# 1 Organizational Aspects

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|---|---|---|
| **Project:** | **D1.Project1** | |
| **Name:** | **Simulator Simple 2** | |
| **Document:** | **Problem_Description** | |
| **Responsible:** | **Deiß** | |
| **File-Pathname** | | |

| Type of change | Date | Version | Person |
|---|---|---|---|
| Start | 21.09.94 | 1.0 | Deiß |
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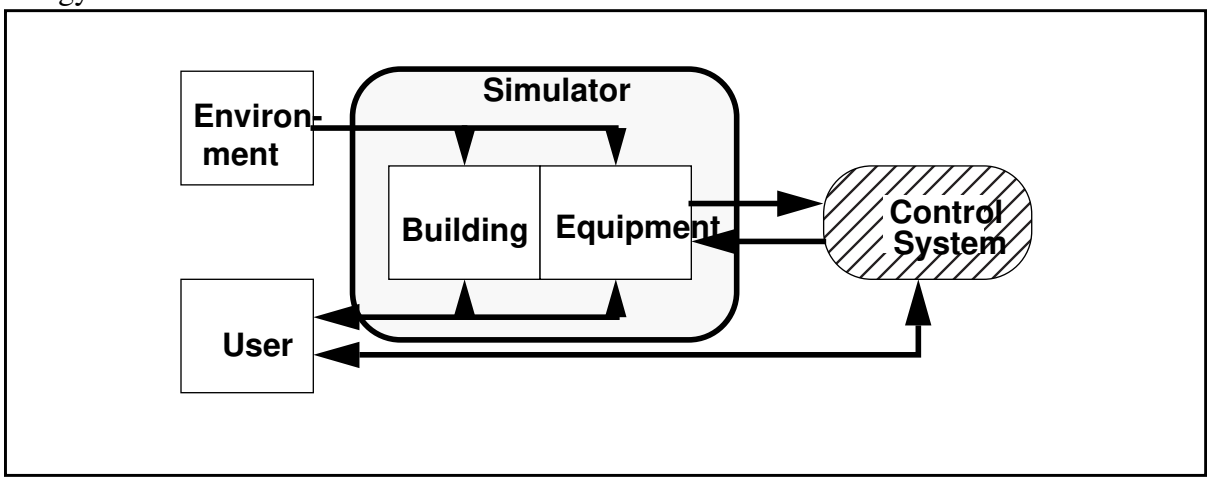
# 2 Short Description

The ultimate goal of the project is a generator that creates a simulator for every building based on requirements on functionality and a model of the building. Therefore all objects should be designed such that they can be reused as templates for the generator library.

The goal is a system that simulates the heat flow in a given building in realtime or multiples of realtime. The application is the test of control systems and the demonstration of properties of a building to the architect, the customer, and the user.

The architect wants to try properties of the building and installation, for example the radiators standard heat outputs. The customer wants to experiment with different controller descriptions before he orders a controller. The customer also wants to test the delivered controller before he installs it in the building. The user may want to test different settings of the controller for energy conservation reasons while he lives in the house.




The above picture shows the simulator in its environment

**General simulator requirements**:

The simulator shall be able to maintain an ongoing model of the physical reality of the house, starting from a defined state of the house. One simulation starting from a defined state and eventually halting in another state will be called a simulation run. Before a simulation run parameters of the installation (e.g. the size of windows, the standard heat output of radiators), initial values of the physical quantities (e.g. air temperature), the input/output configuration of the simulator and several parameters controlling the run itself can be set. Furthermore it shall be possible to present the currently set initialization values to the user of the simulator. It shall be possible to stop a simulation run and to change the values of some of the physical quantities, but not the parameters of the installation. It shall be possible to resume a stopped simulation run or to abort it definitely.

A simulation run starts from a specified point in time (simulation time) and continues until it is stopped by an user or the simulation time reaches another specified point in time. It shall be possible to run the simulation as fast as possible, or with a strict binding between real-time and simulation time: Simulation time is passing a fixed factor faster than real time. The simulation time is allowed to be a constant amount of time behind real time. Violation of this condition has to be reported by the simulator. The user can decide before a simulation run whether the simulation has to aborted in this case or whether it can continue.

The simulator has to accept inputs during a simulation run. The inputs can be commands controlling the simulator, new values for physical quantities (e.g. the outdoor temperature) and commands send to the installation or the building blocks of the house (e.g. a command to close

a radiator valve or a request for the air temperature of a specific room). There may be several simultaneous sources of inputs. These are an user of the simulator, a control system and files. Colliding inputs shall be detected and reported, all except one of them shall be discarded and simulation shall continue with the remaining input.

Outputs can be the current values of physical quantities as well as the current state of the installation. It shall be possible to distribute the outputs to several destinations (even the same output may be send to several destinations). Similar to inputs sources, output destinations can be a control system, an user and files. The outputs can be generated on explicit request, periodically or on change of the quantitiy. In case of explicit requests, the answers are sent to the requester.

