

# LESO-PB

**User not present : Energy optimisation (using  
visual control systems), Edificio, Subtask AD3**

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## EDIFICIO, subtask AD3

### User not present: Energy optimisation (using visual control systems)

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Preliminary definitions:

- "Alpha" is the fraction of the window not obstructed by the blind. So,  $\alpha = 0$  means that the blind is completely closed and  $\alpha = 1$  means that the blind is completely open.
- "Beta" is the tilt of the venetian blind's slat. A tilt of  $0^\circ$  means that the slats are horizontal and a tilt of  $90^\circ$  means that the slats are vertical (closed position). Beta is positive when the side of the slats towards outside goes down.

### Introduction

When the user has not been present for a certain amount of time (typically for 15 minutes at least) the controller switches from the visual optimisation to the energy optimisation algorithm.

Different things are carried out:

- The artificial light is switched off
- The slats (in the venetian blind case) are closed (position  $\beta = 90^\circ$ ), so the control takes place only through the alpha value
- If there are several blinds, the alpha of each blind follows the same command. It means that all the blinds have the same value of alpha.

Remark: if there is no blind, the energy optimisation (using visual control systems) is limited to switching the artificial light off.

In order to compare different control algorithms, simulations have to be carried out.

In these simulations, the thermal model of the room is a two-node model (considered as an S-function in the MATLAB simulation, see appendix C). One node corresponds to the indoor air (with also the furniture) and the other corresponds to the massive part of the rooms (walls, etc...).

The external weather conditions come from synthetic values produced by the METEONORM program (ref. [1]). The appendix D shows how the initialisation of the simulation is done (concerning weather parameters, thermal room parameters, etc...).

There are two variants of controller of the heating/cooling system.

In the first case, the controller is a simple on/off switch with an hysteresis, which keeps the indoor temperature between  $19^\circ$  and  $22^\circ\text{C}$ . In fact, the heating begins to heat (with full power: 1000 W) when the indoor temperature is below  $19^\circ\text{C}$  and continue to heat until the temperature reaches  $21^\circ\text{C}$ . Similarly, the cooling begins when the temperature is  $22^\circ\text{C}$  and cools until the temperature reaches  $20^\circ\text{C}$ .

In the other case, the controller is predictive. It comes from the NEUROBAT project (ref. [2]) and has been adapted to our problem. SIMULINK diagrams of these two cases are shown in the appendixes (A and B).

It's important to notice that the heating/cooling system is sometimes only a heating system, so separated simulations are carried out for "only heat" and "heat/cool" systems.

## Simulations results: first study

First, four different blind controllers have been studied:

- "Without season" (\*) is a simple blind controller, which helps the heating system without regarding the current season. The controller uses fuzzy logic (see appendix E for details).
- "With season" (\*) is a blind controller, which helps the heating system regarding the current season. The controller uses fuzzy logic (see appendix E).
- "Alpha = 1" corresponds to a blind **always open**.
- "Alpha = 0" corresponds to a blind **always closed**.

(\*) The basic idea comes from the DELTA project: we consider the system "window + blind" as a heat provider to the room, through the heat losses and solar heat gains balance that depends on the blind position (see ref. [3] and also appendix E).

The simulations are done on the period that corresponds to the last five days of February. The choice has been done in a way that different weather conditions are represented (sunny and cloudy days). The appendix F gives a more detailed picture of the weather conditions during this period.

The results are given in the table 1.

