Li-BIM– A model to simulate the occupant behavior from Building Information Model

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1. Overview

1.1 Purpose

Building design involves many challenges and requires to take into account the building user. Different occupant behavior models implemented with building simulation tools (thermal, air quality, lighting, etc.) have been proposed. Among these ones, models based on the agent approach seem to be the most promising. However, existing models poorly describe the human cognition. Moreover, they are often oriented towards a specific use (thermal simulation, waste management, etc.) without being transposable to another field, The Li-BIM model aims at filling this gap by simulating the behavior of occupants in a building. It is structured around the numerical modeling of the building (IFC format) and an evolved occupational cognitive model developed with a Belief-Desire-Intention (BDI) architecture. The model has been implemented under the GAMA platform.

1.2 Entities, state variables, and scales

The Li-BIM model is composed of four types of agents (fig 1):

- *Occupant*: The *Occupant* agents are based on a BDI architecture. They have two types of attributes: (a) characterization attributes (worker, smoker, ideal temperature, etc.) that are constant during simulation, and dynamic attributes regarding their physical/psychological state (comfort, tiredness, hunger, cleanliness, etc.). These latter attributes evolve at each time step of the simulation according to the occupant environment and action.
- *Household*: *Household* agents correspond to a group of occupants living in a common housing unit;
- *building*: the *Building* agent, which manages the global indicators (total energy consumption, global warming potential, etc.), is composed of a set of IFC components.
- *IFC components*: every object constituting the building in the IFC files is transformed into an agent (IFC components). Each IFC agent loads its attributes (and their values) from the BIM model: one object *Wall* in BIM is transformed into an agent *Wall* in Li-BIM with the same composition, geometrical characteristics, thermal resistance, etc.

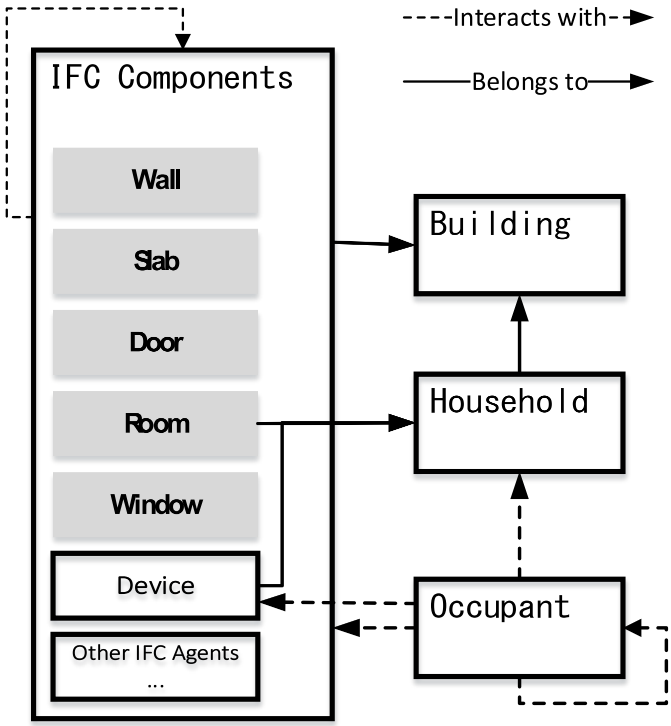

Fig 1. Li-BIM Agents

The simulation step is a parameter of the model; a default value of 5 minutes is proposed. The simulations were run for 1 year. The model simulates the behavior of occupants in a house designed into the IFC file; an example with a house of 90 m2 is proposed.

1.3 Process overview and scheduling

Each simulation step follows the same process (Fig. 2). Firstly, the model updates the environmental data (e.g. outside temperature, humidity, etc.) contained in the environmental files imported as CSV (see part 3.3.2). Secondly, based on these environmental data and on the IFC components, the building data (i.e. parameters of the different IFC component agents and of the *building* agent) are updated. Different physical models can be used to calculate the new values of these parameters. For example, the inside temperatures can be computed by a thermal model thanks to the environmental data (e.g. outside temperature) and to the IFC component characteristics (e.g. thermal resistance of wall). These characteristics can be impacted by the actions previously performed by occupants (e.g. opening of windows).

Some plans carried out by the *occupant* agents can last more than one simulation step, and thus, in order to finish its plan, the agent will keep the same intention for the required numbers of simulation steps. A plan can be composed of several actions. However, some actions can be instantaneous (e.g. switch on the heater) or can be performed simultaneously with other actions (discuss with another occupant). In this case, and if the intention is not yet achieved, the agent will keep its unfinished intention and continue to execute the current plan (i.e. the other actions of the plan). If the intention is achieved, then the desire base is updated and the agent selects a new intention corresponding to the desire with the highest priority, and execute the most appropriate plan to fulfill this intention.

