1 Organizational Aspects

This is a Hypertext document. Click *here* to get more information.

Project:	**D1.Project1**	
Name:	**Building Simulator Simple1**	
Document:	**Problem_Description.v3**	
Responsible:	**Zimmermann**	
File-Pathname	**irz1:zimmerma/SFB-501**	

Type of change	Date	Version	Person
Start	1.12.94	-	Zimmermann
change	6.12.94	-	Zimmermann
addition	23.12.94	v1	Zimmermann
addition	9.1.95	v1	Zimmermann
refinement on request from team 25.1.95	25.1.95	v2	Zimmermann
reformat to hypertext document, changes	3.2.95	v3	Zimmermann
changes	10.2.85	v4	Zimmermann

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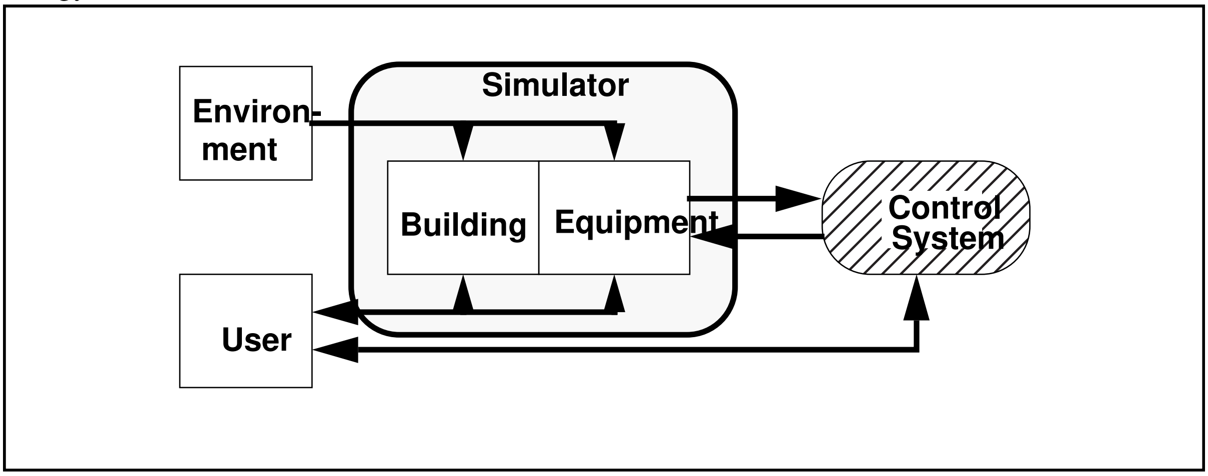
2 Short Description

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 object should be designed such that they can be reused as templates for the generator library. p 1

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. p 2

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. p 3



The above picture shows the simulator in its environment p 4

Inputs can be changed during the the execution of one simulation run. The simulation can be stopped to get the correct timestamp for larger inputs or it can continue to execute during input. In the last case the time of the “enter” action determines the time stamp. p 5 p 19

Inputs are control values for *persons (position and activity)* in the building.

Inputs from the *control system* and the *user* are control values for all components of the *installation*, for example the control valve opening of a radiator, and for those parts of the *building* that can be controlled, for example opening a door or a window. p 6

Inputs from the *environment* are **one** *outdoor temperature*, **one** *ground temperature* under the building, and four *irradiances* perpendicular to the walls from the directions left, right, front, back. Irradiance is the radiation power per area (Wm^{-2}) through transparent *openings.*

Inputs are air pressure values at the four sides of the house. p 1

Input **sources** can be files, the keybord, or another system.

Outputs can be controlled to be sent to the terminal, a file or another system, either by request (polling), automatically at the time of a change or at predefined time intervals. In any case outputs occur as close to the real time to which the value is assigned as possible to be able to watch values as in the ral world. p 7 p 20

Outputs are the *room temperatures* of all rooms , the wall surface temperatures (2 for each wall element, the energy consumption of each rooms and of the building cumulative as a funktion of time (heat and electrical energy), the state of all components of the installation and of parts of the building that are necessary to control the building.

