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Combined Heat, Air Moisture and Pollutant Simulations (CHAMPS) For Buildings

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This topical issue was motivated by the discussions among participants of CHAMPS 2011—the 8th International Forum and Workshop on Combined Heat, Air, Moisture and Pollutant Simulations (March 20–23, 2011, Nanjing, China). Immediately following the workshop, CHAMPS 2011 participants and other researchers in the field were invited to submit papers for this 1st topical issue of the Building Simulation journal on the subject.

Why CHAMPS for buildings?

We live in a world in which natural resources and energy are increasingly scarce due to industrialization, and where human health and wellbeing are increasingly threatened due to pollution. To build a sustainable world, we need to conserve energy, utilize resources efficiently, and improve environmental quality and human health. Buildings play a key role in both energy conservation and human health. In industrialized countries, buildings account for over 30% of total energy consumption, more than any other individual sectors such as transportation or manufacturing. Potential to reduce energy consumption in buildings is enormous. It was estimated that through energy conservation measures such as better insulation of walls and windows, reduction of air infiltration, use of energy recovery system and thermal storage system, and promotion of favorable energy usage behavior via energy monitoring and display, can lead to over 60% reduction in energy consumption. This, supplemented by the use of renewable energy on site, such as solar and geothermal, can result in net-zero or even net-positive energy buildings. In industrialized countries, people also spend majority of their time (over 80 to 90%) in buildings. Improving indoor environmental quality can significantly reduce instances of sick building syndrome and building related illnesses, and lead to substantial improvement in productivity, learning performance, and potentially creativity performance.

To realize these potentials in energy saving and human health improvement, it is essential to understand the Combined, Heat, Air, Moisture and Pollutant (CHAMP) transport phenomena in buildings and their surroundings. It will help us to identify where are the major "leaks" of energy or intrusion paths of pollutants, identify opportunities and develop new approaches to control the energy and pollutant flows, regulate the variable renewable energy generation to match the dynamic energy demand by using effective energy storage and distribution methods, and minimize human exposure to various pollutants. This is where our collaborative effort in CHAMPS development and applications can make a big difference.

A brief history on CHAMPS forums, workshops, and collaboration

The history of CHAMPS forums and workshops is quite simple. It was initiated out of the desire of a group of scholars and researchers to enhance the collaboration, knowledge accumulation and dissemination in developing methodologies and common platforms for building performance simulations. In 1999, Syracuse University had a major research initiative that was aimed at developing intelligent building and urban ecosystems to improve indoor and urban environmental quality, and improve human health and performance. Understanding of the pollutant emissions, transport, deposition and retention, and how the thermal environment affects these processes was crucial in developing such intelligent environmental quality systems. At the same time, Dresden University of Technology in Germany had a long history of developing advanced thermal and moisture simulation models for building's durability and energy efficiency analyses. We shared a common vision to develop methodologies and a common platform for Combined Heat, Air, Moisture and Pollutant Simulations, CHAMPS in short, that can be used for both energy and environmental performance analyses for buildings.

The first official CHAMPS forum and workshop was held in Dresden University of Technology, Dresden, Germany in 2004, and it became an annual event since then. It was intended for scholars and researchers to exchange the state of the art knowledge in CHAMPS, establish and advance close working relationships in collaborative effort, and provide opportunities for training new graduate students and coordinating their dissertation research so that each can contribute organically to the overall goal of developing a common CHAMPS platform. Since 2004, the CHAMPS forums and workshops had been formally hosted by University of la Roche, France, Dresden University of Technology, Germany and Syracuse University of USA, and most recently by Nanjing University, China. Different from other major international conference series, we also encourage and engage more frequent, smaller group and perhaps less formal joint seminars on CHAMPS development. In the past, such seminars had taken place in other leading research universities including Technical University of Denmark, University of Tokyo, Tsinghua University, Southeast University, University of Hong Kong, Hong Kong Polytechnic University,

as well as several other universities in USA (e.g., Virginia Tech and University of Texas at Austin). Extended stay and exchange of graduate students and scholars among collaborating universities, frequent one to one discussion via internet communication tools have also been an important component of the CHAMPS development effort. In short, CHAMPS forums and workshops extend beyond the scheduled annual events. The objective is to foster and advance close-working relationships among collaborators to develop methodologies and a common platform for combined heat, air, moisture and pollutant simulations for building energy and environmental systems. The simulation tools developed through CHAMPS collaboration are open to public to encourage their use for the analysis, design, optimization and intelligent controls of building systems. The ultimate goal is to help create healthy environment for people in an energy efficient and sustainable manner.