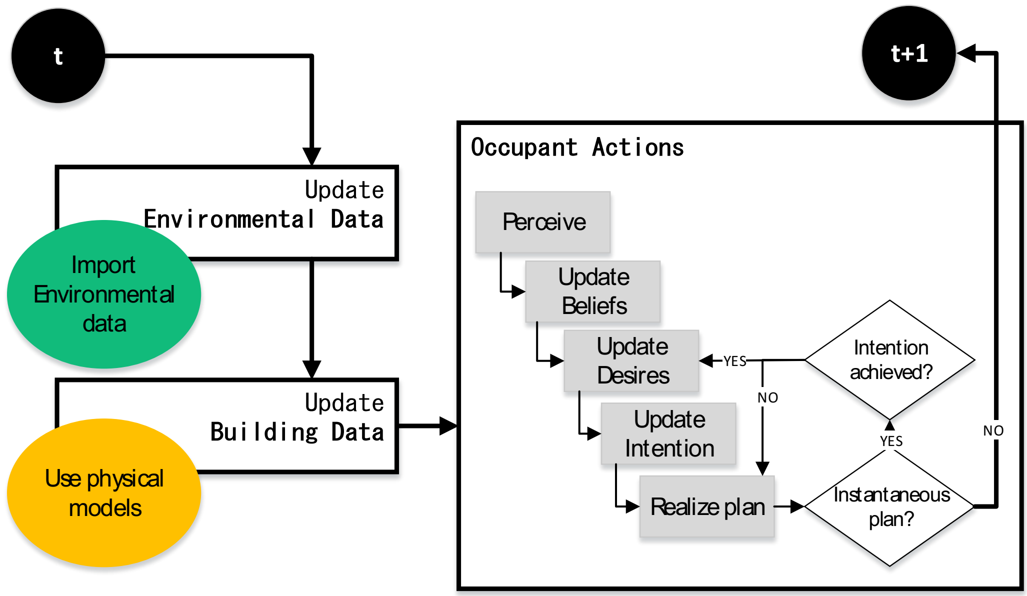

Fig 2. Li-BIM Dynamic

The environmental and building attributes are updated at each simulation step:

- Weather (outside temperature, relative humidity, sunset and sunrise time) from imported CSV files specific to the building location
- Inside temperature calculated thanks to the thermal model
- Clothing deduced from the season and the thermal comfort
- Total thermal transmission calculated according to the windows and blinds position
- Total heat gains calculated as the sum of the released power by the occupants, the lighting devices and the electrical appliances

Then, *occupant* agents update their belief, desire and intention bases. Finally, they select a plan among the 17 implemented plans. Table 1 references all the current possible activities available to the occupants.

Table 1: Implemented occupant actions

Activity	Depends on	Leads to	Room
Blinds pulling down/up*	Sleeping state Solar gain in winter or summer	Thermal transmission	Bed room
Changing clothes*	Thermal discomfort		Any room
Cleaning	Cleaning frequency	Heat gains Cleaning devices switch on	Every room
Cooking	Current time Hunger	Meal ready Heat gains Cooking devices switch on Hot water device switch on	Kitchen
Discuss*			Any room
Eating	Meal ready		Living room

Going outside	Weather Current day Discussions with others		Outside
Toilets	Peeing state		Toilets
Heating regulation*	Thermal discomfort	Heat gains Modify boiler power	Any room
Relaxing	Default action	Heat gains Relaxing devices switch on	Living room
Showering	Cleanliness	Hot water device switch on	Bath room
Sleeping	Current time Lightness Tiredness	Pull down blinds	Bed room
Smoking	Smoking frequency	Open window	Any room
Turn on lights*	Lightness Not sleeping	Heat gains Light device switch on	Any room
Washing clothes*	Washing frequency	Heat gains Washing machine switch on	Bath room
Windows opening*	Thermal discomfort Smoking activity	Thermal transmission	Any room
Working	Current day		Outside

** Instantaneous action*

2. Design concepts

Basic principles

The Li-BIM model meets three criteria: (a) advanced cognitive model, (b) interoperability and flexibility, (c) accessibility to non-computer scientists. The model is structured around an agent based model and the BIM representation of the building imported as IFC files. The agent based model is implemented under the open source multi-agent platform GAMA, which integrates a BDI architecture and a new plug-in dedicated to the importation of IFC files (now available for all GAMA users).

Adaptation

Occupant behavior is based on BDI architecture. It allows them to perceive their environment (belief base), to update their desire regarding it and finally to adapt their behavior regarding their feeling.

Objectives

Occupant aims at feeling well and at accomplish their duty. For instance, their want to have neither cold or hot; they will try by their behavior and action to regulate the perceive warmness (add clothes, switch on heater, open the windows…). They have also some constraints as going work or to school.

Sensing:

Occupants perceive their environment (is it night or day, temperature, other occupant…) and have their own feeling on its (occupants are more or less sensitive to cold…).

Interaction:
Different kinds of interactions are used in the model: interaction between occupants, interactions between occupants and building equipment's, etc.

Stochasticity:
The Li-BIM model is deterministic.

Observation
The model has for outputs two types of data: a direct graphical output at each simulation step and the final CSV files available at the end of the simulation. In the graphical mode, several variables evolving at each simulation step are available. In the context of this study, the focus is put on the energetic performances of the building. Thus, the indoor and outdoor temperature, the comfort range of temperature for each occupant as well as the regulation of the heating are shown to the user (Fig. 3). The user can also follow the activity and the state of each occupant during the simulation.