Parameter are set before the simulation starts and do not change during a simulation. Parameters can be changed when the simulation is stopped and take effect, when the simulation is continued. p 8

Parameters are the *radiators standard heat outputs*, the *electric power* of *lamps*.

The system is to be a hybrid object oriented simulator that encapsulates the physical functions of all components in objects. It uses partitioning, adaptive time increments for each partition, event sheduling and other methods to reduce computing time. The accuracy should not be higher than necessary to test control algorithms and provide reasonable responses for the users of the building.

The floorplan and resulting relations between objects is encapsulated in the simulated objects. p 16

The simulator sees an abstact view of the objects and does not distinguish between different types, e.g. rooms and windows. The objects also check value types, ranges etc. The simulator reacts with an error message if data are input for objects that do not exist. p 17

Simulation objects are **not allowed to create feedback loops** at the same time instance. p 21
This would be an error in the simulation model. If simulator outputs are fed back to the inputs with unchanged time values, an external feedbackloop could occur with questionable purpose and unpredictable result.

All input and output streams have the same format. So outputs can be used as inputs. Only changes are transmitted. Values between changes are constant. Initial values have to be entered. Each change is a tuple of valueName, objectName, time, value. Changes have a monotonic order in time in each input stream. p 18

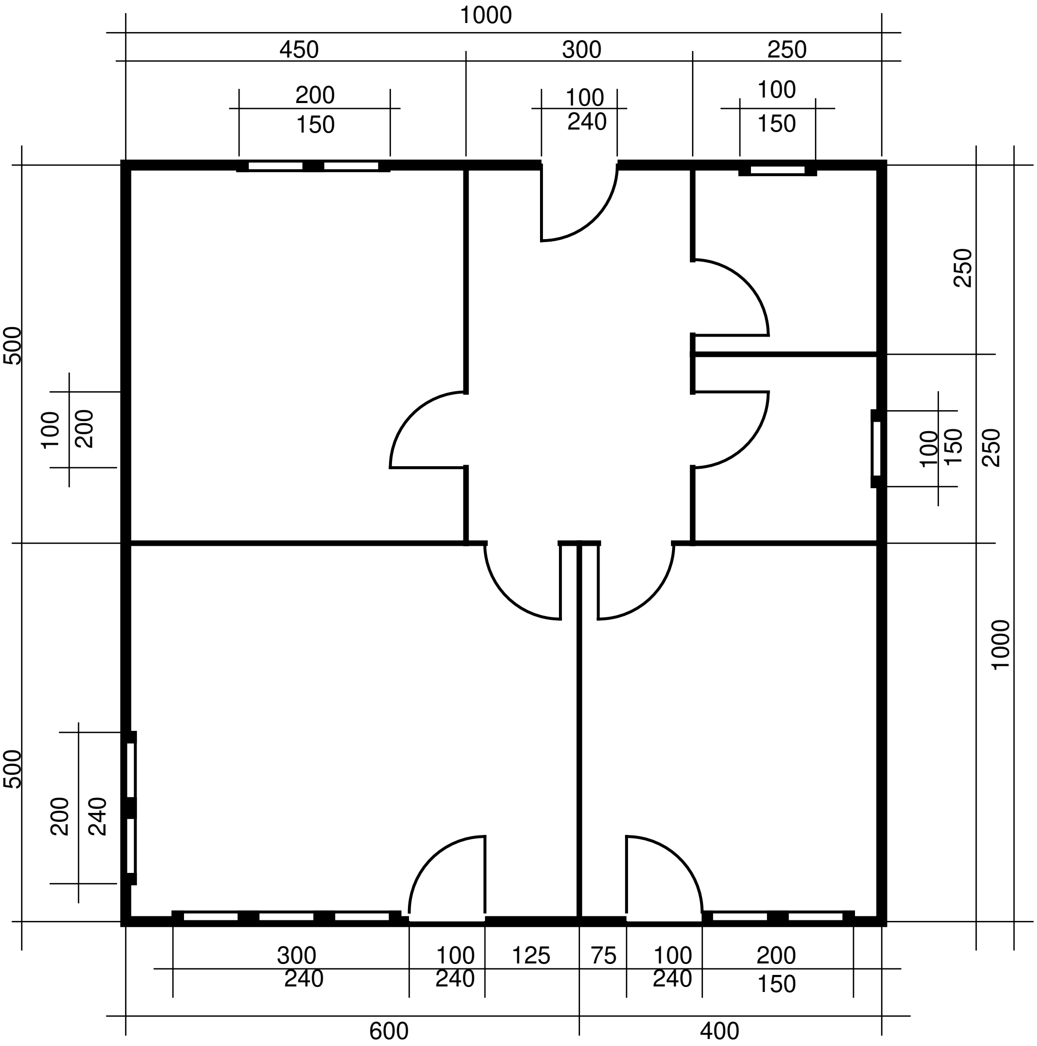
Converging input streams can be seen as one stream in the correct order of time. In the case of collisions (same valueName, objectName, time, different value) a priority assigend to the input stream decides which value is overrides. Such collisions cause a notification. collisions with equal priority cause warnings (continuation with first-come-base selection) or errors (halt and user reaction (continue with user selected value or abort simulation).