What are the major challenges in CHAMPS development?

CHAMPS developmental challenges can be categorized to center around three areas: (1) multi-scale interactions; (2) multi-objectives optimization of different performance aspects of a green building; and (3) multi-disciplinary coordination.

First, building energy and environmental systems are intrinsically multi-scale in time and space. The outdoor climate and traffic conditions vary with time in different scales—e.g., they change hourly, daily, weekly, monthly, seasonally, and annually. The building renovation activities and indoor occupant activities also vary. Spatially, the scales include the nano and micro-scale in materials, a person-scale around individual occupant, the room-size scale, floor-size scale, whole building scale, district or neighborhood scale, urban regional scale and beyond… It is challenging to account for all these different scales in CHAMPS models, and hence identification of the most influential scales is necessary. It is also challenging to account for the interactions among these different scales, and among the associated subsystems. Novel and intelligent coupling approaches will be necessary for different component models of a CHAMPS simulation platform, e.g., between HVAC system and building enclosure, between building enclosure and renewable energy generation and storage, between whole building air conditioning distributed personal environmental control system, etc.

Secondly, building performance has many aspects, including sustainable site, water efficiency, energy and atmosphere, materials and resources, and indoor environmental quality, as identified by many performance rating programs or standards in different countries. However, the understanding of interactions among the different aspects is limited. Knowledge is insufficient to enable the multiobjective optimization considering all performance aspects. The challenge for CHAMPS developers is to provide a robust simulation tool for the component and overall system performance analysis and optimization, both quantitatively and heuristically.

Thirdly, building design and operation require knowledge from multi-disciplines. For example, coordination among the architects, engineers, contractors, project managers and clients are necessary throughout the building design process. Since the building design process is typically staged including conceptual, schematic and detailed designs, the required level and nature of coordination among different disciplines also differ from one stage to another. How can the coordination be streamlined? How can the design information and data be shared among different disciplines efficiently and conveniently without the need for duplicate entering of data? How timely feedbacks from another discipline and from another stage can be taken into account in the current design stage? How can the CHAMPS be customized for different design stages and disciplines while ensure overall coordination and performance optimization? All these present significant challenges for CHAMPS developers.

In a nut shell, the major challenges for CHAMPS developers are to advance the methodologies and develop a simulation platform that can account for the multi-scale interactions, enables multi-objective optimization both quantitatively and heuristically, and facilitates a fully coordinated design process.

Where will we be in 10 years?

Within the context of the challenges identified above, we envision the following in 10 years:

1) CHAMPS models and platforms that:
   a. are mathematically and computationally capable of modeling the multi-scale building energy and environmental systems, including whole buildings as well as building components, and their interactions with the surrounding environment;
   b. enable multi-objectives optimization of the various performance aspects of a green building; and
   c. integrate well with the multi-disciplinary design process to produce fully coordinated and optimized building system design.
2) Many applications and case studies using the CHAMPS methodologies and platforms developed and documented as libraries or databases.

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3) Better education of the next generation of architects and engineers who are willing and capable of using CHAMPS platforms to explore the feasibility and potential of various design options for healthy and sustainable buildings.

CHAMPS 2011—the 8th international forum and workshop on combined heat, air, moisture and pollutant simulations, and publication of this Topical Issue represent another milestone in our collaborative goal of creating healthy and sustainable buildings and communities.

