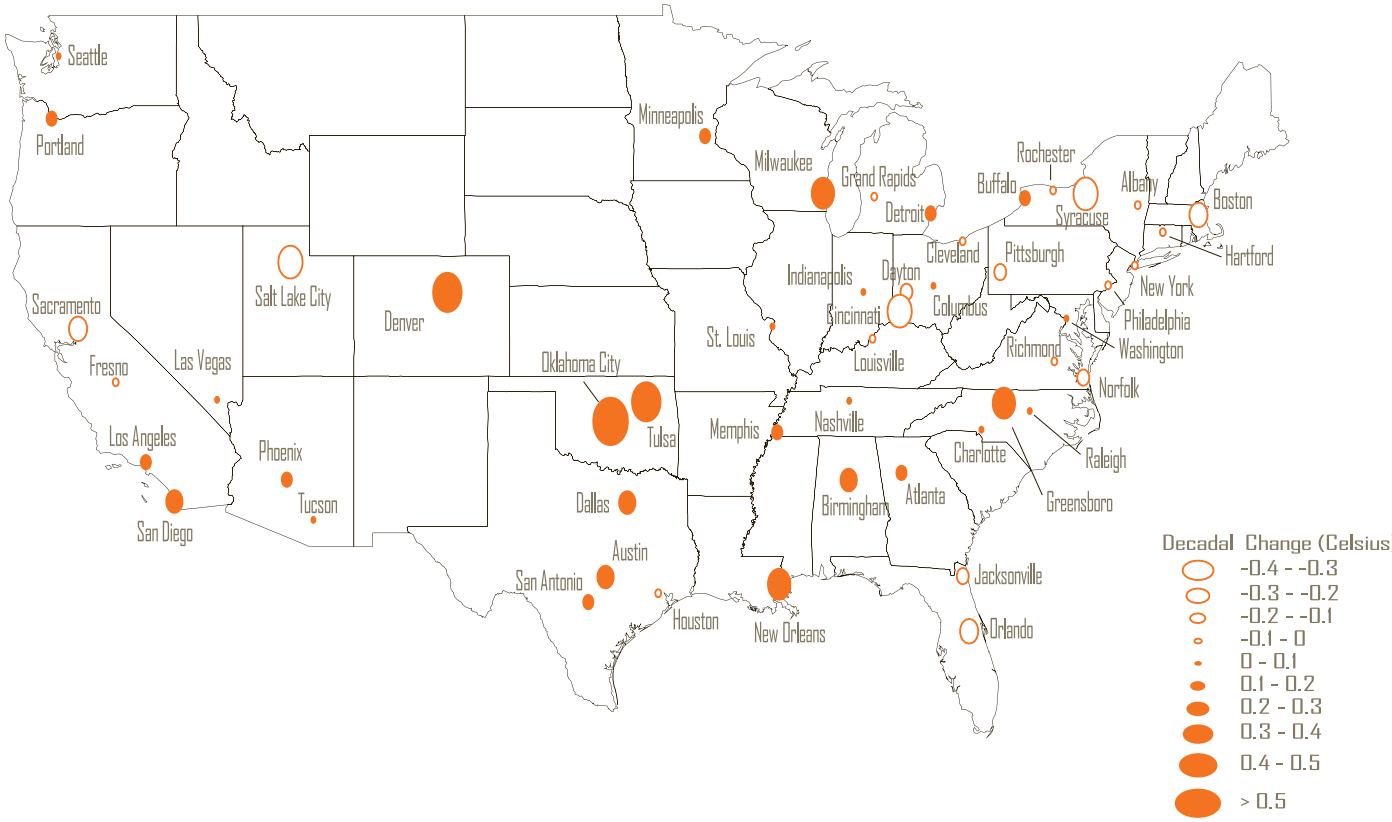
College of Architecture
Georgia Tech

PhD Focus

Fall 2006

WARMING IN LARGE U.S. CITIES



How rapidly are large cities in the United States warming? This question is important for two reasons. First, extreme temperatures are now responsible for more annual fatalities than all other forms of extreme weather and natural disasters combined, including hurricanes, tornadoes, and earthquakes. In a warming world, the public health threats of extreme heat are expected to intensify. Second, annual analyses of mean global temperature change omit urban weather station data, as urban temperature trends are known to reflect both background warming rates and localized warming anomalies, such as the heat island effect. As a result, global estimates of climate change are likely to significantly underestimate rates of warming in the very places where most of the global population now resides: cities.