Inputs and outputs shall have the same format. A time, when the input has to be considered or the output has been generated, the object for which the input is determined or which produced the output and the actual message. There shall be a special symbolic time meaning ‘as soon as possible‘ for the inputs.

**Realization requirements:**

The actual simulation is done within ‘simulation objects‘ encapsulating the physical properties of the house and its installation. Therefore the simulator can be system as a system between the various kinds of ‘users‘ and the simulation objects which has three main tasks.

Inputs have to be transmitted to the simulation objects and outputs from the simulation objects have to be transmitted to the users. This has to be done in a timely fashion, corresponding to the simulation time. Outputs shall be output as fast as possible, the times of the outputs shall be non-decreasing.

The simulation objects have to invoked to perform their simulation. The objects must be invoked within a certain amount of time, which may vary from object to object and for one object within a simulation run. It is allowed to invoke the objects earlier. These invocation times and the I/O times have to correspond.

The simulator has also to provide mechanisms to ensure, that the simulation objects computing at the same point in time use the same values, i.e. double buffering of variables has to be supported.

**Other requirements**:

Incoming data has to be checked for correctness (e.g. inputs to nonexisting objects are not allowed). Incorrect input shall be reported, but shall not lead to abortion of a simulation run. Simulation objects shall be able to signal that their internal state is inconsistent, this situation shall lead to abortion of the run. In all other casesthe simulator shall try to maintain the ongoing physical model of the house, but errors shall be reported.

The simulator shall be able to proceed simulation time 500 times faster than real time for the house described in the rest of this document. (for a typical workstation, e.g. Sparc 20, single processor, 50 Mhz)

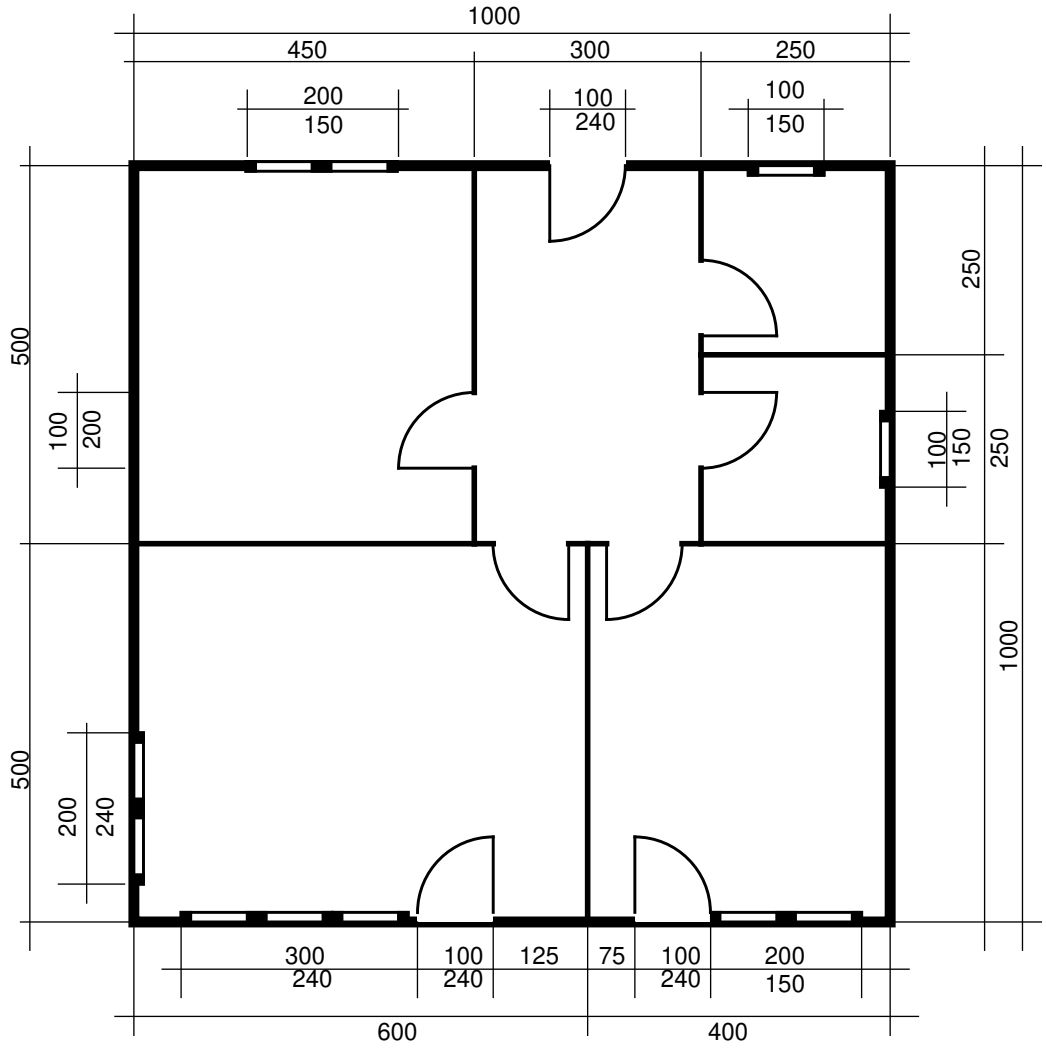
The simulator shall be able to write checkpoints without stopping a simulation run and dumps when a run has been aborted due to inconsistent internal states of the objects. It shall be possible to use a checkpoint or dump (perhaps after some manual editing) as initialization data for another simulation run.

