Innovations in Design & Decision Support Systems in Architecture and Urban Planning

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TABLE OF CONTENTS

PREFACE

It has been a real pleasure to work with the authors of the papers in this volume; they have contributed with interesting reports on relevant and innovative research projects, which allowed us to compose an inspiring book. Our gratitude goes also to the members of the international scientific committee for their invaluable effort in reviewing and editing these works. Special thanks also go to our colleagues Mandy van de Sande, Marlyn Aretz, and Leo van Veghel, who took great responsibility in organising the practical aspects of the DDSS conference and made it a pleasant and fruitful event.

Eindhoven, July 2006

Jos van Leeuwen and Harry Timmermans
Editors and conference chairs

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INTRODUCTION

The International Conference on Design & Decision Support Systems in Architecture and Urban Planning is organised bi-annually by the Eindhoven University of Technology. This volume contains a selection of papers presented at the eighth conference that was held at the Kapellerput Conference Centre in the village of Heeze, near Eindhoven, The Netherlands, from 4 to 7 July, 2006.

Traditionally, the DDSS conferences aim to be a platform for both starting and experienced researchers who focus on the development and application of computer support in the areas of urban planning and architectural design. This results in an interesting mix of well-established research projects and first explorations. It also leads to a very valuable cross-over of theories, methods, and technologies for support systems in the two different areas, architecture and urban planning.

This volume contains 31 peer reviewed papers from this year's conference. The volume is organised into two parts: the first part containing three sections in the area of urban planning; the second part containing four sections on design support.

In part one, on urban planning, five of the chapters in section one deal with simulation of land use; the sixth chapter is on visualisation of land use. Section two contains five chapters on multi-agent systems for the computation of movement simulation. The five chapters in the third section are also on multi-agent systems, but relate to processes of urban development. The final chapter in part one discusses the acceptance and application of this type of tools in today's urban planning practice.

Part two, on design support systems, starts with a section containing five chapters on the management and deployment of design knowledge. The second section contains three chapters discussing tools and strategies for urban decision-making. The first three chapters in section three discuss the possibilities to allow designer interaction with systems that automate design; the fourth chapter presents a solution for the exchange of building information models. The final section is on virtual environments, with one chapter focusing on urban environments and another on design environments.

The following paragraphs provide a brief summary of the two parts and the seven sections of this volume.

DEVELOPMENT OF DDSS IN URBAN PLANNING

The literature on design and decision support systems in urban planning is rich of many different tools and modelling approaches that potentially can support decision makers in better understanding the consequences of their decisions or help them in the decision-making process itself. The nature of these tools and systems and their stage of development largely reflect more general trends in science. The first generation of models and systems was often based on statistical input-output relations, weak in terms of behavioural principles, large scale, and implicitly or explicitly based on the assumption of perfect and full information in the sense that uncertainty was rarely addressed. Next, with the increasing popularity of chaos theory, the often complex models were replaced with simple or even simplistic models, based on the belief that simple rules and principles are sufficient to generate complex emerging patterns. Cellular automata models constitute a good example. More recently, realizing that urban developments but also plans are the result of interactive or even strategic choices of actors involved in the process, scholars started to work on multi-agent systems, some still based on simple, primarily data-driven principles, other trying to significantly improve the behavioural foundations of the models. These approaches should not be viewed as successions, but rather are still further developed and applied and still constitute frameworks within which different groups are making progress. This is also reflected in the papers on design and decision support systems in urban planning that were selected for the first part of this volume.

Land Use Simulation and Visualisation

Emberger, Ibesich & Pfaffenbichler describe an integrated land use transportation model system, called MARS. In terms of its key features, it is a conventional approach, put into a new jacket. The authors argue that the system has proven its usefulness. This is also illustrated by another paper on the same model system.

Pfaffenbichler, Monzón, Pardeiro & Vieira describe an application of MARS to Madrid. A series of sustainability indicators is derived from the model, allowing the user to evaluate alternative plans in terms of these indicators. In addition, a cost-benefit analysis is conducted.

As for cellular automata, *Gohnai, Ohgai, Ikaruga, Kato, Hitaka, Murakami & Watanabe* clearly illustrate how useful these models are for simulating dynamical processes such as the spread of fire. This is illustrated by the model itself, but also by experiences gained in the application that is described in this chapter.

Jiao & Boerboom argue that a distinction should be made between transition potential rules and conflict resolution rules. In addition, they provide a useful overview of a few existing methods for deriving these rules from empirical data or for eliciting expert knowledge.