Dr. Brian Stone, of the City and Regional Planning Program, has analyzed five decades of meteorological observations recorded by weather stations located within and in proximity to fifty of the most populous U.S. cities to measure the rate of change in "urban heat island" intensity – localized hotspots created by urban infrastructure and waste heat emissions – in each decade between 1950 and 2000.

To measure historic rates of change in urban heat islands, Stone identified three rural weather stations in proximity to each city, based on the intensity of night light associated with each station, as recorded by a satellite radiometer. Average rural temperature trends were then subtracted from the annual average temperature of an urban weather station to compute heat island intensity. The results of this analysis, averaged by decade for each city, are reported in the figure above. Black circles in the figure denote regions in which urban stations are warming more rapidly than rural stations, while white circles denote regions in which rural weather stations tend to be warming more rapidly than urban stations. On average, the heat islands of the most populous U.S. cities increased during this period at a rate of 0.5 OC per century – a level of warming that is about three times greater than that for all U.S. cities. And for those cities experiencing growth in heat islands over time (black circles), the average rate of warming is 2 OC per century. This finding suggests that, if historical rates of temperature change continue through the present century, growth in the urban heat island effect will amplify background rates of global warming by between about 35 and 140% for many large U.S. cities, greatly elevating the need for climate-responsive design strategies to counteract urban warming trends.

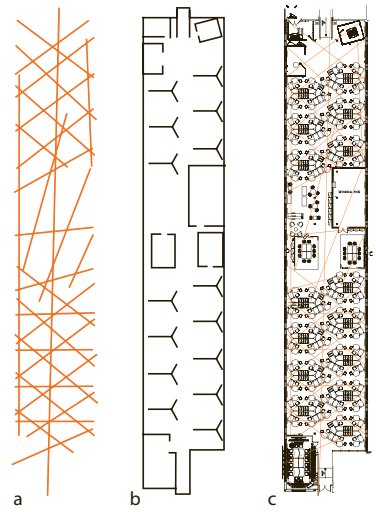
Decision tools for ill-defined design problems

Recent research, sponsored through a $90,000 grant from the General Services Administration, helps designers make strategic decisions about office layouts.

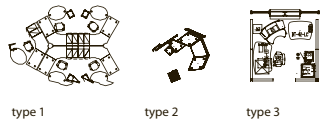
The layout of offices not only provides passive accommodation but also influences the emergent social and organizational activities and patterns of work. The generative effects of layout include increasing or limiting the potential of unexpected encounters, contributing to general awareness, and ultimately helping to create and maintain informal social networks which form the backbone of a productive organization.

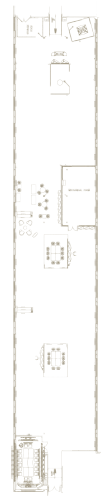
To understand how layouts function we visualize them using abstract diagrams that clarify critical relationships amongst their constituent parts. The trouble is that these diagrams, used by previous research at Georgia Tech and elsewhere, demand a high degree of abstraction and analytical treatment. The challenge, therefore, is to develop general guidelines, or rules of thumb, that predict the effect of design decisions while limiting our dependence upon complex analytical evaluation procedures.

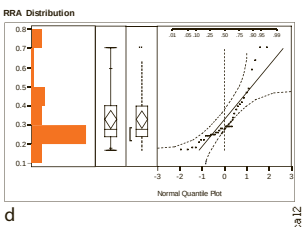
Assistant Professor Sonit Bafna, and Ph.D. student Ranah Hammash, in consultation with Professor John Peponis, Professor Craig Zimring, and alumnus Mahbub Rashid, (Associate Professor, University of Kansas) have addressed the challenge in two steps. First, they developed quantitative profiles of layouts with desirable properties. Second, they developed an inventory of typical design choices involved in a generic layout design and used statistical analyses to check which, if any, of these design choices are associated with the profiles established in the first step. Their results show, rather unexpectedly, that local but repeatedly implemented design decisions, such as those regarding the shape of cubicles or the degrees of enclosures of workstations, have more systematic effects on the resulting spatial structure of the layout than gross decisions such as the imposition of an overall circulation grid. This suggests that the design of furniture and office systems affects overall layout properties more powerfully than previously understood.



