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INTEGRATION OF DISTRIBUTED SYSTEM SIMULATION TOOLS FOR A HOLISTIC APPROACH TO INTEGRATED BUILDING AND SYSTEM DESIGN

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ABSTRACT

Advanced architectural developments require an integrated approach to design where simulation tools available today deal only with a small subset of the overall problem. The aim of this study is to enable run time exchange of necessary data at suitable frequency between different simulation environments in order to allow the usage and integration of all attainable modules for building and system simulation.

INTRODUCTION

Advanced architectural developments require an integrated approach to design (Hensen 1993). Domains of, for example, building physics, heating, ventilation, air-conditioning and thermal storage systems are often closely related and it is only by taking into account their interactions that a complete understanding of building behavior can be obtained.

There are only two suitable methods for holistic approach to integrated building and system design: real scale experimentation and numerical simulation. The latter is far superior in terms of associated time and financial resources and hence, the preferred option.

In terms of modeling and simulation of innovative buildings and systems, two of the most restrictive shortcomings of current simulation-based design tools are: each tool has only a limited number of systems it can represent and inter-process communication between tools is not available yet (Hensen *et al.* 2004). A frequently encountered problem by engineers, who would like to simulate the future behavior of a design alternative, is that certain performance aspects or specific building and system components are represented in one simulation environment while other performance aspects or components are only available in another. On the other hand, wide range of simulation tools is already available. Different tools have been developed to undertake non-trivial building performance appraisals. There is no need for more programs, but there is definitively a need for better useable and more effective software. Building performance simulation is a small market, it is not interesting for the main software industry, and it is highly unlikely that there ever will be a single program that combines all necessary features (Hensen *et al.* 2004). The problem may be solved by "opening" the existing simulation environments by allowing sharing developments in different domains.

The current project aims to further development of multiple-domain simulation approach.

METHODOLOGY

The objective of this research is to develop and verify a prototype cooperative building and system design environment for optimization of building energy performance and indoor environment. A software rapid prototyping is used to deal with the problem. Here, by the rapid prototype, it is meant a working model that is developed from existing software to highlight a specific function with a minimum amount of effort. Existing, proven, building and system simulation environments is a starting point. This paper gives an overview of developments of the first prototype.

Although the current work starts with run-time coupling of specific simulation environments, the coupling mechanism and data-exchange protocol that is developed should ensure that the approach has a wide and general applicability.

The initial idea is to base the coupling mechanism on the external exchange of simulation data using intermediate files and to focus on the core coupling issue: which data or information and at what frequency need to be exchanged between separate simulation environments.

EXTERNAL COUPLING

Expanding the capabilities of existing software by adding new modules into an existing program is the "traditional" way of coupling, known as internal coupling. On the other hand, external coupling enables use of existing tools in different domain. It represents a run-time communication between two separate programs where at least one of the programs is running. It is believed that external coupling that enables run-time exchange of information between simulation environments can alleviate their limitations.

Presently, there are two projects, besides this one, focusing on developments and implementation of external run--time coupling. One (Djunaedy *et al.* 2003) in the domain of CFD and building energy simulation tools, and the other (Yahiaoui *et al.* 2003) in the domain of control and building energy simulation tools.

First case study – base for initial prototype

Low energy housing in Korea is used to model and simulate in this stage (Figure 1). Building is described in detail elsewhere, (Jong H.Yoon *et al.* 1997). It includes an underground earth to air heat exchanger that preheats ventilation air in the winter or precools it in the summer. The building incorporates a double-skin south facade, which can act as a solar collector for additional heating of ventilation air, coming from the ground coupled exchanger, during the heating season, while in summer it is bypassed to avoid overheating of the air. In the summer, double skin facade is naturally ventilated.

The building itself, including double skin façade, is modelled in ESP-r and, the system (earth-to-air heat exchanger) is modeled in another stand-alone application, called EARTH.

The initial prototype is based on communication between these two simulation packages.