# 3 Detailed Description

Floorplan

## 3.1 Measures and Materials

**This information shall only be used for understanding the problem. It is not part of the specification!**




unit: cm , all dimensions are center line
Building height is 281 cm ( clear dimension 250 cm)

All indoor *doors* are 100x200 cm, 4 cm *softwood*

All *windows* are *double insulating glass* with wood *frames* with *fitting*

All exterior *walls* are 36cm *Poroton* + 2 cm *gypsum plaster* indoors + 2 cm *cement plaster* outdoors (Total 40 cm)

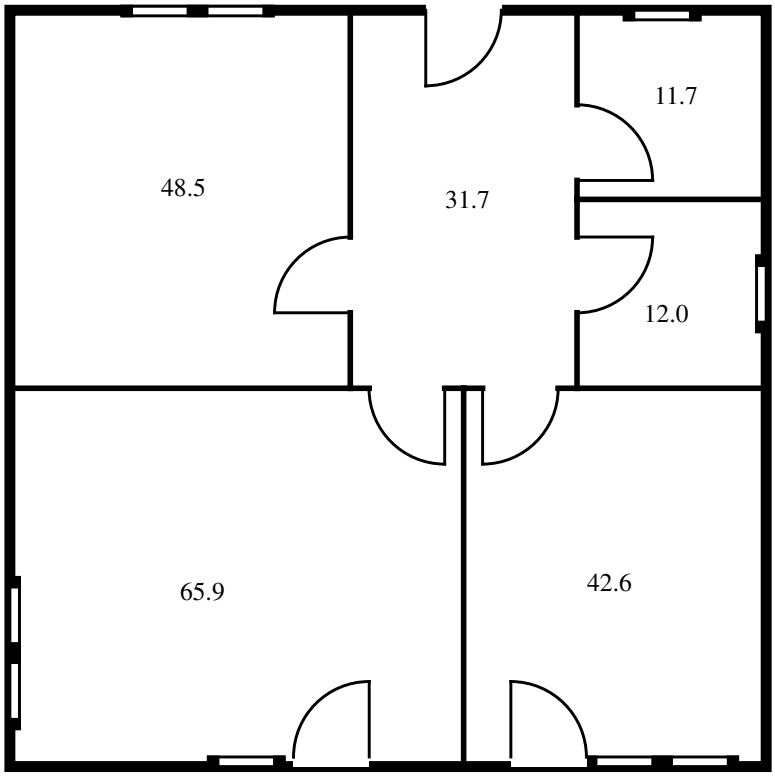
All interior *walls* are 24 cm Poroton +2 x 2 cm *gypsum plaster* (total 28 cm)

The *floor* is 1cm *carpet* over 5 cm concrete over 4 cm *insulation* over 20 cm *concrete* over *dry sand* (total 30 cm)

The *ceiling* is 1 cm *gypsum plaster* under 20 cm reinforced *concrete* under 10cm *insulation*

under 1 cm *bitumen felt* (Total 32 cm)