Osaragi & Aoki suggest some valuable improvements for estimating land use transition probabilities, which are central to cellular automata models. In particular, arguing that transition probabilities are required at the level of building lots and assuming raster data are available, they develop an improved method to estimate such transition probabilities and propose a method to estimate time series changes in the land use transition probabilities, based on the concept of land use utility.

Interpretation and correct judgement of the qualities of a landscape on the basis of two-dimensional land use maps is a difficult task, even for experienced professionals. Particularly the implications of changes to land use cannot easily be perceived from maps. *Borsboom-van Beurden, van Lammeren, Hoogwerf & Bouwman* report on their efforts to integrate 3D visualisations of the (changed) landscape with the land use model output. They describe two approaches. One is to insert 3D iconic (exemplary) representations of new land uses into the land use model. The other is to use 3D components of GIS tools to represent existing land use features. The combination of both approaches seems to lead to promising results, but to achieve them technically on a large scale still proofs to be very challenging.

Multi-Agent Models for Movement Simulation

Multi-agent models are potentially relevant to simulate movement. Models of pedestrian movement have recently regained considerable interest, especially due to safety, crowding and feasibility issues. *Bandini, Manzoni & Vizzari* present a general framework and a situated cellular automata model as a special case of a multilayered, multi-agent situated system to address this problem. The advantage of their approach is that both interactions between pedestrians and the interaction between pedestrians and their environment can be easily incorporated in the model. Good examples of 3D visualization to portray simulation dynamics are also presented. The system is illustrated using an underground station as an example.

It could be argued that the behavioural mechanisms underlying pedestrian behaviour in this context are relatively simple in the sense that pedestrians probably wish to leave the station as quickly as possible or go to the train in a convenient way. Behavioural principles in large-scale retail environments are considerably more complex. Pedestrians may be utilitarian or hedonic, some may behave in rational ways, others in satisfying ways, reflecting bounded rationality. There will also be significant heterogeneity in terms of shopping aims, agendas, environmental knowledge, etc. *Zhu &*

Timmermans therefore explore the potential of gene programming to identify the behavioural principles (alternative model specifications) that best describe observed movement patterns. The approach goes beyond genetic programming in that not only parameters are fitted but also the best functional form of the model can in principle be derived. A potential limitation of the suggested approach is that it requires parallel computing, especially for large-large-scale applications.

Chen & Chiu use a less formal approach but show how agent technology can be used to visualize pedestrian movement and guiding users in navigating through streets. Their system, called SCALE, is a platform supporting digital data and a media suitable for advertising and city guide information. Space-tags are virtual objects that can be accessed only within a limited area and for a limited time. The functionality of the system is described and illustrated using a small sample.

Another type of movement is traffic. *Boussier, Estraillier, Sarramia & Augeraud* describe a very interesting hybrid system for traffic simulation. Their multi-agent system is divided into three subsystems: (i) one is concerned urban traffic simulation, with agents representing vehicles, bicycles, pedestrians, etc; (ii) another is with the information system service behaviours, with agents modelling employees and the computing system of the information system itself, and (iii) the third one is dedicated to the decision support objective of the system. Traveller behaviour is modelled using questionnaire data based on Taguchi experimental designs, while belief theory is employed to identifying preference distributions of transport modes. An example involving students illustrates the potential of the system.

Remaining in the context of traffic, *Balmer & Nagel* show how to simulate the interaction between the capacity of an intersection and the shape of a single roundabout using agent technology and evolutionary algorithms. Their contribution is exceptional and extends the typical application area of multi-agent models and traffic simulation. An application to the central roundabout of Zürich shows the potential of this approach.

Multi-Agent Models for Urban Development

Multi-agent models have not only become of interest to simulate movement patterns, such as for example pedestrians, but also to simulate urban change processes. A few such examples are included in this volume. *Diappi & Bolchi* describe an application of a multi-agent system to simulate the gentrification process in Milan, Italy, using Smith's rent gap theory. Different agents represent the actors in this process (homeowners, landlords, tenants and developers). Key in the simulation is the principle that investments are made when the difference between potential rent and capitalised rent is greater than a certain threshold. The rent variables evolve

over time. Because expected rents are an average of neighbourhood capitalised rents, a spatially varying process constitutes the result of the simulation. As often the intention in these applications, the model shows evidence of self-organisation in that nonlinear interactions at the local level produce different emerging macro-level configurations.

Zimmermann illustrates the application of the software generation process PROBAnD to a simplified version of Devisch et al's housing market model. In addition to some interesting substantive results, this chapter provides evidence that computing platforms have become available to develop quite complex multi-agent models in a short period of time.

