs. J.W. Croon used DELPH 2, an expert system shell developed by TU Delft, to investigate formal operational relations in dimensioning steel construction elements in buildings.

5. ONGOING PROJECTS

5.1 Design argumentation and protocol in a security system for buildings

R. van der Bijl is researching the argumentation structure of the problem of security of buildings. The study aims at developing a design support system providing designers or managers of projects with advice about theft and vandalism.

5.2 Drawing text and femininity: the construction of Simon Stevin's architectural knowledge systems

The partially published writings of S. Stevin on architecture are studied by H. de Mare. The research explores the knowledge structures underlying these texts and drawings to reveal the role of belief systems in giving shape to Stevin's theories. The project is undertaken in collaboration with Prof. W. Frijhoff.

5.3 Choosing construction materials, a computational approach

M. W. Ludema works on the development of a framework for an expert system for resource allocation in Ministry of Defense buildings. The knowledge based system will provide support for decisions in choosing and acquiring construction materials considering their total life costs and not only their price at the moment of acquisition. The project is undertaken in collaboration with Prof. H. B. Roos.

5.4 Style and frame-based design rules in van Doesburg

The heuristic role of sketch drawing in the design process and its representation conventions is being researched by J.S. de Boer.

5.5 A cognitive approach to the study of industrial housing in the Netherlands

V. Mitossi is working on industrialized housing in the Netherlands between 1940-1965 as a case study towards the development of an automated knowledge base of buildings, analyzing and integrating data concerning architectural plans, construction, space use, of space and industrialization.

5.6 A model for optimal designing

The subject of the research of ir. M.A. Noordzij is the improvement of the process of development of building plans at the very early stage of the design process, the 'conceptual' or 'pre-parametric' level, using computational methodology. Towards this goal a technique of design will be developed applying genetic algorithms. Genetic algorithms are search algorithms based on the mechanics of natural selection and genetics. The principle of neural Darwinism is used as a metaphor for an artificial optimization algorithm. The thesis is interpreting the pre-parametric level of design as a manipulation of space arrangement represented through the mathematical conventions of topology using graph theory. Topological concepts of buildings descriptions will be mapped into the representation systems of genetic coding. Genetic algorithms have been selected because of their capability to search a solution space in a parallel manner using many search points, generating through combining out of many partial high performance solutions and exploiting historical information, optimal solutions. There is however a difficulty in defining the genetic coding and the genetic operators when applying a genetic algorithm to a specific type of problem. The speed of the algorithm and the quality of generated solutions highly depends upon the knowledge in designing the genetic operators. These

positive and negative aspects will be explored in the thesis.

The results will be tested in real life problems.

5.7 Virtual office support system for concurrent design in architecture

The design of building increasingly requires architects to act as the coordinator of a multi-agent design team composed of agents outside the architect's office, engineers, client representatives, community representatives, municipalities, etc. For such distributed design processes to be effective and efficient, the smooth and efficient communication between all participants in this process is absolutely essential. This communication is becoming an important issue, especially in light of the increasingly prevalent practice of 'fast-tracking', as this requires the actors to continuously revise their knowledge of the design project in light of the activity of their associates. John Linke Heintz is developing a dialogical model of the communication, coordination and integration of the various points of view of the various actors.

The proposed study will investigate contemporary architectural design practice, showing the increased practice of techniques known in other engineering professions as concurrent design. As part of an ongoing research project with the École d'Architecture de Saint Etienne, two case studies will be undertaken. The two cases are both public buildings, one by the Dutch firm Mecanoo Architecten, and one by the French firm Ferrier Architecte.

These case studies will permit the development of a model of contemporary architectural design practice as it occurs between the architect, the client, and the other consultants and parties to the project. In particular, the centrality of the role of the architect in concurrent architectural design will be examined. In creating the model the techniques of dialogical modeling will be used to describe the argumentative role of messages passed between agents, while an analogy with parallel and distributed processing computer architectures will be used to describe the role of messages of various types in furthering the design process through the distribution of information and tasks.

Based on this model, a Virtual Office Support System for Concurrent Design in Architecture will be developed. This support system will assist the various agents in the design process to integrate the results of each others design decisions, and to monitor and distribute information and tasks in a more efficient and effective manner. The support system will be designed to be of particular value in moving information from the agent generating it to agents requiring it in a prompt manner. The support system will be developed to the level of computational theory.

