IDA INDOOR CLIMATE AND ENERGY APPLICATION

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ABSTRACT

IDA Indoor Climate and Energy (ICE) is a recently developed tool for simulation of thermal comfort, indoor air quality and energy consumption in buildings. It covers a range of advanced phenomena such as integrated airflow and thermal models, CO_2 modeling, and vertical temperature gradients. It has a multi-level user interface to accommodate different types of users. It is primarily intended for HVAC designers and architects, but is also appreciated by educators and researchers. In this paper the advantages of the modern simulation tool are shown in prediction of indoor climate.

KEYWORDS

Modeling, comfort, energy, displacement ventilation

INTRODUCTION

IDA Indoor Climate and Energy is the first one in a new generation of building performance simulation tools, where the mathematical models are described in terms of equations in a formal language, NMF. This makes it easy to replace and upgrade program modules. For the end user, this means that new capabilities will be added more rapidly in response to user requests and that customized models and user interfaces are easily developed.

The library of the building components is made in project of International Energy Agency SH&C Task 22 Subtask B. The application is a commercial spin-off from the IDA and the IEA projects. The model library is validated in Subtask A against measurement and other programs. The model library is freeware and it is available via Internet. The models can be used in several modular simulation environments via translators.

NEUTRAL MODEL FORMAT

The model library is written in the Neutral Model Format [1]. NMF is a program independent language for modeling of dynamical systems using differential-algebraic equations. NMF serves both as clear model documentation for human readers and as input for automatic translation into the format of several simulation environments.

A great deal of work has been done with traditional languages and it is crucial that well-known and validated subroutines can be reused. This is accomplished via external function calls in NMF.

When the same models, and actually the source code, could be used in several different environments, quality and features of the models can be improved by several research groups around the World. SIMONE (**si**mulation **mo**del **ne**twork) is a central page for web-based network to exchange the models. The page could be found from address http://www.brisdata.se/nmf/simone.htm.

IDA SIMULATION ENVIRONMENT

IDA Simulation Environment is a general purpose modeling and simulation tool for modular systems where components are described with equations. IDA Simulation Environment has a solver called IDA Solver, which can solve non-linear algebraic problems without requiring initial guesses from the user. This can be quite a task for a problem with a few thousand unknowns.

Main features of IDA Solver include:

- Modeling is input/output free, i.e. variables have no irrevocable roles as given or calculated. Input/output free modeling naturally leads to models described by equations rather than the traditional calculation procedures, thus getting closer to the physical relationships known to the modeler.
- The integration of dynamical systems uses variable timestep and order, for efficiency and for consistent, easy to use, accuracy control.
- Discontinuities in driving functions and in model equations are handled properly. The timestep is adjusted to hit points of state and time events. Special solution methods are used to cross discontinuities.

MODEL LIBRARY

The mathematical models of building components have been developed at the Royal Institute of Technology in Stockholm (KTH) and at Helsinki University of Technology (HUT) within the framework of IEA SH&C Task 22. Whenever appropriate, models recommended by ASHRAE have been used. The model library is freeware and it is available via Internet in SIMONE page.

VALIDATION

Extensive comparative studies have been done against the BRIS program [2]. BRIS is a heat balance program for room climate studies; it was developed in Sweden in the early sixties. The program is based on detailed non-linear physical relations. BRIS has been validated against measurements in a number of studies. After several extensions, it is still widely used and well trusted by the Swedish building industry.

The central models have been validated against measurements in the scope of IEA Task 22. Preliminary validation results are published at Building Simulation ’99 -conference [3]. The full validation report will be available from IEA.

The IEA tests were carried out in the spring of 1998 with a beta version of IDA ICE. Some problems with the library models were revealed and rectified in this process. Unfortunately, a severe impact of thermal bridges in the test cell was discovered. They were accounted for by some but not all participants. This creates some difficulty in correctly assessing the results. However, after correction of thermal bridges, IDA ICE performed very well in the test.

APPLICATION

IDA Indoor Climate and Energy application is a commercial spin-off from the IDA-project of KTH. Company called Bris Data has been developed the application within IDA Simulation Environment from IEA model library.

The application has a multi-level user interface to accommodate different types of users; an occasional user appreciates simplicity (Figure 1) and an advanced user appreciates the flexibility and options to change the existing models or add models of his own (Figure 2).