| Heat system                       | Blind controller | Average indoor temperature [°] | Energy* used [MJ] | Temperature min. [°] | Temperature max. [°] |
|-----------------------------------|------------------|--------------------------------|-------------------|----------------------|----------------------|
| On/off<br>No cooling              | Without season   | 19.9                           | 185               | 19                   | 22                   |
|                                   | With season      | 20.3                           | 131               | 19                   | 23.5                 |
|                                   | Alpha = 1        | 20.2                           | 128               | 19                   | 23.5                 |
|                                   | Alpha = 0        | 20.0                           | 215               | 19                   | 21                   |
| On/off<br>Cooling is possible     | Without season   | 19.9                           | 188               | 19                   | 22                   |
|                                   | With season      | 20.1                           | 148               | 19                   | 22                   |
|                                   | Alpha = 1        | 20.0                           | 151               | 19                   | 22                   |
|                                   | Alpha = 0        | 20.0                           | 215               | 19                   | 21                   |
| Predictive<br>No cooling          | Without season   | 20.1                           | 172               | 18.5                 | 23.5                 |
|                                   | With season      | 20.4                           | 139               | 18.5                 | 24                   |
|                                   | Alpha = 1        | 20.4                           | 137               | 18.5                 | 24                   |
|                                   | Alpha = 0        | 19.4                           | 207               | 18                   | 20.5                 |
| Predictive<br>Cooling is possible | Without season   | 20.2                           | 179               | 18.5                 | 23.5                 |
|                                   | With season      | 20.4                           | 137               | 18.5                 | 23.5                 |
|                                   | Alpha = 1        | 20.3                           | 134               | 19                   | 23                   |
|                                   | Alpha = 0        | 19.6                           | 209               | 18.5                 | 21                   |

\* Energy used = | heating energy | + | cooling energy |

Table 1: Indoor temperature and energy used for different heating systems and different blind controllers

## Discussion of the first study

First, one sees in the table 1 that the blinds have an important effect on the power consumption. The relative differences in power consumption between "blinds always open" and "blinds always closed" are more than 30% (!) whatever is the heating system.

The other obvious conclusion one can make is that it seems to be **very interesting to take into account the season** for an energy optimisation. The algorithm "with season" allows saving 15-30% of the energy consumption in comparison to the algorithm "without season" depending of the used heating system.

One can notice that the energy consumption is less in the case without cooling than in the case with, because of the use of some energy to cool the room while the indoor temperature goes too high (overheating occurs sometimes also in winter). The maximum temperature reached during the simulation shows that the "heat only" system without cooling leads to higher maximum temperature than the "heat/cool" system (especially for the non-predictive system, a little bit for the predictive one).



It's interesting to see the differences between the predictive and the "on/off" systems.

With the blinds always closed, there are obviously no significant differences between all the scenarios because no solar gains are accepted.

With the blinds always open, the differences are not very big. But one can see all the same, that the predictive system (without cooling) gives less good results (more power consumption) than the "on/off" system (without cooling) and conversely, the predictive system (with cooling) gives better results than the "on/off" (with cooling).

When the blind controller is "without season", the predictive system gives better results in the two cases (with and without cooling) but when the blind controller is "with season", the predictive system is only better in the "with cooling" case. It confirms the fact that the predictive system is very useful to avoid overheating that would lead in the "on/off with cooling" case to frequent uses of cooling. It confirms also the fact that the "with season" blind controller is better because of some inherent prediction capabilities.

In conclusion, this first study has demonstrated that our simulations seem to be quite relevant (results are understandable and predictive system seems to work) and has shown that the blinds have a great effect on the power consumption. Moreover, the variable season seems to be very important when one tries to do energy optimisation using the visual control system.

Now, as second study, we'll try to find the best algorithm to control the blinds efficiently all year long.

## Simulation results: second study

Nine different controllers are studied in this section. They are explained in the appendix E. The simulations are done on a period of one week during the three different seasons (winter (days 52-59), mid-season (days 100-107), summer (days 192-199), see appendix G for details about the weather conditions). For each season, the controllers are tested in two cases: with an "only heat" system and with an "heat/cool" system. These two systems are predictive (inspired from NEUROBAT project), and the "on/off" heat systems are not used anymore.

The results are given in table 2 for winter, in table 3 for mid-season and table 4 for summer.

For the mid-season a graph (graph 1) has been done to see better the differences, in energy consumption, between all the controllers.