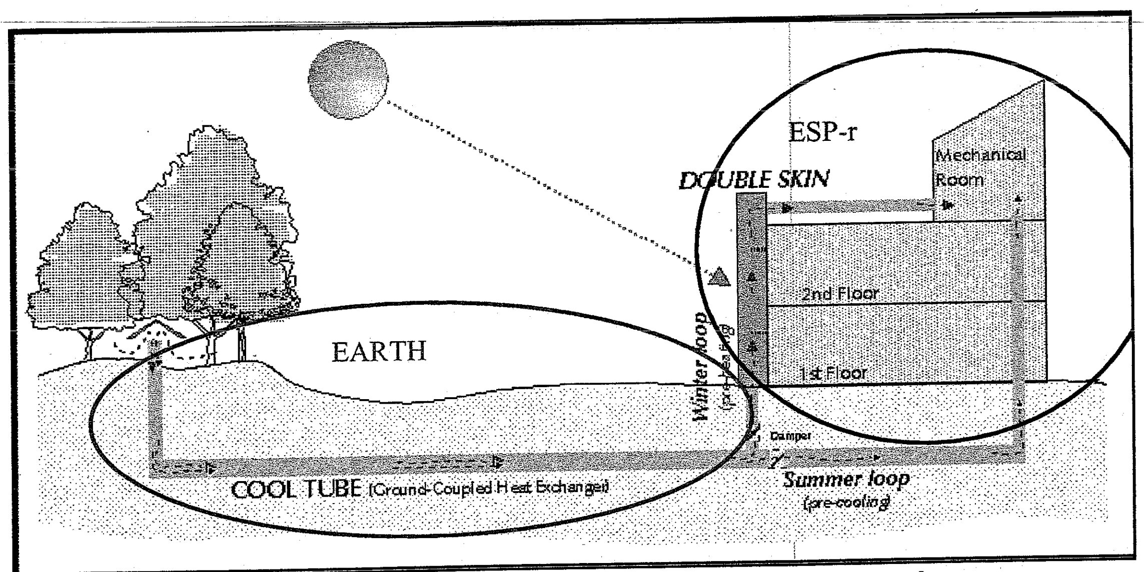

Figure 1 Case study on which the first prototype is based

Initial prototype

The initial prototype is a result of external coupling of ESP-r and EARTH.

The software is adapted for the purpose of coupling and solving the problem of how to keep data concerning ground condition throughout the simulation period. An additional component for air is developed in ESP-r. This component maintains and controls the coupling. ESP-r is a master that controls the simulation and initiates EARTH when needed. The exchange of data is via intermediate files.

This specific coupling could be seen as unidirectional because the building does not "influence-back" the system, but the prototype is developed in more general sense. The data is exchanged in both directions. The mass flow rate, inlet temperature and information on stage of the simulation are sent from ESP-r to EARTH. The calculated temperature from EARTH is forwarded back to ESP-r, where further on, matrix coefficients are generated, based on the coupled data (Figure 2).

The prototype has an option for a user definition of frequency at which the external program is invoked. The frequency may differ from building and plant calculation frequency in the ESP-r environment.

ESP-r starts EARTH in every specified time step. This results in an initialization of soil temperature from a certain function of EARTH each time. The reality is that the air passing through the tubes influences the ground temperature distribution. Therefore, there is a need to keep the information of the soil temperature in-between the external program (EARTH) calculations at different time steps. To overcome this potential problem, the soil temperature data are kept outside the program, in an external file. The data is read from the file always, except at the first invoking time when the first information is written into the file.

In order to generalize the prototype, together with the necessary information for the specific coupling, additional data is exchanged: the second face mass flow to the external program and both the first and the second face mass flow from the external program.

