*ibpsa*NEWS

volume 13 number 2
October 2003

BS 2003 Eindhoven

Reflections
Awards
Papers

. . . and BS 2005 Montreal announced

plus other events, software announcements and more

www.ibpsa.org

The journal of the International Building Performance Simulation Association

Contents

BS 2003:
Simulation for Better Building Design

Larry Degelman, IBPSA Newsletter Chairperson, reflects on BS 2003

Since its beginning in 1989, IBPSA's highlight activity has always been its biennial Building Simulation Conferences, and the 8th one was no exception. Building Simulation 2003 was held at the Technische Universiteit Eindhoven (TU/e) from 11 through 14 August. Though IBPSA's BS conferences have all been highly successful, this one had several landmarks and "firsts" to boast about.

With this conference, the number of peer-reviewed papers crossed the 1000 mark in IBPSA's published proceedings. The number of papers presented at this conference was 195 - higher than any of the previous conferences. Three highly esteemed international journals, *Energy and Buildings* and *Building and Environment* published by Elsevier Science and *Building Services Engineering, Research & Technology* by Arnold Publications of the UK, will publish 35 selected papers from the BS-2003 conference. For the first time ever, IBPSA presented the "Outstanding Practice Award." We also awarded five student travel fellowships to attend the BS-2003 conference, and we continued the awards for Distinguished Service and the Outstanding Young Contributor. (These awardees are all recognized individually in this issue of IBPSA News.) Finally, as usual, IBPSA's international flavor continued to shine, as delegates to this conference came from 34 different countries worldwide.

The conference began with the opening of the exhibitions and a half-day of keynote speeches by world-renowned building experts, Michael Pearce, Ardeshir Mahdavi, and Mark Chown, who introduced the conference theme, "building simulation for better building design". The remaining three days were filled with several parallel sessions of the 195 technical presentations and poster papers, and there were several very informative plenary/panel sessions that enabled a high degree of interaction among the delegates. Coffee/tea breaks were another enabler of participant interactions and learning while we floated around the vendor exhibits and software demonstration areas. There were also tours of various areas of Eindhoven, which added much to the cultural experience of being in the Netherlands.

A conference of this nature is an enormous undertaking. This event had 13 exhibitors who stayed throughout the entire conference; there were three keynote speakers; the conference organization committee had 22 members; the scientific committee that reviewed and evaluated all the papers presented had 141 members; the scientific executive committee had 7 members; and there were 10 different sponsors of the conference. IBPSA is understandably proud of the outcome of this conference, but none of this could have been done without the specific individuals involved. We need to recognize Jan Hensen (TU/e, Netherlands), who served as conference convenor and co-chair of the scientific committee, and Godfried Augenbroe (GA Tech, USA), who

served as chairman of the scientific committee. I might also point out that this conference would not have functioned without the nine or so student helpers from TU/e who implemented the presentations with high-tech equipment and generally made everything work. This was an enormous undertaking that had lots of opportunity for mishaps, but everything went like clockwork. Thanks go to everyone who made this happen so smoothly — we really appreciate it.

The conference organizers implemented numerous novel approaches to the program presentation streams, plenary sessions, panel discussions, poster sessions, and the integration of the vendor exhibits into the ongoing activities of the conference. These all worked so well that they have become recommended practice for all future conferences. The scientific committee also made some valuable observations regarding advances, maturity and diversity of simulation software now available in the industry. Also, new works in visualization, decision support, and dynamic control seem to be setting the scene for the future. Additional scientific and educational benefits gained from the conference are too numerous to mention here, but these are all compiled in records held by the scientific committee and will be passed on to future conference organizers. By doing so, IBPSA's conferences should continually improve over time.

To give some perspective of the diversity of subject matter presented at the conference, three of the papers from the BS 2003 conference have been selected for publication in this issue. Look for these within (**pages 38**, **46** and **54**), and for those of you that did not get to Eindhoven, please visit the **photo album** on the conference web site **www.bs2003.tue.nl/default.htm**, and enjoy some of the sights and personalities at the conference and about Holland.

So, where's the next biennial conference? BS 2005 is in Montreal — look for the announcement in this issue (**page 12**) and also on the **IBPSA home page**.

Looking forward to seeing you at BS 2005,

Larry Degelman, Newsletter Chairperson

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IBPSA Central membership form

Publications order form

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IBPSA Building Simulation conferences

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IBPSA Website

For full information on how to order IBPSA's publications, or to look at Proceedings of past IBPSA Building Simulation conferences or past IBPSA Newsletters, please look on the IBPSA Website at: **www.ibpsa.org**.

IBPSA Regional affiliates

For information on joining IBPSA, please contact your nearest regional affiliate. If there is no affiliate in your region, join IBPSA by using the Central membership form.

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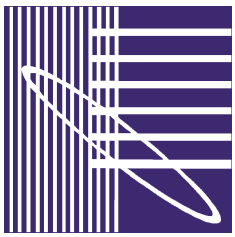

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2003 IBPSA Awards

IBPSA Distinguished Service Award
Presented to Professor Curtis O Pedersen, PhD, PE

"a long and distinguished career in the building simulation field"

Professor Pedersen has had a long and distinguished career in the building simulation field, with thermal systems simulation, energy consumption in buildings, and system optimization techniques as his main professional interests. He directed the BLAST Support Office at the University of Illinois at Urbana-Champaign from 1983 until 1998, when it was renamed the Building Systems Laboratory, and still directs the Building Systems Laboratory. Under his direction, a significant number of new models were added to BLAST and a large number of graduate students were introduced to building simulation. More recently, he has been heavily involved in developing the EnergyPlus program and preparing a Toolkit for Building Load Calculations for ASHRAE. He has also directed a number of other ASHRAE research projects related to heat transfer in buildings, building simulation, and load calculations.

Recently, one of these projects has helped influence the ASHRAE Load Calculations Committee to undergo a transformation from endorsing highly heuristic design methods to endorsing simulation-based methods. The 2001 ASHRAE Handbook of Fundamentals chapter on load calculations was significantly revised, replacing the discussion of the older methods with discussion of the simulation-based methods.

Professor Curtis Pedersen

Among Professor Pedersen's stellar contributions is his impact on the careers of numerous PhD students that he advised. Most are now on faculties across the US, teaching and researching in the building simulation field and other closely related fields and hold distinguished recognitions of their own.

Professor Pedersen holds the PhD degree from Carnegie-Mellon University, the MS from the University of Minnesota and a BS from South Dakota State University. He is currently Professor Emeritus of the Department of Mechanical and Industrial Engineering at the University of Illinois (UIUC) and Director of the Building Systems Laboratory. He held the professorship rank at UIUC from 1987 to 1993, Associate Professor, 1972-87, and Assistant Professor, 1967-72. He has also held positions at Carnegie-Mellon University (1964-67), PPG Industries Glass Research Center (Senior Research Engineer, 1963-64), General Electric Company (Development Engineer, 1958-63), NASA Johnson Spacecraft Center (summers of 1971-72), Westinghouse Electric Company (1957) and Honeywell Inc (1955-56).

Professor Pedersen has received numerous awards, fellowships, memberships and recognitions from professional and technical societies throughout his career. He has published innumerable papers at innumerable conferences worldwide and has a textbook to his credit — *Cooling and Heating Load Calculation Principles*, C O Pedersen, D E Fisher, J D Spitler and R J Liesen, ASHRAE 1998.

IBPSA Outstanding Young Contributor Award Presented to Pieter de Wilde

"a strong and unique contribution to this field"

Pieter de Wilde is Research Scientist with TNO Building and Construction Research, Sustainable Energy and Buildings, Delft, the Netherlands and a graduate of the architectural department at TU Delft. His research deepens the design perspective on the building simulation profession, and he does this in a novel and refreshing way. His Doctoral thesis — due to be finished in the second half of 2003 — promises to make a strong and unique contribution to this field.

Pieter's award was based on his excellent achievements toward the improvement of simulation in building design world. His publication record is very strong for a researcher of his age. The breadth of his work, his intellectual contributions, and his service record are simply outstanding. His research work is providing hard evidence on the actual uptake of building performance simulation tools during the design of energy-efficient buildings, through case-studies and a case-study related survey. This work demonstrates that while simulation tools are used for optimization of parameters and for checking of overall energy usage of (more or less completed) designs, the uptake of simulation tools is marginal when it comes to making informed choices between different building design alternatives.

Pieter de Wilde

Pieter is a member of IBPSA, Nederlands Vlaamse Bouwfysica Vereniging (NVBV) the scientific committee of Building Simulation 2003 in Eindhoven, and he is a participant in the Knowledge Centre Building Systems TNO-TU/e.

Prior to taking his current position at TNO, Pieter has also held the following appointments:

- Research Scientist I, Design Analysis Integration Initiative, Georgia Institute of Technology, College of Architecture, Doctoral Program, Atlanta, Georgia, USA
- PhD student with Delft University of Technology, Building Physics Group, Delft, the Netherlands; appointment as Research Assistant at Delft University of Technology, Building Physics Group and as Visiting Researcher with the Energy Research Centre of the Netherlands (ECN), Renewable Energy in the Built Environment Unit, Petten, the Netherlands
- freelance researcher with Delft University of Technology, Building Physics Group; preparatory work for PhD research; world tour
- study of architecture, Delft University of Technology, Delft, the Netherlands; Master thesis in Building Physics: *The Solar Garden House: a preliminary study on the efficiency of a new concept for low-energy design*

Pieter has published dozens of peer-reviewed scientific papers and technical reports at international conferences in Belgium, Brazil, Canada, Chile, Finland, Hungary, Japan, Netherlands, and the USA. He has also published articles in esteemed journals such as *Architecture*, *Building and Environment*, *Engineering*, and *Construction and Management*.

IBPSA Outstanding Practice Award Presented to Michael Holmes

Michael Holmes is Associate Director of Arup Research & Development where he is leader of the Building Energy and Performance Unit, responsible for support and development of Arup standard, thermal, ventilation models and the application of computational fluid dynamics software. In his position, he has been concerned with the research, development and application of models and techniques for energy prediction, improved design and environmental conditions in buildings. He has also carried out many investigations into the performance of various types of equipment, thermal behaviour of materials and air movement patterns. He is a member of the Chartered Institution of Building Services Engineers, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), and has recently been appointed visiting professor at the Department of Civil and Building Engineering at Loughborough University.

Michael Holmes

Most of Mr Holmes' projects involve energy, ventilation and thermal modelling of leading low energy building designs. Example projects are:

- new Parliamentary Building
- Inland Revenue Building, Nottingham
- Arup Associates building No 3, The Square, Stockley Park
- British Pavillion for EXPO'92, Seville
- Leslie & Godwin building, Farnborough
- new Wiggins Teape headquarters, Basingstoke
- Liverpool Festival Building
- National Exhibition Centre, Birmingham
- IBM Cosham Headquarters
- development of CIBSE Energy Code Part 2
- development of the theory for Factory Heating Target Project and setting up the site work, and selection of instrumentation and analysis techniques.

Arup uses a wide variety of building simulation tools throughout the design process in work across the world. Arup's software development arm OASYS, in conjunction with its Research and Development group, continue to develop proprietary innovative software tools to analyze unique design problems, and OASYS tools benefit from constant development and modification to meet the demands of new project requirements. They supplement commercially available tools, providing analytical solutions and validation to a wide variety of building design challenges. Arup is also actively involved as an industry partner in the development of several public software programs, including EnergyPlus.

Arup routinely uses tools for whole building energy analysis, detailed zone thermal and comfort analysis, computational fluid dynamics, daylighting, and 2-D and 3-D heat transfer, throughout the design process, alongside simulations in other fields such as geotechnics, fire and acoustics. At least some of these tools are used on almost every project to make Arup's designs as energy and cost efficient as possible while meeting the aesthetic challenges of the architectural design. This expertise in building analysis enables innovative solutions and evaluation of new technologies that increase project value.

IBPSA Student Travel Awards

In order to encourage participation of building simulation oriented PhD students in our conference, IBPSA initiated a graduate student travel award program this year. Applicants were judged on paper quality and their advisor's recommendation. We had a number of excellent candidates, but the selection committee eventually chose five students. Each student was awarded $1000 to defray travel expenses. Here, IBPSA President Jeff Spitler presents the awards to the smiling students at the conference banquet.

Recipients of the travel awards are from left to right: Robert Crawford (School of Architecture and Building, Deakin University, Australia), Kazuya Takahashi (Department of Urban and Environmental Engineering, Kyoto University, Japan), Monjur Mourshed (Department of Civil & Environmental Engineering, National University of Ireland), Faidon Nikiforiadis (School of Architectural Studies, University of Sheffield, U.K.), and Michael Wetter (Mechanical Engineering Department, UC Berkeley, U.S.A.)

Building Simulation 2005

Week beginning 15 August 2005
Building Simulation 2005
9th International Building Performance Simulation Association
CONFERENCE + EXHIBITION
Montreal, Canada

IBPSA-Canada is proud to announce that Montréal has been selected to be the host of the 9th IBPSA International Building Performance Simulation Association conference and exhibition. The conference will be held at École Polytechnique de Montréal during the week beginning 15 August 2005.

Montréal was founded in 1642 by Paul Chomedey de Maisonneuve. It is the world's second-largest French-speaking city, with approximately 3 millions habitants, and a metropolis of international repute. It is the perfect marriage of North American modernity and European elegance. Montréal is one of Canada's most important scientific hubs with four major universities (2 francophones and 2 anglophones).

Further details will be published on IBPSA-Canada's website www.ibpsa.ca as they become available.

The organizing committee are:

Michel Bernier, École Polytechnique de Montréal
Stanislaw Kajl, École de technologie Supérieure
Radu Zmeureanu, Concordia University

Other forthcoming events

Calendar

Date		Event	Venue
2003			
October	21-22	CAE 2003: Competitive Advantage Engineering	Sydney, Australia
October	22-24	VisualDOE 3.1 Professional Training Seminars	near Chicago, USA
October	24-26	PHH 2003: Passive House Happening	Turnhout, Belgium
November	19-21	VisualDOE 3.1 Professional Training Seminars	San Francisco, USA
2004			
June	7-9	ISC '2004: Industrial Simulation Conference 2004	Malaga, Spain
June	9-11	IBPSA-Canada: eSim 2004	Vancouver, Canada
June	21-24	HEFAT 2004	Cape Town, South Africa
August	4-5	First IBPSA-USA conference	Boulder, Colorado, USA
2005			
August	***15-***	***BS 2005***	***Montreal, Canada***

21-22 October 2003
Sydney, Australia
www.mscsoftware.com.au/events/conferences/cae2003/index.htm

CAE 2003: Competitive Advantage Engineering
MSC.Software Australia

MSC.Software Australia invites you to the premier engineering simulation technology event, CAE 2003. Come and see leaders from the engineering community present case studies showing how Virtual Product Development has helped their companies achieve a competitive advantage within their engineering process.

In parallel with the presentations, this event also offers you the opportunity to attend practical and informative workshops on specific applications of Virtual Product Development.

Attendance is free, but places are limited.

For more information, visit the CAE 2003 website at **www.mscsoftware.com.au/events/conferences/cae2003/index.htm** or contact us at:

Level 13
309 Pitt St
Sydney NSW 2000, Australia
tel: (02) 9260 2222
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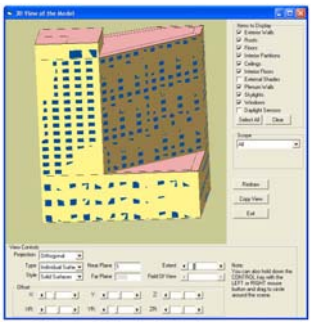
22-24 October 2003
Chicago Area, USA
+
19-21 November 2003
San Francisco, USA
www.eley.com/gdt/visualdoe/vd_training.htm

VisualDOE 3.1 professional training seminars

Eley Associates

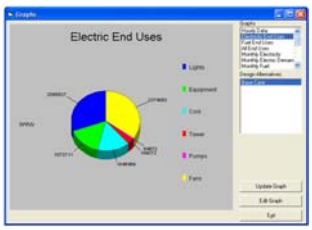
Eley Associates is offering two professional training seminars which provide hands-on DOE-2 simulation experience and cover the full range of VisualDOE 3.1 features. The optional third day focuses on using VisualDOE 3.1 to perform LEED (Leadership in Energy and Environmental Design) energy saving calculations.

A CD-ROM of training materials and hard copies of slides and exercise instructions will be distributed on the first day of training. A certificate of VisualDOE training is also available.



VisualDOE 3.1 is an updated green building design tool based on DOE-2 engine that allows users to evaluate energy and demand impacts of design alternatives. The program covers all major building systems, including building envelope, lighting, daylighting, water heating, HVAC and central plant.

Version 3.1 takes the ease-of-use and power of VisualDOE to a new level. The program is targeted for use by architects, engineers, MEP firms, energy consultants, utilities, national laboratories, universities, energy service companies, HVAC equipment manufacturers, and building product manufacturers.



Eley Associates' web site at **www.eley.com/gdt/visualdoe/** gives further details of Visual DOE3.1 and links to pages with further information about the seminars and an online registration page.

For questions about training seminars and the VisualDOE software product, please contact:

VisualDOE Team
Eley Associates
142 Minna Street
San Francisco, CA 94105, USA
tel: (415) 957-1977
fax: (415) 957-1381
email: **training@eley.com**

24-26 October 2003
Turnhout, Belgium
www.passiefhuisplatform.be

PHH 2003: 1st Benelux Passive House Symposium & Technology Forum

PHP vzw

Following the success of the first Passive House Happening last year, PHP have organised a second event to keep practitioners up to date with the state-of-the-art in passive house design and technology in the Benelux area. It is aimed at materials producers, contractors, designers, energy consultants, energy providers, city planners, simulation software producers and anyone involved with energy conscious design and planning, and energy legislation.

PHH2003 will include presentations on innovative developments in passive building technology, project case studies, and legislation and approval procedures, and opportunities for practitioners to meet, network and visit passive houses.

The three elements in the Happening are:

- 1st Benelux Passive House Symposium
  24 October 2003, Europeion, Turnhout, Belgium
- Passive House Technology Forum
  24-25 October 2003, Europeion, Turnhout
- Visits to Passive Buildings
  26 October 2003, several locations in Flanders, Belgium

For further information, visit the PHH2003 web site at **www.passiefhuisplatform.be** or contact:

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e-mail: **info@passiefhuisplatform.be**

7-9 June 2004
Malaga, Spain
www.eurosis.org

ISC '2004: Industrial Simulation Conference 2004

European Technology Institute/European Simulation Society (EUROSIS)

The European Technology Institute and the European Simulation Society (EUROSIM) have issued a first Call for Papers for their annual international industrial simulation conference to be held in Malaga, Spain next June. ISC '2004 aims to give a complete overview of industrial simulation-related research and provide an annual status report on present-day industrial simulation research for the European Community and the rest of the world. The integration of artificial intelligence, agents and other modeling techniques have made simulation an effective and appropriate decision support tool as well. With **papers** on simulation methodology and simulation applications in the main conference, **workshops** on modeling and simulation in the textile industry, intelligent transport systems and nanosim, an **exhibition, 'partners for projects' sessions** and — last but not least — **poster sessions** for students, ISC '2004 will provide an ideal forum for universities and industry to exchange techniques and ideas about integrating simulation into the everyday workplace.

The conference is being hosted by the University of Malaga and will be chaired by Javier Marin of the University's Department of Electronics. It is co-sponsored by ENSAIT, UPV, KFKI and Ghent University.