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*

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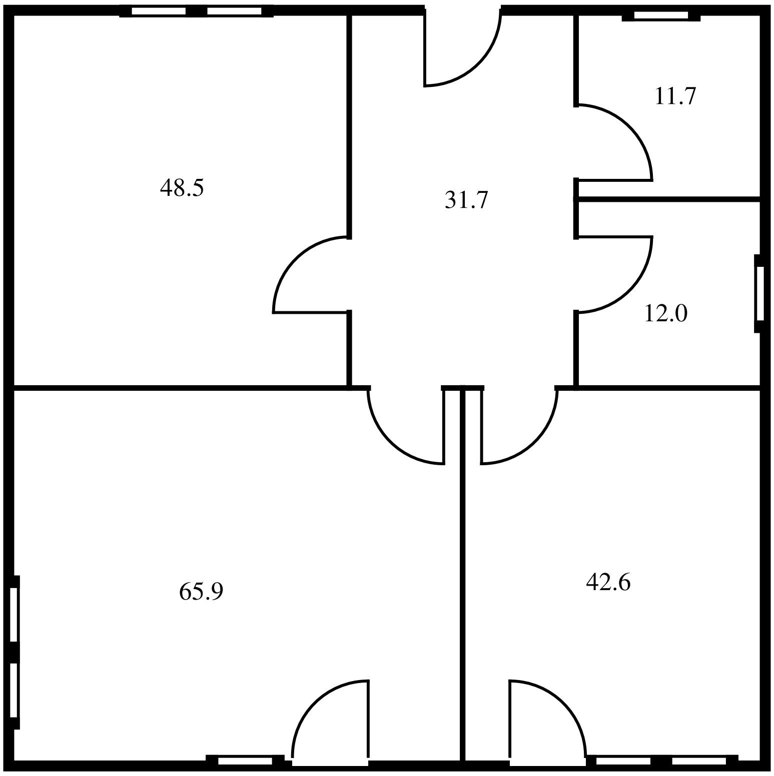
under 1 cm *bitumen felt* (Total 32 cm)