Note: in summer, the initial temperatures of the two nodes of the model of the room (see appendix C) are set at 22°C instead of 20°C, in order to be more realistic.

| Heat system         | Blind controller | Average indoor temperature [°C] | Energy used [MJ] | Temperature min. [°C] | Temperature max. [°C] |
|---------------------|------------------|---------------------------------|------------------|-----------------------|-----------------------|
| No cooling          | Without season 1 | 20.1                            | 237              | 18.5                  | 23.5                  |
|                     | Without season 2 | 20.1                            | 248              | 18.5                  | 23.5                  |
|                     | Only season 1    | 20.3                            | 204              | 18.5                  | 24                    |
|                     | Only season 2    | 20.3                            | 204              | 18.5                  | 24                    |
|                     | Only season 3    | 20.3                            | 204              | 18.5                  | 24                    |
|                     | Complete 1       | 20.3                            | 204              | 18.5                  | 24                    |
|                     | Complete 2       | 20.3                            | 204              | 18.5                  | 24                    |
|                     | Complete 3       | 20.3                            | 204              | 18.5                  | 24                    |
|                     | Complete 4       | 20.3                            | 204              | 18.5                  | 24                    |
| Cooling is possible | Without season 1 | 20.6                            | 264              | 18                    | 24                    |
|                     | Without season 2 | 20.5                            | 275              | 18                    | 24                    |
|                     | Only season 1    | 20.8                            | 218              | 18.5                  | 24                    |
|                     | Only season 2    | 20.8                            | 218              | 18.5                  | 24                    |
|                     | Only season 3    | 20.8                            | 218              | 18.5                  | 24                    |
|                     | Complete 1       | 20.8                            | 219              | 18.5                  | 24                    |
|                     | Complete 2       | 20.8                            | 219              | 18.5                  | 24                    |
|                     | Complete 3       | 20.8                            | 219              | 18.5                  | 24                    |
|                     | Complete 4       | 20.8                            | 219              | 18.5                  | 24                    |

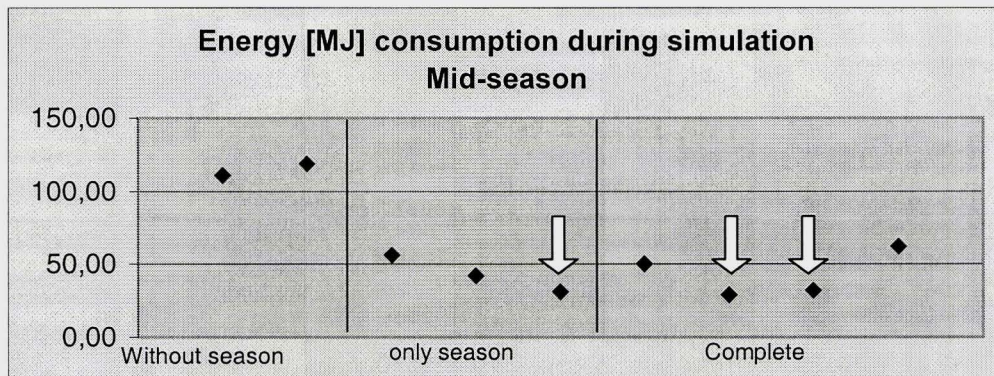
Table 2: Indoor temperature and energy used in *winter* for different blind controllers

| Heat system         | Blind controller | Average indoor temperature [°C] | Energy used [MJ] | Temperature min. [°C] | Temperature max. [°C] |
|---------------------|------------------|---------------------------------|------------------|-----------------------|-----------------------|
| No cooling          | Without season 1 | 21.6                            | 111              | 20                    | 23                    |
|                     | Without season 2 | 20.7                            | 119              | 18.5                  | 23                    |
|                     | Only season 1    | 21.7                            | 56               | 19.5                  | 26                    |
|                     | Only season 2    | 22.2                            | 42               | 19.5                  | 26.5                  |
|                     | Only season 3    | 22.5                            | 31               | 19.5                  | 26.5                  |
|                     | Complete 1       | 21.6                            | 50               | 19.5                  | 26                    |
|                     | Complete 2       | 23.5                            | 29               | 19.5                  | 27.5                  |
|                     | Complete 3       | 22.2                            | 32               | 19.5                  | 26.5                  |
|                     | Complete 4       | 21.4                            | 62               | 19.5                  | 25                    |
| Cooling is possible | Without season 1 | 20.5                            | 103              | 19.5                  | 24                    |
|                     | Without season 2 | 20.5                            | 127              | 18                    | 25                    |
|                     | Only season 1    | 21.4                            | 62               | 19.5                  | 25                    |
|                     | Only season 2    | 21.6                            | 62               | 19.5                  | 25                    |
|                     | Only season 3    | 21.9                            | 53               | 19.5                  | 25                    |
|                     | Complete 1       | 21.2                            | 58               | 19.5                  | 24                    |
|                     | Complete 2       | 22.2                            | 38               | 19.5                  | 24.5                  |
|                     | Complete 3       | 21.5                            | 44               | 19.5                  | 24.5                  |
|                     | Complete 4       | 20.9                            | 70               | 19.5                  | 23.5                  |

