AUTOMATING BUILDING ENERGY MODELING FOR SIMULATION PURPOSES

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ABSTRACT

Building energy modeling is data intensive, repetitive and error prone. This paper presents a methodology to support the automatic building energy model generation based on the Energy Performance Certificate (EPC) input and monitoring data. Preliminary results support model generation scalability and performance. A proof of concept has been performed for 3 typical building geometries. The benefits of this method are reduction of modeling effort, improvement of the energy performance evaluation and comparability between buildings with similar geometries. This method is aimed to ease building renovation planning and rapid prototyping for tenders and design competitions.

INTRODUCTION

Due to the uniqueness of each building, automated building modeling solutions are very scarce. Regarding automated building simulation, both commercial and open-source solutions have been made available in the past years.

Internal thermal loads of the building can be estimated, based on the Energy Performance Certificate (EPC, in most countries the mandatory legal implementation of Directive 2010/31/EU, 2010) input and the energy consuming components in the building. These may include building energy systems, such us heating cooling and air conditioning (HVAC) and lighting system loads, solar loads, computers, and many more. In conjunction with the typical physical properties of the construction type chosen, heating and cooling loads of the building as well as electric load profiles can be computed. The loads may then be compared to actual amount of energy used for heating, cooling and electricity to get an idea of the building performance.

This comparison gives first insights whether the object monitored and evaluated consumes a reasonable amount of energy, and should raise the awareness of the user with respect to his energy consumption, and the CO2 emissions that can be derived from this consumption.

Fig. 1 shows an example of a simplified building model generated for simulation purposes.

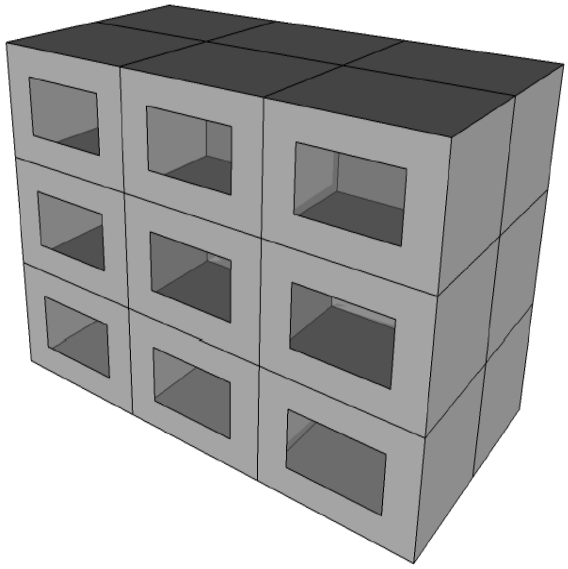


Figure 1 Simplified building model

RELATED WORK

Modeling costs may be reduced by decreasing the accuracy and the complexity of the building model [Zucker and Hettfleisch, 2010]. Much research has been done on model simplification to reduce the modeling effort and easing the development of dependent technologies (for example in [Thron 2001], [Zucker et al., 2011]). A dynamic adaptation of the models level of detail according to the state of planning is possible and reasonable [Brychta et al., 2010].

The arrangement of the building into different zones may not be seen as just a division of the built area, but also a detailed breakdown of the entire building envelope up to the zone level [Lichtmeß, 2010]. In addition, individual zones can be further subdivided into areas regarding its usage or purpose. The processing time required for the mathematical description of the building is a predominant part of the surface entry or recording, and the zoning [Erhorn-Kluttig et al., 2005] [Roemmling, 2008] [Maas 2008]. In addition, for example, a transformation of spaces and/or zones in a building requires a redetermination of these areas. Practical experience shows that the processing time and associated costs for creating an energy balance with current software solutions is high. Solutions for automating building energy modeling for simulation purposes have been developed [EnergyPlus Example File Generator., 2012], although neighborhood modeling solutions are less common.

BUILDING ENERGY MODELING

Using the EPC and monitored building data it is possible to:

1) generate a simplified building model,
2) perform an initial baseline simulation and
3) validate the expected building performance.

The costs associated to building modeling and simulation may be reduced by automating the modeling process. At first details about the monitored building, especially geographic location, construction type and area are extracted from the existing EPC. An approximation of the heating and cooling load is computed from this information by applying the physical parameters deducted from the building type with a simplified model of the building.
The results of the simulation are joined with the estimation of the internal loads provided "energy awareness service" and compared the actual energy use, also reported by the components. This comparison gives first insights whether the object monitored and evaluated consumes a reasonable amount of energy, and should raise the awareness of the user with respect to his energy consumption, and the CO2 emissions that can be derived from this consumption.

METHODOLOGY

To implement a service to calculate an approximation of the energy performance of a building object, we should have under regular conditions, a model based on:

- a simplified geometry (area, ration of windows),
- the geographic location of the object,
- physical parameters deducted from the construction type of the building,
- further internal loads estimated from the usage of the object.