1 Three types of workstations (below) with different degrees of enclosure and different geometries are used to generate 48 fictional layouts in an empty floorplate (right).







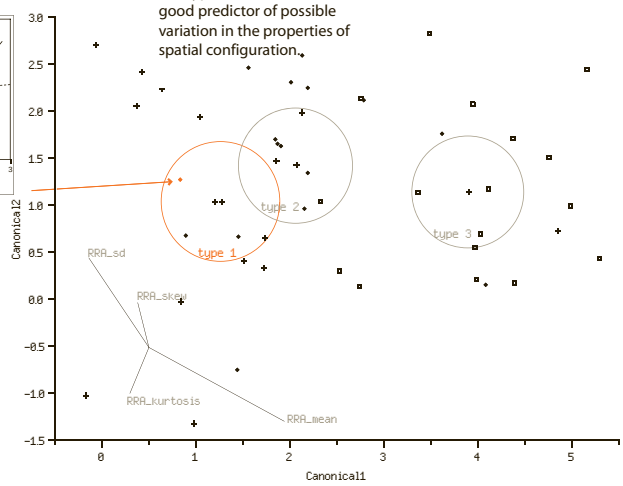
d

2 A skeletal network (a) of lines of access, based on the shape of partitions (b) in each fictional layout (c) is analysed to give a distribution (d) of centrality values (RRA) of all lines in the layout.

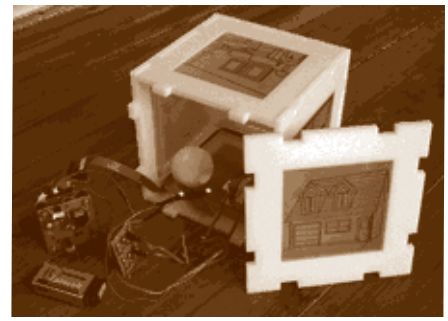
The characteristics of the distribution give each layout a unique location in a 4D space in a canonical plot (right) created for discriminant analysis.

3 Discriminant analysis (below) shows that layouts with similar type of workstations fall into distinct clusters in the canonical plot (square boxes indicate layouts with type 3 workstations; diamonds, type 2; and pluses, type 1).

The type of workstation, thus, is a good predictor of possible variation in the properties of spatial configuration.



Ambient intelligence for home energy use



Could devices providing ambient awareness of levels of energy consumption help people conserve energy in their homes? Research shows that occupant behavior is the most powerful determinant of energy consumption. Furthermore, the key to energy conservation lies in education and behavior modification. The question is what kind of monitoring will best help educate energy users. A multi-disciplinary team at Georgia Tech is investigating this problem under the direction of Professor Ellen Yi-Luen Do. The project "Ambient Devices for Home Energy Awareness" is one of six that received a Creating Energy Options Seed Grant from Georgia Tech's Energy Strategic Initiative (http://www.energy.gatech.edu). Researchers are designing, engineering and building devices that integrate physical and graphic user interfaces to reduce the cognitive loads of keeping track of energy use in the home.

The intent is that utility companies will offer customers a toolkit to encourage energy conservation. The toolkit will be used to create a simple sensor network by attaching easy-to-use devices to major appliances or power outlets. The information collected by the sensor network will then be displayed in non-intrusive devices such as an Energy Cube, Energy Magnets, Energy Calendars, or an Energy Doll. An Energy Cube would glow red when energy consumption is reaching high levels or blue when the situation is normal. A Palm Sensor would use temperature and texture to alert the residents as to whether household devices are running smoothly or not. An Energy doll would be quietly reading books when energy consumption is low and flash red light while shedding tears when consumption increases. An Energy Calendar can afford different layers of information tracking such as historical use (as compared to current use) by categories (electricity, gas, water, etc) compared with appropriate benchmarks (neighborhood usage or national average). Thus, information which is usually metered outside the house will become part of the everyday environment. For more information visit http://wiki.cc.gatech.edu/ambient, or contact <ellendo@gatech.edu>.