Topics at ISC '2004 will include:

- modeling and analysis methodology
- discrete event simulation languages and tools
- electronics manufacturing
- complex systems modeling
- verification, validation and accreditation
- Virtual Reality and graphical simulations in industrial applications
- the future of industrial simulation

and simulation applications in:

- manufacturing
- robotics
- aerospace
- engineering processes
- multibody systems
- military and defense
- automotive systems
- electronics, computers and telecom
- industrial and product design
- energy and power systems
- chemical and petroleum engineering
- logistics, traffic, transport and harbours

Submission requirements and deadlines

Abstract deadlines 15 December 2003 - 20 January 2004, depending on the type of paper

Please send submissions **electronically**, either through the abstract submission site (url to be announced) or as files sent to **Philippe.Geril@ugent.be** with 'ISC 2004' and the designated track in the subject line of the covering email. All submissions should be in uuencoded, zipped Microsoft Word format, PDF or Postscript format. Please provide your name, affiliation, full mailing address, telephone / fax number and email address on all submissions, and indicate the designated track and whether the submission is a full paper or an extended abstract. Only original papers, which have not been published elsewhere, will be accepted for publication.

Registration fees

	Authors	EUROSIS members	Others
Registration before 15 May 2004	485 euro	485 euro	545 euro
Registration after 15 May 2004	*[pre-registration required]*	545 euro	595 euro

Further information

For further information about paper submissions or the conference, please contact:

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9-11 June 2004
Vancouver, Canada
www.esim.ca

eSim 2004
IBPSA-Canada

IBPSA-Canada will be holding its next biennial eSim conference for professionals and students interested in building energy simulation issues and applications in Vancouver, British Columbia on June 10 and 11, 2004. There will be pre-conference workshops on June 9. **eSim 2004** will be hosted at the downtown campus of the British Columbia Institute of Technology (BCIT).

The deadline for submitting abstracts or indicating interest in demonstrating software is November 7, 2003. Abstracts must be in English or French and a maximum of 1 page.

Abstract deadline 7 November!

The themes of the conference are:

- recent developments for modelling the physical processes relevant to buildings (thermal, air flow, moisture, lighting)
- algorithms for modelling conventional and innovative HVAC systems
- methods for modelling the whole-building performance, including integrated resource management, renewable energy sources and combined heating, cooling and power generation
- building simulation software development and approaches to quality control
- use of building simulation tools in code compliance and incentive programmes
- moving simulation into practice: case studies of innovative simulation approaches
- validation of building simulation software
- user interface and software interoperability issues
- data visualization and animation
- optimization approaches in building design.

For more information consult the conference web site **www.esim.ca/2004/English/esim_home.htm** or contact:

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web: **www.encs.concordia.ca**

21-24 June 2004
Cape Town, South Africa
www.hefat.com

HEFAT 2004: 3rd International Conference on Heat Transfer, Fluid Mechanics and Thermodynamics

HEFAT 2004 is the third conference in the HEFAT series, which aims to bring together researchers engaged in the application of experimental and/or computational heat and mass transfer, and fluid flow, in all areas of science and engineering. HEFAT 2002 was held in the Kruger National Park, and attracted 200 papers from all over the world; HEFAT 2003, held at the Victoria Falls, attracted about 250. A fourth conference is planned for 2005, in Egypt. Further details, and order forms for proceedings from the first two conferences, are available on the conference website **www.hefat.com**.

Paper deadline 15 November!

The organisers are now inviting papers for HEFAT 2004. The original deadline for 500 word abstracts on topics from any area on experimental and/or computational heat and mass transfer, thermodynamics and fluid flow was 30 September 2003. The deadline for submission of final papers is 15 November 2003; format guidelines are given on the website. These will be peer reviewed by an international panel of experts. Improvements to the paper content and format may be required before final acceptance. Accepted papers will be published in the conference proceedings. If too many papers are received, selected papers will be scheduled for a poster session.

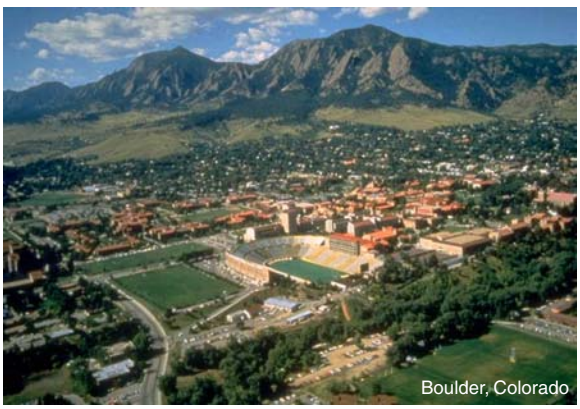
For further information about abstracts and papers, please email **hefat2004@mweb.co.za** or fax 27 12 653 2547.

4-6 August 2004
Boulder, Colorado, USA
www.ibpsa.org/ibpsa_usa/BP_04.htm

Building Performance '04: Where Simulation and Reality Meet in a Low Pressure Environment
IBPSA-USA

IBPSA-USA will hold its first conference next year on the campus of the University of Colorado, Boulder on 4-6 August 2004.

The conference program will include technical papers, applications of simulation and performance assessment in practice, presentation of student research projects, and software demonstrations. Further information and a call for papers will be issued shortly through the conference web site at **www.ibpsa.org/ibpsa_usa/BP_04.htm**.


Boulder, Colorado

Software news

EnergyPlus : version 1.1 released, course materials and training

Dru Crawley, US Department of Energy

An interim update, version 1.1.1, of the EnergyPlus building energy simulation program with many new features was released on 17 September 2003. Many updates and extensions have been made through the existing building envelope, daylighting, and HVAC equipment and systems portions of the program. New features include:

Input

- Complete set of compact schedules for EnergyPlus use (including ASHRAE Standard 90.1-1989 schedules)
- All schedules are extensible--fields can be added to IDD as needed
- EPMacro variable names no longer case sensitive
- Users can change the number of warm-up days for certain input files if warranted
- Users can additionally specify dew point temperature in the design days or a relative humidity schedule
- Users can also set when minimums and maximums occur.

Geometry/Windows/Walls/Shading

- Transform geometry automatically while rotating
- Shading surface transmittance accounted for in detailed daylighting calculation
- Added return air as destination choice for airflow windows
- Radiant system surface group is now extensible to any number of surfaces.

Daylighting

- Daylight illuminance maps
- Tubular daylighting devices including illuminance, solar gains, and thermal resistance
- Daylighting shelves.

COMIS

- Added venting availability schedule to COMIS venting control at zone level
- Individual window/door COMIS venting control
- Automatic calculation of COMIS wind pressure coefficients for rectangular buildings.

Electrical power

- Photovoltaic power calculations now integrated at time step, along with better reporting.

HVAC

- All chillers report COP at the time step
- Flow limits, outside air, and schedules added to Purchased Air
- Free cooling chiller works with all chiller types and may be on any branch
- Autosizing for Chiller:Direct Fired Absorption
- Frost control options
- Control supply air temp to a setpoint when the air-side economizer is active
- Light-heat-to-return now included in air loop autosizing
- Lights return air fraction as function of return plenum temperature and air flow
- Simplified demand controlled ventilation
- Stand-alone energy recovery ventilator zone equipment (directly connected to a zone)
- Autosized HVAC templates for Purchased Air, 4 pipe fan coil, VAV, and boiler and chiller loops
- New variable speed DX coil performance curves (5ZoneAutoDXVAV example file)
- Conversion utility for DOE-2 performance curves
- New temperature controlled (constant flow) hydronic low temperature radiant systems
- Additional evaporative cooler model
- Fluid properties set
- Pond heat exchanger
- Glycol reference data set
- Four new condenser loop operation control schemes based on environmental parameter ranges for hybrid ground source heat pumps

.

Output

- Standard, sizing, and daylight map reports can now be saved as CSV, TXT, or tab-separated
- New standard report for time-binned outputs
- End Use category for electric equipment
- Overcast sky daylight factors written to the EIO file
- New monthly reports which can be written in CSV, TXT, tab or HTML formats. Users can define custom reports, or use predefined reports which are similar to DOE-2 standard reports:
  - Building Loads (DOE-2 LS-D)
  - Space Loads (DOE-2 LS-E)
  - Energy Consumption (by energy source, DOE-2 PS-B)
  - End-Use Energy Consumption (by energy source, DOE-2 PS-E)
  - Peak Energy End-Use by Source (by energy source, non-coincident)

Utilities

- Many enhancements to IDFEditor including support for new units, pull down lists for choices, zero values
- Significant improvements (more than 20x) in execution speed for ReadVars
- ReadVars now can write more than 254 variables (Excel still will only read in the first 255 columns).

- ReadVars users can now specify the delimiter on their output files by selection of the proper file extension.
- WinEPDraw detects non-planar surfaces and degenerate surfaces but will still produce a DXF
- EP-Launch supports the new style output (delimiter) files

More information on these and other new features in this version is available on the EnergyPlus web site **www.energyplus.gov.**

University Course Materials on EnergyPlus and building simulation

The US Department of Energy has also announced the availability of university course material for teaching building simulation using EnergyPlus. This is targeted specifically to the university environment for teaching students about building simulation while introducing them to EnergyPlus.

The course comprises 25 complete PowerPoint lectures (over 800 total slides) which cover topics from strategies for using energy simulation, expectations, building input, primary and secondary systems, and advanced features. While many of the lectures deal explicitly with how to model various components and systems with EnergyPlus, the lectures also provide an appropriate overview of building systems so that the students can understand the context and purpose of the technology within the building. The presentations include text, graphics, photographs, color-coded input, and other features designed to make teaching and understanding the concepts of building energy analysis easier. The course material also includes notes to instructors about assumptions made when developing the course as well as a course outline/schedule to help the instructor organize the semester and homework assignments and projects.

The best feature? It is available now at no charge from the EnergyPlus web site. Those who download the course are simply requested to share feedback, example problems, experiences, etc. with DOE so that other instructors can benefit--and so that we can notify you of new material and updates in the future. Instructors and other interested parties can register and download the entire package of course material from the EnergyPlus web site at **www.energyplus.gov** — look under training.

EnergyPlus training workshops

GARD Analytics plan to offer three different types of EnergyPlus training workshops over the next year:

Introductory Workshop for Beginning Modelers (4 days)

The objective of this course is to introduce EnergyPlus to beginning modelers and to teach the basic concepts of building energy simulation such as thermal zoning, building geometry, specifying materials and construction, internal loads, and schedules. It will discuss the basic techniques involved in properly applying simulation tools during the

building design process, for example, comparing two or more alternative systems.

Introductory Workshop for Experienced Modelers (2 days)

This workshop is intended for persons with experience using different building energy simulation software. The workshop covers the same EnergyPlus concepts as the Introductory Workshop for Beginning Modelers, but covers them at a faster pace assuming that the students already understand basic modeling concepts such as thermal zoning, building geometry, etc.

Advanced Workshop (2 days)

This workshop is intended for persons with experience using EnergyPlus. The objective of this course is to introduce more complex features of EnergyPlus that provide greater power and flexibility to advanced modelers. This workshop builds on concepts introduced in the introductory workshops and introduces some of the more advanced and complex simulation concepts.

All three training courses are fairly evenly divided between lectures and workshop time designed to allow students to enter and run simple EnergyPlus models on their own laptop computers.

Workshop dates and locations for the coming year have not been finalized yet. To receive future workshop announcements, please e-mail **EnergyPlus-Training@gard.com**. Workshop announcements will also be posted at **www.gard.com/training.htm**.

Building Energy Tools Directory

Dru Crawley, US Department of Energy

The web-based Building Energy Tools Directory at www.energytoolsdirectory.gov contains information on more than 270 building-related software tools from around the world. Haven't visited lately? Many new tools have been added over the last several months including AGI32, EnerCAD, PVSyst, CtrlSpecBuilder, REScheck, SkyVision, The Lightswitch Wizard, Energy CAP, ABACODE, and SMOC-ERS.

For each tool in the directory, a short description is provided along with information about technical expertise required, users, audience, input, output, validation, computer platforms, programming language, strengths, weaknesses, technical contact, availability and cost. A link is also provided for directly translating the web pages into more than 8 languages.

If you know of a tool (yours?) that isn't in the directory, visit **www.eere.energy.gov/buildings/tools_directory/your_software_here.html** or contact Dru Crawley at **Drury.Crawley@ee.doe.gov**

VisualSPARK 2.0 released

The Simulation Research Group of Lawrence Berkeley National Laboratory and Ayres Sowell Associates have released version 2 of their VisualSPARK environment for simulation of advanced building energy systems.

New features include:

Multi-valued inverse functions

In SPARK 1 all inverse functions were single-valued, that is, the inverse returned only one value. SPARK 2 allows inverse functions to return two or more values simultaneously.

Residual inverse functions

For complex equations, some inverses may be difficult or impossible to obtain as functions in explicit form. Or, it may be that special knowledge about the problem under investigation suggests that a particular inverse should not be used, because it might lead to numerical difficulties. To deal with such situations, it is now possible to specify inverses in 'residual form' that do not return the values of the target ports but instead return the residual values for the equations assigned to each target port.

Callback framework

An extended callback framework in SPARK 2 enhances the object-oriented capabilities of the SPARK atomic classes by providing support for data encapsulation. The callback framework consists of instance callbacks and static callbacks. Instance callbacks are fired for each instance of the inverse, whereas the static callbacks are fired only once for each inverse type appearing in the problem. The callback functions are categorized into four groups: modifiers, structors, non-modifiers and predicates.

Private data

The SPARK 2 callback framework makes it possible to attach private data to each inverse. We distinguish between instance data that is specific to each instance of the inverse and static data that is shared by all instances of the same inverse. The structor callbacks are used to allocate and deallocate the private memory required by each inverse instance. Private data can then be retrieved and updated from within the other callback functions.

Improved solution methods

- Integrated newest release of UMFPACK for the sparse linear solver
- Added perturbed Newton solution method
- Added keys in the Preference file for safety factors used in convergence test(for Prediction/Iteration stage and Break/Normal unknown variables)
- Added a key in the Preference file to specifiy the minimum number of iterations when solving the strong components
- Added variable scale for all problem variables

Sparse linear solution method

This method reduces calculation time by orders of magnitude on large simulation problems that have a sparse Jacobian matrix.

New runtime control parameters

Added the following keys in the .run file:

- InitialConsistentCalculation to indicate whether or not to calculate consistent values at the initial time by solving for the time-derivatives of the dynamic variables using the specified boundary conditions
- InitialTimeStep to specify the value of the initial time step
- VariableTimeStep to specify a variable time step if required
- MinTimeStep to specifiy the smallest allowed time step
- MaxTimeStep to specifiy the largest allowed time step.

New driver API

- Now supports both static and dynamic build operations in the driver function
- The runtime problem loader now supports explicit linking from dynamic libraries.

XML problem description

The problem topology is now described by an XML file. This allows saving a compiler- and linker-free SPARK as long as all atomic classes are compiled and built as dynamic libraries.

Read URL mechanism

This is a generalized way of specifying where and how input values are obtained at runtime. With this mechanism SPARK can now read:

- EnergyPlus, DOE-2 and TMY weather files
- DOE-2 schedules
- Algebraic expressions
- ASCII formatted files.

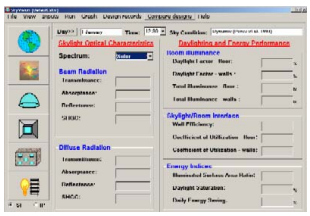
Variable time stepping

This uses an Euler integration method to cut calculation time and control truncation error.

Interface improvements

- Tree-view of problem showing objects associated with the problem
- Right-clicking on a project name now pops up a menu with choice to edit the problem file or show the tree structure of the problem
- Right-clicking on a class name pops up a menu from which you may choose to edit the class file or show the tree structure of the class
- Checkbox to allow variable time step and inputs for min and max time step
- Wallclock entries to choose date and time for run (eg for reading weather file data
- Plots comparing the same variables from multiple runs on one graph
- New tab showing Structure and Defaults:
  - Structure: shows problem structure as a tree; you can browse inverses, parameters, input variables and unknowns
  - Defaults: shows default values for solution methods, max iterations, etc.
- Component tab shows component structures as trees, where you can browse unknowns and objects, including their inverses, targets and callbacks.

For more information on VisualSPARK or to download the program free of charge, please go to **http://SimulationResearch.lbl.gov** and select VisualSPARK.



Second beta version of SkyVision released

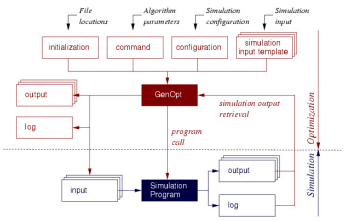
The Institute for Research in Construction (IRC) of the National Research Council of Canada (NRC) has released the second beta version of SkyVision. SkyVision is WindowsTM-based, analysis software that calculates the overall optical characteristics of conventional and tubular skylights, and predicts their energy-saving potential. SkyVision accounts for the skylight shape and glazing type, geometry and surface characteristics of the indoor space, lighting and shading controls, building site location and prevailing climate. The main additions to the first beta version (released in March 2003) include calculation of the monthly and annual lighting energy savings, improvement of the Graphical User Interface, and reported bug fixings.

The software can be downloaded free of charge from the IRC web site at **http://irc.nrc-cnrc.gc.ca/ie/light/skyvision/**. Comments or suggestions are very useful and appreciated; please send them to Dr Aziz Laouadi at **aziz.laouadi@nrc-cnrc.gc.ca** or ring him on + 1 613 990 6868.

GenOpt 2.0β
Generic Optimization Program

GenOpt 2.0b released

Michael Wetter, Simulation Research Group, LBNL

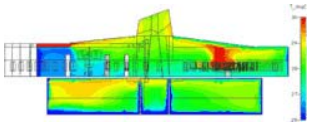


GenOpt® 2.0b has been released. GenOpt is general purpose numerical optimization software that integrates with any simulation program which can use text files for input and output. It runs on any operating system that supports Java, such as Windows, Unix, and Linux, and can be used to solve a wide variety of engineering optimization problems to reduce cost, enhance comfort, or improve controls of complex systems. GenOpt has been specifically designed for situations where the cost function is computationally expensive and its derivatives are not available or may not even exist.

Any simulation program that can use text files for input and output — such as EnergyPlus, TRNSYS, DOE-2, SPARK, or any user-written program — can be coupled to GenOpt without any code modifications.

GenOpt has a library with several algorithms that can be used to solve local and global optimization problems with continuous and/or discrete independent variables. This contains Generalized Pattern Search algorithms (Hooke-Jeeves and Coordinate Search algorithm), various Particle Swarm Optimization algorithms, hybrid optimization algorithms for global and local optimization, a Discrete Armijo Gradient algorithm, and Nelder and Mead's Simplex algorithm, as well as algorithms for one-dimensional optimization and parametric studies. Additional optimization algorithms can easily be added using GenOpt's algorithm interface.

For a free download and more information, visit **http://SimulationResearch.lbl.gov** and select GenOpt.



MicroFlo CFD code gains a Windows interface

Don McLean, Integrated Environmental Solutions

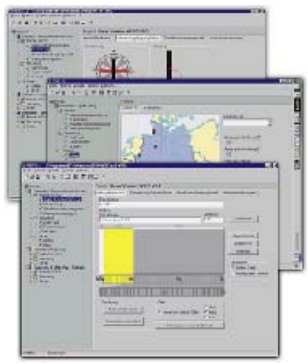
IES are launching a Windows version of their CFD code, MicroFlo, in January 2004. To date, MicroFlo has only been available under Unix.