5.8 Multi-aspect architectural precedent thesaurus

A prototypical system for analyzing the representation of the fabric of buildings from multiple points of view on different levels of detail-part-whole hierarchical relations, and different degrees of abstraction and parametrization is the subject of research by D. Giannisis. Continuing his previous exploratory investigation of a case-study of Le Corbusier's Unite d'Habitation, he aims at developing an information system for organizing an intelligent data base of precedent cases of design solutions for 're-use' which will aid architects in solving novel problems. Particular emphasis is paid to the multi-functionality of the precedents and its latent potential, permitting alternative re-uses. The project is implemented using a hyper-document system.

5.9 Architectural and musical conceptual structures compared

drs. B.M.M. Wintjes (-van Haaften) is carrying out a comparison between architectural and musical conceptual structures. The cases are drawn from 17th and 18th century theories.

5.10 An automated approach to building evaluation

H. S. Roozenbeek is developing a user friendly computer program which implements different types of multi-criteria design evaluation techniques as well as a data base of architectural criteria for performance evaluation. The system builds on the program adapted from ELECTRE and introduced in architecture in 1974 by Salama and Tzonis. Two different approaches, stemming from the American school of M.C.E. are also employed: SMART (Simple Multi-Attitude Rating Technique, Von Winterfeldt and Edwards, 1985) and the multiplicative variant of the AHP (Analytic Hierarchy Process, Lootsma (1987), originally Saaty (1980)). The system is implemented in an object-oriented programming language, (Borland C++).

5.11 Word and image in design discourse

The research of D. Bilodeau examines the definition and organization of knowledge in 18th century French instructional books on architecture (1671-1793). Principle themes are the institutionalization of architectural education, and the recognition of architecture as an autonomous domain of knowledge. Commencing with the publication of the germinal work of Francois Blondel, the investigation focuses on educational texts associated with the Academie Royale d'Architecture and the French military and professional engineering schools. The study explores in-depth: the conceptual systems and discontinuities which dominated this period; the specific contribution of each book to the formalization of knowledge; the opposition between architecture as science and architecture as art; the analytic and synthetic natures of architectural knowledge; and visual versus verbal representation.

5.12 Precedent and innovation in post-war Italian architecture

Luca Molinari is studying the role of belief-systems and precedent knowledge in design innovation, in the work of the post-war Italian architect, Ernesto Rogers. This cognitive historical case study involves in-depth research in the archives of the firm.

5.13 Architectural basics in computerized design education

Development of automated interactive, modular design tutorials Architectural Basics in Computerized Design Education - ABCDE: The purpose of ABCDE, a collective project of the group, is to substitute the traditional passive coverage of architectural knowledge (including detailed presentation of case studies and examples by the teacher, as well as supervision of exercises) during the first two years of professional education with a computational framework more suited to current paradigms and tools of creative problem solving. ABCDE includes modules on morphology, typology, design solution search, means-ends analysis, design diagnostics, sub- and global project evaluation, programmatic analysis, space-time analysis of projects, and use of precedents.

5.14 Design method

Prof. A. Tzonis and J. L. Heintz are preparing a text book in programmatic analysis and design. The method is based on a repeating cycle of generation and testing of design schemes against criteria which themselves evolve through the process. Problem solving techniques are introduced and shown to have applications in design. In testing the schemes, multi-criteria analysis is introduced, and a series of objective single criteria evaluation tools are demonstrated. The text follows a design case through the stages of programme analysis and preliminary design.

5.15 The Garland architectural archives

The Architectural Archives project (Prof. A. Tzonis, General Editor) is undertaken within the framework of the publishing program of Garland Publishing of New York. The Garland Archives present the totality of a corpus of documents accompanied by standard assisting information. There is no editorial pre-selection of the material. Architectural documents are seen to be as significant as painters' sketches and poets' notes, and no longer just as their poor relatives. The idea is to offer the researcher maximum access with the least bias to these documents. Among the archives already published are those of Le Corbusier, Mies van der Rohe, Buckminster Fuller, Louis Kahn, Walter Gropius and Alvar Aalto. Members of the group are involved in preliminary research towards the transformation of the existing book-based material into a CD-ROM library.