Table 3: Indoor temperature and energy used in *mid-season* for different blind controllers

| Heat system         | Blind controller | Average indoor temperature [°C] | Energy used [MJ] | Temperature min. [°C] | Temperature max. [°C] |
|---------------------|------------------|---------------------------------|------------------|-----------------------|-----------------------|
| No cooling          | all              | 23                              | 0                | 21.5                  | 24                    |
| Cooling is possible | all              | 23                              | 0                | 21.5                  | 24                    |

Table 4: Indoor temperature and energy used in *summer*



Graph 1: Energy consumption during the mid-season simulation

In the Graph 1, the arrows show the three best controllers.

## Discussion of the second study

First, one can see again that the worst controllers are those without the season taken into account. There are the ones that use the more energy. Although, with the "without season 2" blind controller (which tries to cool the room when the heat/cool system is off, see appendix E) the results are not better. The variable season is definitively essential in order to have a good blind controller.



If one ignore the two controllers "without season", all the controllers are very similar during the winter period. It comes from the fact that all the controllers (with the season taken into account) accept the maximum of solar gain in winter when the cooling system is off (the heating system can be on or not).

This phenomenon is even more obvious during the summer period: there are absolutely no differences between all the controllers. The reason is that all the blind controllers work in the same way: they reject all solar gains in summer (blind completely closed).

This leads to a power consumption of zero (no cooling and no heating occur) during this period. The weather (typical of Switzerland's climate) we have simulated by METEONORM is not enough warm in summer, to have the usefulness of a cooling system...

So, no interesting comparisons between blind controllers can be done from the results of the winter and summer simulations.

On the other hand, in mid-season the situation is very interesting.

Clearly, if we except the two controllers "without season", the worst controller is "complete 4" which gives a negative window heat in mid-season when the heat/cool system is off. In the two cases ("heat/cool" and "only heat") it leads to more power consumption (almost 10% more than the others controllers). We'll see later that the behaviour of the controller in mid-season when the heat/cool system is off is very critical.

Moreover, one can see that the "only season" controllers are less efficient than the "complete 2 and 3", especially with a heat/cool system. Nevertheless, the "only season 2" and "only season 3" controllers lead to better results than the "complete 1". It comes from the fact that the fuzzy variable mid-season is narrower in these two cases and then the variable winter has more effect during the simulation. So, the solar gain are more accepted and the power consumption is reduced. It's important to notice that the inverse could also occur: if the outdoor temperature were higher the variable summer could be the "dominant" one and the solar gain would be more rejected, that would lead to higher power consumption. So, it's dangerous to shrink the variable mid-season, in order to have better results, without knowing exactly what are the effects.

The only difference between "only season 2" and "only season 3" is the behaviour in the mid-season when the heat/cool system is off. We have seen that the effect of this behaviour is important (see above, the results for "complete 4"), and the conclusion was that it's not a good idea to have a negative window heat in this case. The "only season 2" has a zero window heat and "only season 3" has a low positive value ( $200 \text{ MJ/m}^2$ ) of the window heat in the considered case. Clearly, one can see that the "only season 3" is better. In fact, the energy consumption is reduced of 25% with the "only heat" system and of 15% with the "heat/cool" system. The reason is that the controller "only season 3" accept some solar gain and then save some heating energy.