MicroFlo is one of the tools in IES's <Virtual Environment>, a unique software system of integrated building performance analysis tools for use by architects and engineers, planners and facilities managers. The <Virtual Environment> operates from a single building model, bringing together all the design strands designers need in one unified system with a single, clear user interface, and making it easy to transfer data from one application to another. It includes daylighting simulation, rights to light, thermal simulation/natural ventilation, HVAC and controls design, heat loss and heat gain calculations, thermal simulation/bulk airflow, solar analysis, value management and value engineering, environmental pollution analysis, cost planning and lifecycle analysis, carbon emissions, electrical lighting and design simulation, UK Part L and Part J Building Regulations calculations, lift simulation, CAD importing and 2D and 3D CAD export.

For an overview of the functionality of the IES <Virtual Environment>, go to the IES website www.iesve.com or contact Don McLean at:

IES Limited
141 St James Road
Glasgow G41 3AU, UK
tel: +44 141 552 8368
fax: +44 141 552 8371
email: don.mclean@iesve.com

WUFI: calculating coupled moisture and heat transfer in building components



The Fraunhofer Institute for Building Physics (IBP) in Germany has developed a menu-driven PC program which allows realistic calculation of the transient coupled one- and two-dimensional heat and moisture transport in multi-layer building components exposed to natural weather. WUFI (Wärme und Feuchte instationär) only requires standard material properties and easy-to-determine moisture storage and liquid transport functions, and it can use measured weather data — including driving rain and solar radiation — as boundary conditions. It is based on the newest findings regarding vapour diffusion and liquid transport in building materials and has been validated by detailed comparison with measurements obtained in the laboratory and on IBP's outdoor testing field.

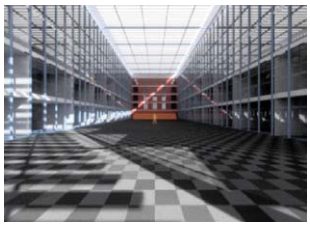
For additional information, visit www.wufi.de or email Andreas Holm, holm@hoki.ibp.fhg.de.

ALware's design tool: 3D Lighting 1.2

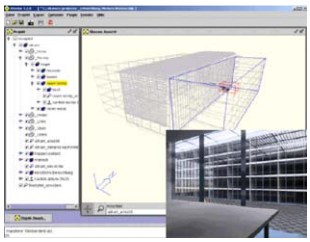
Andreas Lahme, ALware

3D Lighting is a highly functional, innovative software program for realistic daylight and artificial light calculation in 3D geometries. It is designed to offer designers scientifically accurate information early in the design process and to be simple and user-friendly, leaving users free to concentrate on design issues. Features include:

- Fast input and trouble-free modification of 3D geometries
- Simple handling
- Fast processing
- Combined daylight and artificial light calculations
- Scientific calculation engine based on Rayfront and Radiance
- Clear presentation and documentation of input data and results
- Interface compatible with other design and drawing programs
- Project-related training available.



Daytime view of an atrium



Easy geometry assembly by tree structure

Daylit room, partly with daylight redirection system

Artificial lighting in a club hall

Multiple daylight calculations

3D Lighting enables you to construct even complex 3D geometries quickly and to relocate, reinsert, or resize both single and whole building parts later. When enough details of the building and its surroundings have been defined the program can provide a wealth of daylighting data including luminance curves, illuminance values and daylight factors, and calculate the potential savings in electric lighting. It can accurately calculate the effect of daylight redirection systems on the lighting conditions in rooms, using Raydirect.

Validated calculation engine

3D Lighting uses the scientifically-validated Rayfront and Radiance programs as its calculation engines. Developed by Lawrence Berkeley Laboratory, Radiance even allows for the way the human eye perceives luminance.

Artificial light calculations for every luminaire

Technical luminaire data (such as light distribution curves for specific models) can be imported in international standard formats. The program takes this into account to calculate artificial lighting with scientific accuracy.

The results

Results are output as freely selectable views, illuminance curves, or daylight factor curves.

3D Lighting is available in German and English. For further information about it, and about other ALware products and services, visit www.alware.de or email info@alware.de — and see the case study, next page.

ALware
Leopoldstr. 7a
D-38100 Braunschweig, Germany
tel: +49 531 250 72 80
fax: +49 531 250 72 81

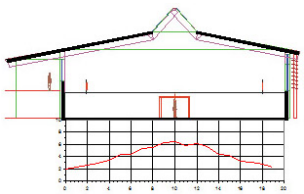
Walking on new paths for daylight simulation: ALware's 3D Lighting in action

Comparing simulation (above) and reality (below)

3D Lighting was used in the design of a stadium in Esens, Germany to enable maximum use of daylight while ensuring visual comfort for the sportsmen and avoiding overheating in summer. The designers used the program to avoid excessively high luminance contrasts and discomfort glare from the roof lights in sunny weather, and to optimise shading systems for the windows in the southern facade.

Using the program

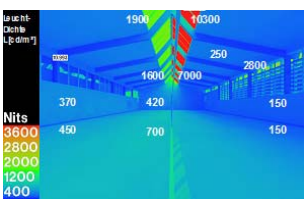
The simplicity of data input into 3D Lighting allowed the designers to meet the daylight factor requirements of the DIN 67526 (German Institute for Standardisation) standard very quickly. The program makes it easy to modify or add details, so they were able to examine a number of design variations without having to reconstructing the basic geometry of the model; for example, window frames and external horizontal blinds were late additions to the southern facade. The surfaces the walls and ceilings were designed to be as bright as possible, and 3D Lighting enabled the glossiness of surfaces such as the floor to be represented realistically in the simulation. The program offers a wide range of transparent and translucent materials, so the designers were able to simulate the use of diffusing glass in the roof lights (to avoid direct solar radiation) and low emissivity glass in the vertical side windows. With rapid simulation of different variations, the architect and client were able to develop an optimal solution together as the design process progressed.



Daylight factors across the hall

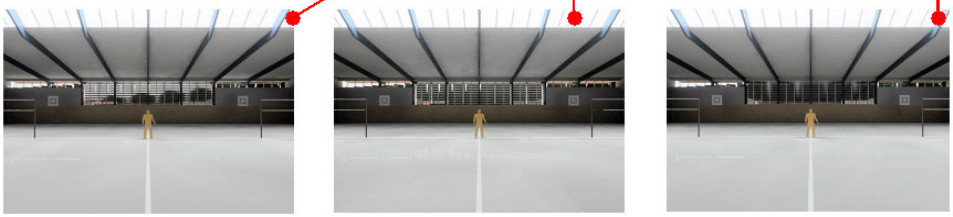
Wide ranging analysis of daylight

To optimise the geometry of shading devices, the designers used 3D Lighting to simulate solar radiation into the hall at several representative times of day and year. Sports can be played both along and across the stadium, so discomfort glare had to be avoided in all directions of view. To check this, luminance distributions were computed as false-color images from a variety of directions, allowing the luminance of the windows and solid walls to be directly compared and design details adjusted to avoid disturbing glare. The simulation showed that the horizontal blinds outside the southern wall — designed to be darker on their lower then their upper sides — would only need to be adjusted to three different angles during the year to keep glare within acceptable limits. 3D Lighting was also used to calculate when daylighting would be sufficient each room, and estimate the energy savings resulting from the reduced need for artificial light.



False-color image showing the luminance values in the hall

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Changes		01 Feb		01 Apr					01 Sep		01 Nov	
Tilt	30°	20°		horizontal					20°		30°	
Shading fraction	25%	50%		100%					50%		25%	



Seasonal adjustment of the horizontal blinds' tilt angle and its effect on the reference to the outside through the southern facade

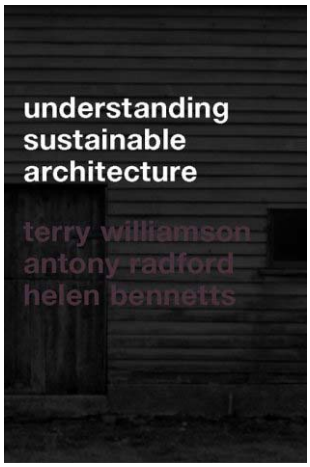
Validated software as calculation engine

Accurate simulation results are guaranteed in 3D Lighting by the use of independently-validated Rayfront and Radiance software as calculation engines. Rayfront is used to simulate both artificial light and daylight, while Radiance takes account of they way the human eye perceives illuminance. 3D Lighting combines their proven accuracy with a user-friendly interface to provide quick and realistic simulation results.

Freedom to design

3D Lighting has a data interface compatible with other common design and drawing programs, so daylighting analysis can be combined with thermal simulation to calculate the risk of overheating and optimise designs to avoid it. The designers of the Esens stadium used a common 3D geometry both for their daylighting analysis and for investigating the hourly energy balance of the building using Bsim 2000: the ability to export the building geometry from 3D Lighting avoided the need to develop a new geometry for the thermal simulation. 3D Lighting can equally well import data from other 3D simulation programs, eliminating many of the complications of working with separate lighting and thermal models.

Announcements



Publication by an IBPSA board member

Terry Williamson, IBPSA board member and Associate Professor and Dean of the School of Architecture, Landscape Architecture and Urban Design at Adelaide University, Australia, has written a book on ***Understanding Sustainable Architecture*** with co-authors Anthony Radford (Professor at the same school) and architect Helen Bennetts. The following information is taken from publisher Spon Press's description of the book.

Understanding Sustainable Architecture is a review of the assumptions, beliefs, goals and bodies of knowledge that underlie the endeavour to design (more) sustainable buildings and other built developments.

Much of the available advice and rhetoric about sustainable architecture begins from positions where important ethical, cultural and conceptual issues are simply assumed. If sustainable architecture is to be a truly meaningful pursuit then it must be grounded in a coherent theoretical framework. This book sets out to provide that framework. The authors argue the ultimate importance of reasoned argument in ecological, social and built contexts, including clarity in the problem framing and linking this framing to demonstrably effective actions; design decisions must be based on both an ethical position and a coherent understanding of the objectives and systems involved.

There are chapters on **Sustainability** (with sections such as A Cultural/Philosophical Framework and The Manageable (But Fragile) Earth); **Images** (The International Culture of Architecture, Architectural Expression, The Natural Image, The Cultural Image and The Technical Image); **Ethics** (addressing issues such as Rights and Duties, Intergenerational Equity and Environmental Ethics); **Objectives** (on topics like Stakeholders, Design Advice and The Globaliazation of Standards and Regulations); **Systems** (covering Buildings As Systems, Social and Cultural Relevance, The Occupants, Economic Performance, The Life-Cycle of a Building and Environmental and Economic Assessment; **Green Houses (on** International Politics and Global Warming and Building Design); and **Cohesion** (including discussions of Credibility, Transferability, Dependability and Conformability).

Sample pages are available in eBook form through the Spon Press web site at **www.sponpress.com** (select 'Find a Book', search by title and follow the links).

Understanding Sustainable Architecture has 176pp, 18 black and white photos, 3 line drawings and 4 tables. It is available in hardback (ISBN 0415283515, priced at $95.00/£65.00) and in paperback (ISBN 0415283523, $30.95/£18.99).

Software for building refurbishment

Integrating building energy simulation in the design process

C A Balaras, Group Energy Conservation, Institute for Environmental Research & Sustainable Development, National Observatory of Greece, I. Metaxa & Vas. Pavlou, P. Penteli, Greece

Abstract

This paper presents an overview of new generation decision-aid software for assessing renovation or refurbishment strategies in residential, office and hotel buildings. The tools include a structured methodology for performing a diagnosis of an existing building condition, modules for load calculations and the assessment of energy conservation potential resulting from different interventions, the improvement of indoor environmental quality (IEQ) and building's environmental impact, and at the end provide a cost estimate of different intervention scenarios. The methodologies and software were prepared or are currently in the phase of development, as a collaborative effort between several European organizations in the framework of projects supported by the European Commission. The tools can be easily adapted to national needs and characteristics. Some of the software has already been adapted and is available in different national versions.

Introduction

Building renovations (ie repairs and restorations to good condition) and refurbishment (ie upgrading to better condition) of the existing and ageing building stock offers an opportunity to take cost-effective measures and transform them to resource-efficient and environmentally-sound buildings, with an increased social and financial value. Building retrofits have gained an increasing importance in the building construction sector. In many European countries they even reach equivalent levels of activity with new building construction.

In the Member States of the European Union there are around 56 million flats that were built after 1950. The majority of these flats are now in great need of refurbishment since to meet today's requirements for higher living standards and requirements for improved indoor environmental quality (IEQ), and to meet higher expectations for improved energy performance and to reduce their environmental impact.

The total stock of office buildings in Europe is estimated at 1200 million square meters of conditioned floor space (Caccavelli and Gugerli 2002). About 70% of this stock is

less than 25 years old, which implies that they are relatively new buildings. However, the office building retrofitting market has been growing strong since the life span of office buildings is much shorter than residential buildings, occupants needs and expectations have increased demanding working spaces with improved amenities for comfort, infrastructures and services. In addition, retrofitting a building costs much less (even for high investment retrofitting operations) than demolition and reconstruction (about half to one-third of the cost).

Most of the existing hotels were built during the 1970 - 1980s. Low quality buildings, at least for today's standards, energy consuming installations, low performance equipment, as well as unsustainable exploitation of the natural resources are some of the very common features of these constructions. Most of these buildings 15 - 25 years after their construction need complete or partial refurbishment. New hotel construction spending has plummeted from an average growth rate of 8% per year in the 1970s and 1980s to an average to 1% per year. On the other hand, the hotel refurbishment / conversion market is booming. The development of this market is mostly driven by the integration of European hotels into large hotel chains.

Building renovation or refurbishment can play a determinant role in the effort to reduce the energy consumption in the building sector that currently represents about 35-40% of annual European Union (EU) final energy use, contributes about a third of greenhouse gas emissions, uses about one third of all the raw materials and have a major impact on landfills. Energy efficient and environmentally friendly design and construction of new buildings has attracted a lot of attention and much progress has been achieved. However, given the low turn-over rate of buildings (lifetime of 50 to more than 100 years) and the high number of existing buildings, it is clear that the largest potential for improving energy performance in the short and medium term is in the existing stock of buildings. This can also have a significant impact on the efforts to reduce greenhouse gas emissions in accordance to the Kyoto protocol and the ratified commitments by most EU member states. Accordingly, the challenge is to properly retrofit buildings in a manner that will use the minimum nonrenewable energy, produce minimum air pollution as a result of the building operating systems, minimize construction waste, all with acceptable investment and operating costs, while improving the indoor environment for comfort, health and safety.

A new generation of European methodologies and software tools enable architects and engineers to make an accurate first assessment of the overall building's existing condition, taking into account its energy performance, indoor environmental quality, and some other criteria depending on the building use. The tools support the user during the building audit that can be performed in a short amount of time and ensure that all necessary data is collected. The tools provide a global view of the building renovation or refurbishment process and support the user during the decision making process to define well targeted actions and to assess different refurbishment scenarios with an estimate of the total cost.

The backbone of these methodologies is EPIQR that was developed for apartment buildings. Following on a similar approach, TOBUS was developed for office buildings and XENIOS is currently under development for hotels. INVESTIMMO is enhancing the work on apartment buildings by addressing additional criteria in the decision making process, like housing market, tenant expectations, upgrading potential associated to the building's aesthetics, historical or cultural value and the environmental impact of building refurbishment and retrofit measures in relation to its energy consumption and natural resources. All the methods are supported by multimedia computer programs that assist the user to audit a building and to collect all necessary data, that is then used to evaluate different scenarios for upgrading the building structure and improving its energy and environmental performance, to make well targeted and effective decisions with an accurate cost estimate.

Overview of the tools

EPIQR (energy performance and indoor environmental quality retrofit) is a methodology developed to assist architects, engineers and other professionals during the refurbishment or retrofitting (upgrading) actions of **apartment buildings** (Jaggs and Palmer 2000). The building is decomposed into discreet elements such as load bearing structure, windows, façade finish, roof, heat and cool production system, electrical installations etc. For each building element, it is possible to have different types. During the building audit, the user specifies the specific elements/types for a given building and determines their stage of deterioration, for example, excellent condition to very poor condition. This is done by selecting a deterioration code "a, b, c, or d" described by the method, that best fits the observed state of each element/ type. Before making the selection, the user can review the corresponding text with a detailed description and several pictures that illustrate the four possible deterioration stages (**Figure 1**). Numerous pictures and drawings support the user to select the appropriate deterioration code. The software (Flourentzos, Droutsa, Wittsen 2000) contains for each building element a description of usual deterioration and corresponding refurbishment work including costs, potential upgrading work as well as related national standards and guidelines.

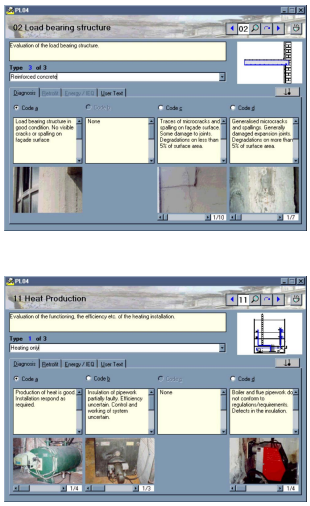


Figure 1: Examples from the software interface, for the diagnosis of building elements/ types during the building audit, to determine the deterioration state of the load bearing structures (above) and the heat production (below).

Use the zoom tool for a closer view

Actual building energy consumption data collected from the energy bills give a first assessment of the building's current energy performance. The actual energy consumption is compared to the standard and best practice values of the country to illustrate the saving potential. Energy calculation modules are then used to estimate the building's energy balance and assess the energy conservation potential for space heating and cooling, domestic hot water production and artificial lighting. A user-friendly interface expedites energy data input. Building related data collected for the diagnosis and refurbishment cost calculations are used as input. A database with typical building constructions (i.e. for walls, floors, roofs and windows) helps a non-expert user to easily enter the appropriate thermal data for the building components. The software also includes the necessary climatic data for different European locations. A simplified heating energy balance calculation based on EN-832 (Wittchen and Aggerholm 2000) is used to estimate the breakdown of the building's heat losses and guides the user to retrofit measures

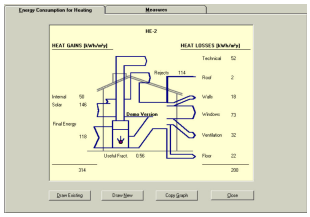


Figure 2: Heating energy balance. The results are given for the existing condition or follow-up retrofit actions. A similar interface is also used for the cooling energy balance.

with a higher energy saving potential (**Figure 2**). The cooling load calculations are based on the ASHRAE's Total Equivalent Temperature Differential values and a system of Time Averaging, TETD/TA method (Parsons 1989). Energy conservation measures that can be assessed include building envelope and thermal insulation, heating production system efficiency, infiltration losses, solar control, ceiling fans, solar collectors, and energy efficient lighting. For the selected action(s) the results include the initial annual building cooling energy (kWh), the resulting annual energy conservation (kWh and %), typical costs expressed in national currency as well as the typical pay back period. Representative results from case studies in Hellenic buildings are available in (Balaras et al 2000).

The software also contains a questionnaire that may be distributed to the occupants to collect data associated with IEQ (Bluyssen 2000). The data is then entered in to the software that automatically performs a statistical analysis of the questionnaire data and relates complaints with refurbishment work and energy retrofit measures. It then alerts the user during the audit for problems associated with specific elements/types.

