GUEST EDITORIAL
Special Issue on Building Performance Simulation and the User

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In 2016 we wrote a position paper for ibpsaNEWS[1] arguing that the simulation community has paid insufficient attention to the needs of the users of Building Performance Simulation (BPS). There is little work on what people use BPS for and how they would prefer to interact with it, meaning that tools do not always respond to or support the way the building industry operates or the way professionals in practice interact with their work. This could potentially lead to a poor take-up of BPS, and so we proposed that a user-centred approach to BPS development is required. Such an approach could potentially make use of techniques and methods developed in the digital and product design industries to produce software and interfaces to better support the needs of users and would see BPS as part of a wider system(s), which ultimately is concerned with designing buildings and energy systems that affect our environment in less harmful ways.

The challenges related to BPS and its users and uses may be viewed from various perspectives and disciplines including building engineering and building design, Human Computer Interaction and Interaction Design, and computer systems development. As the role of the user of BPS has been insufficiently explored to date, there is a need for conceptual, theoretical and empirical work on this topic. We wanted to acknowledge and explore this wide range of perspectives and approaches. Aiming to encourage the community to take a more 'user centric' approach to BPS, this special issue includes work that addresses the following:

- Goals and tasks of BPS users, i.e. what BPS is used for and why;
- The different levels of knowledge needed to use BPS;
- The interaction of users with BPS.

Goals and Tasks of BPS users

While the main outputs of BPS are performance results, the goals and tasks of BPS users are usually more complex or have greater scope. This is because the goals and tasks of users are linked to a wider context and objectives, for example using BPS to reduce heating loads, to test a new product, or to explore the effects of different design possibilities. In general, BPS is used to support decision-making or to understand more about a building and its systems. Understanding just what the user needs from BPS follows from understanding the types of problems that users need to address, as well as how users interact with these problems in attempting to solve them.

The systems and methods proposed by Rezaee *et al*. and Loonen *et al*. in this SI are distinctly different from what is currently seen in BPS practice because the intended users of those systems have very distinct requirements. The former propose a procedure to integrate energy oriented design decision making into the early design stages, where the user can bring a range of uncertainties to BPS modelling. Their proposal takes energy performance targets as input and generates a 'menu' of feasible parameter values from which the user may choose to fix or to explore further. The procedure embodies 'the iterative nature of design' and enables the achievement of performance targets, which is most probably the goal of a sizeable proportion of designers? Acknowledging the reduced and limited knowledge of building designers in the domain of building physics, consideration of the user goals and tasks has resulted in a very specific procedure. The authors propose a combination of methods to respond to designers' needs, including a simplified energy method, linear inverse modelling (linear regression models acting as surrogate energy models), and computer based sampling methods. One could imagine this combination of methods having further applications, for example integrated into a parametric design environment. The question is also raised as to whether 'user-oriented BPS' will of necessity use a combination of methods in making BPS processes and results more available to users?

Whereas this combination of methods can potentially be 'predicted' for users such as building designers, the same cannot be said for BPS users undertaking exploratory research and development (R&D) where the tasks are typically ill-defined. Loonen *et al*. discuss the use of BPS as a virtual laboratory for the development of

[1] 'A User-Centred Approach to Building Performance Simulation' IBPSA Newsletter, Vol 26, 1

innovative facades. They argue that BPS could be used more regularly for R&D but that an account of modelling processes used in this interdisciplinary environment is missing from the literature. A careful examination of problem formulation is provided through several case studies, focusing on the mismatches between what R&D needs and what BPS currently offers. This highlights that one of the major obstacles to use BPS for R&D is the lack of suitable component models and algorithms in current BPS tools that would enable performance prediction of what is being tested. A close linkage between the development of low energy building technologies and use of BPS is illustrated, and a case made for using BPS alongside emerging digital production technologies in the construction industry.

The different levels of knowledge needed to use BPS

The discussion around how much domain knowledge one needs to use BPS is not new. However, little of it is directly related to what BPS is used for. Alsaadani and Bleil de Souza, and Beausoleil-Morrison, present examples of teaching BPS to different types of users and consider the different levels of proficiency in domain knowledge that users need in relation to the context in which they are operating.

Alsaadani and Bleil de Souza are interested in who is using BPS, or who might be using it. They are also interested in 'theoretical foundations for BPS teaching' and review the literature on BPS teaching for ways to structure this knowledge. Through a thematic content analysis of the literature, they suggest the three user categories (paradigms) of 'expert', 'consumer' and 'performer' (of BPS). The teaching of 'experts' normally explores the potential BPS can offer in terms of analysis and evidence generation for design decision making whereas the teaching of 'performers' and 'consumers' is actually undertaken within the building design process to illustrate how BPS can be used to support design decision making. Categorising users in this way would allow educators (and developers?) to focus more clearly on the particular needs of these groups. Their paper concludes by stating that questions (as yet largely unexplored) could be structured in terms of the elements of knowledge that need to be conveyed to each of these three categories, and how this can effectively be done.