Building simulation at the crossroads: new perspectives

Prospects for building simulation

Building simulation became a recognized discipline in the late 1970s when researchers started to apply models and theories from physics, mathematics, material science, biophysics, and human behavior sciences to buildings.

The main scientific contribution of the field resides in the modeling and computational treatment of the complex interplay of thousands of building components. Building behavior results from the aggregation of the physical behavior of every component and the multiplicity of its interactions with other components, the environment, control systems and human occupants.

The nature of these interactions is governed by (bio) physical laws, expressions of control logic and human behavioral theories. The computational treatment of the resulting equations employs diverse modeling paradigms, ranging from continuous to discrete, from symmetric to non-symmetric, and from autonomous to user controllable. It is the quest of building simulation to deal with the resulting complexity of scale and modeling diversity to predict, assess and verify building behavior in a sufficiently reliable manner.

The current generation of building simulation software has made essential contributions to energy savings, development of new HVAC concepts, increased occupant satisfaction, better protection against hazards such as fire, smoke, mold and other airborne contaminants, and improved lighting and acoustic systems. Applications reported at the bi-annual Building Simulation conferences show that the robustness and fidelity of available (commercial) simulation software is adequate to make these contributions. Continued model calibration and improvement of user interfaces has meanwhile empowered the profession to secure a recognized role in design and engineering teams. But many promises of building simulation have remained unfulfilled. This seems the appropriate point in time to reflect on the directions that building simulation needs to take from here to consolidate and extend a permanent role for itself in future decision making about the built environment. For this objective we introduce a short and long term perspective.

Short term perspective

The simulation of building behavior is never a goal in itself. It is invoked to inform a "process" that involves decision making driven by a multitude of stakeholders with multiple and possibly conflicting objectives. The biggest short term challenge for the building simulation discipline is to be able to respond and adapt to the dynamic settings of these multi stakeholder decision processes, whether they relate to component manufacturing, building design, urban planning, health assessments, risk evaluations of public space, cost control of future maintenance, or any other. The key objective is to understand these processes better, formalize their logic and the information that support the decision, management, planning and design evolution methods. It is important to realize that the output of building simulation is only effective if it can relate to pertinent decision making, which is typically driven by group dynamics under incomplete and uncertain information and partly unknown future conditions. This begs for simulation processes rather than tools, with emphasis on decision making rather than generation of behavioral data per se.

Meanwhile, the introduction of autonomous, "invisible" and pervasive simulation will continue to progress as the intelligence of the built environment around us increases. Different active and passive interaction paradigms are emerging for this purpose. Building simulation will be incorporated in systems that control the way we work and live, what air we breathe, what temperature and lighting conditions make us do the task at hand with the highest performance, what acoustic environment we prefer etc. This will radically influence the way simulation is performed and its outputs evaluated, exemplified in the following trend shifts:

-From simulation of phenomena to support of decision making;

-From "number crunching" to the "process of simulation";

-From concerns about tool interoperability to concerns about flexible deployment in collaborative design processes;

-From static computational models to flexible recalibration and self-organization of autonomous and self aware simulation models;

-From deterministic results to probabilistic information accompanied by risk and uncertainty analysis;

-From mere production of simulation outputs to the automatic and embedded verification of quantified performance objectives and virtual inspections of what-if and sensitivity scenarios.

Long term perspective

Although the shifts outlined above are profound, there is another, longer term shift that is already on the horizon. This shift concerns the "commoditization" of simulation in different forms. To identify this direction, a system theoretic framework based on the holonomy principle is useful. In this view a system is a set of interacting holons. Each holon is both a whole and a part. Among parts multiple hierarchies co-exist. In this holonomic view, simulation will be reflected at both part and system level, and will manifest itself in many parallel systems of different scale. Every act of simulation will show up (in different manifestations) within each holon. The consequences will be far reaching:

-Every single manufactured product will have a unique simulation model which is made available for networked "on-demand" simulation, whereas simulation architectures will become inter-organizational and service oriented;

-The construction of simulation models will be based on networks of components with locally defined physical behavior;