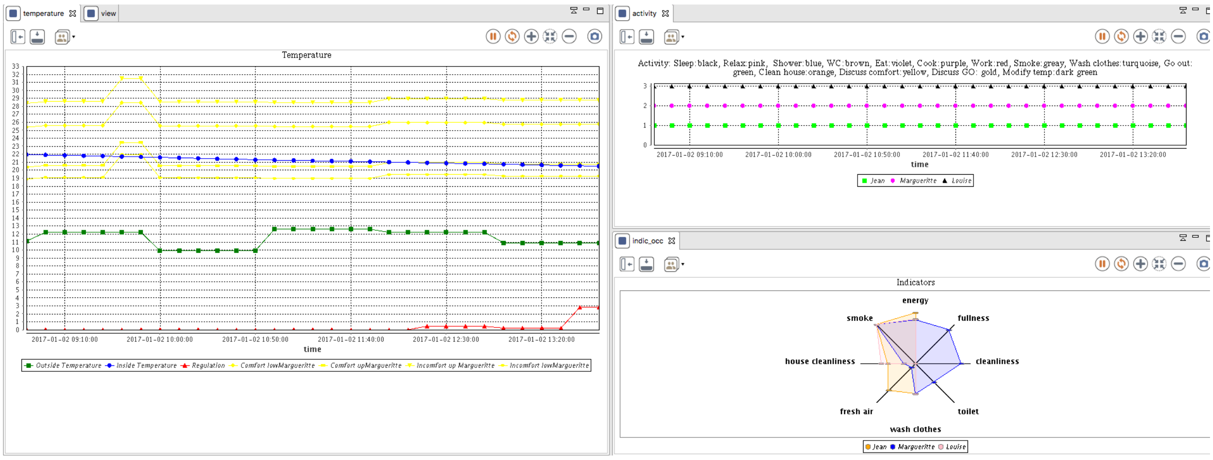

Fig 3. Indicators during simulation

Regarding the final output file, three types of variables are proposed as output data: (a) activity, (b) comfort and (c) energy consumption. Activity file gives for each occupant the number of time she/he performs the different activities. It gives information to check the consistency of the simulation and enables to understand the energy consumption. Comfort output gives the average comfort of the occupant; it is an important criterion to assess the quality of a building. Finally, energy consumption gives the consumption of the different devices on the simulated year. It is the main output of this implementation of Li-BIM which aims at assessing the impact of the occupants's behavior on energy consumption.

3. Initialization

The simulation begins the 1st January 2017. The occupants are in the house, sleeping.

4. Input data

The input data concerns three domains:

(a) Description of occupants (CSV file)
(b) Description of the building (IFC files)
(c) Environmental data (CSV files)

In order to simulate the behavior of occupants, it is necessary to characterize them with a set of parameters. The data integrating all the occupant attributes is formalized into a csv file which is directly imported in the agent-based model. These attributes deal with occupant habits (duration of sleeping, smokes or not, etc.) and with preferences (green consciousness, etc.).

The environmental data is linked to three domains: weather data, solar calendar and working days. The imported weather data is about the *Outside temperature* and the *Outside relative humidity*.

The building data is imported from a BIM description of the building (IFC file). The direct integration of this numerical model allows interoperability between different tools and an easier description of the building. Indeed, it makes possible the data transfer between Li-BIM and external physical models. As a consequence, Li-BIM is easy and fast to use: no supplementary effort is asked to the user as BIM is already required in the project.

5. Submodels

The model is divided into two parts: physical and cognitive. The cognitive model, presented in Section 3, defines the occupant behavior and is based on the BDI architecture coupled with a model of social relation. The occupant reacts to physical stimulus obtained thanks to the physical model and interacts with the physical components of the building (data exchange), then, the physical model takes into account these changes in the components' state.

Li-BIM aims at being sufficiently flexible to integrate different types of building and the related behavior as thermal performance, energy consumption, air quality… The model can be easily updated to cover new dimensions (e.g. acoustic, lighting, etc.). In addition, in order to ensure a better adaptability of the model, Li-BIM does not depend on a specific physical model. Still concerning its adaptability to different context, the model enables to integrate a set of csv files to describe the environment (e.g. weather data, outside air pollution data, sound data, etc.). Li-BIM constitutes a hub between different physical models to an occupant behavior model that can easily be adjusted. Thus, it allows the user to study the impact a wide variety of occupant behaviors regarding different physical models. For instance, a building designer can simultaneously investigates the impact of the occupant behavior (and related resulting performance indicators), on air quality (toxicity), and energy consumption; nowadays, no other model is able to integrate such combinations of occupant behavior and physical models.

The current implementation of the model integrates a thermal comfort model and a thermal model. The thermal comfort is conditioned by the occupant's characteristics (sensitive to cold, clothing, etc.) and by the external environment (relative humidity, indoor temperature, etc.). The developed comfort model determines a comfort temperature range for each user at each time step which depends on both a comfort temperature and how sensitive to cold they are. The used thermal model calculates the inside temperature at each time step, based on classical flow equations.