A detailed example focusing on teaching the expert is provided by Beausoleil-Morrison. He starts his paper with the statement that 'teaching BPS is a topic that deserves as much attention as the development and validation of models and simulation tools'. The importance of an experiential teaching approach is emphasised, highlighting the benefits it brings to the acquisition of in-depth knowledge of fundamentals of building physics, modelling literacy and tools applicability. Claiming that the tool user is actually the main source of uncertainty, he argues that tools, despite seeming easy to use, are actually complex and require proficiency for reliable and accurate operation. An integrated teaching approach of BPS and its fundamentals is proposed combining theory, experimentation, scrutiny of results, followed by reflections and reviews of the whole process. The idea is to train students to become experts in setting up virtual experiments to assess cause and effect relationships so these can be applied to any context of BPS use. The central role of experience in the learning process is emphasised as the main feature to transfer knowledge and adapt the use of BPS to different contexts. It could also be argued that this level of competence is also the basic level needed for understanding and managing the complexities of BPS?

The interaction of users with BPS

Mendes and Mendes, and Jones and Reinhart present examples of interface developments to foster user interaction with BPS. Both papers position the user as being engaged in experimentation. Experimentation can be interpreted at two different levels: experimenting throughout the learning process, and experimenting while solving a context-based problem.

Mendes and Mendes believe that learning through experimentation can cater for different levels of knowledge and therefore propose an interactive learning environment to teach BPS to different types of user. Based on a constructivist approach, they propose an e-learning scheme to enable a range of users (architects, engineers, energy consultants) to make use of BPS to address national energy efficiency regulations for buildings in Brazil. This context has guided the construction of a system that aims at linking knowledge and information on building design, building physics and BPS, in an integrated environment.

The authors state that 'contextualized problem-solving is considered the highest point of stimulating students' complex thinking'. The complexity of BPS used in low energy design is addressed by integrating a number of different systems and approaches, including an 'interdisciplinary knowledge tree of Building Energy Simulation' (bioclimatic architecture and building physics), a hypermedia navigational aid to the simulation software and a concept map of building energy simulation, all supported by an online cooperative problem-based learning environment. The latter holds context based simulation problems that can be solved using their BPS tool through instructor directed peer discussion with a range of users. The whole system is intended to support complex thinking and 'non-linear interaction with knowledge'. Checks on the way that students are using the system are made through data mining and applied semantic analysis. This generates concept network graphs thereby giving feedback that could lead to further refinement and development of the system and its parts. One can imagine this interface design being used to apply and test other propositions on learning BPS (such as those from Alsaadani and Bleil de Souza, and Beausoleil-Morrison, presented elsewhere in this issue).

The aim of Jones and Reinhart is to enhance the interaction of users with BPS through improving the system response time. Their argument for providing 'real time' feedback is based mainly on not disrupting the creative flow of the designer, so that s/he has the impression that the task requires less effort and can be done in a semi-automated mode. They acknowledge that designers need high levels of interactivity with the tool and that decisions are made during active design. Designers using their interface interacted more with their work by exploring the design space more thoroughly. The study accomplishes what is unfortunately too rare – it measures human performance, comparing BPS tools to understand more about the effectiveness (or otherwise) of the tools tested. As such, it makes use of established Human Computer Interaction development methods. As well as providing a clear account of the experimental methodology and results, it shows an example of user testing of BPS that may be useful to those seeking to do similar work in relation to interaction and interface development.

The future

Our aim in this SI has been to present a range of work that has strong links to 'the user' so as to introduce this aspect of BPS to a wider audience. On reflection, the work presented here generally shares a number of characteristics that could provide pointers for those wishing to look further into this area:

- It focuses on what users need from BPS and how they interact with their problems in attempting to solve them.
- It questions how much domain knowledge is required to use BPS, and what that knowledge should be.
- It shows that experimentation is the main way for users to interact with BPS either when learning about it or when using it for problem solving.

The work also tends toward the multidisciplinary and interdisciplinary, and demonstrate a readiness to use research methods from outside those usually applied in engineering (i.e. qualitative as well as quantitative), and/or theory from other fields and disciplines. The presented papers all have as an underlying or explicit narrative: the question of how to make better use of BPS in design contexts (building design, product design), showing that this question continues to hold the attention of many researchers.

We hope that this special issue will encourage further work to be directed toward the different users of BPS and that researchers will continue to creatively apply the appropriate research methods to enable the development of increasingly useful systems and interfaces.