This enables to perform a thermal building simulation for the measurement period and an appropriate time horizon, using e.g. EnergyPlus [EnergyPlus 2012].
The created model is based on some basic information concerning the building. This information may be static, or dynamic. Static data is the one concerned with the building (building data). The dynamic data is concerned with the building systems (monitoring data).

Among the minimum required building data are:

- building area,
- building height and
- building type/building year.

After that, further building data should be obtained, with the easiest possibility being the EPC. Most import is the thermal characteristics, consisting of the U-values of the building envelop, but also

- wall type (heavy or light)
- fenestration (%)
- location (weather/solar path/orientation)
- infiltration rate and/or ventilation
- internal gains

To simplify the modeling process, only HVAC set-points are considered. Individual HVAC elements and HVAC system configuration are not regarded.
Complementary monitoring data might be sensed, such as electrical characteristics, including electrical overall consumption of the building, as well as electric energy source that may be present, such as combined heat and power plants (CHP) or photovoltaic panels (PV).
A website establishes a two-way communication with the database for seamless integration of building data entered by the user and delivering energy analysis.
To perform on the automatic building energy modeling context means to rapidly create a model which may be used for simulation purposes, even though few data concerning the building are available.

A modular system ensures performance and scalability. It is composed by the following modules (Fig 2):

- a data interface,
- a model generator and
- a simulation interface.

The data interface, describes the data communication between the database and the baseline simulation. Model generator, describes the process of generating simulation models based on the information from the database. Simulation interface, describes the communication between the generated model and the simulation tools.

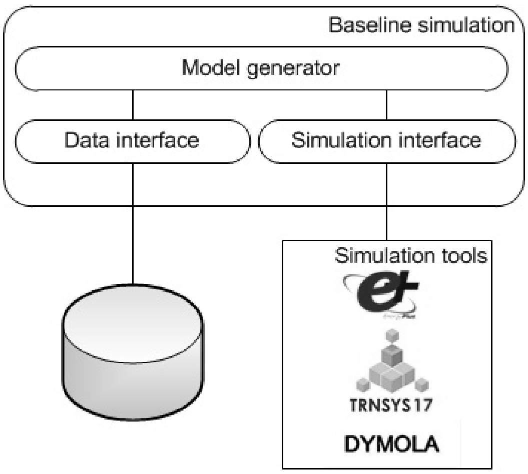


Figure 2 Baseline simulation system architecture

At first data concerning the building geometry, geographic location, physical parameters and internal loads estimates are requested from the system database. A data interface is responsible to handle and parse any data which is necessary for the modeling task.

Then a model generator module prepares a primary model of the building, using the requested building information and template models for common building types. Fig. 3 shows an example of a typical U form building.

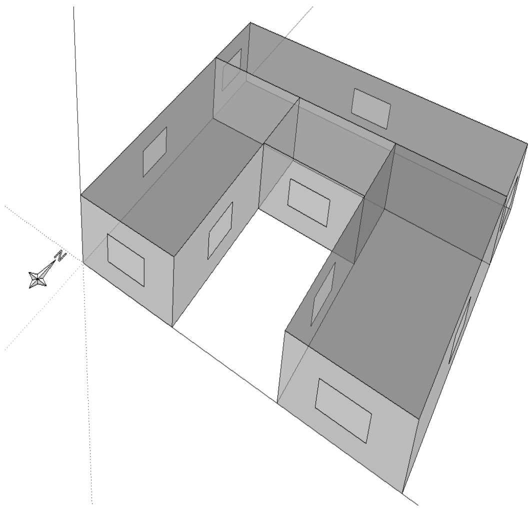


Figure 3 Typical U-form building

After a simulation interface establishes communication with a standard simulation tools (e.g. EnergyPlus [EnergyPlus 2012] or TRNSYS [TRNSYS 2012]), feeding-in the automatic generated model, and idling until the building energy performance simulation is completed.

Finally building simulation results are stored in the system database, for future use. This data is condensed for use on a website where the average energy consumption of monitored buildings is displayed.

CASE STUDY

Preliminary results support model generation scalability and performance. A proof of concept has been performed for 3 typical building geometries, namely square, U-shape and square yard (table 1).

As simulation hardware, a PC equipped with a dual core 2.50GHz processor and 3.16 GB RAM was used. As building performance simulation tool, EnergyPlus [EnergyPlus., 2012] was selected.

Tests were extended to a whole ensemble of buildings, representing a neighborhood (Fig. 4). Each building model generation individually consumes 1 second of processing time. In total for a neighborhood with 5 buildings, model generation used 4 seconds of processing time. Regarding simulation time, it was performed in 153 up to 179 seconds (between 02:33 and 3:59). For the entire neighborhood 837,59 seconds (13:54,59) of processing time where necessary.

