Evaluation of building design variants in early phases on the basis of adaptive detailing strategies and system-based simulation of energy flows for such models

Markus König[1], André Borrmann[2], Philipp Geyer[3], Patricia Schneider[2], Werner Lang[2], Frank Petzold[2], Martina Schellenbach-Held[4]

[1] Ruhr-Universität Bochum, [2] Technische Universität München

[3] Katholieke Universiteit Leuven, [4] Universität Duisburg-Essen

* p.geyer@kuleuven.be

Researcher group on multi-level detail BIM in early design phases

In the early phases of building design, design decisions are taken that have major consequences regarding the performance of the resulting building. Today, the highly complex and iterative development process is supported only to a very limited extent by computational methods. Most importantly, the interactions between architectural concept design and detailed engineering simulation methods have not been systematically investigated so far. The continuous and seamless use of digital building models throughout the design, the construction and the operation of buildings is denoted as Building Information Modeling (BIM). BIM is an important trend in the construction industry and will result in a significant modernization of the working procedures. Particular potential lies in the direct reuse of data hold by the model for diverse analysis and simulation tasks, as e.g. the structural analysis or the energy performance simulation. Today, the use of these tools requires a mostly completed and very detailed building design. This, however, renders the application of simulation tools in the very important early phases including the assessment of different design options impossible. Primary reasons are that building information models are not able to represent the vagueness involved with un-elaborated designs and that current simulation methods are mostly not capable to handle vague and incomplete input information. To fill this technological gap, this research unit is devoted to the development of methods that allow the assessment of alternative building designs which are partly incomplete and vague. To this end, the concepts of formally defined levels of development (LOD) and design variants are introduced into BIM data models and used as basis for communicating with simulation tools. The outcomes of this development will allow to better support the early phases of building design and help to find the most suitable design option. Key objectives of the research unit are the provision of methods for (1) handling building information models with multiple LODs, (2) describing vague and incomplete design information, (3) managing different variants of building design, (4) supporting and documenting the design process and the decisions taken, and (5) seamlessly integrating of analysis and simulation models by extending their capabilities to handle vague and incomplete information. The combination of these methods will allow the transparent and grounded evaluation and assessment of building design options in early design phases. Facing the major societal challenges for more efficient and sustainable buildings and taking the recent developments in BIM technology into account, this research project is of utmost relevance and topicality. To realize this objective, an intense collaboration between scientists in architectural design, building information modelling, structural design as well as energy-efficient and sustainable construction is necessary.

System-based Simulation of Energy Flows

Decisions in early design phases highly influence the overall consumption of energy and resources throughout the lifecycle of buildings. However, there are no computer-aided methods adequate for the Level-of-Development (LoD) in these phases which allow a simulation and analysis of the overall resource demand of the planned building. Available monolithic simulation platforms for energy processes in buildings are suited only for later phases because of the high information demand and modelling effort. These platforms do not allow for exploiting the potential of early design phases. The project, which provides a chief analysis method for the researcher group for the evaluation of buildings in early design phases, aims at the development of a modelling and simulation approach that allows for a simple, quick and sufficiently exact estimation of the operational and embedded energy demand for a multi-LOD model. This approach needs to manage incomplete and fuzzy information and, if necessary, to make further assumptions or to request further information. Additionally, it should deliver an estimation of the reliability of the results that includes information on their accuracy and which information could improve them. Methodical basis of the project is the paradigm of parametric object-oriented and flow-based systems modelling and simulation of buildings. The system model to be developed shall have two chief modelling levels: First, the system flow modelling and, second, a modelling of parametric interdependencies. The systems flow modelling captures the relevant energy and material flows, if necessary, in a dynamic way. The model of parametric interdependencies stores the calculation methods of the flow quantities. For real-time design assistance, surrogate models are developed on the basis of the second-level model that captures parametric interdependencies. Mathematical-statistical surrogate models (black box) as well as simplified physical models (white box) and combinations of both methods (grey box) are tested in order to develop this model. The necessary representation of fuzziness takes place on the basis of stochastic approaches. For the tracking of effects of changes as well as fuzziness, methods of error propagation become part of the systems model. For the synchronization with the Multi-LOD product model, the project includes the development of rule-based and knowledge-based transformation methods of the systems model. Basis for these rules are graph transformations that serve the purpose of the initial derivation of the systems model from the product model and of updating. In this context, an examination of the possibilities of an adaptive partial recalculation takes place to allow a reaction to selective changes and detailing processes as well as an effective analysis of variants.

Acknowledgements

The described research is funded by the DFG as research unit (Forschergruppe) with the funding id FOR2263.