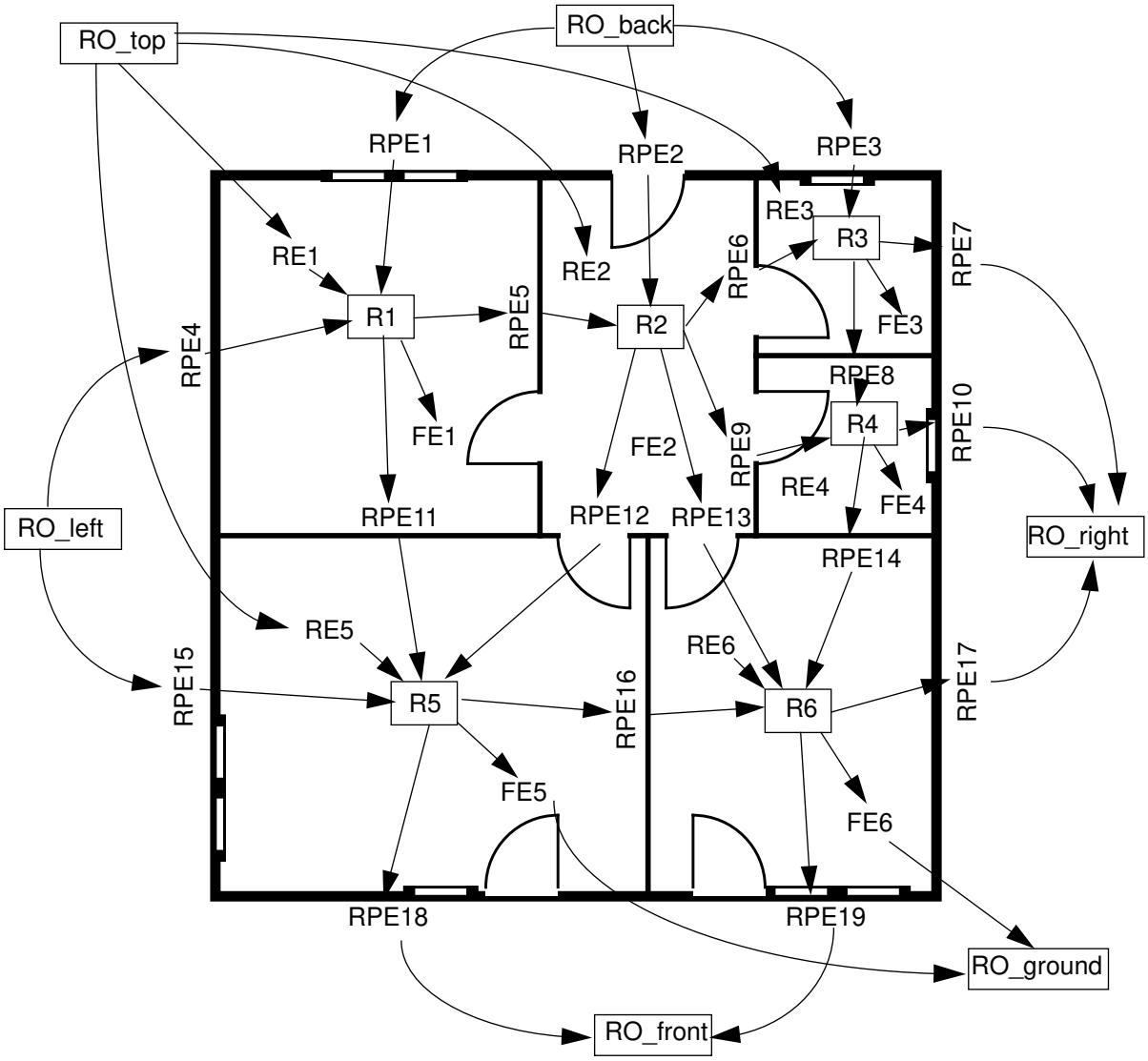
## 3.2 Room Volumes




unit: $m^3$

The values are calculated from clear dimensions (lichte Weiten) and thus can be taken as the air volume for heat storage calculations.

## 3.3 Object-Relations




**R** stands for aindoor *room*

**RO** stands for *outdoor space*

**RPE** stands for room partition element

Not all relations are shown

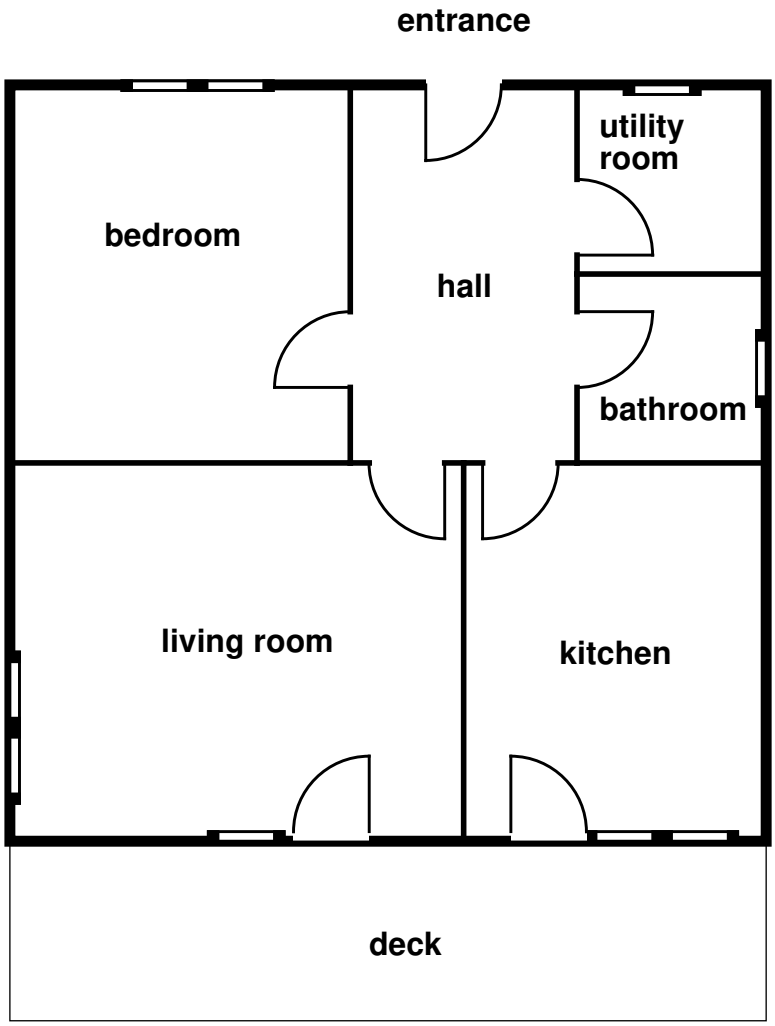
Graph is bipartite and directed (not necessarily)