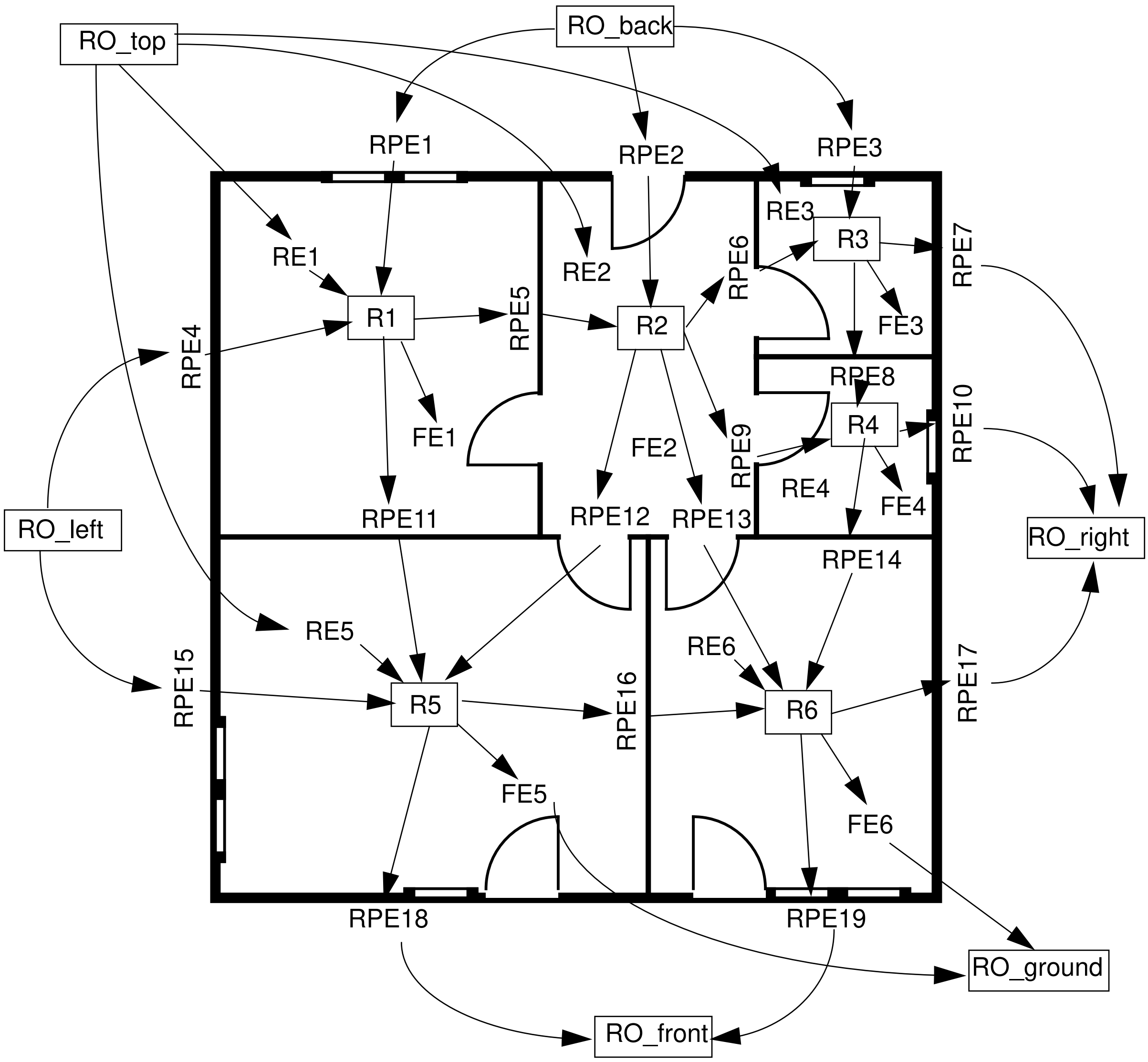
3.2 Room Volumes



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

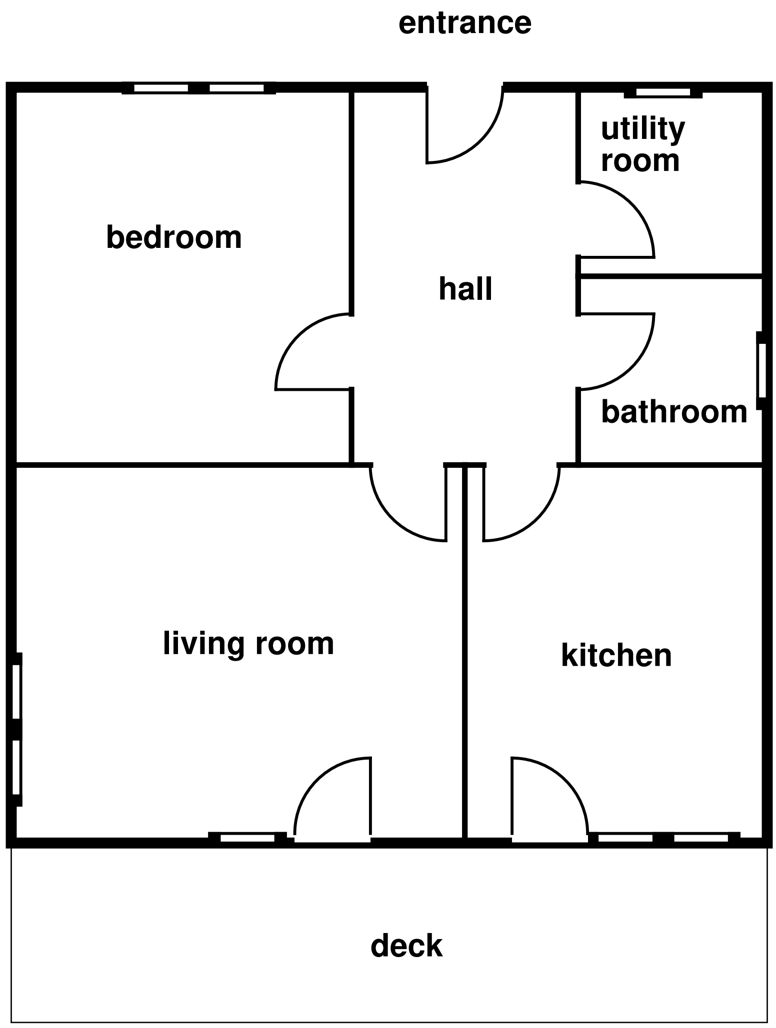
Graph is bipartite and directed (not necessarily)