A residential building audit to collect the necessary data with EPIQR can be performed within half-a-day. The analysis of the data and report preparation are then supported by the software. The tool summarizes the building deterioration state for all the building's elements and the refurbishment cost. The user can then select a set of actions and directly assess the effect on the total cost. Different energy conservation scenarios are also assessed providing an estimate of energy savings and a simple payback period. The national EPIQR versions are available in French, German, Danish, English, Greek, Italian and Polish. The main difference in the national versions apart from the language is the description of the refurbishment works and related costs, in accordance to national practices.

TOBUS (a decision-making tool for selecting office building upgrading solutions) methodology and software was a follow-up work for **office buildings** (Caccavelli and Gugerli 2002). The philosophy is the same as in EPIQR but with additional features to handle the more complex installations of office buildings and the addition of one more decision-criteria based on functional obsolescence of building services.

The new features include additional elements/types for the electromechanical installations encountered in office buildings, like central heating, air-conditioning and ventilation, fire protection, low current networks etc. The current state of the building envelope and its electromechanical installations is diagnosed in a similar manner, by the deterioration codes a, b, c and d that correspond to "a - good condition", "b - need for minor repairs", "c - need for major repairs", "d - need for replacement". Additional calculation modules are also included to perform energy saving estimates for controls in air handling units, energy recovery systems, ice and chilled water storage, daylighting, low energy office equipment, zoning of elevators and service quality, and sanitary water savings (Balaras et al 2002a).

The additional obsolescence criteria include compliance with user needs, flexibility, divisibility and maintainability (Allehaux and Tessier 2002). For each criterion, there

are three possible codes. The user assesses the obsolescence codes for each object and each criterion and the tool proposes a standard description text to assist the user. The user can also set priorities for the urgency of actions on each element/type, for example, "obsolete, high priority for action", "obsolete, but not high priority for action", "no necessary action".

Currently, the TOBUS software is a research prototype, and is available for one country only (Switzerland), since the databases were filled-in with Swiss data (Flourentzou et al 2002). However, its open structure allows for an easy adaptation to other countries. National versions are under development.

XENIOS (an audit tool for hotel buildings and the promotion of RUE and RES) is an ongoing project for developing a similar tool for **hotels**. Hotels rank in the highest levels of energy consumption in the tertiary building sector. They are also located in areas with high seasonal energy loads, and frequently high energy cost and low supply (i.e. islands). In addition, possible energy conservation techniques for rational use of energy (RUE) and exploitation of renewable energy sources (RES) have a unique demonstration potential and a high exposure to millions of people that visit hotels at one time or another. The hotel sector is uniquely placed to provide the impetus for change in business behavior within tourism, because of its multiplier effect - on guests, staff and suppliers as well as the central role that hotels play within local communities.

XENIOS prepares a methodology implemented in a multimedia software for carrying out a hotel audit, supported by the necessary tools for making a first assessment of where and how to integrate the most cost-effective energy efficient renovation practices. The tool includes calculation modules for estimating the energy savings from various retrofits actions in heating, cooling, ventilation, lighting, use of central energy management controls, integration of solar systems, heat recovery of wasted heat, and can then be used to assess different scenarios based on energy savings and cost. The audit scheme also identifies potential problems and risks with the indoor environment. Recommendations will also be integrated in the tool to assist the user on how to improve indoor air quality (i.e. sources of indoor pollutants, control legionellosis and microbiological water quality in hot and cold water services, heating and cooling systems), identify and assess measures to save natural resources (i.e. water, waste management). Additionally, the XENIOS project aims to increase awareness on the benefits of using RES and RUE techniques in the hotel sector, by preparing dissemination material for hotel managers and hotel guests and to organize dissemination campaigns to local authorities, hotels and hotel associations. The project will be completed at the end of 2003. The English version of the software will be available from the XENIOS web page.

INVESTIMMO (A decision-making tool for long-term efficient investment strategies in housing maintenance and refurbishment) is an ongoing project for developing a tool that can assist a user in elaborating long-term financial investment strategies in **apartment buildings'** maintenance and refurbishment. It is addressed to owners of a large stock of buildings that need to decide on which buildings and their components have priority for investment and also when this is an optimal investment.

The necessary input data is collected using EPIQR to perform the building audits. The tool will then assist the user in the decision making process to take into account different criteria, in addition to the building's deterioration state, like the building's environmental impact from the use of natural resources (including water, materials, energy and land) and the production of pollutants (i.e. waste, noise and dust) through a simplified life cycle analysis, the potential energy savings from different interventions, the lifespan of different building elements, the local and urban neighbourhood quality, the cultural perceptions, the rental market nature and its evolution. The different quantitative and qualitative parameters (i.e. physical, social, cultural and economic) will then baggregated to emphasise the concept of investment over simple financial criteria that are commonly used when addressing individual criteria.

About 350 European residential buildings have been audited, using EPIQR to collect the necessary input data for the work that is underway. The database, along with a presentation of all the audited buildings, is available on a multimedia CDROM (Balaras et al 2002b). Additionally, a series of related guidelines have also been prepared on building deterioration assessment, building environmental impact, rental housing and neighborhood quality impact, financial effectiveness of the investment and building global value, samples of which are available from the INVESTIMMO web page. The project will be completed in early 2004.

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ENCLOSURE SYSTEMS DESIGN AND CONTROL SUPPORT VIA DYNAMIC SIMULATION-ASSISTED OPTIMIZATION

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ABSTRACT

This paper presents a computational environment for performance-based integrated building enclosure design and control support. The key concepts and features of this environment include: virtual enclosure, construction mapping, and shading device recommendation. Optimization methods are adapted and dynamically applied to derive the basic properties of a "virtual" enclosure for a given set of indoor climate requirements. These values are then mapped to a construction database to identify an actual building enclosure construction. The support for the real-time operation of the dynamic components of the building enclosure makes use of the time-step utilization of optimization methods. The functionality of the system is demonstrated via illustrative case studies.

INTRODUCTION

Building enclosure plays an essential role with regard to the overall performance of buildings. Specifically, energy performance, thermal comfort, and lighting conditions are significantly affected by the quality of enclosure design and its operational status. Previous research attempted to support the design of specific elements of building enclosure such as windows (Thiratrakoolchai 1986) as well as multiple parameters: U-value, solar transmittance, visible transmittance, glazing ratio, etc. (Jurovics et al. 1985, D'Cruz & Radford 1987, Bouchlaghem & Letherman 1990, Mathew & Mahdavi 1998, Pal & Mahdavi 1999). Most previous systems for optimal thermal performance usually consider only the illuminance level as the indicator of visual performance. Moreover, previous systems only help identifying the optimal material properties (i.e. thermal resistance, visible transmittance). Depending on this information, the user has to figure out what the actual enclosure should be. In addition, previous research studies did not address what the appropriate choice of shading devices (i.e. internal movable, external fixed, external movable) should be.

SYSTEM FUNCTIONALITY

The functionality of the proposed system is expected to: *a)* allow the user to explore different enclosure parameters; *b)* help identify the desirable material properties of building enclosure layers; *c)* retrieve appropriate enclosure components from a construction database; *d)* suggest appropriate shading devices; *e)* suggest an operation regime for the dynamic components of the building enclosure in response to thermal and visual performance criteria.

VIRTUAL ENCLOSURE

In this research, the facade is seen as a "virtual enclosure" which is an abstract representation of the relevant behavioral properties of the interface between indoor and outdoor environment (an "optimized" virtual enclosure allows for mapping into multiple possible (actual) realizations, depending on the applicable (e.g. locally available) repertoire of constructions). It consists of an opaque wall portion and a transparent (glazing) portion (Fig. 1). The opaque portion is modeled as a three layer composite wall. Each layer has two main properties, thermal resistance and thermal capacity. Thermal capacity (TC) is defined as the product of thickness, specific heat, and density. The glazing portion is specified in terms of thermal resistance, solar transmittance, and visible transmittance. The glazing percentage of the enclosure is also considered. In addition, the system will allow the user to control or modify the window geometry (proportion, position).

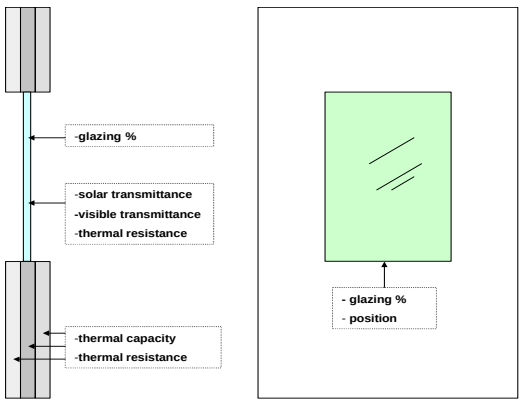

Figure 1: Parameters of the virtual enclosure

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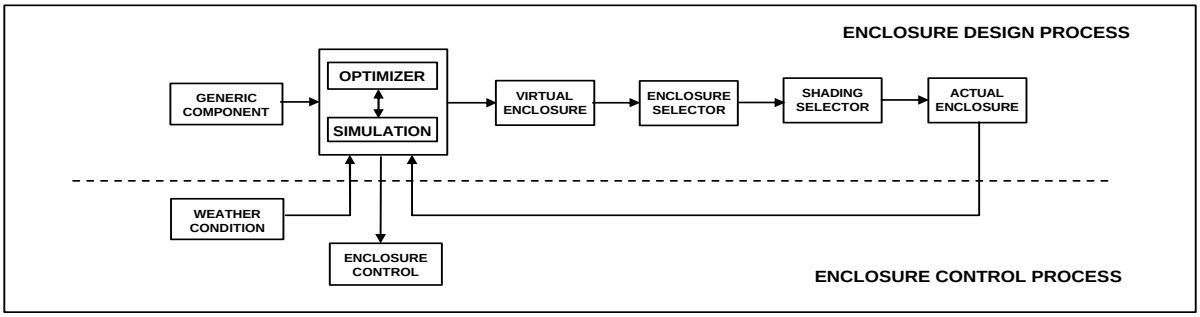

Figure 2: Proposed system functionality

SYSTEM IMPLEMENTATION

Overview

In order to support the aforementioned functionalities, the proposed system includes six main components (Fig. 2): *i)* thermal and visual simulation tools; *ii)* optimizer; *iii)* component database (wall, glazing); *iv)* enclosure selector; *v)* shading device selector; *vi)* graphical user interface.

A typical use case involves the following steps:

1. Virtual enclosure - This is an abstract representation of physical transfer phenomena and not a set of actual building layers. Optimization methods are adapted and dynamically applied to derive the basic physical properties of the enclosure (both opaque and transparent parts) for a given set of indoor climate requirements.
2. Enclosure Selection - The basic components of the building enclosure are determined in that the attributes of the optimal virtual enclosure are mapped to a database of actual building enclosure constructions.
3. Shading device selection - Using a knowledge-based mapping method, the "passive performance signature" of the basic enclosure configuration is used to derive recommendations for secondary enclosure devices for shading and light redirection.

The system can also be used for optimally controlling dynamic enclosure components (such as movable louvers) in order to provide the preferable visual and thermal performance at a specific time.

Simulation Tools

Thermal and visual performance simulation modules in SEMPER (Mahdavi 1999, Mahdavi et al. 1996) have been adopted for this research. These modules are NODEM (Mathew & Mahdavi 1998) for thermal simulation and LUMINA (Pal & Mahdavi 1999) for lighting simulation. NODEM is based on a transient heat balance method, whereas LUMINA is based on a hybrid radiosity and ray-tracing method.

In order to simulate the effect of daylighting on electrical lighting power consumption and thermal performance, the electrical lighting power consumption needs to be input in the thermal simulation tool. Therefore, the lighting and thermal applications must exchange data. LUMINA calculates the electric lighting power needed to make up the difference between the required illuminance and the available daylight.

Optimizer

Optimization methods – The criteria for choosing the optimization methods suitable for active design support are adapted from Mahdavi & Mathew (1995). These criteria are: *i)* the reliability of the algorithms used to predict the performance attributes *ii)* the transparency of the convergence process, and *iii)* the speed of computation and the state-to-state transition times. All optimization techniques discussed here can be used without simplifying thermal and visual performance evaluation methods. In addition, since all of them are based on iterative improvement, the processes of convergence are transparent. The optimization techniques that have been investigated are: *i)* Hillclimbing multi-restart (Russel & Norvig 1995); *ii)* Simulated-annealing (Kirkpatrick et al. 1983); *iii)* Hillclimbing with STAGE (Boyan 1998).

Objective functions – There are two main objective functions proposed in this research. For enclosure design, the building is considered in passive mode. The temperature profile for a whole year can be used to determine the appropriate shading device needed. The objective function for passive building is to maximize preferences for temperature as well as visual performance (illuminance, daylight glare index, and uniformity) (Equation 1). For buildings with HVAC, the objective function is to maximize energy and visual performance preferences (Equation 2).

$$OBJ_P = \frac{S_T W_T + S_E W_E + S_G W_G + S_U W_U}{W_T + W_E + W_G + W_U} \quad (1)$$

$$OBJ_A = \frac{S_L W_L + S_E W_E + S_G W_G + S_U W_U}{W_L + W_E + W_G + W_U} \quad (2)$$

where OBJ_P: objective function for passive building; OBJ_A: objective function for active building; S: preference score; W: weighting factor; T: temperature; L: energy load (heating, cooling, electrical); E: illuminance; G: daylight glare; U: uniformity.

Constraints – The following constrains are applied to reduce the search space, facilitate mapping from the virtual enclosure to real building constructions, and derive an appropriate window geometry:

1. Opaque wall - Minimum and maximum values of thermal resistance and thermal capacity are considered for each layer (to cater for the location of thermal mass, opaque walls are represented in virtual enclosure in terms of three layers, resulting in three sets of attributes). In addition, by considering the relation between thermal capacity and thermal resistance for building materials (Fig. 3), a constraint function was established. The search space, therefore, is limited to the region under the curve.

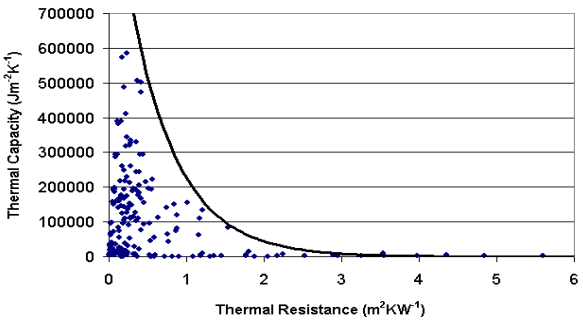

Figure 3: Constraint function for material properties of the layers

2. Glazing - Minimum and maximum values of glazing properties (thermal resistance, visible transmittance, and solar transmittance) are derived from glazing database.
3. Glazing percentage - During the optimization process, the glazing percentage of an enclosure is modified by adjusting the window dimensions. However, a new glazing percentage can not result in windows overlapping or moving out of a wall boundary.

Database

SEMPER provides multiple libraries that contain building information such as schedules, and construction types. The database used for this research has 201 material types, 97 wall construction types, and 207 glazing types.

Enclosure Selection

The optimum properties of the "opaque wall" and "glazing" components of the virtual enclosure are used to search for wall and glazing constructions in the database. However, since the real construction can have less or more than three layers, those layers must be aggregated or partitioned before comparison. "Thermal diffusivity" is used for appropriate aggregation. For a single layer construction, the layer is divided into three layers of equal thickness with the same thermal capacity and resistance. For two layers, the layer with the higher thermal diffusivity is divided into two layers. For a wall construction of more than three layers, all possible layer aggregations are considered and the one with the minimum average thermal diffusivity deviation is selected.

The most preferable wall construction or glazing is the one which has the minimum deviation of all properties from the optimum one (virtual enclosure). Since the impact of optimization parameters on the objective function may vary, the calculation of the deviation score for all optimized variables needs to be weighted. This is achieved based on the past optimization trajectories (Fig. 4). For each parameter a weight (W) is computed according to Equation 3. The wall construction properties' deviation is defined according to Equation 4, and glazing properties' deviation according to Equation 5.

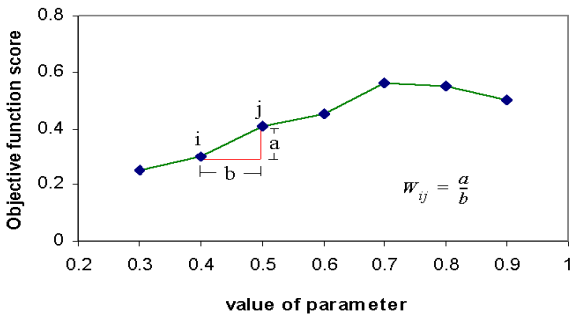

Figure 4: Demonstrative illustration of the effect of an optimization parameter on the objective function

$$W = \frac{1}{n}\sum_{i=1}^{n}\frac{|OBJ_j - OBJ_i|}{|V_j - V_i|} \quad (3)$$

where OBJ_i: previous objective score; OBJ_j: current objective score; V_i: previous parameter value; V_j: current parameter value; n: Optimization parameter value change frequency

$$D_W = |R1_O - R1_C| \cdot W_{R1} + |T1_O - T1_C| \cdot W_{T1} + |R2_O - R2_C| \cdot W_{R2} + |T2_O - T2_C| \cdot W_{T2} + |R3_O - R3_C| \cdot W_{R3} + |T3_O - T3_C| \cdot W_{T3} \quad (4)$$

where D_W: wall construction properties deviation; *R1*, *R2*, *R3*: thermal resistance of layers; *T1*, *T2*, *T3*: thermal capacity of layers; *o*: optimal property; *c*: compared property (from database); *W*: weighting factor

$$D_G = |R_O - R_C| \cdot W_R + |S_O - S_C| \cdot W_S + |V_O - V_C| \cdot W_V \quad (5)$$

where D_G: glazing properties deviation; R: glazing thermal resistance; S: glazing solar transmittance; V: glazing visible transmittance.

Shading device selection

The purpose of the shading device selection functionality is to find out: *i)* if a specific primary enclosure needs a shading device to achieve the desired thermal and visual performance, and *ii)* in case a shading device is needed, what type it should be.

Suppose the preferred temperature and illuminance in a space is defined in terms of preferred ranges (e.g. from t_{min} to t_{max} for temperature and from E_{min} to E_{max} for illuminance). According to these preference ranges, the results of both lighting and thermal simulation for every hour in a predefined time period can be categorized in terms of a number of discrete regions within a temperature-illuminance graph (see, for example, the regions A to I in Figure 5). Each point in each region represents an indoor condition (temperature, illuminance) at a specific time. By performing simulations in passive mode (without heating, cooling, and lighting system operation), the "natural" behavior of a building can be predicted and represented in the aforementioned graph.

Such a graph allows for formulation of general recommendations for the need for and the type of shading devices. An illustrative example of such recommendations is as follows:

1. No shading device is recommended for regions A, D, E, G, H. For E both temperature and illuminance are in the preferred range. For G, more solar gain and daylight is needed, therefore applying a shading device would not improve the performance of either. For H, more solar gain, and for D, more light would be desirable. The high temperature in A is unlikely to be the result of solar gains, given the low illuminance levels.
2. Interior movable shading device is suitable for I and F. An interior shading device allows solar gain to enter the space and thus improve the thermal performance in I. At the same time, an interior shading device can be adjusted to reduce excessive daylight penetration.
3. Fixed exterior shading device is more suitable for C, since an exterior shading device can reduce both solar heat gain and daylight penetration.
4. Movable external shading device may be more suitable for B. An exterior shading device can reduce solar heat gain. At the same time, it can be adjusted to control daylight penetration.