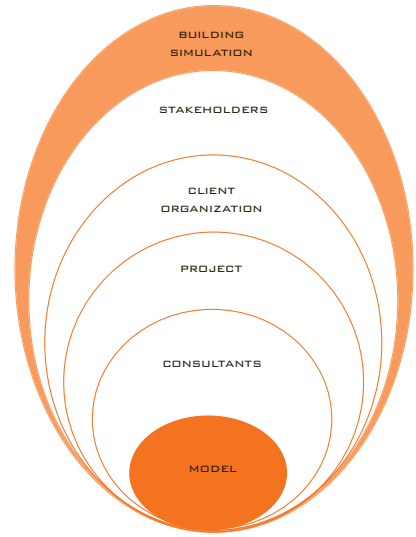
-The simulation model will respond to its simulation environment and is aware of the skills/ knowledge of the simulation expert and client environment;

-Intelligent control systems will learn from their environment and become more accurate representations over time reducing the uncertainty of predictions by incorporating the witnessed effects of dynamic change;

-New models will be based on a reverse-engineered generation of "minimalistic" simulation models, engineered "just right" to inform the decision at hand;

-Humans will become behavioral agents in "hybrid" simulations. Human models will be based on perception-belief-action models. They translate social and cultural perception and action models of occupants, service personnel, emergency responders etc. into configurable agents in discrete event simulation;

-Simulation will start resembling current video-gaming environments.



Future tools will simulate (designed) organizational processes in their (designed) physical environment. Tools will become "self-reflective", showing their manifestation in different holons, such as client organization, project setting, consultants, and their social networks.

Conclusion

Building simulation can grow beyond its current limited role. A short and long term perspective were presented to indicate major directions of growth for the scientific base of the discipline.

Godfried Augenbroe

A reinforced concrete BIM consortium

Many sectors of the construction industry use advanced 3D engineering and design software. The structural steel sector was first, followed by the precast concrete industry. Also, mechanical, electrical and piping contractors have several 3D packages to work from. The design software for these industries provides for integrated analysis, interfacing to automation equipment, such as numerical control machining, and automatic Bills of Material.

No similar software design tools exist for reinforced concrete, which is an inherently on-site building material. In the Spring of 2006, a group or architecture, engineering and construction companies with strong interests in reinforced concrete, organized a consortium to develop such an advanced parametric modeling tool. The consortium includes Accu-Crete and Grand River Construction, as concrete sub-contractor specialists, Thornton Tomasetti and Bechtel as engineering companies, Barton Malow, Walter P. Moore and M.A. Mortenson as contractors, Ghafari and SOM as AE firms, and Atomic Energy Canada, a major owner-operator. The project is funded by Tekla, who will implement the software specification. Tekla arranged for Georgia Tech to provide technical leadership, with Chuck Eastman as the lead, and Yeon-Suk Jeon, a post-doctoral fellow and Donghoon Yang a Ph.D. student providing support. Also participating is Rafael Sacks, a faculty member from the Technion (a prior Post Doc at Georgia Tech) and Ronan Barak, a student there.

While most BIM fabrication technology is oriented toward off-site production methods, reinforced concrete is largely on-site. Only the reinforcing and post-tensioning materials and all steel embeds can be prepared off-site. Formwork design, placement and scheduling is a major aspect of reinforced concrete planning, and the SW will facilitate and track its planning as part of the concrete design. Also, pour planning and management, tolerance control, quality control, drawing and other report generation, are parts of the specification. It is expected the specification will be complete early in 2007. The new software is expected to improve the productivity of reinforced concrete design and construction and facilitate the design of new, unusual types of structures.

The development of BIM for reinforced concrete will imrpove productivity and support unusual designs.

Theses

Dr. Jose L. Fernandez-Solis: *Is building construction approaching the threshold of becoming unsustainable? A system theoretic exploration towards a post-Forrester model for taming unsustainable exponentialoids*
Advisors: Linda Thomas Mobley and Godfried Augenbroe

The construction industry is formulating short and long-term 'sustainability targets'. The thesis argues that measures like LEED, and all of the presently conceived green, high-performance measures and even Carbon Trading strategies, are insufficient to achieve the necessary reduction targets in a timely manner.