The papers published in this topical issue cover the theoretical and practical aspects of CHAMPS research including coupled heat and moisture transfer in porous building materials, building information modeling, energy-efficient building design and eco-urban planning:

- The first paper by He et al. discusses the potential building energy savings of double skin facades (DSFs). The authors first numerically examined the thermal performance of DSF windows based on the climate of Hangzhou, China, which belongs to a climate zone with "hot summer and cold winter". Then they discussed the potential energy benefits of DSFs and its design for ventilation. The DSF window was found to be more energy efficient than a double glazing window in summer either with an open or closed cavity in the DSF.
- A second paper by Weller et al. describes ThermalOpt—a methodology for automated BIM-based multidisciplinary thermal simulation that is intended for use in multidisciplinary design optimization (MDO) environments. In the paper, the authors explained how ThermalOpt could improve design process speed, accuracy, and consistency, and enable designers to explore orders of magnitude larger design spaces using MDO environments to better understand the complex tradeoffs required to achieve zero energy buildings.
- The paper of Diao et al. also discusses the building information modeling (BIM). The authors proposed an optimal building design aid system that integrated computer aided design (CAD), building environmental simulation tools and an optimization algorithm based on BIM. A case study was provided at the end of the paper to demonstrate how the system could be used for building design during several stages.
- A forth paper by Ding and Tong creates a new area for CHAMPS application—Urban/community planning. The paper proposes how the building position affects the street spatial pattern. Based on the viewshed analysis in GIS, the variance between the form of the urban fabric and the street view shed pattern were measured. The study samples were 600 meters square samples of urban fabric images selected from different cities of Europe, America, Asia, and China. The results indicated: (1) there were strong relationship between the form of urban fabric and street spatial configuration; (2) the integrative degree could be used as an index clearly outlining the form of urban fabric; and (3) visual statistical diagrams could indicate the street spatial characters.
- The fifth paper is a technical note written by Hiyama and Kato. The authors developed a method that calculates sensitivities from heat sources to an arbitrary point in an indoor environment and integrates them into simulations with unsteady boundary conditions. In the proposed method, CFD analysis is employed under steady boundary conditions to calculate the response factors, and the resulting sensitivities are integrated into simulations under unsteady boundary conditions. The proposed method was applied to optimize the variables of an air conditioning control system, and simulate three-dimensional spatial distributions to enhance the accuracy of the calculation such as energy simulations.
- The topical issue also includes three other papers on related topics including CFD modeling of large-scale power plant buildings, natural ventilation and optimal tree design for sunshine and ventilation in residential district, and prediction of natural ventilation flows in whole buildings.

In addition to the papers published here, we would also like to draw your attention to several important presentations at CHMAPS 2011, which include: "Challenges in modeling and simulating natural and hybrid ventilation systems" by Francis Allard (France); "Current and future challenges in studies of hygrothermal performance of buildings" by Carston Rode (Denmark); "Future building simulation focus areas" by John Grunewald (Germany); "Urban and indoor air environments: Relations and design principles" by Shinsuke Kato (Japan); "Virtual design studio" by Jensen Zhang and Michael Pelken (USA); "Current progress on IEA ECBCS Annex 53: Total energy use in buildings—Analysis and evaluation methods" by Hiroshi Yoshino (Japan); "Sources of volatile organic compounds and emission modeling in real buildings" by Xudong Yang (China); "Advancement of EnergyPlus and its coupling with CHAMPS—Whole building" by Lixing Gu (USA) etc. Some of these presentations may become official papers in the future topical or regular issues of Building Simulation journal.

Finally, we would like to thank all who made CHAMPS 2011 and this topical issue possible. We especially thank Nanjing University for hosting CHAMPS 2011. Special thanks also go to Prof. Xudong Yang of Tsinghua University and Editor-in-Chief of Building Simulation journal for his encouragement and support in publishing this

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topical issue. We thank all authors and co-authors for their tireless effort in writing and revising their papers for this topical issue, and all peer-reviewers for their rigorous reviews and constructive suggestions.

CHAMPS 2012—9th International Forum and Workshop on Combined Heat, Air, Moisture, and Pollutant Simulations will be hosted by Prof. Shinsuke Kato, Institute of Industrial Studies, University of Tokyo. It is scheduled to take place in Tokyo, Japan, June 1–3, 2012. We warmly welcome you to join the CHAMPS collaboration, and to make our collective vision for CHAMPS development and application a reality.

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