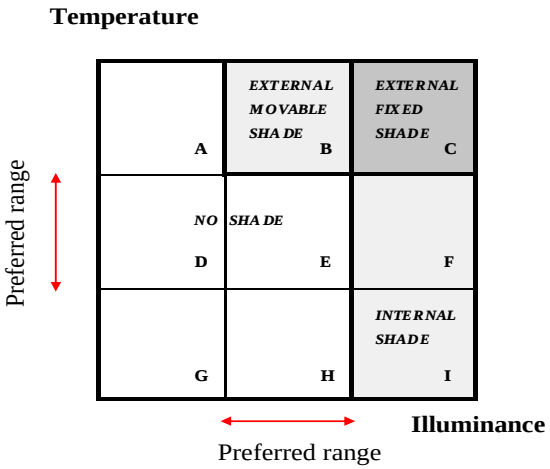

Figure 5. Shading device recommendation for each group of space conditions

However, the thermal and visual conditions calculated for every hour of the reference time period would be distributed in more than one region. Thus, applying a certain type of shading device could result in improved performance in some instances while worsening the performance in other instances. Therefore, the relative distribution of results in each region must be considered when selecting a shading device. To arrive at an aggregate recommendation, heuristic rules may be applied. An Illustrative instance of such rules is given in the following table (Table 1).

Table 1. Rules for shading recommendation

Shading Type	Condition
External (fixed)	[(B+C+F+I) > (A+D+E+G+H)] and [(B+C) > (F+I)]
Internal (movable)	(F+I) > 10% of all instances
External (movable)	[External (Fixed)] AND [(B > C)]
No shade	[NOT External (Fixed)] AND [NOT External (Movable)] AND [NOT Internal (Movable)]

Building Enclosure Control

Once a building enclosure has been designed, the system can be used for real-time control of external movable shading devices and electrical lighting.

During the optimization process, the current weather data is sent to both LUMINA and NODEM. The current dimming power of all luminaires and daylight coefficients (according to current louver position) is updated before LUMINA performs a simulation for the current time step. LUMINA sends the lighting power consumption to NODEM and also provides the system with the current visual performance output information (illuminance, glare index, uniformity). NODEM calculates the energy used for heating, cooling, and electricity (lighting and equipment). Illuminance, glare index, uniformity, and energy consumption data are used by the optimization program to compute the objective function. The best solution found from the optimization is used to set the current louver position and light dimming for the current time step.

Graphical User Interface

A user can input building geometry by drawing a plan on a canvas. The GUI provides default space properties (type, schedule, wall construction, glazing type and percentage) which can be modified by the user. The user can draw window geometry and external enclosure elements such as overhangs or louvers on the selected wall. In addition, the user can draw electrical lighting, occupant's viewing angle, and receiver points, and set the lighting properties (luminaire type, schedule, dimming curve). Data necessary for enclosure design and control optimization (e.g. optimization variables, performance variables considered in objective function) can be specified via GUI.

OPTIMIZATION SETTINGS

For all three algorithms, a new state is chosen by randomly selecting one of the optimization variables and then creating a perturbation in the value of this variable. The perturbation can be made by increasing or decreasing the current value. For hillclimbing, the perturbation direction is decided according to the previous direction that improved an objective function. For simulated annealing, since the previous state can be accepted even it does not improve the objective function, the perturbation is made by randomly increasing or decreasing the value.

Restart begins when the state reaches a local optimum (no optimization variable can improve objective function, either by increasing or decreasing its current value). The new restart point is made by random selection. The selected variables have to satisfy the previously mentioned constraints. For hillclimbing with STAGE, a new restart point is made according to a new restart state computed by the algorithm.

According to experimental results based on optimization settings described above, hillclimbing and hillclimbing with STAGE algorithms perform better than simulated annealing. However, for control purposes (where time is of essence) STAGE might be less suitable.

ILLUSTRATIVE CASE STUDIES

Overview

This section demonstrates the capabilities of the system. There are two main parts of the system: enclosure design and enclosure control. Enclosure design demonstrates three main functions: virtual enclosure optimization, enclosure selection, and shading device selection.

Enclosure Design

Case description – Consider a 10 x 6 m office in a commercial building (Fig. 6). There are three relevant enclosures (E0, E1, E2). Floor, roof, and interior wall (E3) are considered to be adiabatic. Passive building operation is assumed. NODEM and LUMINA are used for simulating thermal and visual performance. The lighting system can be dimmed to maintain an average illuminance at 550 lx. The light power calculated by LUMINA for every time step (1 hour) is used by NODEM. During the optimization process, glazing percentage is adjusted by increasing or decreasing window's width and height. The performance variable values and corresponding weights are shown in Table 2. The optimization variables are listed in Table 3.

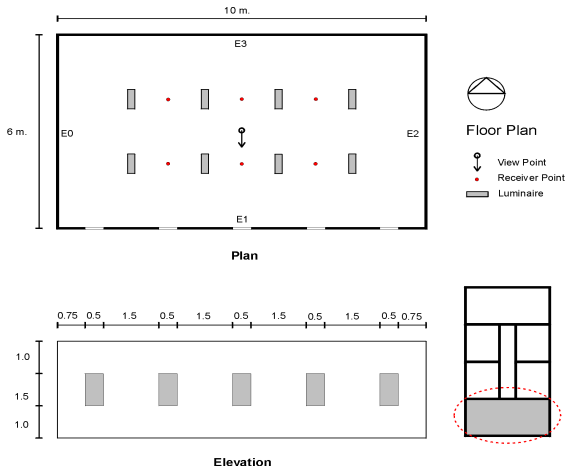

Figure 6. Description of the test case configuration

Table 2. Illustrative performance variable values and corresponding weights for design and control

Performance Variable	Weight	Performance variable scale and normalized score									
1. Temperature (^{0}C)	1.0	5 0.00	11 0.25	16 0.50	20 0.75	23 1.00	26 0.75	30 0.50	35 0.25	41 0.00	
2. Illuminance (lx)	0.5	0 0.00	100 0.10	300 0.50	500 0.80	1000 1.00	2000 0.80	3000 0.50	4000 0.25	5000 0.00	
3. Daylight Glare (-)	0.3	0 1.00	16 0.60	18 0.50	20 0.40	22 0.30	24 0.20	26 0.10	28 0.00		
4. Uniformity (-)	0.2	0 0.00	0.25 0.25	0.50 0.50	0.75 0.75	1.0 1.00					
5. Energy Load (Whm^{-2}) (for 15 minutes)	1.0	60 1.00	80 0.90	100 0.80	120 0.70	140 0.60	160 0.50	180 0.40	200 0.30	220 0.20	240 0.00

Variables 1, 2, 3, 4 are for enclosure design. Variables 2, 3, 4, 5 are for enclosure control.

Table 3. Settings for optimization of enclosure variables

Enclosure	Variable	Initial	Min	Max	Perturbation
0,1,2	R1	0.03	0.00003	1.79	0.20
0,1,2	R2	0.18	0.00003	1.79	0.20
0,1,2	R3	0.04	0.00003	1.79	0.20
0,1,2	TC1	25,610	120	597,839	5000
0,1,2	TC2	95,235	120	597,839	5000
0,1,2	TC3	39,345	120	597,839	5000
1	G-VT	0.10	0.05	0.95	0.10
1	G-ST	0.10	0.03	0.90	0.10
1	G-R	0.19	0.15	1.50	0.20
1	G-%	8.33	10	90	5

Virtual enclosure – Table 4 shows the optimization result of the "virtual enclosure" using a hillclimbing algorithm. For this example, the total number of function evaluations is set at 150. Figure 7 displays the progress of an optimization run. The initial objective score is 0.4515. The maximum objective score is 0.7510. The objective score is improved by increasing all design variables' values except wall TC2 and TC3. During the optimization process a user can see the simulation results for both thermal and visual performance (temperature, illuminance, glare index, uniformity). Figure 8 shows the elevation of the virtual enclosure.

Table 4. Optimization results using hillclimbing

Optimized Variables	Initial Value	Virtual Enclosure	Real Construction
R1	0.03	0.78	0.38
R2	0.18	1.79	1.18
R3	0.04	1.76	0.04
TC1	25,610	211,432	216,362
TC2	95,235	18,015	1,363
TC3	39,345	1,253	39,345
G-V	0.10	0.51	0.54
G-S	0.10	0.18	0.26
G-R	0.19	0.78	0.81
G-%	8.33	24.52	-
Objective score	0.4515	0.7510	0.7176

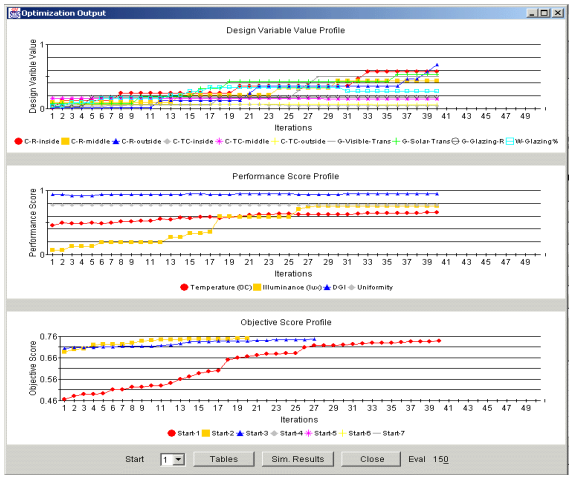

Figure 7. The progress of an optimization run: (top) optimization variable value (all values are scaled from 0-1), (middle) performance score of all performance variables, and (below) objective scores of each restart

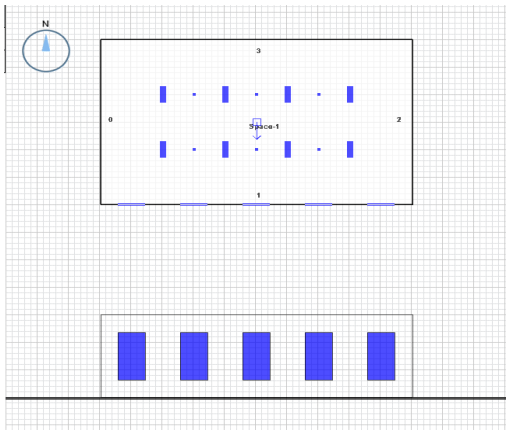

Figure 8. Virtual Enclosure Elevation

Enclosure selection – Once the virtual enclosure has been derived, the wall and glazing properties can be used to identify actual wall construction and glazing type. The user selects the preferred "virtual enclosure" by specifying the start and iteration number and the ranking number (Figure 9). The default start and iteration number is the one that has the highest objective function. The system searches for wall construction and glazing in the database. Once the search process is completed, the system generates a ranked list of possible wall constructions and glazing types. The user can then select which combinations are to be tested. The testing process is done by updating the properties of the walls and glazing, simulating thermal and visual performance, and calculating a new objective function. Table 4 shows the properties of wall and glazing selected from the database. Details of the wall and glazing are shown in Table 5.

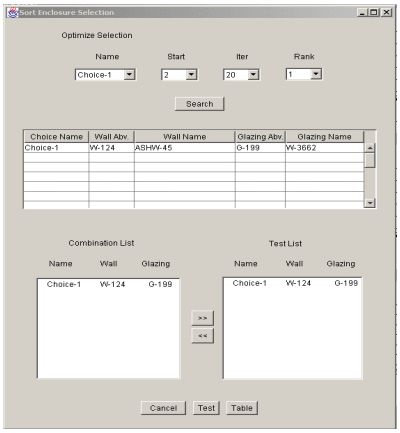

Figure 9. Wall and glazing search in the database

Table 5. Wall and glazing selected from the database

Wall (inside-outside)	Glazing
- plaster (20 mm) - clay tile (200 mm) - insulation (50 mm) - stucco (25 mm)	triple low-e clear insulating glass

Shading selection – Figure 10 shows a shading device recommendation. For this case, a movable interior shading device is recommended.

Enclosure Control

A 5 x 4 m office is considered in active operation mode (Figure 11). Temperature set points are 25 ^{0}C for cooling and 20 ^{0}C for heating. The lighting system can be dimmed. The time step for control is 15 minutes. The control variables are shown in Table 6. The performance scores are shown in Table 2. The system is used to find the best control option for dimming power and louver position according to the current weather condition. For testing purposes, Pittsburgh weather file is used.

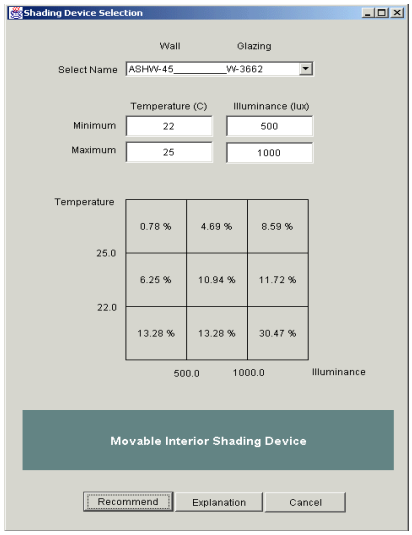

Figure 10. Shading device recommendation

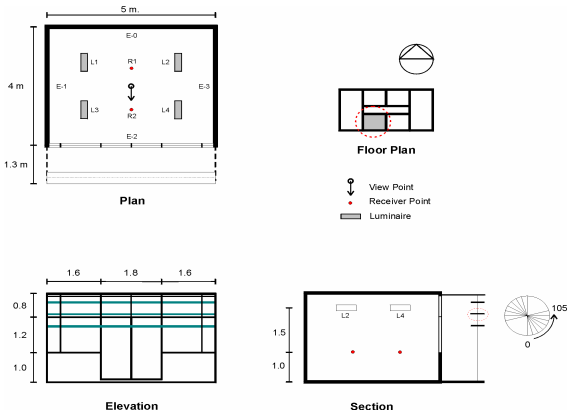

Figure 11. Configuration of the enclosure control

Table 6. Settings for optimization of device operation

Optimized Variable	Initial Value	Min	Max	Perturbation
Louver	90	0	105	15
Luminaire-1	1	0	1	0.1
Luminaire-2	1	0	1	0.1
Luminaire-3	1	0	1	0.1
Luminaire-4	1	0	1	0.1

To evaluate the performance of optimization method for control, the visual and thermal performance inside a space for three control options are compared (using objective function shown in Table 2):

1. Fixed louver position 90^0, luminaires dimming 1;
2. Fixed louver position 45^0, luminaires are automatically dimmed to maintain illuminance at 550 lx;
3. Louvers and luminaries are controlled by using hillclimbing multi-restart method.

The above settings are simulated for 9 to 5 pm (every 15 minutes) in December. The results show that by using an optimization method for control the objective score for both visual and thermal performance (Figure 12) can be improved over option 1 and 2.

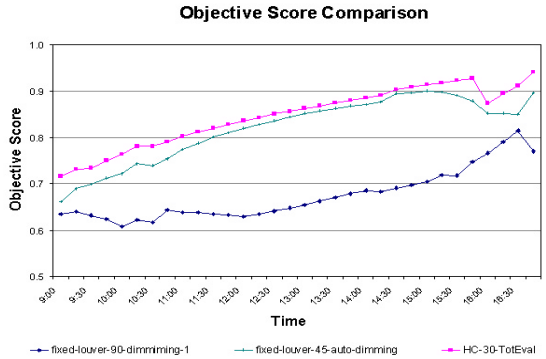

Figure 12. Objective scores comparison for three different options of louvers and luminaires

CONCLUSION

We presented a computational environment that uses building performance simulation and dynamic optimization to support the design and control of building enclosure systems. For a given context and desired indoor environmental (thermal and visual) conditions, the system derives the optimal properties of a virtual enclosure. These properties are then mapped to a construction database to select an actual enclosure system. Using the performance signature of the building in passive mode, a knowledge-based approach helps to decide if and what type of shading devices (internal, integral, external) would be desirable. Building enclosure operation support (real-time control of adjustable enclosure devices) is supported via dynamic utilization of the optimization tool. Future research must address additional features that are needed to accommodate queries pertaining to specialized constructions (e.g. double facades, active radiant enclosure configurations). In addition, a more comprehensive set of simulation applications are necessary to consider a richer set of performance indicators. Finally, the performance of the system in identification of optimal enclosure configurations and their control strategies must be documented on the basis of a more comprehensive validation study.

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3D DIGITAL GEOMETRIC RECONSTRUCTION OF THE URBAN ENVIRONMENT FOR DAYLIGHT SIMULATION STUDIES

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ABSTRACT

In principal, the algorithms used in advanced lighting simulation software are equally applicable to interior and exterior situations [Ashdown 1994][Ward 1998]. In practice the scope is limited: a realistic CAD model of a building in a complex urban geometry can have two/three orders of magnitude more data elements than a detailed model of a room. This is reflected in the computer power needed and, significantly, in the time required for the collection and input of data. These factors, in turn, determine the usefulness of the computation within the design process and place limits on the stages in which it can be incorporated. This paper examines the techniques available at the present time that can be used to aid the collection, recording, design and reconstruction of 3D Model Geometry for use in Computer Daylighting Simulation.

INTRODUCTION

This paper deals with an important area of building simulation and analysis, that of appropriate modelling to enable accurate use of Global Lighting Simulation systems. Designers are starting to recognise the value that performance simulation modelling can have as part of the design process. Computerised building lighting performance simulation is a powerful tool for the virtual toolboxes of architects, engineers and developers.

Such modelling provides valuable information that not only helps designers to make better decisions about the characteristics of building envelopes, glazing, lighting and daylighting systems but also aids the study of a buildings aesthetic and general design. This enables designers and associated professions to employ computer simulation modelling of the building envelope, interior space and surroundings to carry out solar access and daylighting studies in the context of building design and building performance evaluation.

Daylighting simulation of complex urban environments as with many other Virtual Reality applications requires as an input the construction of complex and relatively accurate three-dimensional models, which represent real-world scenes. This has always been a time consuming and frustrating process in simulation model design and execution.

In order to achieve reliable results at the end of the simulation process, it is crucial to identify from the beginning all the factors that could influence the simulation system and consider them as parameters during the simulation execution. It is therefore impossible to start a daylighting simulation process unless a large amount of preparatory work has first been carried out in order to define and set up the simulation system and its parameters. There are three basic types of inputs required:

a) 3D Model Geometry

b) 3D Model Materials, (physical attributes: Textures and Colours)

c) Sky type description and Sun position according to Date and Time

The recording and reconstruction of the geometry of the urban environment are at the same time the most difficult and important tasks. This paper examines the techniques available at the present time that can be used to aid the collection - recording and design-input of 3D model geometry in daylighting simulation. (Figure 1)

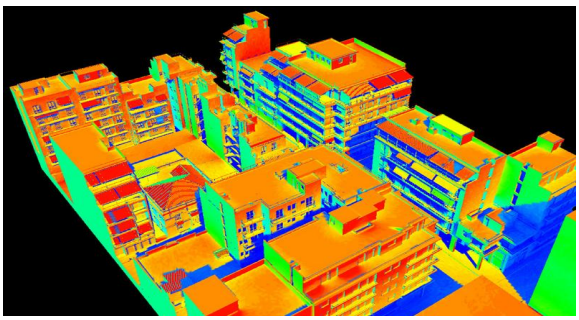

Figure 1
Large scale 3D Model used in Daylighting Simulation.