The dissertation articulates that hard dynamic systems, based on reductionism, are no longer adequate representations to study the dynamics of complex systems such as whole industries. The dissertation develops a deeper understanding of sustainability as a process, measured in so-called "exponentialoids". Achieving a sustainable future is then re-framed as the (artificial) force that tames an unsustainable exponentialoid.

The work introduces a novel method of analysis that identifies the directions of increasingly detailed research work to be performed in the future.

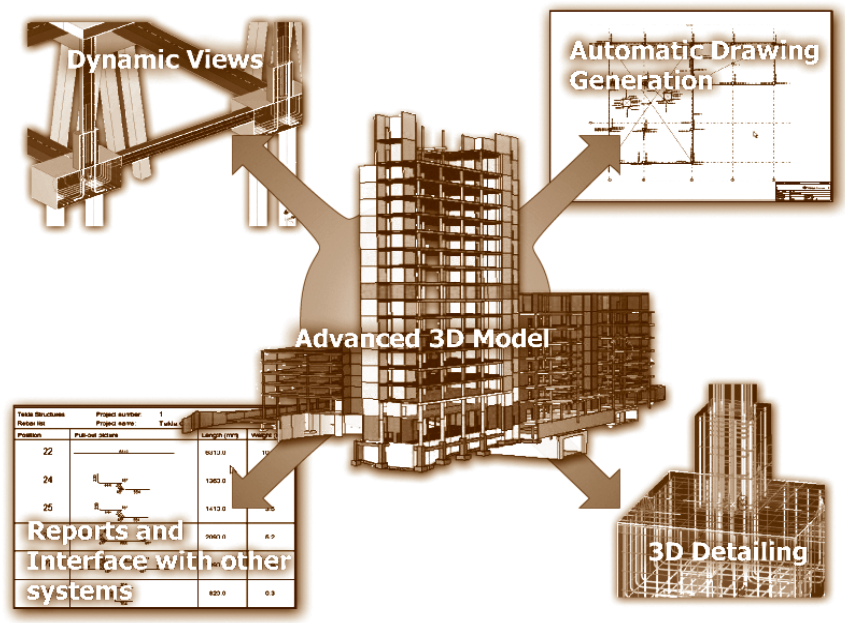
Dr. Chun-Heng Ho: *Spatial Cognition in Design*
Advisor: Chuck Eastman

Studies suggest that 3D visualization is fundamental to design spatial cognition, but present no definitive supporting evidence. A study of 251 Georgia Tech students shows that correlations between studio performance and the tested factors are salient only among female students. Female students generally have lower spatial capabilities than male students and take advantage of their general reasoning capability to compensate. Stepwise regression reveals that, for female design students, the general reasoning capability is the only predictor for design performance. No significant interaction is observed for male design students between tested capabilities and design studio performance. Thus, there exists a threshold requirement in spatial capabilities for design major students. After passing this threshold, other factors seem to dominate. Although the results show the tested capabilities are all important for design students, design education does not appear to contribute any improvement of these underlying capabilities.

Dr. Ali Shakoorian: *Performance Assessment of Building Commissioning Process as part of a Quality Assurance System*.
Advisors: Saeid Sadri and Godfried Augenbroe

The thesis investigates the effect of different commissioning delivery systems (CDS) on the performance of the commissioning process, in order to assist owners in identifying the appropriate commissioning delivery option for their project. A qualitative analysis, based on experts' performance assessment of each CDS, coupled with quantitative analyses of generic process models is used to conduct a comparative analysis..

Owner-led Commissioning shows a higher performance rating than Designer-led Commissioning in four out of the five performance aspects. Hence, it is identified as a better alternative for procuring commissioning services in construction projects. A more thorough investigation of the communication aspect of the commissioning process is suggested as follow up investigation.



News

Papers

Camarata K, Do E Y-L, Gross M D "Energy Cube and Energy Magnets" *IJAC - International Journal of Architectural Computing* **4** (2) 49-66

Eastman C, 2006, "University and industry support of research in support of BIM" in *Report on Integrated Practice Ed. M Broshar, N Strong, D Friedman* (American Institute of Architects, Washington D.C.) section 2/11

Eng M, Camarata K, Do E Y-L, Gross M D, 2006, "FlexM: Designing a Physical Construction Kit for 3D Modeling" *IJAC - International Journal of Architectural Computing* **4** (2) 27-47

Frank K, 2006, "The potential of youth participation in planning" *Journal of Planning Literature* **20**(4) 351-371.