Relations are noted as from-to-where: for example bf means back-to-front, lr means left-to-right and tg means top-to-ground

**Table 1: Relations between rooms and room partion elements**

| **Rooms** | | | **R1** | **R2** | **R3** | **R4** | **R5** | **R6** | **RO_l** | **RO_r** | **RO_b** | **RO_f** | **RO_t** | **RO_g** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **floor area $m^2$** | **19.4** | **12.7** | **4.7** | **4.8** | **26.4** | **17.1** | | | | | | |
| **Room Partit. Elemnts** | | **air volume $m^3$** | **48.5** | **31.7** | **11.7** | **12.0** | **65.9** | **42.6** | | | | | | |
| RPE1 | | | bf | | | | | | | | fb | | | |
| RE1 | | | tg | | | | | | | | | | gt | |
| FE1 | | | gt | | | | | | | | | | | tg |
| RPE2 | | | | bf | | | | | | | fb | | | |
| RE2 | | | | tg | | | | | | | | | gt | |
| FE2 | | | | gt | | | | | | | | | | tg |
| RPE3 | | | | | bf | | | | | | fb | | | |
| RE3 | | | | | tg | | | | | | | | gt | |
| FE3 | | | | | gt | | | | | | | | | tg |
| RPE4 | | | lr | | | | | | rl | | | | | |
| RE4 | | | | | | tg | | | | | | | gt | |
| FE4 | | | | | | gt | | | | | | | | tg |
| RPE5 | | | rl | lr | | | lr | | | | | | | |
| RE5 | | | | | | | tg | | | | | | gt | |
| FE5 | | | | | | | gt | | | | | | | tg |
| RPE6 | | | | rl | lr | | | | | | | | | |
| RE6 | | | | | | | | tg | | | | | gt | |
| FE6 | | | | | | | | gt | | | | | | tg |
| RPE7 | | | | | rl | | | | | lr | | | | |
| RPE8 | | | | | fb | bf | | | | | | | | |
| RPE9 | | | | rl | | lr | | | | | | | | |
| RPE10 | | | | | | rl | | | | lr | | | | |
| RPE11 | | | fb | | | | bf | | | | | | | |
| RPE12 | | | | fb | | | bf | | | | | | | |
| RPE13 | | | | fb | | | | bf | | | | | | |
| RPE14 | | | | | fb | | | bf | | | | | | |
| RPE15 | | | | | | | lr | | rl | | | | | |
| RPE16 | | | | | | | rl | lr | | | | | | |
| RPE17 | | | | | | | | rl | | lr | | | | |
| RPE18 | | | | | | | fb | | | | | bf | | |
| RPE19 | | | | | | | | fb | | | | bf | | |