Information and documentation was acquired from a detailed case study dealing with the digital reconstruction of an urban canyon in Athens, Greece. The case study was carried out for the purposes of a detailed investigation of solar access and the daylighting simulation research of urban canyons [Nikiforiadis Pitts 2002]. (Figures 2 and 3)

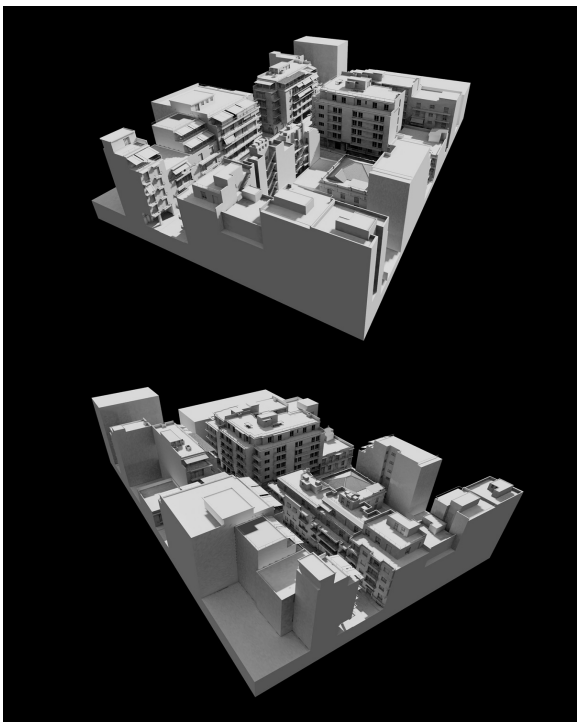

Figure 2
The large scale, urban model that was created for the needs of the case study in Athens.

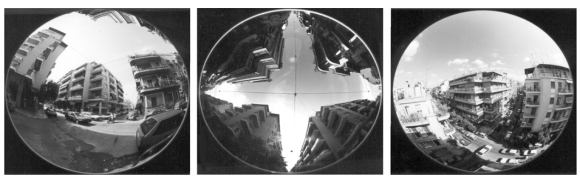

Figure 3
Fish-eye lens photos of the residential apartment building and its urban surrounding

In this paper different approaches are presented emphasising both strong and weak points of their application.

The list of issues addressed includes:

a) Facing detail and abstraction needs of daylighting simulation

b) The use of digital photos together with photogrammetry for the recovery of geometry

c) Solid modelling vs surface modelling

d) Parametric modelling.

The work part of which is described here should enable future daylighting simulation users make the appropriate choices of modelling strategy from an early stage saving time and reducing the cost of their investigation. It is also an opportunity to introduce the advantages of Digital Photogrammetry as a tool for reconstructing 3D models for daylighting computer simulation and to point out strengths and weaknesses of current CAD and 3D modelling packages when used for simulation needs.

The information and conclusions presented will help to serve as a design guide for the digital reconstruction of 3D geometrical models of the urban environment used as an input for daylighting computer simulation studies.

FACING DETAIL AND ABSTRACTION

Abstraction, in other words the way to represent physical reality within the model, is a key concept in all aspects of a computer model creation and simulation. It must be considered at all stages, from deciding which parts of the built environment to model to the definition of representative occupancy schedules mimicking real life conditions. The aim is to keep the model as simple as possible consistent with the avoidance of significant errors resulting from oversimplification.

A common mistake is to create an overly complex model: as model grows more complex, the potential for input errors and the cost of quality assurance increases [Fishwick 1995]. The level of modelling detail affects accuracy – the user must judge, as discussed above, whether all the design variables that are likely to have the major impact on the performance question of interest have been included in the model.

One of the most common assumptions made today in natural lighting assessment and simulation is that of ignoring external obstructions caused by the surrounding environment, as if the building is in a featureless plain landscape. For broad issues of daylight design, such an assumption may not be a problem, however, in detailed or complex lighting situations it could lead to serious errors. The main difficulty is the exclusion from assessment of external features especially in climates where sun-shading is used in the building envelope and mutual shading of buildings is common, or where surfaces of nearby buildings have a significant influence on daylight penetration.

The above issues are also related to the bigger problem of the lack of ability to properly describe the surrounding environment and the microclimate.

Topography, the surrounding terrain and the natural three-dimensional features (such as vegetation), which also experiences a seasonal variation, as well as many geometric features of surrounding buildings are excluded from the normal simulation/assessment system. One of the main difficulties is the recording and inputting such complicated data in the computer simulation software.

In general models built for daylighting studies need to be assessed in greater geometrical detail than those used for example in thermal modelling studies. The accurate placement of fenestration, shading devices, internal fitting and external obstructions is a definite requirement.

The most obvious and important aspect of daylight simulation and design is the variable nature of the source. The results of calculation are tied to a prediction of external conditions that vary with the time of day, the date in the year, and with the weather. In Southern Europe it is usual to consider two types of conditions: firstly an overcast sky and secondly a clear sky with or without sunlight. In Northern Europe and particularly the British Isles the former condition is so common that it is necessary to base daylighting technique on the provision of minimum standards of lighting under overcast conditions alone [Philips 1964].

Where overcast skies are more common, over comparatively small changes in latitude, it is practical to think of the light admitted as a percentage of the total light available from the hemisphere of the sky. Orientation and location plays then a less important role. This fact forms the basic difference in approach between Southern and Northern Europe.

For the needs of daylight factor (DF) prediction, it is normally necessary to include nearby external obstructions but in such a case building façades can be simply modelled using a single material whose reflectance is an area-weighted average of the reflectance of major façade elements. [Mardaljevic 1998] With clear sky conditions it is possible and practical to work with actual values of illumination that will vary considerably with orientation, location and season.

Often spaces face complex exteriors; the geometrical surfaces of their objects can either act as obstructions or as reflectors of both the sunlight and skylight (such as in the cases of overhangs, balconies, extensive glazed areas). Identifying their role and finding ways of including them in an abstract form in the simulation model becomes an impossible task as their role changes with the constantly varying position of the sun. This leads to the unavoidable need to give a detailed geometrical description of the surrounding environment and allow the simulated light to determine their exact role in the scene. Therefore a totally different approach is needed in the case of illuminance predictions taking into consideration the effects of both direct sunlight and diffused light reflected from the surrounding environment as in the case of nearby building structures.

As it is not always possible to identify and limit the number of surfaces that participate directly in the indirect irradiance calculation at the cost of simulation time, it is necessary to model the nearby external environment in fine detail as its shaded and illuminated surfaces have a crucial impact on the internal light levels of spaces facing them. This is why in such a case abstraction at least of the geometrical form should be avoided. As a rule especially where visual realism is intended, the scale of modelling complexity should normally be commensurate with the scale of the effect of the modelled structures on internal light levels.

As explained above the accurate description of 3D geometric form together with that of the physical attributes of the exterior materials of a building is critical as it has major effect in the quantity and direction of the light distributed in the built model. Obtaining a substantial body of data for prediction of daylight levels and overall light loss based on the relationships of geometry; obstruction and daylight could be very valuable for building planning and lighting energy management especially extended to other types of speculative buildings situated in the urban areas.

USE OF PHOTOGRAMMETRY FOR THE RECOVERY OF GEOMETRICAL FORM

This work examines the use of photogrammetry as a technique to model external obstructions that have as a main characteristic their great complexity of form, and size.

Photogrammetry is the science of making measurements from photographs. It uses photographic records for precise measurement of distances or dimensions. Photogrammetry is often used today in advanced archaeology building surveying and has been recently introduced in advance surveying computer tools.

Photogrammetry software produces three-dimensional models based on images of the object made from known locations. The procedure entails importing an image either by scanning printed photographs or directly from digital camera. “Object points” (typically corners) are then marked on the images so as to enable the three-dimensional model to be

constructed. Marked object points on the different photographs are then identified and referenced.

The software uses the camera positions and orientations to calculate co-ordinates of every marked and referenced object point and the result is the basic three-dimensional model with estimates of errors for every point. A model is scaled by entering into the programme a known (measured on-site) distance between two object points. The bigger that distance the more accurate the distance approximation. Once a model is scaled and augmented if necessary, it can be exported to other packages to act as the basis of lighting calculations. Accuracy depends on several factors, notably the quality of the camera used, the viewing directions of the photographs, the number of photographs on which each point is marked and the capability of the software to interpret the image (for example recognition of hidden or partially hidden surfaces). In order to reconstruct the three-dimensional model of the urban environment described in the case study a total of more than 300 photographs were taken using a professional analogue camera. The photographs were digitised at a later stage using a flat scanner. This allowed images to be obtained in higher resolutions, than those possible by today's digital cameras.

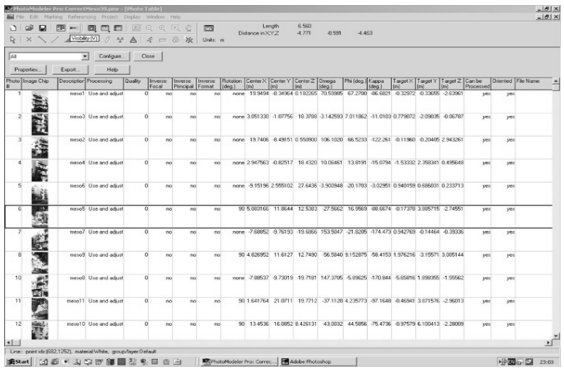

Figure 4
Table of photographs used for the reconstruction of a single building

In the case of this investigation an average of ten to twenty photographs were taken per building to allow recording retrieving detail of both the building form and fabric. Once the images had been processed in Photomodeler the resultant three-dimensional wire-frame model was exported in DXF format to AutoCAD and based on that a three-dimensional model of the building was constructed using Constructive Solid Geometry. (Figures 4 and 5)

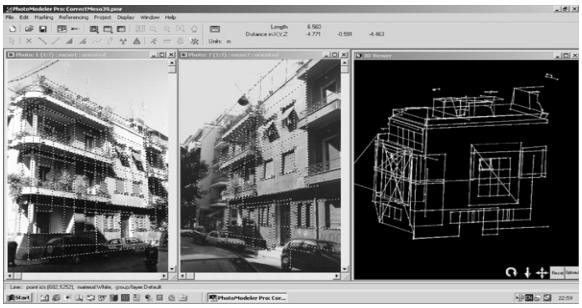

Figure 5
Wire-frame model created for a single building in Photomodeler

USING CONSTRUCTIVE SOLID GEOMETRY

Constructive Solid Geometry (CSG) is a CAD design method used in certain areas of engineering design in which the emphasis is placed on modelling individual parts as objects; In CSG modelling, the history of successive operations constitutes an object's representation. The more commonly encountered Boolean operations in the B-rep-based systems used in architectural design do not record histories of operations as part of object representations. They are applied locally to parts of objects, rather than globally to the whole model. As a result using CSG modelling to form complicated geometrical forms is computationally expensive and for this reason not commonly used in architecture. [Szalapaj 2001]

This case is an exception to the general rule. The use of CSG was the most efficient and productive way to convert an accurate wire frame model exported by the photogrammetrical software package to a volume model reconstructed inside a CAD package (Figure 6).

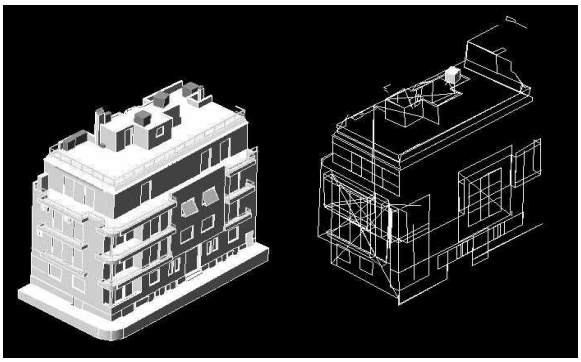

Figure 6
Solid model built with CSG using the dimensions provided of the Wire-frame model

Each building was approached as an object. Modelling was carried out by applying successive global Boolean operations to geometric primitives such as cubes, cylinders, spheres, cones, etc. At a later stage each individual building (designed as an object), was divided inside the CAD package into groups of surfaces placed into different layers according to the materials they represented.

This layer organisation made the assignment of specific materials attributes inside the Global Lighting Simulation Software an easier task.

COMBINING USE OF SURFACE AND SOLID MODELLING

In contrast to its urban surrounding the principal building investigated was modelled from the beginning in a CAD environment.

The building was built in the 1965 and all the existing plans found were in the form of blueprints. Those plans were converted to digital images and then were imported in AutoCAD to be used as a background for line tracing. The model was then built by extruding mainly traced lines into surfaces.

The scans could have been vectored after being digitised but that would have brought in the modelling process a serious number of errors. Previous experience revealed many problems in building 3D models in this way as it is impossible to have the accuracy needed to easily create 3D surfaces without possible errors. (Figure 7)

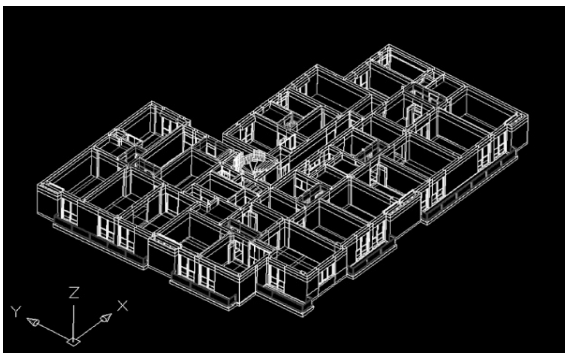

Figure 7

Surface model of the typical floor built with successive extrusion

Both the exterior and interior surfaces of the building were modelled so that when the simulation is completed there is the option of checking the daylight performance in any selected room of the building.

The first stages of the work were tedious and frustrating and the principal difficulty lies in the fact that surfaces need not only to be accurately designed but also placed in the correct layers according to their material. As a result it took substantial amount of time to organise the model in the appropriate layers. (Figure 8)

The same task would have been more or of equivalent difficult using CSG. The main reason was that the existing blueprints were in the form of critical views and sections and did not show the principal building in a 3D view. If this approach had been adopted forming the building as a single volume would have been relatively easy but dividing it into surfaces according to material would have been almost impossible. It was estimated that more time would be spent in organising than designing.

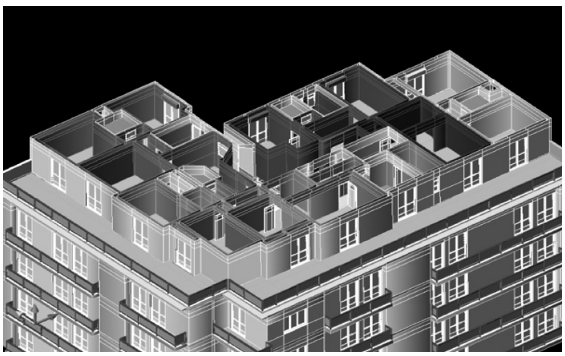

Figure 8

Nearly complete surface model of the principal building

USE OF PARAMETRIC MODELLING

The Operation would have been slightly different if the investigation had been of a new proposed building. In most cases, several design alternatives would be of interest. A reference or base case design would have been required against which these alternatives could have been compared. The reference would have normally been then the initial design intent. It would have been sensible to exclude any novel or unusual features from this reference model. Design alternatives could have then been incorporated within model variants compared with the reference.

In such a case the use of constructive solid geometry or even better parametric modelling as it is available today inside some commercial software (for instance Revit, Inventor and Mechanical Desktop) could have been the ideal approach.

DISCUSSION

The case study permitted the trial of photogrammetry methods on a live design problem. The technique was used to model the exterior urban built environment

surrounding of a particular building (including buildings, streets etc).

The capacity to produce a model from a series of photographs is a major advantage. In some urban environments the scale, movement of objects and everyday life of the living population prevents the gathering of the extensive detailed measurement required to produce easily, in any other way, a three-dimensional model.

The method also allowed the insertion and merger of the geometry of the urban surrounding with that of the principal building although the second was modelled in CAD starting from digitised scans of the original blueprints drawn in the mid 1960s.

Although the techniques of photogrammetry have been shown to have potential as an aid to daylighting design tools, a number of problems and limitations were encountered.

The main problem was focused on the capturing of enough information to permit translation of the photographs of complex environments within Photomodeler. A major barrier to data capture was the limited range of camera positions available for certain buildings and the lack of previous experience while attempting the photographic survey. Ideally each object should be wholly visible in four photographs, each separated by an angle of 90 degrees but in practice at least a dozen were necessary to cover the scale and complexity of a multi-stories building.

Even with the simple arrangement of buildings in a crossroad it proved difficult to capture the necessary images of each building because of the scale, height, density and complexity of their forms. An advantage realised at a later stage was the fact that their form was in most cases repetitive in their vertical dimension.

Once in the photomodeler environment, the accurate marking of the individual building (object) points proved difficult particularly where the building envelope had little colour or contrast difference.

Fortunately the choice of scanning in high resolution all the photographs of the urban environment proved to be a great advantage when trying to determine exact edges and vertices (although it created some problems with their file size). This was even more easy in the areas of the urban environment were greater photometric and colour contrast had been captured in the photographs.

In any method of modelling a complex interior it is likely that errors will occur. The production of a conventional CAD model requires physical measurements of transcription in the "conventional" surveys as a preliminary. The use of photgrammetry reduces the amount of physical measurement to that required scaling the image.

On the other hand, errors can be made in the marking of the photographs or images in the photogrammetry programme. These can be minimised by increasing the resolution of the photographs and/or increasing the number of photographs taken for each building or scene object. Many of the problems of image identification would be overcome by the use of the more sophisticated photogrammetry programs that are now on the market which have better interpretative capacity including automatic recognition and modelling of specific configurations and hidden, or partially hidden surfaces.

THE FUTURE OF 3D RECONSTRUCTION AND SCIENTIFIC VISUALIZATION OF LARGE SCALE ENVIRONMENTS

There now exists an era when the acquisition of 3D data will be ubiquitous, continuous, and massive. These data are coming from multiple sources including:

- High-resolution, geocorrected imagery from aerial photography and satellites;
- Ground-based close-up images of buildings and urban features;
- 3D point clouds from ground 3D laser scanners (Cyrax) and airborne laser range-finding systems (Lidar); and
- Imagery from Synthetic Aperture Radar (SAR).

Currently mobile geo-located systems are being developed, some containing calibrated laser range-finders and cameras [Allen 1998], that will collect street-level detail at unprecedented resolution.
(http://graphics.lcs.mit.edu/).

In the future, mobile individuals or robots will be equipped with cameras and other sensors and the computational power to pervasively collect and organise geolocated data.
(http://www1.cs.columbia.edu/~atanas/research/avenue/)

To make these data useful, they should be employed to model the real world and the model should then be available for interactive exploration and analysis.
However, the modelling aspect is not straightforward since almost all the collected data has omissions (due to obstructions or poor acquisition conditions), and no single acquisition mode is likely to produce complete models. Ground-based laser range finding can offer highly detailed geometry for the lower floors of buildings, less for upper floors, and almost no information about roofs.

In both cases, appearance information is missing but can be provided by properly rectified imagery. The overall modelling problem is then one of fusing multi-source data consistently and accurately.