The two bests controllers are "complete 2" and "complete 3". Here also, the only difference between "complete 2" and "complete 3" is the behaviour in the mid-season when the heat/cool system is off. "Complete 2" allows  $200 \text{ MJ/m}^2$  of solar gain (this value is the value used in the DELTA project) and "complete 3" allows only  $100 \text{ MJ/m}^2$ . Even if the difference between the two controllers is small, it leads to significant differences in the results.

The "complete 2" controller reduces, in comparison with "complete 3", the energy consumption of 10% in the "only heat" case and it reduces of more than 20% in the "heat/cool" case, because of the supplementary solar gain the controller "complete 2" accepts. But one can see that it can lead to overheating in the room (temperature max. of  $27.5^\circ\text{C}$  during the simulation, only  $26.5^\circ\text{C}$  for the "complete 3" controller).

Since "complete 2" leads to more overheating than "complete 3", it should use more energy, in the "heat/cool" case, than "complete 3" in order to keep a decent inside temperature. It's not the case. A possible explanation is that the energy saved thanks to the supplementary solar gain (in the "complete 2" controller) is bigger than the energy used to avoid the new overheating.

So, one can say that it's not good to have a negative or zero window heat when the heat/cool system is off in mid-season. Positive values ("complete 2 and 3" and "only season 3") give clearly better results, but there is no particular interest of finding the "perfect" value, because it completely depends of the room parameters and of the "heat/cool" system used. Moreover, we hope that this "perfect" could be found by the adaptation loop (loop 3 in the project).

The graph 1 gives an overall view of the results of the mid-season period. All the results previously discussed are confirmed by this graph. It shows also that the three best controllers are "complete 2", "complete 3" and "only season 3", in that order.

In conclusion, four things have been pointed out:

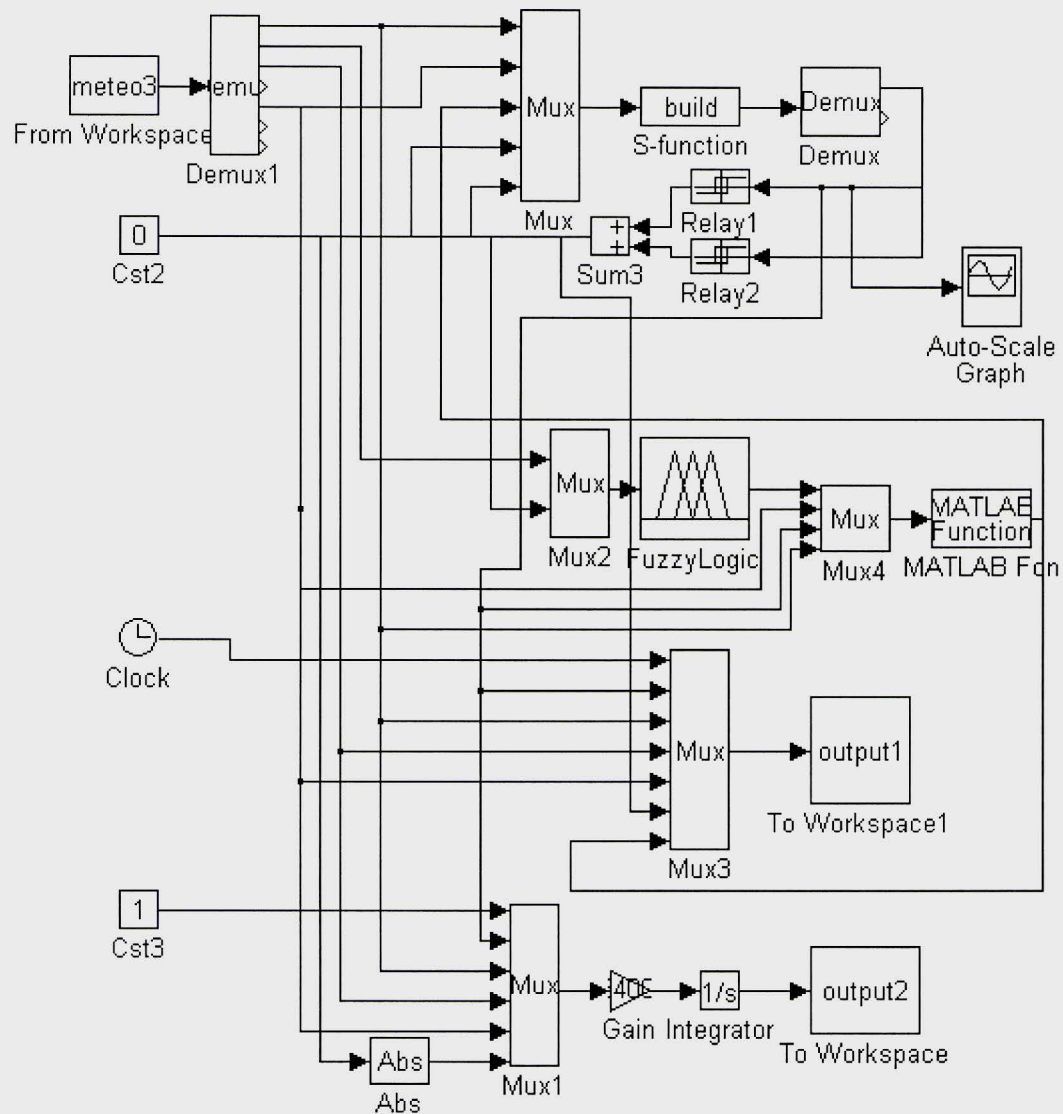
- The variable season is essential in order to have a good blind controller.
- The differences between controller are particularly visible during the mid-season.
- It's best to have a positive window heat in mid-season when the "heat/cool" system is off.
- The exact value one have to take for the window heat in this case has not been defined, it depends strongly of the kind of "heat/cool" system and of the different window and room parameters.
- Three controllers are clearly better than the others: "complete 2", "complete 3" and "only season 3".

