2018 Building Performance Analysis Conference and
SimBuild co-organized by ASHRAE and IBPSA-USA
Chicago, IL
September 26-28, 2018

USING DIGITALIZATION FOR MORE RELIABLE AND LESS EXPENSIVE BUILDING PERFORMANCE ANALYSIS

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ABSTRACT

This paper analyses the current state of simulations and proposes ways to reduce the costs and to increase the reliability of building performance analysis. Functions in machine-code can be used to generate automatically simulation models for numerous simulation environments. Simulations models are proposed which adapt their accuracy and can therefore be used from very early up to late stages of the planning process. BIM based on semantic technologies can provide more flexibility and make it easier to find the right components. A semantic international product data base is planned to make it easier for practitioners to identify most suitable product.

INTRODUCTION

Digitalization has already reduced the costs of many tasks in the global economy and has improved the quality many tasks, too. It is therefore reasonable to assume that digitalization can contribute to more reliable and less expensive building performance analysis. However, the current use of digital processes in average building processes is still limited and it is not obvious which digital processes will succeed and which will not.

This paper analyses four aspects of current building simulation practise. Based on this analysis, four new approaches are proposed and discussed. The aim is to increase the cost-benefit ratio building performance simulation and with that to buildings with a good quality at reasonable costs.

CURRENT SIMULATIONS

Within this section, four aspects of current simulations are analysed.

First, there is a large number of building performance simulation software available, from very simple tools up to very accurate ones (Horvat and Wall 2012; Crawley et al. 2008). In construction processes, engineers tend to use simple tools and to estimate average values for complex components. Scientists tend to develop detailed simulation models with a high accuracy for a specific complex component. Of course, "engineers" and "scientists" are merely roles which can be embodied by many different people.

One step towards more accurate building performance analysis including innovative complex components is that the detailed simulation models are shared between scientists and engineers for example as a TRNSYS Type in (Maurer et al. 2013). As many simulation environments are used by engineers, a simulation model of a new complex component should be available in each environment.

Most simulation environments have certain programming languages which are usually used for a simulation model. Therefore the simulation model of the new component would need to be implemented in the programming languages of all simulation environments. Whenever there is an update, a scientist would need to update the code of each of these languages manually. This is very expensive and error-prone.

Another option can be co-simulation between several simulation environments (Trčka, Hensen, and Wetter 2009; Janak 1997; Djunaedy; Wetter 2011; Beausoleil-Morrison et al. 2012). For this, a license for each of the simulation environment is needed and typically does not reach the computing times of natively programmed components, because it operates at a higher programming level. There has been work on have also been attempts to translate code from one on translating code fully automatically into another programming language (Sahlin and Sowell 1989), but this is hard to achieve with complex code.

Second, even if an accurate model has been developed for a component with complex properties, this model typically requires many inputs and parameters. In early planning phases, engineers continue to use rough approximations either because the necessary inputs and parameters are not available or it is too time-consuming to use the accurate model.

In theory, it could be a solution to use the detailed model with default values and to change only few inputs or parameters. However, the risk of using the detailed model in a wrong way seems to discourage unexperienced users.

Even when the inputs and parameters are available at a later stage of the planning process, it is often time-consuming to switch from one calculation method to a more detailed one for example because the inputs and parameters may be needed in other formats.

Third, current BIM data exchange formats such as the Industry Foundation Classes (IFC) have a hierarchical ontology. For example, IfcLamp inherits its attributes from IfcFlowTerminal, IfcDistributionFlowElement, IfcDistributionElement, IfcElement and more. IfcWall inherits its attributes from IfcBuildingElement, IfcElement and more. If an interior wall element is invented which is at the same time a light source, then there is no IfcElement ready for exchanging the data and a workaround is necessary which results in additional effort for the stakeholders of the planning process.

When there is an IFC entity for an innovative product, then the attributes may not be sufficient to characterize the innovative behaviour. Although this is a long process, the IFC could be extended to provide entities for a large amount of possible components for which there is no suitable entity currently available. However, this would add considerable complexity to the current IFC entities and attributes which could confuse the people working with the BIM data.