This does not mean that only advanced multi-agent systems are relevant in supporting urban planning in the context of housing. This is adequately shown by *Celikyay,* who implemented in a geographic information system McHarg's ecological evaluation method and Kiemstedt's utilization value analysis to analyse the potential of the natural resources for new residential development. In particular, he reports an application in Bartın city to define potential residential areas and shows that some residential areas have been selected improperly.

Zhou, Kondo, Gordillo & Watanabe address the problem of the location of waste disposal facilities vis-à-vis residential areas. Various probabilistic models, based on distance and testing for sociodemographic differences, are estimated for the city of Chengdu. Differences between the models are small only.

Heurkens also describes a multi-agent tool to support decision-making with respect to urban development related to a possible organisation of the Olympic Games in the Netherlands in 2028. In particular, this paper focuses on a multi-criteria method for choosing the best design.

Based on examples such as the ones described in this volume, one would expect that design and decision support tools (or planning support tools) would have found their way in practice. *Vonk, Geertman & Schot* argue that this has not been the case. They reflect on this lack of application by discussing issues related to the instrumental quality of these systems, user acceptance and extent of diffusion. Results based on interviews show that lack of experience, lack of awareness and lack of instrument quality of PSS are the main bottlenecks blocking user acceptance, and that these effects are enhanced by hampered user acceptance and diffusion. Interesting to note is that this position is at variance with the first paper on urban planning included in this book, which argues and provides evidence of success. Hence, this discussion continues…… and it should.

DEVELOPMENT OF DESIGN SUPPORT SYSTEMS

Whereas in the past decades the tremendous technological innovations in ICT have enabled the development of powerful support tools for architectural and urban design, today there is a common and increasing awareness of the need to remain in control, as designers, of this computational power. It is no longer sufficient for the R&D community in this domain to deliver 'conventional' tools for the generation of design solutions, for the optimisation of design, for the integration or exchange of models, for efficient production of models for architectural and urban designs. While these tools find their way into the practice of designers and the construction industry, reluctance remains to fully accept such tools, rooted in the feeling experienced by many designers of loosing control over the design process. Hence, a focus can be discerned in ongoing research that aims to increase the designer's control of tools. The results expected from this research allow the designer to influence the generation process in generative design and the selection of methods and criteria for the optimisation of design solutions, to have a central, interactive role once again in the design process. Tools will become available that help control the development of corporate knowledge, to control the complex decision-making processes where multiple stakeholders are involved and where the large public claims respect. Tools will provide means to maintain the quality and validity of models and allow designers to take back control over work methods, information flows, and communication routines. The papers selected for the second part of this volume report on the progress made in this line of research.

Managing and Deploying Design Knowledge

Knowledge is probably the most important asset of any design practice. Successful architectural design practices actively manage their corporate knowledge. *Cerulli* introduces a knowledge management tool that offers a bottom-up approach to knowledge acquisition and knowledge sharing. The tool uses a recommender system approach to increase the relevance of the system's knowledge retrieval. It is targeted for use by emergent communities of users across the various hierarchical levels in a design organisation.

Design tasks can be supported by design optimization tools that help the designer to arrive at design solutions in the context of the design problem, the design objectives, and the design constraints. While such tools indeed support the optimization of the design process, the selection and usage of the most suitable tool becomes a problem in itself. *Peng & Gero* present the design and implementation of a so-called 'situated agent' that observes and

learns from the user's interaction with a design optimization tool, using this knowledge to improve the behaviour of the tool and thus optimize its future usage. Another issue with optimization tools is to allow for interaction and modification of the problem, the tool itself, and the design process, but in an ongoing optimization process. *Gero & Kannengiesser* address this issue in an approach that is based on parts of the function-behaviour-structure framework.

Machine learning is a powerful mechanism to enhance the capabilities of design & decision support systems. With the assumption that human expert knowledge is based on applying decision criteria in a given domain, systems can be built that can learn to identify these criteria, with sufficient access to domain specific information sources. *Oh, Hwang, Smith & Koile* present the development of such a system as a proof of concept. Their challenge is to identify the relationship between abstract concepts employed by human experts and low level features in machine accessible databases. The project presented describes an experiment that demonstrates how this mapping can be used in teaching machines to identify 'main streets' in urban settings.

Acknowledging the necessity to incorporate environmental issues in design, *El Fiky & Cox* have developed a design support toolbox that offers green architectural design strategies to designers in the early phases of architectural and urban design. Their research combines local, Egyptian, cultural aspects of current and past practices in green architecture with up to date knowledge resources on this topic into a toolbox that helps the designer to decide what design principles to apply by offering feedback on their cultural acceptance and environmental value.