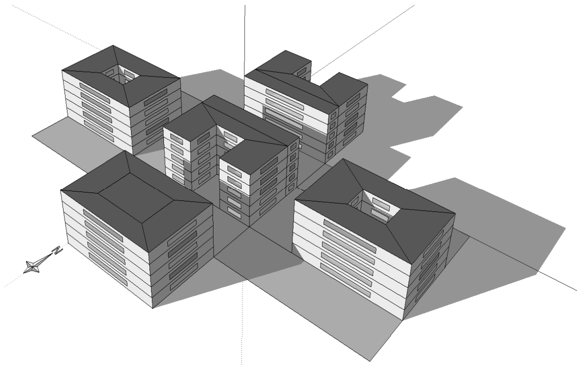


Figure 4 Neighborhood model

Simulated load results for both heating and cooling support the model generation plausibility test. Including the surrounding buildings into the simulation model was straight-forward, as they do not have to be zoned or parameterized, but just act as shading objects with respect to the building in focus (Fig. 5).

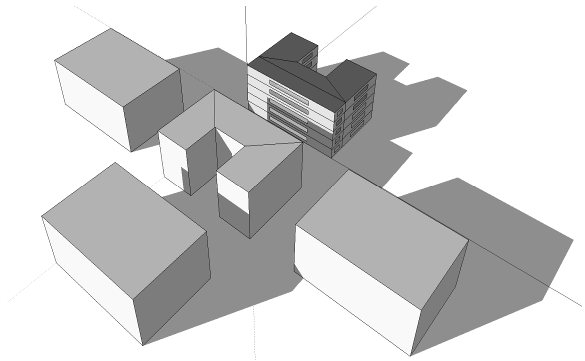
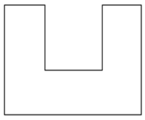
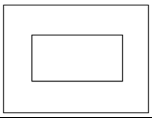
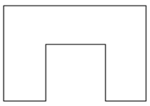
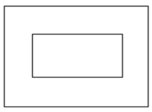


Figure 5 Simplified Neighborhood model

Table 1
Typical building geometries and simulation performance results for a neighborhood.

BUILDING LAYOUT	TIME (mm:ss,ss)		SIMULATED LOAD (kWh/m²)	
	MODEL GENERATION	SIMULATION	HEATING	COOLING
	00:00,83	02:33,32	22,80	37,86
	00:00,79	02:40,71	22,58	37,03
	00:00,82	02:47,87	22,68	35,77
	00:00,83	02:59,78	22,58	37,07
	00:00,82	02:55,91	20,93	36,34
Neighborhood Total:	00:04,09	13:54,59	111,57	184,07

This permits a reasonable simulation model of the aforementioned neighborhood, allowing for the use of this approach in city planning as well as single buildings. The benefits of this method are reduction of modeling effort, improvement of the energy performance evaluation and comparability between buildings with similar geometries.

SIMULATED DATA

Among the results are dynamic simulation of the thermal and energy performance of buildings over time, such as energy demand (heating, cooling, humidification/dehumidification, electric) and performance of the examined HVAC and energy systems (efficiency, uptime, control behavior).
The simulation input data quantity is typically in the order of some kilobytes, due to the reduced building data necessary to generate the model.
The simulation output data in the other hand is much bigger. Typically, a simulation of the electrical energy consume is performed for a period of 1 year, using a time interval of 15 minutes. If a building with 5 zones is simulated, the amount of samples would be 175200. This means, up to 5 MB of data is generated and has to be stored on the database.

CONCLUSIONS

This paper presents a method to support the automatic building energy simulation model generation. This method has the potential to reduce cost related to building modeling and simulation. As such, it makes the employment of energy performance modeling and simulation on the entire building process more practicable, from early conceptual design to decommissioning.
The results of the simulation may be joined with the estimation of the internal loads providing “energy awareness service” when compared with the actual energy use. This comparison gives first insights whether the object monitored and evaluated consumes a reasonable amount of energy.
The next steps in the research include the validation of the model with sensor data and optimization of the model generation process. Additionally investigation of differences between simplified models and detailed model are planned.
Given the limitation of only a set of defined building geometries it is not possible to model arbitrary buildings. Therefore it is planned to add the possibility to combine the existing floor plans and use them as building blocks for more complex geometries.
Building usages have to be commissioned separately for each building, just like the number of floors or the floor plan. Currently this is a coarse description of usage and user behavior, but the model allows extensions by individually configuring each thermal zone.
Furthermore, automatic model generation for buildings can be extended for a neighborhood to a

whole ensemble of buildings, representing a small town or a city. Including the surrounding buildings into to simulation model is not too difficult, as they do not have to be zoned or parameterized, but just act as shading with respect to the building in focus. This would allow a reasonable simulation model of the aforementioned neighborhood, allowing for the use of this approach in city planning as well for single buildings. From the computational point of view, this method for simulating a whole neighborhood can also be parallelized on a local cluster or even with cloud computing, as each building is treated separately, allowing the model generation and / or simulations to be spread to different machines, collecting the and joining the simulation results at the end.

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