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		

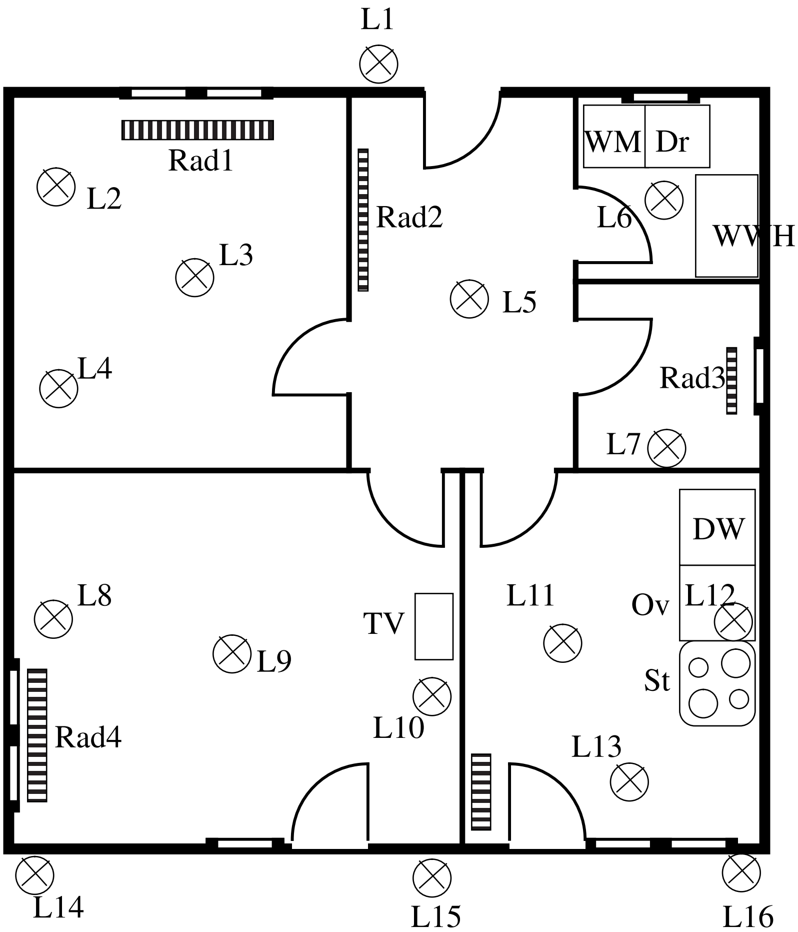
Functional Units



The names of *functional units* shoulb 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