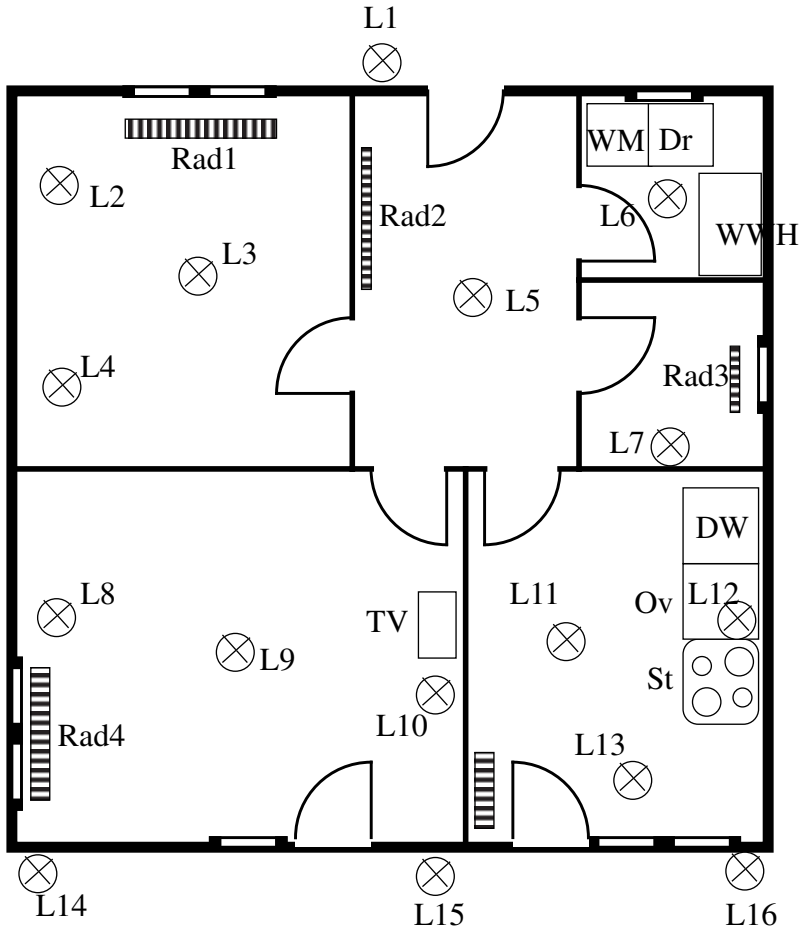
Functional Units




The names of *functional units* should be used as instance names of rooms.

The meaning of the names is in the *design indoor temperatures* (table in dictionary) which should be used as default values.

## 3.4 Installation




unit: cm

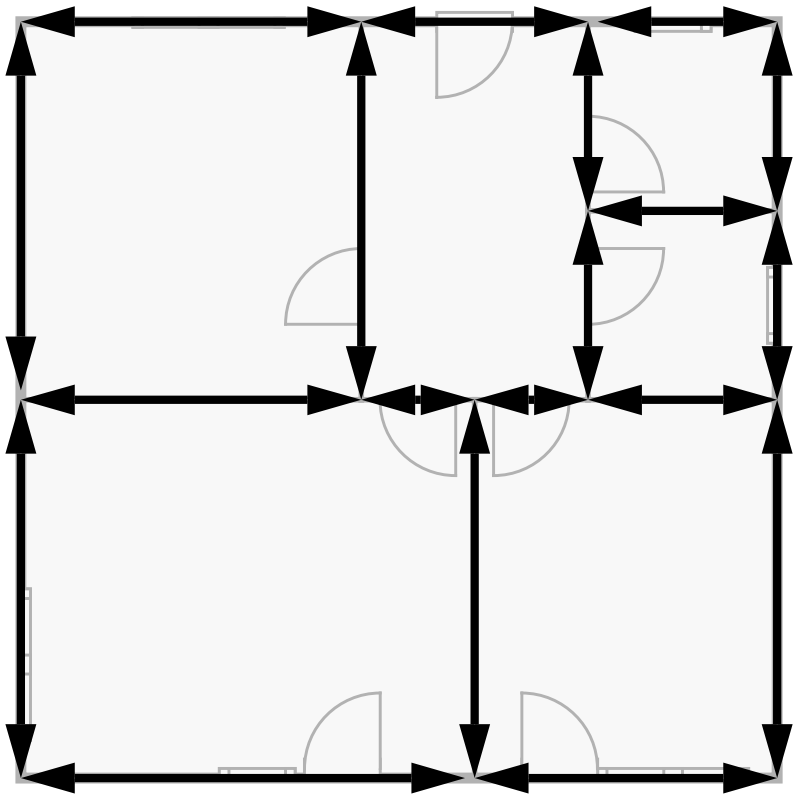
**Table 2:**

| Abbrev. | Equipment | include in specification |
|---|---|---|
| L | Lighting fixture | y |
| Rad | Radiator | y |
| WM | Washing machine | n |
| Dr | Dryer | n |
| WWH | Warm water heater | y |
| DW | Dishwasher | n |

**Table 2:**

| Abbrev. | Equipment | include in specification |
|---|---|---|
| Ov | Oven | n |
| St | Stove | n |
| TV | Televison set | n |
| | | |

## 3.5 room partition element graph



## 3.6 Simulation Objects

The simulation objects will be provided by project D1. The description of their functionality serves illustrative purposes only. The description of the interfaces is sufficient for the specifications of the simulator.

The interface of an object provides access to its state (physical quantities or parameters) and enables invoking the objects for simulation and access to the maximal time delay between two consecutive invocations. The simulation objects are responsible for checking correctness of input values, but not the simulator.

The relations between objects need not be known by the simulator, these relations are incapsulated in the objects. But an object invoked by the simulator may invoke other objects.

The interface description contain variables in and out that can change with time during a simulation run, and parameters that are set before the simulation starts.

### 3.6.1 indoor room (leaf)

Rooms are heat flow nodes with a heat storage capacitance.

In each room the sum of all heat fluxes has to be zero (heat balance).

The room temperature is the temperature of the air as a heat capacitance.