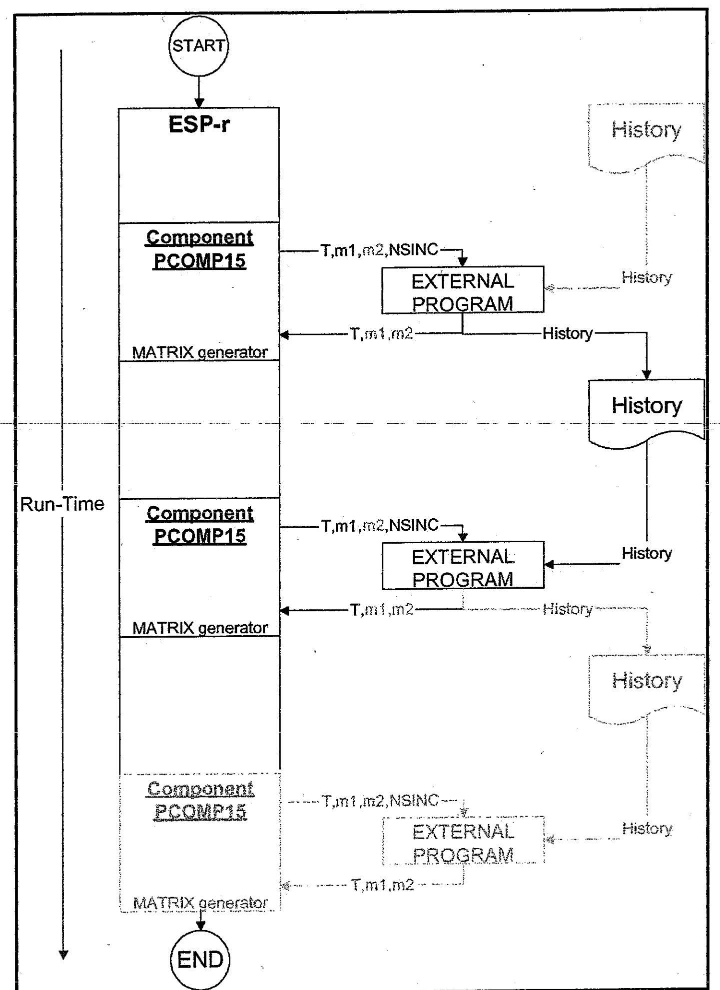

Figure 2 Initial prototype – Flowchart

Preprocessing of data can decrease the number of information exchanged. If the external file that holds the necessary history data is available even before the first initialization of the external program, the information of the time step number (here: NSINC) does not have to be exchanged. Here, preprocessing means performance of pre-calculation in order to initialize the history data. Transfer of history data between different time steps can be seen as an artificial continuous program run.

The coupling of those two simulation environments is a first step towards the developing of a general knowledge about the exchange of specific information between different tools.

CONCLUSION AND FUTURE WORK

The development of the first prototype based on the communication between ESP-r and EARTH recognized a need for a run time exchange of temperature and mass flow data to insure the consistency of simulation results. It was argued that the need for exchanging the information about the stage of the simulation process could be excluded if the preprocessing takes place before the main simulation.

Both simulation environments have been adapted for coupling proposes. A new component has been added in ESP-r. The input and output of EARTH was redirected to external files via which the information is exchanged between software.

The paper does not discuss the frequency of the exchanged data. It will be a part of future work. However, prototype enables the use of user specified time step in which external program is to be invoked. This time step can differ form building and/or plant time steps used in ESP-r.

In future, the prototype will dynamically be improved, by a coupling between different simulation packages. The coupling mechanism and data-exchange protocol will be obtained from maturing the prototype. The generalization of the initial prototype will ensure that the approach has wide and general applicability. In other words, the general knowledge will be extracted from the wide range of specific problem solving.

The coupling will be validated and the results will be implemented and tested in different building domain specific, as well as in domain independent simulation environments. The coupled design tools will be used to assess and compare the performance of various innovative building and systems combinations such as, for example, earth coupled heat exchangers, embedded renewable energy systems, etc.

NOMENCLATURE

variable	*explanation*
m_1	first face mass flow
m_2	second face mass flow
NSINC	simulation time step indicator
T	temperature

REFERENCE LIST

Djunaedy, E., Hensen, J. L. M., and Loomans, M. G. L. C. 2003. Towards external coupling of building energy and air flow modeling programs. 771-787. ASHRAE Transactions.

Hensen, J. L. M. 1993. Towards an integral approach of building and HVAC system. Energy and Buildings 19, 297-302.

Hensen, J. L. M., Djunaedy, E., Radosevic, M, and Yahiaoui, A. 2004. Towards a multiple-domain distributed building performance simulation approach. Proceedings of 21st International Conference on Passive and Low Energy Architecture.

Jong H.Yoon, Euy J.Lee, and Hensen, J. L. M. 1997. Integrated thermal analysis of a three story experimental building with a double skin facade and a ground coupled heat exchanger. Proceedings of International Solar Energy Conference SOLAR 97.

Yahiaoui, A., Hensen, J. L. M., and Soethout, L. 2003. Integration of control and building performance simulation software by run-time coupling. Proceedings of 8th International IBPSA Conference Building Simulation, 1435-1442.