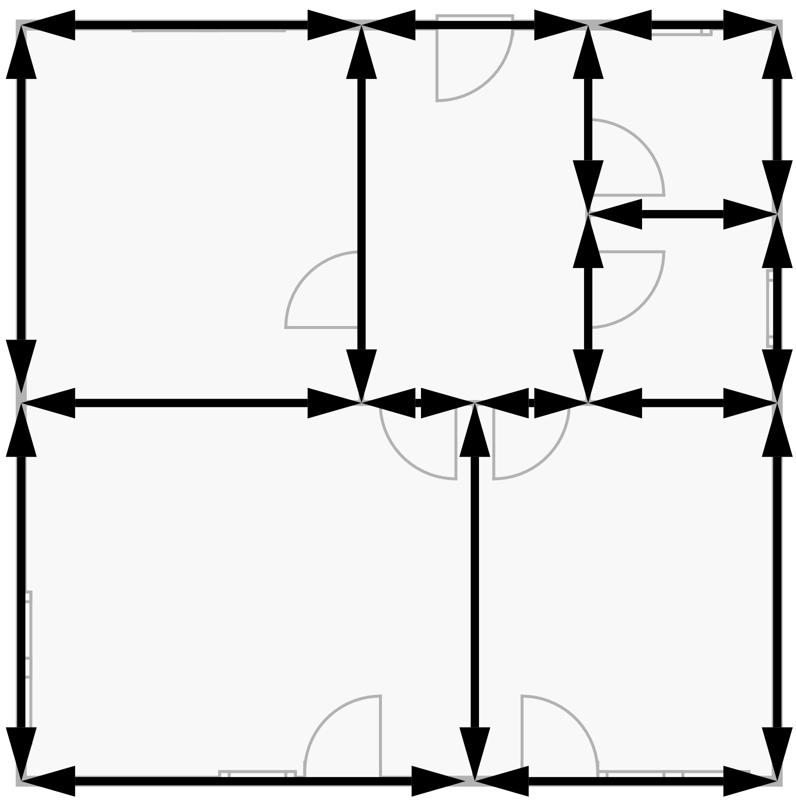
Table 2:

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 Objects

Objects with attribute “leaf” will be provided by customer. Description of functionality serves illustrative purposes only. Interface descriptions must suffice for specifications of simulator.

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 simulator

The simulator is a software component having interaction with the terminal, with files and optionally with physical sensors and actuators via I/O handlers in the operating system.

Possible functions are:

Heat distribution without ventilation and radiation
Ventilation heat loss
Solar radiation load
Lighting

Ventilation is a special problem. In order to determine air flows correctly airodynamic equations would have to be solved. Air flows are dependent on landscape, wind, building details etc. not known at the appropriate level of detail. Therefore only very simple models are applied. These models are calculated in the leaf objects and are of no concern for the simulator. At the interfaces air volume flows, temperatures and pressures are exchanged. p 11

Time intervals between calculations of the models in the objects is one of the critical problems in the planned simulator. This problem is not completely solved, so requirements can change during simulator specification and design phases. The current understanding is the following: p 12

The leaf objects know or calculate dynamically maximum time intervals between calculations to satisfy stability constraints of the numerical method and the sampling theorem. Objects can be triggered to calculate at shorter intervals without lower limit, as long as real time requirements are satisfied. Object output *maximum time intervals* everytime they are active and optionally trigger oder objects after a *trigger delay*. **These variables are default variables of all objects and not completely filled into the tables**.

Variables and parameters are all those of the other objects that show the visibility “simul”.