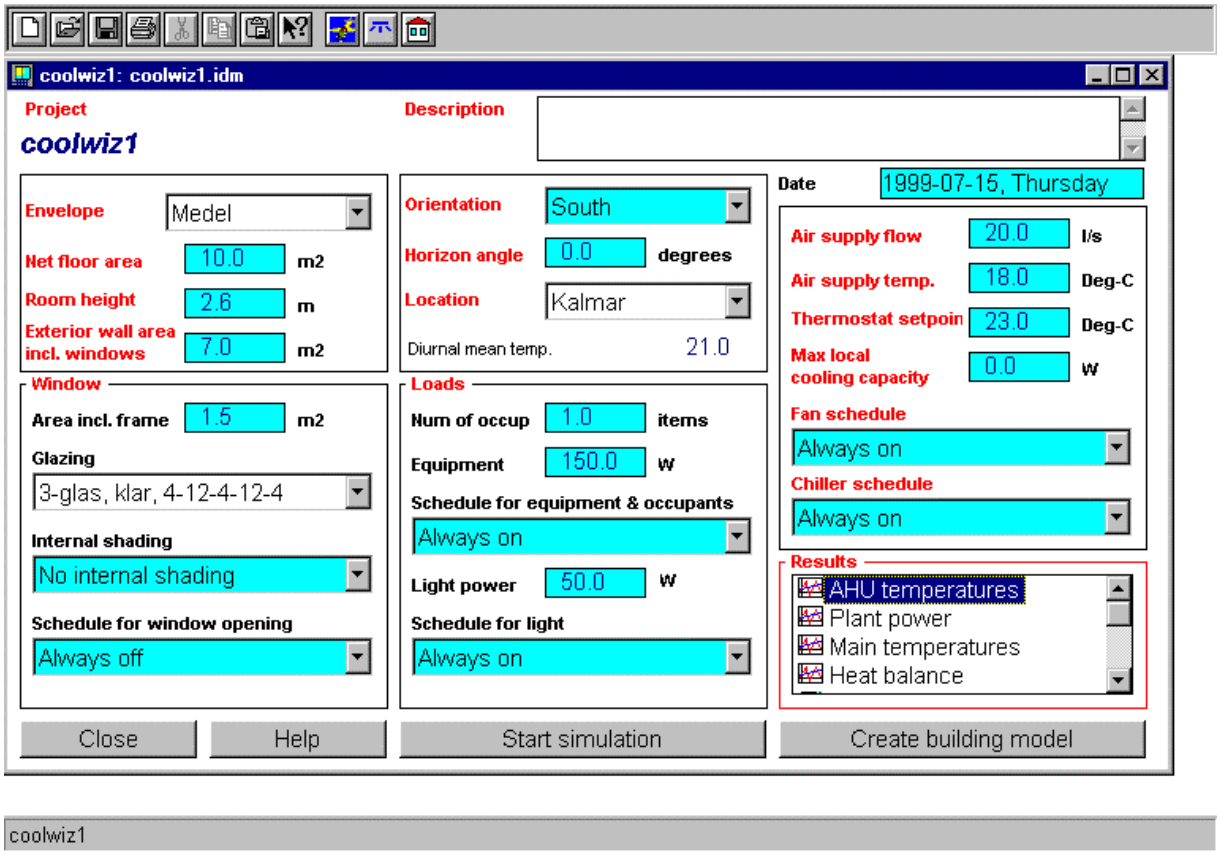

Figure 1. The wizard for occasional users.