There has been work to add semantic information to the IFC such as (Gao et al. 2017; Beetz, van Leeuwen, and Vries 2009; Pauwels and Terkaj 2016) to make it easier to search the BIM data. Semantic technologies were also used to describe the interaction of components so that a system simulation can be assembled automatically (Mitterhofer et al. 2017).

Fourth, the International Glazing Data Base IGDB and the Complex Glazing Data Base CGDB offer a lot of product data regarding glazed areas and solar-shading. Currently, optical measurements for numerous angles of the irradiance, the transmission and the reflexion become more important to characterize innovative shading systems. However, it is difficult to share the detailed measurement results in a way that they can be easily used for the planning of a building.

DISCUSSION AND RESULT ANALYSIS

This section proposes and discusses four ways to use digitalization for more reliable and less expensive building simulations based on the analysis of the preceding four paragraphs.

Machine-code functions

Based on the analysis of the challenges to provide accurate simulation models for innovative components at low costs, it is proposed to exchange functions in machine-code in addition to alphanumerical values (Maurer et al. 2017). When a new simulation model is programmed in one programming language and compiled, a function in machine-code is available which can for example be an object file, a DLL or a shared object. Figure 1 presents a schematic overview.

This function can then be linked to other machine code so that the result can be used in a specific simulation environment. For each simulation environment, a way to include machine-code functions needs to be established. Afterwards, this way can be used automatically.

This means that a scientist only needs to program one code in the programming language which he prefers and the simulation model can automatically be generated for countless simulation environments.

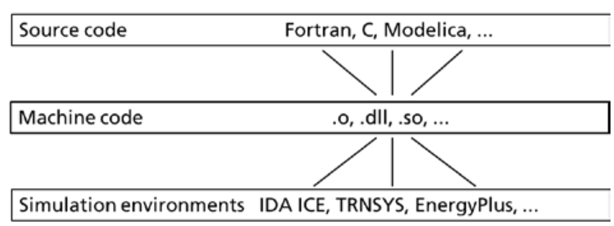

Figure 1 Schematic diagram of the multi-language multi-environment modelling approach (Maurer et al. 2017)

As each programming language has its specific advantages, scientists often have to deal with functions implemented in different programming languages. Instead of translating these functions, they can be compiled and linked together. This reduces the risk of errors and can save a lot of effort when dealing with complex code.

The exchange of functions in machine-code provides several other advantages: The machine code can provide confidentiality. When a company develops for example a unitized façade and a simulation model of this façade, they typically don't want to share the source code of this model because a competitor could learn a lot from it. But they could agree to share their model as machine code which enables other stakeholders to perform much more accurate building simulations.

This means that a company in the future could not only sell a component, but also a simulation model of it, like a digital twin.

When there is an update of a simulation model, it is much easier for the other stakeholders to replace for example the DLL of this simulation model in their simulation environment than to receive alphanumerical values only. In the second case, the stakeholder needs to update the simulation model himself which is time-consuming and error-prone.

Today, often one scientist programs a simulation model. She may be an expert for some parts of the model, but probably there are other scientists who are more experienced in other parts of the model. By combining functions in machine code, scientists can focus on their core competences and use functions of other scientists to create a simulation model which is more accurate and less expensive than programming everything herself.

If a company is afraid that competitors could analyse the machine code of their simulation model, obfuscation methods can be used. The simulations models can also be stored on a company server, allowing only the customer to send inputs and receive outputs. With this approach, the details of the simulation model can hardly be reverse-engineered.

Adaptive simulation models

While it is rather easy to create an accurate simulation model when all necessary data is available, good models for the early planning stages which are very easy to use and still provide acceptable accuracy. Functions in machine code can be useful for this, too. Spreadsheets like Excel are used in early planning phases and can be considered as a simulation environment because simulation models in machine code can be implemented as spreadsheet functions.

In this way, the accuracy of a detailed model can be used easily especially when stationary conditions are considered and default values are provided. For example, an architect can analyse an innovative component for certain summer conditions at an early planning phase.