Components of the heat balance are (input parameters):

transmission load: heat flow through all adjacent room partition elements

ventilation heat loss: gain or loss of heat through doors and windows, depending on the states of the building elements and the climate differences

internal gain: heat output of the radiators, depending on standard heat outputs, state of the radiator control valves, the hot water flow temperature, and the water pressure.

lighting load: heat generated by light fixtures, depending on states and fixture chacteristics.

eqipment load: heat generated by electrical equipment. Heat load is assumed to be 100% electrical power. Depends on states of equipments

Output parameters:

room temperature

hot water return temperature

internal gain

| direction | name | range | visibility | default | units |
|---|---|---|---|---|---|
| in | heat fluxes from room partition elements | | RPE | 0 | W |
| | air volume flows | | RPE | 0 | $m^3s^{-1}$ |
| | air flow temperatures | | RPE | 20 | °C |
| | persons assignment | 0..20 | pers | 0 | |

| direc-tion | name | range | visibi-lity | default | units | |
|---|---|---|---|---|---|---|
| | trigger | | | | | |
| out | air temperature | -20..40 | simul +RPE | 20 | ˚C | |
| | air pressure | | | | | p 11 |
| | maximum time interval | | | | | p 12 |
| | trigger,object, and trigger delay | | | | | |
| param | | | | | | p 13 |

### 3.6.2 outdoor space (leaf)

Calculates radiation on vertical surfaces on the four sides of the building using the input values

Diffuse and direct radiation are depentent on sky cover

| direc-tion | name | range | visibi-lity | default | units |
|---|---|---|---|---|---|
| in | outdoor air temperature | | simul | 20 | ˚C |
| | diffuse sky radiation | | simul | | $Wm^{-2}$ |
| | direct radiation | | simul | 0 | $Wm^{-2}$ |
| | date | | simul | | |
| | | | | | |
| out | air temperature | | RPE | | ˚C |
| | radiation on vertical surfaces (left, right, front, back) | | RPE | | $Wm^{-2}$ |
| | | | | | |
| param | | | | | |
| | | | | | |

### 3.6.3 room partition element (leaf)

consists of wall elements, doors and windows(floorplan)

the element has two distinguishable sides: face and back

| direc-tion | name | range | visibi-lity | default | units |
|---|---|---|---|---|---|
| in | face air temperature | | | | ˚C |
| | back air temperature | | | | ˚C |
| | | | | | |
| out | average face surface temperature | | | | ˚C |
| | average back surface temperature | | | | ˚C |
| | total face heat flux | | | | W |
| | total back heat flux | | | | W |
| | total air flow | | | | $m^3s$-1 |
| param | composition | | | | |
| | | | | | |

### 3.6.4 wall element (leaf)

| direc-tion | name | range | visibi-lity | default | units |
|---|---|---|---|---|---|
| in | face air temperature | | | | ˚C |
| | back air temperature | | | | ˚C |
| | | | | | |
| out | face surface temperature | | | | ˚C |
| | back surface temperature | | | | ˚C |
| | face heat flux | | | | W |
| | back heat flux | | | | W |
| param | area | | simul | | |
| | wall layers | | simul | | |
| | material | | simul | | |
| | | | | | |

### 3.6.5 door (leaf)

| direc-tion | name | range | visibi-lity | default | units |
|---|---|---|---|---|---|
| in | open command | 0..100 | simul | 0 | % |
| | face air temperature | | | | ˚C |
| | back air temperature | | | | ˚C |
| | | | | | |
| out | opening state | 0..100 | simul | 0 close d | % |
| | face-to-back air volume flow | | | | $m^3s$-1 |
| | face-to-back heat flux | | | | W |
| | face surface temperature | | | | ˚C |
| | back surface temperature | | | | ˚C |
| param | area | | | | |
| | composition | | | | |
| | | | | | |

### 3.6.6 window (leaf)

| direc-tion | name | range | visibi-lity | default | units |
|---|---|---|---|---|---|
| in | open command | 0..100 | simul | 0 | % |
| | face air temperature | | | 20 | ˚C |
| | back air temperature | | | 20 | ˚C |
| | face radiation density | | | | |
| | back radiation density | | | | |
| out | opening state | 0..100 | simul | 0 (close d) | |
| | face-to-back air volume flow | | | | $m^3s$-1 |
| | face-to-back heat flux | | | | W |
| | face surface temperature | | | | ˚C |
| | back surface temperature | | | | ˚C |

| direc-tion | name | range | visibi-lity | default | units |
|---|---|---|---|---|---|
| | face-to-back radiation load | | | | W |
| | | | | | |
| param | area | | | | |
| | type | | | | |
| | | | | | |