For the EDIFICIO project we think that **we will use the "only season 3" controller**. Although the "only season 3" controller is not the best considering the energy consumption, this controller doesn't use the "Heating power" variable and therefore avoids a **cross coupling** HVAC-Lighting. This would otherwise occur: the HVAC controller needs the blind position "Alpha" produced by the Lighting controller, and the Lighting controller would need the heating power variable produced by the HVAC controller. This cross coupling could lead to possible instabilities.

## **References**

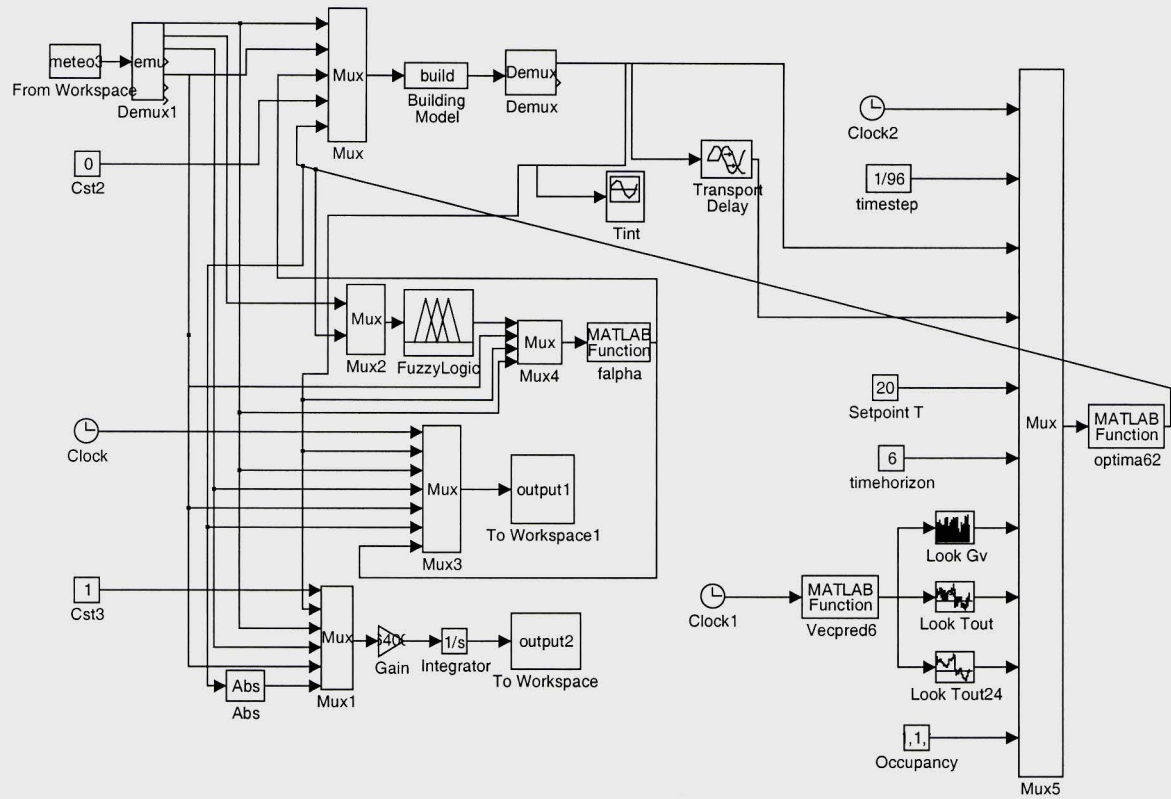
- [1] Meteo Test: Meteonorm 95, v2.0, BEW, Berne, 1996
- [2] J. Krauss, M. Bauer, N. Morel, M. El-Khoury: NEUROBAT, a neuro-fuzzy expert system in building control, final OFEN Report, CSEM/LESO-PB, 1998
- [3] M. Bauer, J. Geiginger, W. Hegetschweiler, G. Sejkora, N. Morel, P. Wurmsdobler: DELTA, a blind controller using fuzzy logic, final OFEN Report, LESO, EPFL, 1996