In other cases, different models may be needed with different accuracy. To minimize the effort of switching between a simple model and the more accurate model, they should be combined in an adaptive model so that the user does not have switch tools and input formats. Instead, the adaptive model can provide automatically the best accuracy possible with the data available at this stage (Maurer and Kuhn 2017). Figure 2 presents a schematic drawing of the adaptive models aiming to cover all stages of the planning process.

As the adaptive model can be used in different simulation models, it can be used for the first calculations in a spreadsheet and at a later planning stage in a detailed simulation environment, with exactly the same inputs and parameters.

An engineer could take the same adaptive model, which was used by the architect in the early planning phase, and implement it together with its inputs, parameters and outputs in a detailed building performance simulation.

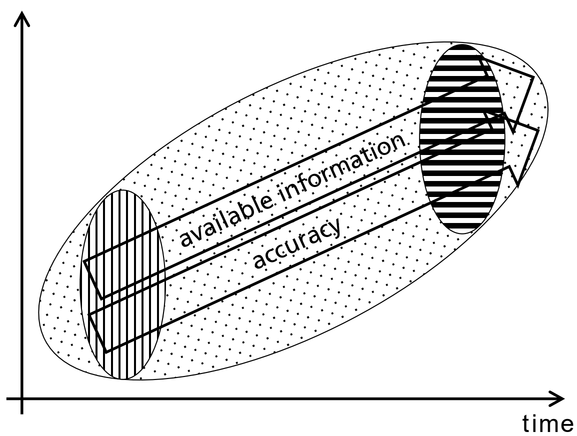

Figure 2 Schematic drawing of the available information in a planning process, the possible accuracy, the situation at a late stage of the planning process (horizontal stripes) and at an early stage (vertical stripes). The situations aimed to be covered by an adaptive model are indicated by a dotted area.

Semantic BIM

Semantic Web uses triples to store information in a way that it can be searched well. Similar approaches can be used to store product data. Dictionaries like the buildingSMART Data Dictionary can be used to make it easy to find for example products for interior walls which include lamps.

The BIM data of a building project can also be saved using semantic technologies. The main advantage is the flexibility of Semantic BIM: new components, properties and formats of information can be added without a fixed structure and can still be found. Of course, scripts need to ensure that redundant data stays up to date, for example if the characteristics of a component a provided in two different formats.

In fact, the fixed hierarchical ontology of formats like the IFC is not needed anymore because most people use the search instead of clicking through the hierarchy. Semantic BIM "structures itself" and makes it easier to find what you need. With this, it solves the problem of having too few or too many entities.

On the one hand side, innovations which go beyond current hierarchies can easily be described with sematic web technologies, by pointing to the entities of a data dictionary. On the other side, there is no complex hierarchy which makes semantic BIM simple for new users.

Semantic Product Database

Lawrence Berkeley National Laboratory (LBNL) plans cooperate with Fraunhofer Institute for Solar Energy Systems (ISE) to create a cloud-based international product data base for architectural glazing, daylighting, solar-shading and active-solar components. It will be based on improved measurement and data-processing methods and use semantic technologies so that practitioners can easily find and include the most suitable available products in their planning.

To date, laboratories can provide an extensive amount of measurement data for components. If a planner receives this data, they can often use only a part of this data. In the future, companies should need to measure their components only once and planners should have access to the detailed measurement data of a large number of components. Furthermore, it should become simple to extract the relevant information and use it directly for a building project.

CONCLUSION

This paper proposes four ways to use digitalization to reduce the costs and increase the reliability of building performance simulation. First, functions in machine-code can be used to reduce the cost of creating simulation models, to facilitate the exchange of capabilities and to reduce errors in this exchange.

Second, simulations models are proposed which adapt their accuracy and can therefore be used from very early up to late stages of the planning process. This enables a higher accuracy and reduces the cost of switching to more accurate models.

Third, BIM based on semantic technologies is proposed to provide more flexibility and make it easier to find the right components.

Finally, a semantic international product data base is planned by LBNL and Fraunhofer ISE to make it easier for practitioners to identify most suitable product.

ACKNOWLEDGMENTS

This work was funded by the German Federal Ministry for Economic Affairs and Energy (BMWi), based on a decision by the German Bundestag.

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