### 3.6.7 radiator (leaf)

| direc-tion | name | range | visibi-lity | default | units |
|---|---|---|---|---|---|
| in | control valve opening | 0..100 | simul | 0 | |
| | max water flow | | simul | 0 | $kgs^{-1}$ |
| | hot water inlet temperatur | 0..90 | | 90 | ˚C |
| | trigger | | | | |
| | | | | | |
| out | hot water outlet temperature | | | 70 | ˚C |
| | heat output | | room | 1000 | W |
| | maximum time interval | | | | |
| | trigger, object, delay | | | | |
| param | standard heat output | | simul | 1000 | W |
| | radiator type | dict | simul | | |
| | | | | | |

p 14

### 3.6.8 warm water heater (leaf)

| direc-tion | name | range | visibi-lity | default | units |
|---|---|---|---|---|---|
| in | hot water return temperature | 0..100 | | 70 | ˚C |
| | burner state | on, off | simul | off | |
| | | | | | |
| out | hot water flow temperature | 0..100 | | 90 | ˚C |
| | gas consumption per burner on period | | | | $m^3$ |

| direc-tion | name | range | visibi-lity | default | units |
|---|---|---|---|---|---|
| | | | | | |
| param | heat output | | simul | 20 | kW |
| | type | | dict | | |
| | gas type | | dict | | |
| | efficiency | 0..110 | | | % |

### 3.6.9 hot water distribution (leaf)

p 15

Consists of water pump, a flow pipe tree and a return pipe tree

**not yet complete**

| direc-tion | name | range | visibi-lity | default | units |
|---|---|---|---|---|---|
| in | pump state | on, off | simul | off | |
| | pump setting | 1..4 | simul | 2 | |
| | radiator outlet temperature (n) | | | | ˚C |
| | | | | | |
| out | pump water pressure | | | | |
| | flow volume | | | | |
| | electric energy consumption | | | | |
| | return water temperature | | WW H | | ˚C |
| param | water pump type | dict | | | |
| | | | | | |

### 3.6.10 light fixture (leaf)

| direc-tion | name | range | visibi-lity | default | units |
|---|---|---|---|---|---|
| in | power state | on,off | simul | off | |
| | | | | | |
| out | lighting load | 0..200 W | room | | W |
| | luminous flux | | room | | |

| direc-tion | name | range | visibi-lity | default | units |
|---|---|---|---|---|---|
| | | | | | |
| param | electrical power | 5..200 W | simul | 60 | W |
| | type | | simul | | |
| | | | | | |

### 3.6.11 Inhabitant (leaf)

| direc-tion | name | range | visibi-lity | default | units |
|---|---|---|---|---|---|
| in | activity | dict | room | sitting | |
| | position(room) | | | | |
| | | | | | |
| out | internal heat production | 52..400 | | 150 | W |
| | | | | | |
| param | unit body surface area | | simul. | | $m^2$ |
| | name | | simul | | |
| | | | | | |

# 4 Usage Scenarios

## 4.1 User Control

All inputs are entered from the keyboard while the simulation run stopped. Default values (in case that the simulation had not been started) or the previous values are assumed when not explicitly changed. If one variable is changed several times, the last value is assumed. Then the simulation is continued. This allows the user to change one input or parameter at a time to see the result. Output is typically to a file and a graphical representation on the screen.

## 4.2 User Control without stopping

The inputs are entered while the simulation is running. The inputs shall be used as soon as possible (simulation time). The user can influence e.g. control valves without having to stop the simulator. The simulator can run with real time compressed by a factor 10..

## 4.3 User and partial automatic control

An external program controls some of the installations (e.g. radiator, warm water heater, and hot water distribution). The rest is controlled as in the scenario ‘User control without stopping‘. This setup can be used to test control algorithms regarding individual changes in inputs, for example to observe how the controller racts to opening of a window. The simulator is running with a strict coupling between real and simulation time.

## 4.4 File and User Input

A weather file has been produced by actual measurements of outdoor climate conditions over a longer time period and the behavior of a building is observed with minimal user interaction, but at 10 times real time. The user will, e.g. change the valve settings of the radiators to achieve reasonable temperatures. This experiment can show where a control is necessary an how much effort should be put into the control.

## 4.5 File and User Input with Persons

The same experiment as above with the addition of movements of persons that seem to control doors, windows, and lights is conducted. This information comes from a recording of an experiment as in the scenario ‘File and User input‘ with the cumbersome input of these data via keyboard. This is already a very realistic setting with the same goal as in the scenario mentioned..

## 4.6 File and User Input with Persons and Automatic Control

By adding automatic control by an external program to the scenario ‘File and User input‘ we can fully test this program. The program itself can be the execution of a specification, a design, or the actual system, if the appropriate case software is available.

## 4.7 Sensor Input

Any of the appropriate inputs of the above experiments can be replaced by sensors and outputs can control actuators. This would give the most realistic touch to any of the above experiments.

# 5 Change Log

### Problem # 1, Detection Date & Version: 23.1.95 v1

### Reason: start of controlled experimed

### Description:

To produce a set of correct and consistent documents based on the work of team1 in the the simulator project, the original problemdescription has been reworked. The new problemdescrition distinguishes between general properties of a simulator and those of the requested solution as an event-based simulator. The changes occur in the section ‘short desription‘, ‘simulation objects‘ and ‘usage scenarios‘.