As acquisition modes are automated and models are produced, there will be an exponential explosion in the amount of data available for analysis and exploration. The models will ultimately include not only buildings but everything associated with the environment, such as trees, shrubs, lampposts, sidewalks, streets, and so on. Data organisations must be developed to efficiently handle these aspects, and scale to cover whole cities with tens of thousands of buildings and other structures. Since the automated acquisition mechanisms will permit repeated collection over time, both the models and the database should be dynamic.

The main mode of exploration for this massive collection will be through interactive visualisation. The database must be specially organised to support interactive visualisation, both in terms of hierarchical structure and multiresolution models. Further novel graphical methods are required due to the extreme depth of the data. Ultimately, one should be able to fly continuously from overviews of a large city to centimetre-size details on the side of any building. Smoothly joining these different scales may require integration of rendering techniques, such as geometry-based and image-based rendering, in new ways.

CONCLUSIONS

This work has introduced photogrammetry in daylight design of buildings situated in densely built urban environments. The processes have shown to work for examples based on real complex obstructions and the case study has demonstrated its potential use in the modelling, modification and evaluation of alternative building configurations in Environmental Daylight Design.

It is clear that a considerable amount of effort is involved in the collection and processing of images and data to produce usable models at the moment. Still the current techniques could be used as a research tool to model external obstructions when investigating daylight design issues in a majority of situations. It could even prove to be an economic proposition in cases where daylight illumination and user satisfaction is critical to produce a safe, healthy and productive environment. The extra work is acceptable to produce a more environmentally sustainable solution. This is an area in which further research is planned.

As digital photography, photogrammetry and 3D laser scanning software develops the amount of manual input required should be able to be reduced to a point where the use of those technologies in daylight and lighting design in general could become more commonplace.

The researcher would like to draw the attention to the following issues:

Obviously it is still very important from the beginning of any study to identify not only the intentions of the investigation but also to select and use lighting simulation software that can serve the scale of the study. The experience of others that have used the same software is invaluable. Still it is most of the time impossible to know what is feasible and what is not unless it is tried.

Today although computer power is continuously multiplying it is important to keep the number of surfaces describing the scene geometry limited in order to allow the simulation to be executed in a reasonable amounts of time. Still the ability to simulate larger and more complex environments grows giving the freedom to describe larger scene geometries as part of the simulation model.

It is the responsibility of researchers to study the relationship between geometric precision and accuracy of daylighting simulation results, as currently there are diseconomies of scale. There is much work to be done as there is a realistic need for validation of daylighting simulation software when they are used in large-scale studies.

The ongoing research at the University of Sheffield has the aim that in the future a series of guidelines and clearly identify techniques to improve productivity will be produced.

ACKNOWLEDGMENT

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A MATLAB-BASED SIMULATION TOOL FOR BUILDING THERMAL PERFORMANCE ANALYSIS

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ABSTRACT

This paper presents the development of a simulation tool based on the Matlab computational environment for building temperature performance analysis with automatic control. The simulation tool contains mathematical models for buildings, HVAC (Heating, Ventilation and Air Conditioning) systems, sensors, weather data and control algorithms. The building mathematical model is described in terms of state-space variables, with a lumped approach for the room air governing equations – energy and mass balances. In this context, the simulation tool structure and components are explained. Five control strategies applied to HVAC systems, integrated to building zones, are discussed as well. A simulation example illustrates the use of the software presented.

INTRODUCTION

The mathematical description of thermal behavior of building systems is complex since it involves the modeling of several interconnect subsystems, each one containing long-time constants, non-linearities and uncertainties such as convection coefficients, material properties etc. Moreover, external unpredicted perturbations, i.e., external weather (temperature, humidity), soil temperature, radiation effects and other sources of energy, such as people, illuminations and equipments, should also be taken into account.

Some points related with building modeling include the analysis of thermal comfort and energy consumption. Several software environments for building simulation are available all over the world, for instance, DOE-2, BLAST, EnergyPlus, Genopt, SPARK, Energy-10. However, computer processing power has been considerably improved in the last decade so that the use of mathematical packages such as Matlab/Simulink can be considered also as a good option for performing simulation-based building thermal analysis. In addition, the use of Simulink features has provided a user-friendly environment for fast configuration of inputs and outputs of the different subsystems included in the building and equipments, such as HVAC (Heating, Ventilation and Air Conditioning).

In this way, a mathematical model for building simulation by using Matlab/Simulink environment is presented in Hudson and Underwood (1999). In this approach, the building is represented by an RC electric circuit and the model is considered adequate for high mass buildings since they are predominantly capacitive. In Mendes et. al. (2001), a lumped approach is used to model the room air temperature and a multi-layer model for the building envelope. The building model allows studying the transient analysis of room air temperature when it is submitted to sinusoidal variation of external air temperature. In Mendes et al. (2002), the model is extended in order to incorporate hygrothermal dynamics of the building and external humidity data. Both works use Matlab/Simulink environment. Another quite interesting example of Matlab/Simulink used in thermal system modeling is the SIMBAD Building and HVAC Toolbox (Riederer et al., 2001). This toolbox provides a large number of ready-to-use HVAC models and related utilities to perform dynamic simulation of HVAC plants. For simulation involving control, this toolbox must be connected to other existing toolboxes.

Another important aspect is the analysis of thermal comfort and energy consumption and its relation with HVAC system control. By using an adequate mathematical model of the building, it is possible to use techniques of automatic control in the regulation of thermal zone temperature and humidity. Some examples of this approach are Dion et al. (1991), Huang and Lam (1997), Ghoumari et. al. (2001), Oliveira et. al. (2003).

The present work describes the development of a toolbox based on the Matlab/Simulink software for hygrothermal building simulation and performance analysis of HVAC automatic control systems. The proposed software version is modularity written, allowing easy expansion and interchangeability of building, HVAC and control systems. The simulation tool contains models for buildings, HVAC systems, sensors and controllers, and actual or typical weather

data. Therefore, analysis of energy consumption/demand and thermal comfort can be made and it is possible to compare different automatic control strategies applied to different building configurations. In the next sections, these main subsystems are described. The mathematical model for a thermal zone, for a HVAC system and a survey of related control techniques applications are also presented. To conclude, some simulation results are presented to illustrate the proposed software environment.

BLOCK-ORIENTED STRUCTURE

The approach of object-oriented software engineering provides a flexible and useful environment for design, development, and modification of classes and their relations in software development.

Each element of thermal system will be a separate module and can be represented by blocks constructed in Simulink. This approach based on blocks makes easier the composition of a complex thermal system. The different blocks of thermal systems for software engineering design based on object-oriented methodology are: building, controller, HVAC system, weather, sensor, and perturbation.

Description of the blocks

The block "Building" provides information about building geometry, material properties and mathematical modeling for predicting thermal loads. Some inputs of this block are the weather data file, ground temperature and perturbations. The outputs are the building zone temperature and humidity.

The block "HVAC system" is also described in the space state form and contains all information related to the available HVAC devices. For heaters, this block presents as inputs the control signal and building temperature and as output the heater temperature.

The block "Sensor" describes the measurement characteristics. The block "Controller" accepts as input the reference temperature or relative humidity (desired room air temperature and relative humidity) and as output the control signal.

The block "Weather" contains data files of several cities.

The block "Perturbation" is composed of perturbations (people, equipment etc.) on internal temperature based on general schedule data.

Building

The first step is the definition of the building geometry and thermophysical properties of all elements. In our first release only a Cartesian geometry can be entered. The mathematical model described below is based on the energy and mass conservation equations for a control volume of a thermally uniform zone.

Thus, for a room enclosed by m surfaces conditioned by an electric heater, we find,

$$r_A c_A V_A \frac{dT_A(t)}{dt} = \sum_{i=1}^{m} h_{\text{int}} A_i \left[T_{n,i}(t) - T_A(t)\right] + h_c A_c \left[T_c(t) - T_A(t)\right] + D(t), \quad (1)$$

where r_A, c_A, V_A, $T_{n,i}(t)$, $h_{int,}$ and A_i are respectively the air density, specific heat, room volume, the n-th layer temperature of wall i, the convection heat transfer coefficient and the i surface area. $T_A(t)$ the room air temperature and $T_c(t)$ the heater temperature (see HVAC systems section).

The perturbation $D(t)$ includes the heat exchanged with the external air through low mass surfaces of the building envelope such as doors and windows and internal gains of energy due to equipment, lights and people. This term can be written as:

$$\mathrm{D(t)} = \sum_{\mathrm{j=1}}^{\mathrm{m}} \frac{\mathrm{T_{eq}}(t) - T_A(t)}{R_j} + q_p + q_e + q_I \quad (2)$$

where q_p, q_e and q_I are the internal gains under the presence of people, equipment and lighting system. T_{eq} represents the equivalent temperature (Air-Sun). The thermal resistance R of j-th surface is calculated as a direct sum of external and internal film resistances and the global conduction resistance.

For each layer k within the wall i, we can obtain the following energy balance equation:

$$r_{k,i} c_{k,i} V_{k,i} \frac{dT_{k,i}(t)}{dt} = K_{k+1,i} A_i \left[T_{k+1,i}(t) - T_{k,i}(t)\right] - K_{k,i} A_i \left[T_{k,i}(t) - T_{k-1,i}(t)\right], \quad (3)$$

where the thermal conductance K, can be estimated by a harmonic mean as

$$K_{k,i} = \frac{1}{(L_{k-1,i}/2)/l_{k-1,i} + (L_{k,i}/2)/l_{k,i}},$$

where $L_{k,i}$ denotes the thickness of layer k and l_k,i, its thermal conductivity. The boundary condition for the external layer can be written as,

$$K_{1,i}\left(T_{2,i} - T_{1,i}\right) = h_{ext}\left(T_{1,i} - T_{eq}\right),$$

For the internal layer ($k=n$) of the i-th wall, we can write the following boundary condition equation:

$$K_{n,i}A_i\left(T_{n-1,i}-T_{n,i}\right)=h_{\text{int}}A_i\left(T_{n,i}(t)-T_A(t)\right)+$$
$$\varepsilon_c A_c F_{s,c-i}\left[T_{n,i}^4(t)-T_c^4(t)\right]+$$
$$\varepsilon_i A_i\sum_{j=1}^{m}F_{s,j-i}\left[T_{n,i}^4(t)-T_{n,j}^4(t)\right],$$

where σ, ε and F_s are Stefan-Boltzmann constant, emissivity and shape factor.

However, for the floor, we consider for $k=1$, a constant soil temperature at a depth of 5m and we apply the boundary condition of imposed temperature.

In terms of water-vapor balance, it was considered ventilation, infiltration and internal generation from equipment and people breath so that the lumped formulation can be written as:

$$\rho_A V_A\frac{dw_A}{dt}=\left(\dot{m}_{\text{inf}}+\dot{m}_{vent}\right)\left(w_{ext}-w_A\right)+\dot{m}_b+\dot{m}_{ger} \quad (4)$$

The water-vapor mass flow from people breath is calculated as described in ASHRAE (1997), which takes into account the room air temperature, humidity ratio and physical activity as well.

HVAC Systems

Heating, Ventilation and Air Conditioning (HVAC) systems are responsible for a considerable amount of energy consumption, especially in office buildings. Therefore, in order to provide some information for simulating thermally conditioned buildings, we present, in a first approach, the mathematical formulation for an electric heater, which can be modeled as:

$$\rho_c c_c V_c\frac{dT_c(t)}{dt}=Q(t)-h_c A_c\left[T_c(t)-T_A(t)\right]-\varepsilon\sigma A_c\sum_{i=1}^{m}F_{s,c-i}\left[T_c^4(t)-T_{n,i}^4(t)\right] \quad (5)$$

where $Q(t)$ is the energy rate generated within the heater by Joule effect, ρ_c, the oil density, c_c, the specific heat, V_c, the oil volume within the heater, h_c, heat transfer convection coefficient between room air and heater and A_c the heat exchange area.

For the air conditioning system, we have two approaches. The first one is based on a steady-state empirical correlation obtained from experimental data for predicting the total cooling capacity (TC), the sensible cooling capacity (SC) and the E.E.R. – Energy Efficiency Ratio. Pereira and Mendes (2003) describe the mathematical correlations for two different 10000-Btu/h room air conditioners; one with reciprocating compressor and the other one with rotating compressor. Those direct Expansion (DX) air conditioners use HCFC-22 as the refrigerant fluid. Their empirical correlations can be written in terms of partial thermal loads or in terms of internal wet bulb temperature and external dry bulb temperature as described by Cherem-Pereira and Mendes (2003).

This steady-state modeling is also used by the building Simulation Program DOE-2.0 and recommended by ASHRAE (1997).

The applicability and functionality of this kind of modeling is also investigated by integrating to the building simulation program DOMUS (Mendes et al., 2003) as this sort of room air conditioners are largely used in Brazil.

The second approach for modeling air conditioning systems is based on their transitory operation, which is much more time consuming and requires many input data that normally are not easy at all to be gathered. However, the dynamic response of HVAC components have a direct impact on the energy consumption/demand and thermal comfort evaluation so that a higher accuracy might be needed in some cases, specially when different control strategies are considered.

Control Approaches for Thermal Problems

The thermal comfort concept depends on some variables such as air temperature, radiant temperature, relative humidity, air velocity, metabolism rate, clothing thermal resistance. Due to such a wider concept, it is not trivial to handle all these features in only one control law. However, sometimes, it is possible to consider explicitly a subset of these factors in a control law. In the following, some control techniques for thermal comfort problems are reviewed, highlighting some favorable characteristics in the context.

Robust Control

In the methods of Classical Control, the knowledge of the system model to be controlled is estimated to be enough accurate, that is, the model uncertainties or the unexpected disturbances are not taken into account when modeling the system.

The uncertainty that affects the system model can have different origins: errors of modeling, parametric variations, parameter uncertainties due to precision, simplifications from linearization and the disregard of high frequency dynamics. Thus, it becomes necessary to adequately represent uncertainties, according to their origin in order to obtain a control law that take it into account.

In this software development, there is the possibility to carry out the control of indoor temperatures, considering, in the controller design stage, the parameter uncertainties of the model, for example, the uncertainties on the convection coefficients. Uncertain parameters may be fixed within pre-defined boundaries or may vary if such variation is slow compared to the system dynamics. The aim of a such new controller is controlling the room air temperature variations minimizing the influences of external temperature, when the room model is subjected to parameter uncertainties. Thus, the control guarantees the system robustness according to parameter uncertainties and/or variations, reducing the effect of external disturbances, by using H_2 (Araujo et al., 2001) or H_∞ (Colaneri et al., 1997) criteria.

Intelligent Control

Intelligent control has been developed for challenging problems that cannot be solved by conventional approaches. In intelligent methods, the representation and manipulation of knowledge are the key issues to be used as an attempt to minimize complexities and eliminate heuristic procedures in process control area providing good transitory and steady-state responses for different operation points of processes.

Intelligent control uses a diverse collection of tools, including expert systems, pattern recognition, and soft computing or computational intelligence (neural networks, fuzzy systems, evolutionary algorithms) methodologies. In general, the tools used for intelligent control depend upon the application.

Fuzzy systems have the advantage of working well with both structured and unstructured data (symbols and numbers input and output). The fuzzy logic controllers can be useful for obtaining thermal comfort. Thermal-comfort-influencing variables are classified in two categories: (i) personal-dependent variables such as activity and thermal resistance of clothing; and (ii) environment-dependent variables such air temperature, mean radiant temperature, relative air speed and air humidity. The fuzzy logic controllers can be employed for inside building air temperature and energy consumption control when the building is subjected to undesired effects of external ventilation, external temperature and humidity (Dounis et al., 1995; Kolokotsa et al., 2001).

The unsatisfactory performance of HVAC control systems is frequently due to the inability of conventional controllers to deal with non-linearities and to adapt to long-term change sin behavior of building thermal systems. Neural networks have been increasingly applied to the control of non-linear systems and are actually finding application in HVAC systems (Curtiss et al., 1994; Fargus and Chapman, 1998).

The evolutionary algorithms — genetic algorithm, evolution strategies, evolutionary programming, and genetic programming — are lines of investigation in simulated evolution, but they are broadly similar: each one maintains a population of trial solutions, imposes random changes to each solution, applies a selection criterion to assess the adequacy of proposed solutions, and determines which to retain for further exploration. The evolutionary algorithms are useful for controllers optimization and tuning procedures of HVAC systems (Huang and Lam, 1997).

A Modified Fuzzy Control for Thermal Comfort

Usually, in the thermal comfort field, there is no need to keep the indoor temperature (and/or relative humidity) in a rigid fixed value; a range of temperatures (and/or humidity) is sufficient to create a comfortable situation. From an economic point of view, there is a need to search for a good trade-off between thermal comfort and energy costs. So, from this point of view, the control schemes that can deal explicitly with these factors are desirable for obtain comfort in a given thermal zone. Thus, the aim is to reduce energy demand and energy costs by keeping some thermal comfort indices within an admissible band and one way to achieve this aim is by setting an appropriate control algorithm.

Fuzzy logic controllers have been used successfully in many applications related with thermal systems, as described in the previous section. However, the fuzzy control scheme proposed in Oliveira et al. (2003) is characterized by consider a band of admissible values for temperature instead of a fixed value. In this work, this is done by following a methodology for the controller membership function adjustment. The analysis is performed on a lumped approach based non-linear model for room air temperature and humidity. The heat transfer calculation is made considering multi-layer envelope for discretization of energy equation (Fourier's law), internal radiation effects and air infiltration. The focus is on the room air temperature control problem by using heating systems. Future works will also include humidity control and the results will be compared with the performance of classic strategies and simulations results show the effectiveness of the proposed strategy.

Adaptive Controllers

Adaptive control techniques include automated identification and control design. From an industrial perspective, adaptation can be considered as a set of methodologies that can significantly improve the performance of a process by providing controllers with automatic tuning, automatic generation of gain scheduling and continuous adaptation. Adaptive controllers are designed to accommodate variations of the behavior of controlled processes. Such controllers can modify their own control strategies to adapt to the new process behavior.

Over the last thirty years, many theoretical developments have been made on adaptive control methodologies but little has been transferred into HVAC systems practice. HVAC systems contain many time-varying and nonlinear processes. Adaptive control techniques are attractive in HVAC applications because process features change widely due to variations in weather and building occupancy (Nesler, 1986). Several adaptive control methods have been proposed in literature for control system of HVAC systems (Georgescu et al., 1994; Wang et al., 1999).

Predictive Control

Another approach that seams to be very appropriated to be used in this scenario is the predictive control scheme, which has already been mentioned in the thermal system control context, as in Ghoumari et al. (2001), Souza et al. (1997) and Dion et al. (1991). Model Based Predictive Controllers (MBPC) are, by definition, based on predicting the behavior of the process to be controlled. The principle of MBPC consists in calculating the control input by the minimization of a cost function over a future time horizon under certain process constraints (Clarke, 1994), and the closed loop performance depends on the choice of an appropriate model for prediction and of several tuning parameters. Predictive controllers can be implemented as adaptive or robust methodologies. So that, model uncertainties can be taken into account.

SIMULATION EXAMPLES

In this section, the building simulation environment is illustrated by two temperature control cases.

Simulation environment:

A workspace for simulation should be generated by connecting the system main blocks (i.e., subsystems) representing building, HVAC, controller, sensor and external weather data. This is based on the Simulink philosophy, where each subsystem is selected in its own library, as shown in Figures 1 and 2. An example of a complete system configuration, ready to perform a hygrothermal building system simulation and analysis, is given by Figure 5. In this environment, the selected building is modeled following the description given in the previous section. The selected HVAC system is a heater and the controller follows the on-off scheme. The libraries are open for further implementations, so more features can be added in the future.