Ho C H, Eastman C M, Catrambone R, 2006, "An investigation of 2D and 3D spatial and mathematical abilities" *Design Studies* **27**(4) 505-524

Pati D, Park C S, Augenbroe G, 2006, "Roles of building performance assessment in stakeholder dialogue in AEC" *Automation in Construction* **15** 415-427

Peponis J, Bafna S, Doghan F, Dahabreh S M, 2006, "Presentational symbolic systems in architectural thinking" *Representation as a Vehicle for Architectural Thinking* Ed. Trova V, Manolides C, Papaconstantinou G (Athens: School of Architecture of the University of Thessaly and Futura Editions), 40-53 (in Greek)

Rashid M, Kampschroer K, Wineman J, Zimring C, 2006, "Spatial layout and face-to-face interaction in offices – a study of the mechanisms of spatial effects on face-to-face interaction", *Environment and Planning B: Planning and Design* **33** 825-844

Ren Z, Anumba C J, Hassan T M, Augenbroe G, Mangini M, 2006, "Collaborative project planning: a case study of seismic risk analysis" Computers in Industry, **57** (3) 218-230

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Proceedings

Brown J, Choudhary R, 2006, "CFD Study of natural ventilation between multiple spaces with stratification", in *Proc. 3rd International Building Physics Conference* Ed. Fazio R, Ge H, Rao J, Desmarais G (Montreal, Canada) pp 731--736.

Castro-Lacouture D, Bryson S, Gonzalez-joaqui J, 2006, "Real-time Positioning Network for Intelligent Construction", in *Proceedings of the Joint International Conference on Computing and Decision Making in Civil and Building Engineering* (Montreal, Canada) pp. 77-86

Gim T Y, Kim Y, 2006, "Physical Patterns of Urban Sprawl and Levels of Air Pollution in the Atlanta Metropolitan Region", in *Proceedings of Hawaii International Conference on Social Sciences 470-498*

Eastman C, 2006, "New Opportunities for IT Research in Construction, Intelligent Computing in Engineering and Architecture", in *13th EG-ICE Workshop* (Springer Press) pp 163-174

Park C S, Augenbroe G, Makarechi S, Brown J, 2006, "Normative thermal comfort assessment", in Proceedings of Research in *Building Physics and Building Engineering*, (Montreal, CANADA) pp 757-763

Grants

Craig Zimring, PI, (with Godfried Augenbroe, Sonit Bafna, Ruchi Chaudhary): "Supporting the Redevelopment of Healthcare in the Wake of Katrina", Robert Wood Johnson Foundation. This project supports LSU Healthcare in redeveloping Charity and University Hospitals and Clinics in New Orleans.

Ellen Yi-Luen Do, Craig Zimring: "Patient Room of the Future" - an interdisciplinary class for Fall 2006: $25,0000 gift from Steelcase

Ellen Yi-Luen Do: "Ambient Devices for Home Energy Awareness". A $6,000 Creating Energy Options (CEO) Planning Award from the Strategic Energy Initiative and the Office of the Vice Provost for Research at Georgia Tech.

Mohammad Gharipour: Houtan Foundation Award on Persian Studies.

Activities

Chuck Eastman organized three workshops for the Reinforced Concrete BIM Consortium, formed to specify an advanced technology BIM system for reinforced concrete engineering. The 3rd workshop was held at Ga Tech.

The Construction Specification institute funded Ph.D. student Elif Yagmur, Chuck Eastman and Fried Augenbroe to write a white paper addressing the changes needed to make Uniformat and Masterformat more compatible with Building Information Modeling. They presented the results in June 21 AT CSI headquarters in Arlington, VA.

Craig Zimring chaired the Healthcare Environments Research Summit, February 8, 2006, an international meeting of 70 healthcare-leaders which developed a roadmap for Healthcare Environments Research. The meeting was sponsored by the Agency for Healthcare Research Quality, the Robert Wood Johnson Foundation and Steelcase.