Urban Decision-Making

Providing computational support for complex decision-making in which many stakeholders are involved, such as in urban development questions, is quite a challenge. *Van Loon & Wilms* describe the development of the so-called Urban Decision Room, an approach and pilot system that offers a mathematical optimisation on the basis of constraints. Constraints, in this system, can be defined to describe the design goals as well as the resources or conditions for the urban the development. The system relates resources and goals of all stakeholders involved and can be used to achieve a Pareto optimum in the collective solution space.

Drawing from the experience of a major urban redevelopment project in the city of Auckland, *Hunt* describes how this project developed a strategy and a course of action for achieving participation of the many stakeholders involved, as well as the involvement of the large public through consultations in the process. This project applied the 'open design' model for multi-stakeholder input in the various stages of project development. Hunt draws conclusions

on the limits of applicability of this model in large projects with public interest and suggests a number of decision support guidelines for the management of participatory urban development processes.

Facilitating the participation of inhabitants in the decision-making process in redevelopment of neighbourhoods is the objective of the work by *van Leeuwen & van Berlo*. Their approach is to involve inhabitants in a game-like dialogue that helps them to express their desires regarding the liveability of their neighbourhood and, at the same time, to evaluate the consequences of their desires and of the changes they propose. This approach has been implemented in a web-based application that utilises a Bayesian network to predict cause and effect relations between people's desires and experiences and the changes proposed for a neighbourhood.

Design Interactivity and Design Automation

Since the introduction in the early 80's of CAD tools and with their ongoing development, conceptual design in architecture has found ways to address new challenges; one of these is the interactive manipulation of 3D shapes. *Wetzel, Belblidia & Bignon* have investigated the role of morphological operators as has been identified in research and analyse significant examples of rather exceptional architectural works that demonstrate this role in practice. This investigation is used as the point of departure for the definition of an intuitive 3D modelling environment for architectural exploration using morphological operators. A first model for this environment is presented.

One of the problems with the application of genetic algorithms in design is the formulation of the fitness function that will lead the process of genetic evolution to the desired or optimal results. *Cheng* presents an evolutionary procedure in which the expertise of the members of a multidisciplinary design team is used in conjunction with a generative design implementation. An experimental system implements this approach in a model that includes two mechanisms: one mechanism for evolutionary development of new generations, based on traditional genetic programming; the other mechanism is a natural selection mechanism that defines the fitness of the generated solutions, determining the input for the next generation of the population.

Traditional rule-based systems, such as shape grammars or fractals, have been very inspiring and led to surprising results. The main drawback of such computational design systems, however, is that the influence of the designer on the system is limited, indirect, and not intuitive. Avoiding this drawback, *Landreneau, Ozener, Pak, Akleman & Keyser* have developed an approach and prototype system that offers designers a high level of interactivity and control over fractal and L-systems. The system was tested in a graduate level architectural course.

The concept of a semantically rich building information model as a core medium for multidisciplinary design processes is very appealing to the design and construction practice. However, several major issues have remained unsolved that inhibit full exploitation of this powerful medium. One of these issues is related to the limitations imposed by the usage of central databases where such a building information model should reside. For practical reasons mostly, design teams prefer to work with local data, even when collaborating in distributed settings. This implies the need for a working mechanism that can compare and merge different versions of a model, enabling the design team members to exchange modifications and keep their data updated. *Arthaud & Lombardo* present an automatic semantic comparison of product models based on the STEP standard.

Virtual Environments and Augmented Reality

The availability of new technologies for computing and communication, such as mobile computing and wireless networks, offers a challenge to integrate our presence in virtual and real environments. The city of Bath was chosen as an experimental playground for research on interaction spaces, in relation to the urban space, by *Fatah gen. Schieck, Penn, Kostakos, O'Neill, Kindberg, Stanton Fraser & Jones*. This work aims to develop a better understanding of the urban landscape when augmented with a digital landscape, for example how do the physical and digital flow of people through the city interrelate. This research is expected to give insight in the impact of using pervasive computing systems in urban environments on people's relationships, with each other and with, e.g., our cultural heritage.

Motivated by, on the one hand, the need of designers to use their body expressively in design actions and, on the other hand, the need for novice students to get a feeling for the scale and texture of their design, *Chen & Chang* have developed and demonstrate an augmented reality design environment that deploys 1:1 projections of a design and allows for direct manipulation of the design through designer interaction using gestures. The system uses a camera to detect hand gestures made by the designer to indicate design activities, such as drawing or manipulating geometry and adding texture to the design.

To conclude, the editors are proud to present this book, which provides an interesting range of innovations in design & decision support systems in architecture and urban planning. We hope and expect that this book will continue to function, after the DDSS 2006 conference, as a means to bring researchers together and as a valuable resource for our continuous joint effort to improve the design and planning of our environment.