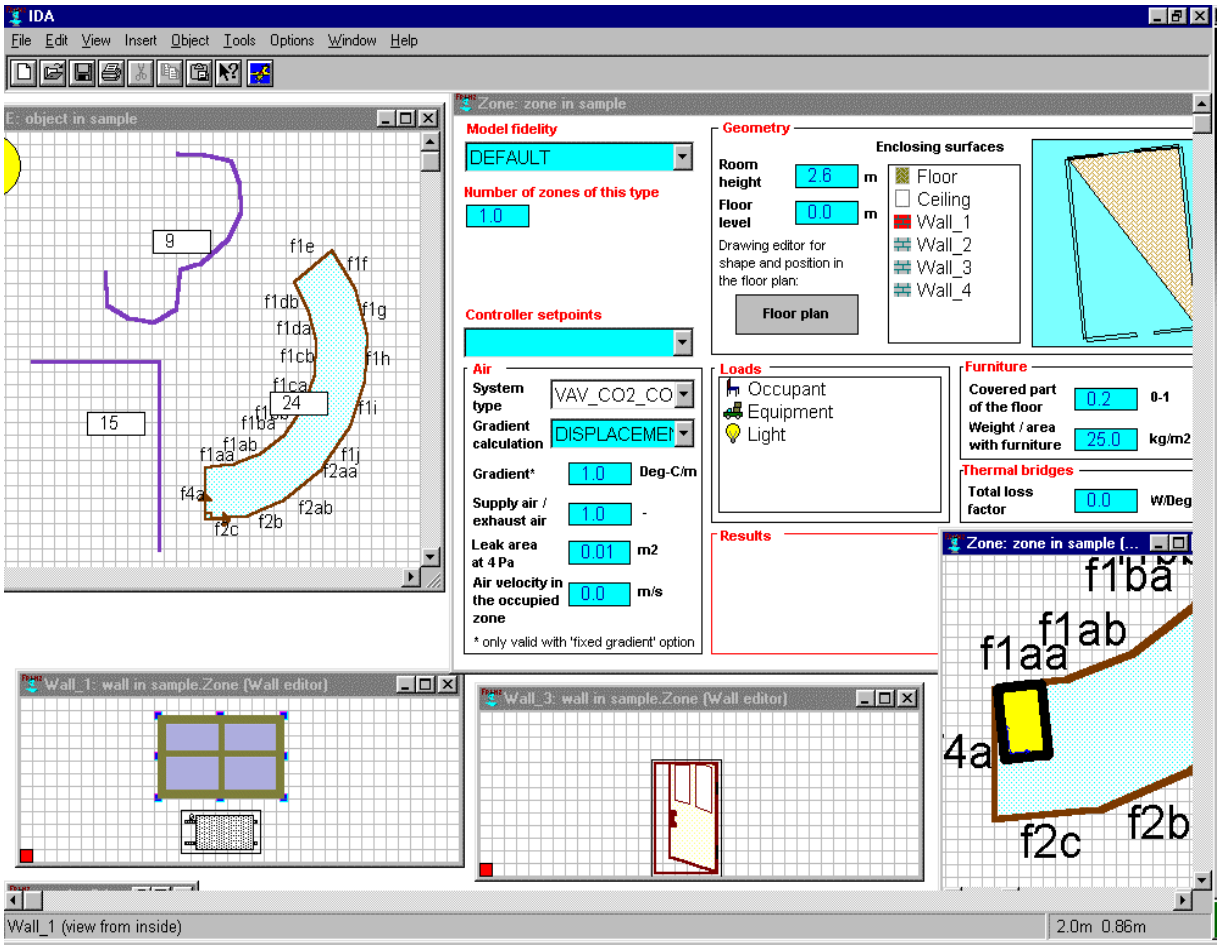

Figure 2. In the standard level interface, building parameters are defined graphically or numerically according to user preference.

The application may be used for most building types for calculation of:

- The full zone heat balance, including specific contributions from: sun, occupants, equipment, lights, ventilation, heating and cooling devices, surface transmissions, air leakage, cold bridges and furniture.
- Solar influx through windows with full 3D account for local shading devices as well as surrounding buildings and other objects
- Detailed heat and moisture load calculation from occupancy [4]
- Operating temperature at multiple arbitrary occupant locations, e.g., in the proximity of hot or cold surfaces. Full non-linear Stefan-Boltzmann radiation with view factors is used to calculate radiation exchange between surfaces.
- Directed operating temperature for estimation of asymmetric comfort conditions
- Comfort indices, PPD and PMV, at multiple arbitrary occupant locations [4]
- Daylight level at an arbitrary room location
- Air CO_2 and moisture concentrations, both which may be used for control of VAV system air flow
- Vertical temperature gradient in displacement ventilation systems

- Wind and buoyancy driven airflows through leaks and openings via a fully integrated airflow network model. This enables study of, e.g., temporarily open windows or doors between rooms.