## Appendix A: "on/off" heating system





## Appendix B: predictive heating system



## Appendix C: building model (MATLAB S-function)

```
function [sys,x0]=build(t,x,u,flag,C,g,Aw,tauw)
% s-function for building model
% input variables: Text, Gv, alpha, Gint, Pheating
% state variables: T1, T2
% output variables: T1, T2
% parameters: C=[C1,C2], g=[g1,g2,g12],
%             Aw=window area, tauw=window trans.

if (flag==0)
    sys=[2,0,2,5,0,0];
    x0=[20,20];
elseif (abs(flag)==1)
    dx=zeros(1,2);
    dx(1)=(g(3)*(x(2)-x(1))+g(1)*(u(1)-x(1))+0.5*Aw*tauw*u(2)*u(3)+...
        u(4)+u(5))/C(1);
    dx(2)=(g(3)*(x(1)-x(2))+g(2)*(u(1)-x(2))+0.5*Aw*tauw*u(2)*u(3))/C(2);
    % sys=dx; % [s]
    sys=dx*86400; % [days]
elseif (flag==3)
    sys=x;
else
    sys=[];
end
```

## Appendix D: initialisation (MATLAB function)

```
% ininrj.m
% initialisation of building model parameters
% in main workspace
% parameters: C=[C1,C2], g=[g1,g2,g12],
%             Aw>window area, tauw>window trans.

% initial parameters
C=[1.5e5,6.8e6];
g=[19,2,440];
Aw=3.77;
tauw=0.7;

% meteo data
meteofile='laushfev.bsv';
year=-1;
indexQhtot=1; % global rad.hor [W/m2]
indexText=3; % outside temperature [°C]
disp('*** Reading boundary conditions (no interpolation)');
eval(['load ',meteofile]);
meteo1=stripext(meteofile,'\');
% put meteo data into matrix 'meteo2'
eval(['meteo2=',meteo1,'; clear ',meteo1]);
[nbTime,nbChannel]=size(meteo2); nbChannel=nbChannel-5;

% recopy meteo2 into meteo3, with a new time specification
% [days], and with only the channels needed:
% Text, Text24, qhtot, qhdiff, qtot, qdiff, theta
meteo3=zeros(nbTime,8);
ts=zeros(nbTime,1);
for k=1:nbTime, ts(k)=timed2s(year,meteo2(k,1:5)); end % time [s]
meteo3(:,1)=ts/86400; end % time [days]
meteo3(:,2)=meteo2(:,indexText+5); % outside temperature [°C]
meteo3(:,3)=aver24(meteo2(:,indexText+5)); % outside temp. during the last
24 hours [°C]
meteo3(:,4)=meteo2(:,indexQhtot+5); % global radiation horizontal [W/m2]
scst=[45.5,-6.2,-1,400,0.3]; % latitude, longitude, time zone, altitude,
albedo
for k=1:nbTime,

solarOutput=solar(0,[1,0],90,0,ts(k),ts(k),meteo2(k,indexQhtot+5),[],[],scs
t);
    meteo3(k,5)=solarOutput(6); % diffuse radiation horizontal [W/m2]
    meteo3(k,6)=solarOutput(1); % global radiation vertical South [W/m2]
    meteo3(k,7)=solarOutput(3); % diffuse radiation vertical South [W/m2]
    meteo3(k,8)=solarOutput(7); % incidence angle [rad]
end

clear ts
clear meteo1
clear meteo2
disp('*** Boundary conditions ok');
disp(' ');

% fuzzy logic controller
disp('*** Reading blind controller data');
algnrj1 = readfis ('algnrj1');
algnrj2 = readfis ('algnrj2');
```



```
disp('*** Blind controller data ok');

% neural model
load annwc2.mat;
disp(' ')
disp('*** Neural model ok')

% init optima62
initoptima=optima62(0,0,1,1,1/96);
disp(' ')
disp('*** optima62 initialized')
```