6. CONFERENCES ORGANIZED BY DKS GROUP

6.1 Precedents in Creative Design

The use of precedents in creative design is the main focus of a series of symposia organized by ALBERTI, in collaboration with I. White, an international interdisciplinary network of researchers with the support of Euroconferences of the European Community. The central role of precedents in the generation of new design solutions is increasingly recognized. Designing is very much re-designing. We know now that precedents not only make possible the solution of hard design problems, but also contribute to design innovation. The aim of this conference is to contribute to the understanding of how precedents are used by designers and how computer systems which use precedents to design creatively can be used. Issues discussed: roles of precedents in design creativity, where precedents come from, how precedents are adapted to be used in new design problems, use of precedents in areas such as law, medicine, science, art, music. Speakers included: S. Anderson (M.I.T.), R. Oxman (TU Eindhoven), W. Böhm (Kaiserslauten), E. de Cointet (Saint Etienne), A. O'Hare (Bradford), C. Tweed (Queen's, Belfast), I. Cross (Cambridge), J. Lee (Edinburgh), I. White (Cambridge), Ph. Boudon (LEREA, Paris), Z. Bankowski (Edinburgh), M. Lèglise (Toulouse), A. Harrison (UWE Bristol), P. Steadman (Open U.), V. Slapata (Prague).

6.2 Automation Based Creative Design

In 1992 our research group was asked to organize an international conference on the occasion of the 150th birthday of the Delft University of Technology and the meeting of the Association of Collegiate Schools of Architecture (A.C.S.A.) of America in Europe (May 15, 1992). The theme chosen was Automation Based Creative Design Education (A.B.C.D.E.). Issues discussed: innovative use of computers in architecture, cognitive foundations, domain applications, new directions, and technological, social and moral implications. Speakers included: G. Stiny (U.C.L.A.), W. J. Mitchell (M.I.T.), D. Schodek (Harvard), D. Schön (M.I.T.), W. Oechslin (E.T.H.), I. White (Cambridge), G. Schmitt (E.T.H.), S. Pollalis (Harvard), J. P. Protzen (U.C. Berkeley), M. Benedikt (U. Texas), R. Aroca (Madrid Polytechnic), R. Oxman (Technion), Ph. Boudon (Paris), L. Kroll, P. Quintrand (E.A. Marseille), Th. Chastain (M.I.T.), C. Boyer (Princeton). Sections on: Design Conception and Reasoning Information Support Systems on Technology, Visual-Spatial Information Systems. Round Table (chaired by prof. S. J. Doorman): Design, Computers, Morality.

6.3 Representation and Recognition

On 19th of September 1990 the A.I.I.A. group organized its second Studiedag, on the subject Representation and Recognition (R&R) of image, with particular emphasis on space representation in design. The meeting was intended as an opportunity for leading researchers and scholars from within the Netherlands and abroad to discuss current studies in perception and representation, as well as related themes from the history of engineering drawing and computerized architectural representation. Among the participants: E. Backer (TU Delft, E.T.), I.T. Young (TU Delft, T.N.), F.C.A. Groen (University of Amsterdam), J.J. Koenderink (RU Utrecht), E.L.J. Leeuwenberg (KU Nijmegen) and G. Goldschmidt (Technion, Israel), Philip Steadman (Open University), and Robin Evans (Central London Polytechnic and Harvard University).

6.4 Architectural Knowledge Systems

On the 29th of November 1988 the group organized its first Studiedag on the topic Architectural Knowledge Systems, with the participation of R. Schaa, R. Hamel, and A.Y.L. Kwee.

7. CONCLUSIONS

The work of the group, while being deeply theoretical and computational in outlook, remains devoted to the notion that practicing architects can improve both the quality of their products and the efficiency of their practices through an intelligent, rational and reflective approach to the design process.

Nevertheless, the companies that are applying Artificial Intelligence to its projects are able to generate 50% more profit. The application of AI does not imply the use of robots to lay out bricks or drive trucks. It implies the use of algorithms that can solve the greatest of challenges and improve efficiency and productivity. The construction companies that have begun taking on AI have generally adopted it in a fairly nascent levels for actions such as

- Building System Planning created GenMEP, an add-on for Revit focusing on the mechanical and plumbing (MEP) design. The software uses machine learning to explore all possible design alternatives and tests to find which design is better, ensuring that the 3d models of the MEP systems do not clash with the building's design.

5. Image recognition.