SIMULATION EXAMPLE

The example is run for a classroom, where 45 minutes classes are given for 30 students. Between classes 15 minutes brake takes place. The size of the classroom is 150 m^2. In Figure 3 the CO_2-concentrations are shown with room height 2.5 m and 3.5 m. Air flow is 1.0 l/sm^2 in CAV-system and 1.0 – 1.5 l/sm^2 in VAV-system, which control setpoints are 700 and 1100 ppm. In the same Figure the effect of window opening during the brakes with CAV-system is shown.

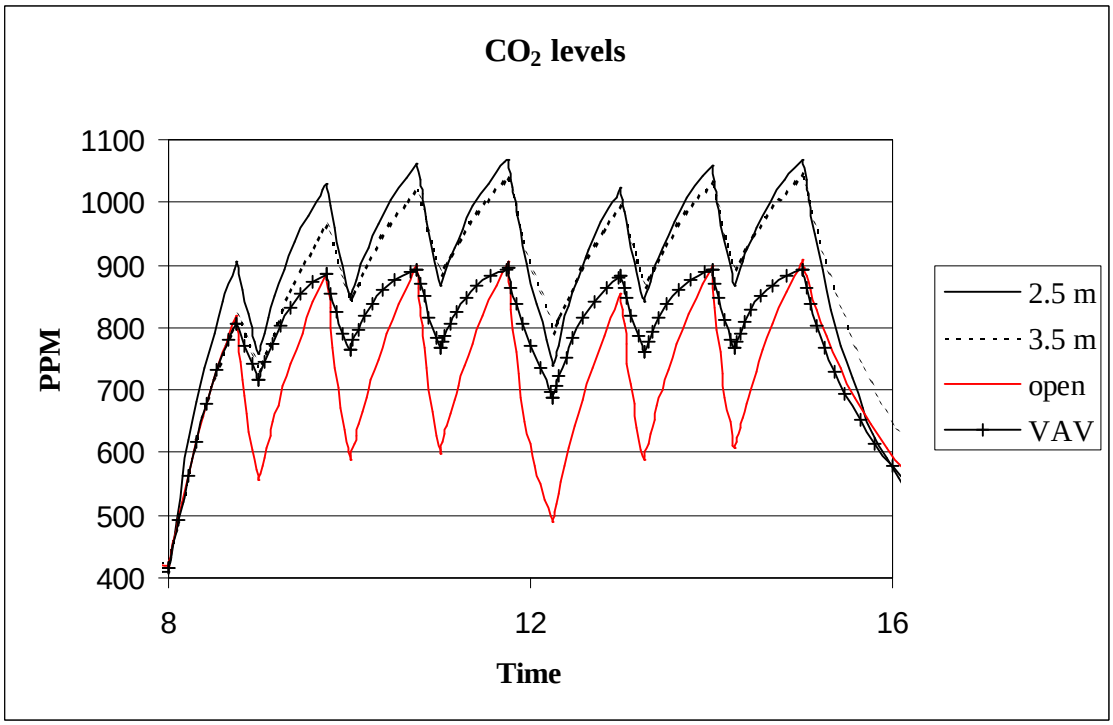

Figure 3. CO_2-concentration with different room heights, window opening and VAV-system.

From the Figure it can be read that air volume of the room has rather small effect after a few lessons. With the same air flow window opening keeps peak values of CO_2-concetration in 900 ppm instead of 1050 ppm without window opening. And VAV-system with selected setpoints have practically similar peak values as CAV-system with window opening.

DISCUSSION

NMF and IDA technology has been used to develop a comprehensive library for thermal building simulation. The library contains more detailed models than most comparable simulation tools. The library has been validated in the framework of an international validation exercise. The library has in conjunction with the IDA Simulation Environment been shown to hold excellent quality, both with respect to accuracy, robustness and attainable

execution speed. The library is publicly available. The features of the IDA ICE-application are waited for to make detailed indoor climate simulations possible.

These conclusions allow us to say the following about the state of object-oriented simulation methods in general:

- The technology is now sufficiently mature to be of excellent service to both developers and end-users.
- The major remaining obstacle is the low level of awareness and expertise among developers, funders and end-users.

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