Ellen Yi-Luen Do edited (with Eckert C M) an issue of AI EDAM, 20 (3), 2006: Understanding, representing, and reasoning about style (editorial: pp 163-165), Cambridge University Press.

Award

Chuck Eastman received the 2006 BuildingSmart Open Data Award by the International Alliance for Interoperability, November 1. It was awarded for his work on the CIS/2 data model.

News

Alumni

Presentations

Augenbroe F, "Perspectives on Indoor Environment" Invited keynote at: IAQ conference, Seoul Korea, 25 October 2006

Do E Y-L, "Things that Think, Spaces that Sense and Places that Play" Keynote Speech at the Smart Living Space Symposium, June 1-2, National Cheng-Kung University, Tainan http://credit.csie.ncku.edu.tw/2006/

Do E Y-L, Invited Speaker, "Exploring Physical Computing" at Atlanta Dorkbot meeting, March 9, Atlanta, Georgia, http://dorkbot.org/dorkbotatl/03092006/

Eastman C, Invited speaker, Integrated Civil Engineering Systems Workshop in Ascona Switzerland June 26-26.

Eastman C, "Building Information Modeling: the Start of a Revolution" Keynote speaker, Academy for Architecture in Healthcare 2006 Conference, Oct 18, 2006.

Eastman C, Lead presentation at the annual workshop of the Technology in Architectural Practice Committee of the AIA, Nov 2 at the National Academy Building in Washington DC.

Roper K, "The Future of Facility Management: Explorations, Challenges and Opportunities," Facility Management Keynote Speaker at the IIDEX/NeoCon Canada conference, Toronto, 29 Sep 2006.

Thomas-Mobley L, 2006, "'Hidden' Evidence Laws and their Influence on Mold Litigation Outcomes in the US" in *COBRA06 – Yearly Conference of the Royal Institute of Chartered Surveyors* (London, UK)

Zimring C, "The role of evidence-based design in the hospital of the 21st Century". Plenary speaker, Annual Meeting of the Environmental Design Research Association. Atlanta, May 6, 2006.

Zimring C. "Evidence-based design." Plenary speaker, Tri-Service Healthcare Facilities Symposium. Boston, July 13, 2006.

Zimring C, Invited speaker, HKS Architects, Dallas, July 24, 2006.

Zimring C, "Designing for Patient Safety" Keynote Speaker, The Leadership Institute, Las Vegas, Sep 7, Oct 4, 2006.

Dr. David Lewis (Ph.D. 1994) an Associate Professor of architecture at the College of Architecture, Art and Design, Mississippi State University, has taken on the responsibilities of Interim Director for the School of Architecture. Dr. David Lewis is a co-principal investigator on a $300 K HUD grant addressing the rehabilitation of the Mississippi Gulf Coast, a recipient of Hearin Foundation Grant and a co-principal investigator on a USDA and Forest Products Laboratory Grant totaling $350K to research construction issues in wood structures related to hot-humid climates.

Dr. Sung Hong Kim (Ph.D. 1995), a Professor of architecture and urbanism at the University of Seoul, is currently curating "Megacity Network: Contemporary Korean Architecture 2007" in cooperation with the Korea Architects Institute (KAI) and Deutsches Architekturmuseum (DAM). Megacity Network is the first joint exhibition outside Korea of contemporary Korean architecture conceived and organized by Korean architects. The exhibition will be held at DAM from December, 2007 to February, 2008. Dr. Kim will be the editor of the exhibition catalog to be published by the Jovis Verlag GmbH in Berlin. Dr. Kim has substantial previous experience as an intellectual leader and exhibition curator. He has worked as a co-commissioner for the Korea Pavilion at La Biennale di Venezia in 2004, for which he helped formulate the theme: 'city of the bang,' an exploration of the micro-spatiality of daily urban life and the representation of urban architectural space in Korea. Dr. Kim spent a part of 2006 as a Fulbright Visiting Scholar at the University of Washington in Seattle. Previously he held a position of the Vice Provost of Office of Planning and Development, University of Seoul for one year. During this time, he coordinated the University's campus master planning as well as strategic planning. Dr. Kim has recently visited Georgia Tech to give lectures and seminars on his research and his curatorial work.

PhD Focus

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