Additional variables and parameters are the following:

direc-tion	name	range	visibi-lity	default
out	histories of all out variables			
param	real time factors	0.01.. 1000		1
	I/O sources/destinations			
	subset of functionality			set
	output set selection			
	smallest output time increment			1 min

3.6.2 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

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

p 11
p 12
p 13

3.6.3 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					

3.6.4 room partition element

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

direc-tion	name	range	visibi-lity	default	units
	total back heat flux				W
	total air flow				m^3s-1
param	composition				

3.6.5 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		

3.6.6 door (leaf)

direc-tion	name	range	visibi-lity	default	units
in	open command	0..100	simul	0	%
	face air temperature				˚C

direc-tion	name	range	visibi-lity	default	units
	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				

3.6.7 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
	face-to-back radiation load				W

direc-tion	name	range	visibi-lity	default	units
param	area				
	type				

3.6.8 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		

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3.6.9 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

direc-tion	name	range	visibi-lity	default	units
	gas consumption per burner on period				m^3
param	heat output		simul	20	kW
	type		dict		
	gas type		dict		
	efficiency	0..110			%

3.6.10 hot water distribution (leaf)

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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		WWH		˚C
param	water pump type	dict			

3.6.11 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		
param	electrical power	5..200 W	simul	60	W
	type		simul		

3.6.12 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		

direc- tion	name	range	visibi- lity	default	units

4 Usage Scenarios

p 9

4.1 User Control

All inputs are entered from the keyboard while the simulator is stopped. Default values or values of the last input are assumed if values are not entered. 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 graph representation on the screen.

4.2 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 “User Control” on page 22. 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.

4.3 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.

4.4 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 “File and User Input” on page 22 with the cumbersome input of these data via keyboard. This is already a very realistic setting with the same goal as in “File and User Input” on page 22.

4.5 File and User Input with Persons and Automatic Control

By adding automatic control by an external program to the experiment in “File and User Input with Persons” on page 22 we can fully test this program. The program itsself can be the execution of a specification, a design, or the actual system, if the appropriate case software is available.

4.6 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, although it will be difficult to test extreme conditions.

5 Change Log

Problem # 1, Detection Date & Version: 23.1.95 v1

Reason: team review

Description:

Last paragraph should be first paragraph

Solution:

Moved up

Change Date & New Version: 25.1.95 v2

Problem # 2, Detection Date & Version: 23.1.95 v1

Reason: team review

Description:

Meaning of last sentence in first paragraph regarding educational aspects unclear

Solution:

removed for simplification of task

Change Date & New Version: 25.1.95 v2

Problem # 3, Detection Date & Version: 23.1.95 v1

Reason: team review

Description:

meaning of roles is unclear.

Solution:

roles are described in new paragraph

Change Date & New Version: 25.1.95 v2

Problem # 4, Detection Date & Version: 23.1.95 v1

Reason: team review

Description:

team wanted a picture of the overall system for better understanding of the interfaces of the simulator in its environment

Solution:

Diagramm was added from overhead vor CMU presaentation

Change Date & New Version: 25.1.95 v2

Problem # 5, Detection Date & Version: 23.1.95 v1

Reason: team review

Description:

Distinction between inputs and parameters was unclear.

Solution:

Clarification added

Change Date & New Version: 25.3.95 v2

Problem # 6, Detection Date & Version: 23.1.95 v1

Reason: team review

Description:

Input list was unclear and not complete

Solution:

List was completely revised

Change Date & New Version: 25.3.95 v2

Problem # 7, Detection Date & Version: 23.1.95 v1

Reason: team review

Description:

Output list was unclear and incomplete

Solution:

List was completely revised

Change Date & New Version: 25.3.95 v2

Problem # 8, Detection Date & Version: 23.1.95 v1

Reason: team review

Description:

Parameter list was unclear and incomplete

Solution:

List was completely revised

Change Date & New Version: 25.3.95 v2

Problem # 9, Detection Date & Version: 23.1.95 v1

Reason: team review

Description:

B1 asked for scenarios

Solution:

Chapter 4 was added

Change Date & New Version: 3.2.95 v3

Problem # 10, Detection Date & Version: 30.1.95 v1

Reason: B1 input Beschreibungsrahmen.v2

Description:

Form of problem description not sufficient for SE

Solution:

B1 provided document "Beschreibungsrahmen.v2" accessible in file problemdescr.template.v2

Document was used to change form of current document. In addition hyperlinks have been introduced to provide fast access to new chapter change log

Change Date & New Version: 3.1.95 v3

Problem # 11, Detection Date & Version: 1.2.95 v2

Reason: team review

Description:

Are air flows to be modeled explicitly as part of the simulator's requirement specification?