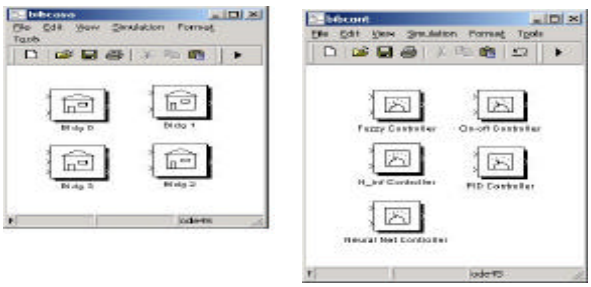

Figure 1: Building and controller library example.

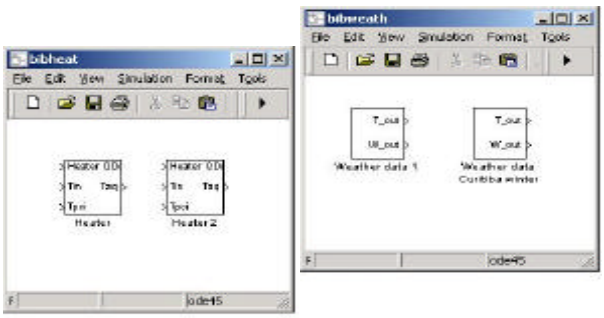

Figure 2: Heater and weather library example.

Simulation Results:

In the following, the closed-loop control performance of two control strategies are compared, the on-off and fuzzy logic based ones. The simulation environment is given by Figure 5 and the changes between the two cases are made just by picking the selected controller in the library. The next step is to set the subsystems parameters.

The building and heater system have the parameters given by tables 1 and 2. The simulations are computed during 48 hours and the unit of all mentioned temperatures is Celsius. The nominal temperature setpoint is 22°C. The internal, external and walls initial temperatures are 11°C and the profile of external temperature is a sinusoidal wave during the whole day.

Figures 3 and 4 present the indoor temperature profile for each controller. Figure 3 illustrates the performance of the on-off controller with a dead-zone defined by $\pm 2^{o}$ around the nominal set-point value. As it is expected, the temperature profile is very oscillatory around the set-point value (22°). The control system takes around 0.46 hours to take the room temperature from the initial state into the admissible temperature band. During the simulation, the regis tered total energy consumption is 269.7 KWh and the system stays 37.5% of the total time using more than 70% of the available power, that is, 15 KW.

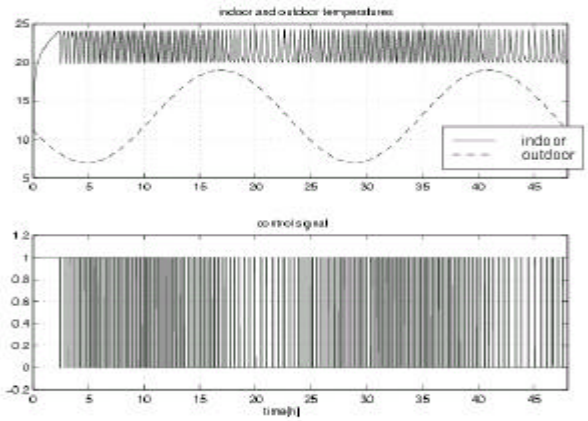

Figure 3: Temperature control using the on-off strategy.

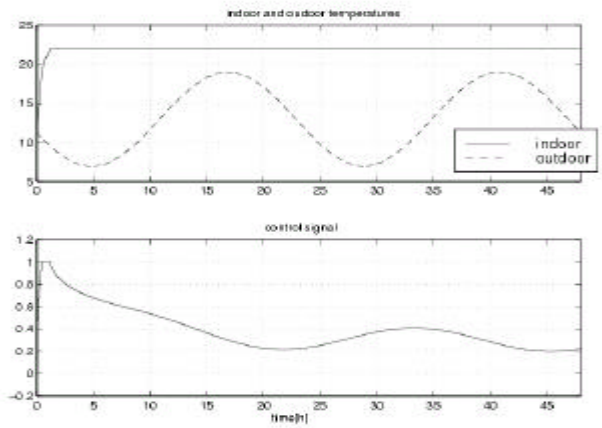

Figure 4: Temperature control using the FLC strategy.

Fig. 4 illustrates the performance of the fuzzy logic controller. It can be noticed that the temperature control performance is improved, in relation to the on-off scheme. The steady state error is zero even on the presence of external temperature disturbances. The control system takes around 0.62 hours to lead the room temperature from its initial state into the admissible temperature band. During the simulation, the registered total energy consumption is 284.4 KWh, that is, an increase of 5.4% in relation to the on-off controller. However, the FLC (Fuzzy Logic Control) system requires only 8.7% of the total time using more than 70% of the available power and, in a steady-state condition, it operates consuming less than 40% of the maximum power. These characteristics reduce the electrical power system demand.

CONCLUSIONS

This paper presented the development of a Matlab-based tool for hygrothermal building simulation and performance analysis of HVAC automatic control systems. The proposed software version is modular allowing easy expansion and interchangeability of building, HVAC and control systems. A description of its block-oriented organization was given and an example of a mathematical model for a thermal zone and for a HVAC system existing in the software tool were also described.

Five control techniques usually applied to HVAC systems (On-Off Control, PID, Robust Control, Adaptive Control and Intelligent Control) were discussed.

A simulation example illustrates the use and the capabilities of the proposed environment in the analysis of control performance and energy consumption.

In future works, the libraries will be extended in order to permit test and analysis of the hygrothermal condition of building system using different types of controllers and HVAC systems. An example is the evaluation of different proposed HVAC control techniques for a summer period using an air conditioning system coupled to a building zone simulation.

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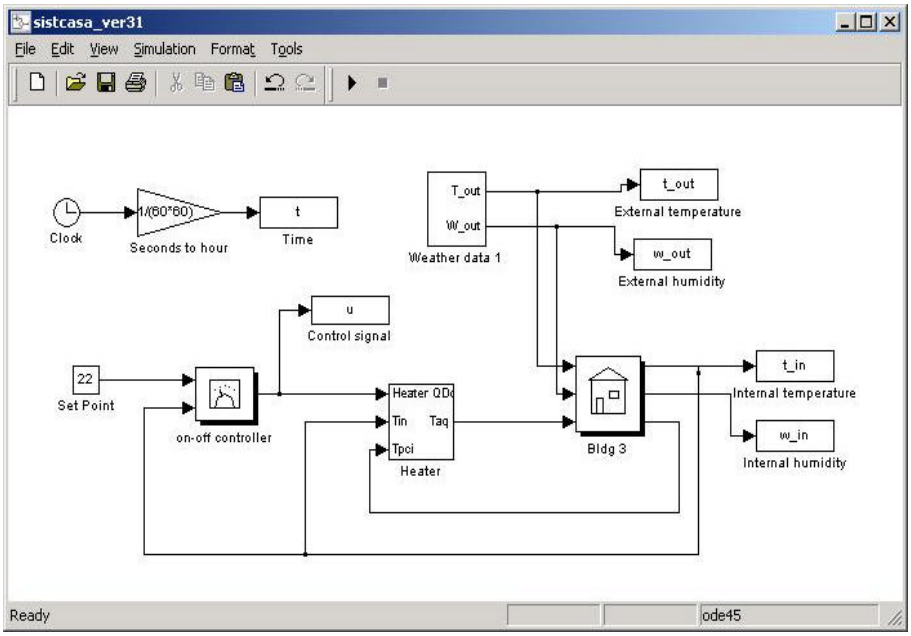

Figure 5: Simulation tool workspace example.

Table 1: Thermal properties.

	ρ (kg/m^3)	c (J/kg-K)	λ (W/m-K)	H (W/m^2-K)
Heater (c)	884.1	1909	---	5.0
Room (A)	1.16	1007	---	5.0
Sensor (s)	8933	385	---	5.0
Walls and ceiling	2050	950	1.92	5.0
	1900	920	0.985	
	2050	950	1.92	
Floor	2050	1840	0.52	5.0
	998	900	1.4	
	550	2385	0.2	

Table 2: Dimensions.

	A (m^2)	L (cm)	V (m3)
Heater (c)	5	---	0.002
Room (A)	25*	---	62.5
Sensor (s)	1.26e-5	0.1	4.2e-9
Walls and ceiling	12.5	2	0.25
	12.5	10	1.25
	12.5	2	0.25
Floor	25	20	5.00
	25	250	62.50
	25	10	2.50

* Floor and ceiling surface area.

News from Affiliates

The contributions from IBPSA Affiliates have all been included elsewhere in this issue:

- from IBPSA-Canada, the announcement of eSim 2004 — **page 17**
- from IBPSA-USA, the announcement of their first conference, Building Performance '04 — **page 18**
- from IBPSA-Greece, Dr Balaras's paper on software for building refurbishment — **page 31**.

IBPSA Membership Information Sheet and Application:

The following information is for membership and orders for IBPSA proceedings. You may order directly from the forms below, or you can request by e-mail a hard copy of the request sheet. Conference proceedings are not part of the membership fee, though they are significantly discounted for members. We are not able to process credit card orders at this time.

IBPSA is comprised of International Regional Affiliates. If you are located within one of the affiliated regions listed on the IBPSA website at http://www.ibpsa.org/regional.htm , please contact the appropriate representative regarding membership in IBPSA. If you are not within any of the affiliated regions, you may join IBPSA central by using the attached form.

Members of the affiliate organization are automatically considered full members of IBPSA-Central. If you are joining IBPSA, please inquire as to the affiliate organization in your region. Additional affiliates may be forming soon.

The IBPSA Newsletter is published twice annually. It contains instructions on how to create an IBPSA affiliate in your region (start-up grants are available from IBPSA), as well as announcements for Building Simulation Conferences. All members of IBPSA's Regional Affiliations receive the newsletter.

TO LEARN MORE ABOUT IBPSA in general, look at the World Wide Web page at "http://www.ibpsa.org"

Thank you for your interest in IBPSA. Join to get more news from the Newsletter.

Jeff Haberl, IBPSA Publications
jhaberl@esl.tamu.edu

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IBPSA MEMBERSHIP INFORMATION

"The professional association devoted to improve the built environment through computer simulation and analysis"

Mission

The International Building Performance Simulation Association (IBPSA) was founded to advance and promote the science of building performance simulation in order to improve the design, construction, operation and maintenance of new and existing buildings worldwide.

Goals:

Along with building designers, owners, operators and developers,

* Identify problems with the built environment that may be solved by improved simulation tools and techniques
* Identify the performance characteristics of buildings on which simulation should be focused
* Identify building performance simulation R & D needs and transfer new developments to the user
* Promote standardization of the building simulation industry
* Inform and educate its members and the public regarding the value and the state-of-the-art of building performance simulation.

Activities:

* Biannual International Building Simulation Conference.
* Resource publication on simulation tools (under development)
* Newsletter announcing upcoming events and software tools.
* Sponsorship of regional workshops and seminars on simulation.

MEMBERSHIP APPLICATION …….. For IBPSA Central……...

Membership Classification Desired (check one): Effective date: Sept. through Aug.

__ Sustaining member.. US$ 500/year
An individual, company, or institution in related practice.

__ Member.. US$ 75/year
A graduate from a college or university, or a registered professional engineer or architect.

__ Student Member.. US$ 25/year
An individual who is a full-time student (Include copy of current enrollment i.d.).

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Item	#Papers/pp	Price (US$)	Conf. Location	Dates
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BS'91	85 / 675	$50	Nice, France	20-22 Aug. '91
BS'93	71 / 570	$50	Adelaide, Aus.	16-18 Aug. '93
BS'95	81 / 717	$50	Madison, WI (USA)	14-16 Aug. '95
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International Building Performance Simulation Association

The regionalization of IBPSA

To whom it may concern

Dear Colleague:

You may be aware of the International Building Performance Simulation Association (IBPSA) which has existed since the late 80s to represent and promote the application of computer-based design and management techniques in the construction industry worldwide.

To further the goals of the organization, we have embarked on a regional development program by which we plan to stimulate the establishment of regionally based, autonomous organizations who are affiliated to IBPSA. In this way we hope to achieve the correct balance between the servicing of practitioner needs at the local level and the provision of information flow at the international level.

I am writing to you to ask whether you might be interested in exploring further the possibility of establishing an IBPSA affiliated organization in your part of the world. To help you reach a decision, there follows details on the regionalization proposal. A copy of IBPSA's Strategy Plan, IBPSA's By-Laws and more general information about IBPSA's activities, biannual Building Simulation conferences, etc. is available from its web site at: http://www.ibpsa.org/

IBPSA very much hopes that you will see merit in this idea and is looking forward to receiving your reply in the near future.

Yours sincerely

The IBPSA President

IBPSA Regionalization Guidelines

IBPSA's Mission
The International Building Performance Simulation Association (IBPSA) is a non-profit making organization that was first incorporated in January 1987. The Association's principal mission is to promote and advance the practice of building performance simulation in order to improve the energy and environmental performance of new and existing buildings worldwide.

IBPSA seeks to achieve its goals through the establishment of a range of products and services aimed at informing and equipping those who are involved in the construction industry and who seek to utilize computer-based tools to good effect. To this end, the **IBPSA Strategic Plan** identifies nine specific areas that encompass the organization's activities. These are:

1. ***Strategic Alliances*** with professional organization such as the engineering and architectural societies. The intention is to engender a better understanding of the profession's requirements and the technology's potential.

2. ***International Conference Series*** to periodically collate and preserve those developments that comprise the current state-of-the-art.

3. ***Technical Development Program*** aimed at influencing the direction the technology of building simulation might take at any given point in time.

4. ***Educational Initiatives*** concerned with the teaching of building simulation in the higher education institutions and in the context of continuing professional development.

5. ***Harmonization Activities*** in an attempt to regularize the application of the different modeling systems through the definition of standard methods for performance assessment and the provision of standard support data.

6. ***Member Recruitment*** aimed at extending the IBPSA products and services to those practitioners who can most benefit from the new technology.

7. ***Products and Services*** devised in response to the profession's evolving needs.

8. ***Technology Transfer*** concerned with the delivery of training in all aspects of computer-based performance assessment at all stages of the building life cycle.

9. ***Regional Development*** to subject the foregoing activities to appropriate regional influences and enable their effective delivery.

This document addresses the last area concerned with regional development in order to more effectively address local needs and create a mechanism for an international exchange of know-how and best practice.

Rationale
IBPSA has achieved significant success at the international level - largely through its biannual conference program (Vancouver '89, Nice '91, Adelaide '93, Wisconsin '95 and Prague '97) and worldwide electronic mailing facility. IBPSA has also recognized the difficulties surrounding the development of products and services that are appropriate to the day-to-day needs of its members.

The underlying causes of these difficulties are twofold. Firstly, the geographical spread of IBPSA members is wide and gives rise to a requirement to cover disparate work practices, technologies and professional needs. Secondly, IBPSA's organizational structure is such that the coordination of activities at the local (regional) level is problematic. At the same time like-minded, but regional, organizations are making significant progress at the local level through their seminar, workshop, publications, training and software development activities.

If the construction industry were to be well supported in its attempts to harness effectively the emerging IT and simulation technologies then the establishment of regionally based support organizations was essential. Equally essential was the creation of a structure by which these organizations could affiliate in order to disseminate their know-how and promote their local best practice. Only in this way could the benefits of the new technology be understood and future standardization enabled. It was with the view of a network of autonomous regional organizations that IBPSA has turned to regionalization and is encouraging existing or newly formed groups to become IBPSA affiliates.

Structure and Operation

Under the existing structure, IBPSA affiliates are financially and administratively independent. In practice, this means that they raise and deploy their funds as long as these funds are under the control of elected officers and are used in pursuit of aims and objectives that are consistent with those of IBPSA. IBPSA-Central concentrates its resources on issues such as inter-region communication, international conferences and product standardization. In this way IBPSA complements and empowers the regional affiliates in their attempts to inform and support their members in the context of local design issues and concerns. The entire IBPSA network is represented by a 15-member Board comprised of an executive and regionally elected officers.

The following guidelines have been devised to assist with the establishment and operation of an IBPSA regional affiliate.

1. Organizers of a new regional affiliate should prepare a brief proposal for the IBPSA Board of Directors. This should outline the proposed name, geographic territory, organizational structure and goals and objectives (if different from those included in the IBPSA charter statement). Affiliation depends only on the organization having a purpose and mission consistent with those of IBPSA. The Affiliate and IBPSA then enters into a specific agreement by defining their working relationship based on regional considerations prevalent at the time.
2. Regional affiliates may be named **"IBPSA <region>"** or they may use any other appropriate name. Their letterhead and other publicity material should indicate that they are "an affiliate of IBPSA".
3. For regions with limited financial resources, IBPSA can provide a limited amount of **matching start-up funds** (see below) to aid the initial set-up of the affiliated organization. A case for support should be submitted to the IBPSA Secretary for consideration by the Board. (See attached proposal guidelines.)
4. The financial structure of a regional affiliate is independent from IBPSA. This means that affiliates will retain all member dues or other funds raised by their activities.
5. IBPSA will provide affiliates with a list of operational guidelines (see attached by-laws), contact information for persons available to assist the local organizer and electronic images of the IBPSA logo.
6. The regional affiliate will provide membership data to IBPSA for use in mailing IBPSA materials.

7. Members of the regional affiliates will automatically be full members of IBPSA. Any given individual or organization will pay dues directly to IBPSA only if there is no regional affiliate operating in their area.
8. IBPSA will make newsletters and other IBPSA materials available to all members of the regional affiliates either in printed form or in downloadable electronic format from the IBPSA web page. This will be at no cost or at a nominal cost depending on the circumstances. Other services may be provided by IBPSA to the regional affiliates for a fee.

Start-up Proposal Guidelines:
It has been the IBPSA Board's policy to grant start-up funds to regions that are in need of matching funds to get the organization officially registered and/or to purchase initial office support equipment. The proposal should be submitted to the IBPSA board and should contain the following elements:

1. Name of Affiliate: i.e., **IBPSA-<region>.**
2. Geographic territory covered.
3. Organizational structure – The IBPSA Charter is founded on a set of board- and member-approved by-laws (see attached). Each Affiliate's organizational structure is therefore expected to adhere to the same or similar principles of operation.
4. Officers -- i.e., Specify the officers that will be constitute the board (e.g., Chairperson, secretary, treasurer, etc. – see IBPSA by-laws)
5. List of goals and objectives – Must be consistent with the mission statement and objectives of the IBPSA Charter.
6. Minutes of the first organizational meeting, indicating organizational business transacted.
7. List of initial members and their affiliations (can be those attending the first meeting).
8. Proposed activities of the affiliate.
9. Proposed amount of annual membership dues.
10. Breakdown of costs associated with set-up of the Affiliate organization.
11. Amount of matching funds provided by the Affiliate.
12. Amount of the requested support from IBPSA. *

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* Please note that IBPSA's policy is to provide start-up funds with the expectation that the Affiliate will return the granted amount once the region reaches financial stability. The Affiliate is therefore asked to return the funds on a voluntary basis, so other regions can be assisted in the same fashion.

Becoming an IBPSA Affiliated Organization

If you would like to become an affiliated organization then please write to the IBPSA Secretary at the address given at http://www.ibpsa.org . Alternatively, you may wish to discuss the matter further with one of the IBPSA office bearers or a representative of one of the existing affiliates whose addresses can also be found at http://www.ibpsa.org.