Solution:

No, this is the task of the basic objects, See "simulator" on page 13.

Change Date & New Version: 3.2.95 v3

Problem # 12, Detection Date & Version: 1.2.95

Reason: team review

Description:

The frequency an object (environment, building, installation) has to be simulated is controlled by a time constant. Are there inherent limitations not to simulate objects more often than the given constant - not counting the performance issue to simulate objects only as often as absolutely required? Are these "constants" really constants or are they functions in time?

Solution:

See "simulator" on page 13.

Change Date & New Version: 3.2.95

Problem # 13, Detection Date & Version: 1.2.95 v2

Reason: team review

Description:

May parameters lead to the dynamic instantiation of simulated objects, e.g. the parameter “3 lamps for room 2” creates three lamp objects as part of the installation of room 2?

Solution:

Dynamic assigments of installation objects by parameters is excluded as a decision of the customer.

Change Date & New Version: 3.2.95 v3

Problem # 14, Detection Date & Version: 1.2.95 v1

Reason: team review

Description:

Do radiators have such a time constant (or function)?

Solution:

Yes, radiators have time constants. See “radiator (leaf)” on page 18.

Change Date & New Version: 3.2.95 v3

Problem # 15, Detection Date & Version: 1.2.95 v1

Reason: team review

Description:

What is the appropriate level of detail the heating system has to be modeled?

Solution:

The hot water distribution connects radiators and warm water heater.
See “hot water distribution (leaf)” on page 19.

Change Date & New Version: 3.2.95 v3

Problem # 16, Detection Date & Version: 8.2.95 v3

Reason: team review

Description:

Are the relations between simulated objects known to the simulator

Solution:

Relations are only known to the objects.

Change Date & New Version: 10.2.95 v4

Problem # 17, Detection Date & Version: 8.2.95 v3

Reason: team review

Description:

Can all simulated object be represented by one abstract object or have the differences to be visible to the simulator? Who checks for data consistency? What happens if data are input for not existing objects?

Solution:

An abstract view seems to be sufficient The objects check data consistency. I fdata are sent to not existing objects the simulator reacts.

Change Date & New Version: 10.2.95 v4

Problem # 18, Detection Date & Version: 8.2.95 v3

Reason: team review

Description:

What is the format and semantic of inputs and outputs to the simulator? What happens if several input streams come together?

Solution:

Format is defined on page 4.

Change Date & New Version: 10.2.95 v4

Problem # 19, Detection Date & Version: 8.2.95 v3

Reason: team review

Description:

Can input from the keyboard only be entered when the simulator stops?

Solution:

No, either when its running or stopped. The decision is wether the input can be done quick enough to get the right time stamp.

Change Date & New Version: 10.2.95 v4

Problem # 20, Detection Date & Version: 8.2.95 v3

Reason: team review

Description:

When do outputs occur?

Solution:

Immediately to be able to observe the functions in realtime.

Change Date & New Version: 10.2.95 v4

Problem # 21, Detection Date & Version: 8.2.95 v3

Reason: team review

Description:

Can feedbackloops occur within the simulator?

Solution:

Simulation objects are not allowed to create feedback loops at the same time instance. This would be an error in the simulation model. If simulator outputs are fed back to the inputs with unchanged time values, an external feedbackloop could occur with questionable purpose and unpredictable result.

Change Date & New Version: 10.2.95 v4

Problem # 22, Detection Date & Version: 8.2.95 v3

Reason: team review

Description:

Should the internal states be intialized to start a simulation in a reasonable state?

Solution:

This is indeed necessary. For this purpose snapshots should be stored that can be used for initialization instaed of having to wait for steady states.

Change Date & New Version: 10.2.95 v4

Problem # 23, Detection Date & Version: 8.2.95 v3

Reason: team review

Description:

What happens if data are input for not existing objects?