## Appendix E: fuzzy rules for the blind controllers

### **Blind controllers "Without season 1 and 2":**

| Heating power      |          |                        |          |
|--------------------|----------|------------------------|----------|
|                    | Negative | Zero                   | Positive |
| <b>Window heat</b> | Neg      | Zero (1)<br>or Neg (2) | Pos      |

The blind controller "without season 2" gives a negative value of the window heat when the heating is off. It comes from the idea that it's more difficult to cool than to heat a system (it's obviously the case when there is no cooling system!).

### **Blind controllers "only season 1-3":**

|                    | Winter | Mid-season                   | Summer |
|--------------------|--------|------------------------------|--------|
| <b>Window heat</b> | Pos    | Zero (1,2)<br>or Pos_low (3) | Neg    |

There is a important difference between "only season 1" and the other ("only season 2 and 3"), that's the width of the fuzzy variable mid-season. In the first case, we consider to be in mid-season when the outdoor temperature (average of the last 24 hours) is between 5°C and 15°C. In the two other cases, the mid-season band is between 8°C and 12°C. This is done in order to avoid that the rules with mid-season match too often, because it's difficult to define a good behaviour for all the mid-season period.

### **Blind controllers "Complete 1-4"**

| Heating power      |          |   |          |
|--------------------|----------|---|----------|
| <b>Window heat</b> | Negative | Zero                                      | Positive |
| <b>Winter</b>      | Neg      | Pos                                       | Pos      |
| <b>Mid-Season</b>  | Neg      | Zero (1) or Pos_low (2,3)<br>or Neg (4) * | Pos      |
| <b>Summer</b>      | Neg      | Neg                                       | Pos      |

\* For the description see page 5

The ideas used to build this table of rules are:

- The blind controller must always help the heat/cool system.
- In winter, solar gains should be accepted as often as possible.
- In summer, solar gains should be rejected as often as possible.
- In mid-season, we don't know what to do, so several possibilities are studied.

At this point, one has obtained a value of the desired window heat. This value is next converted in a value of

blind position ( $\alpha$ ) with the following MATLAB function :

```
function alpha=falpha(u)

% calculation of alpha, from the following parameters:
% u(1)=Ps (desired window heat balance, W)
% u(2)=Gvs (global vertical south radiation, W/m2)
% u(3)=Ti (inside air temperature, °C)
% u(4)=Text (outside air temperature, °C)
% additional parameters:
% g=solar radiation transmission coefficient of window
% ga=solar radiation transmission coefficient of blind
% Uv=U-value of window (without blind, W/m2K)
% R=additional thermal resistance of blind (m2K/W)

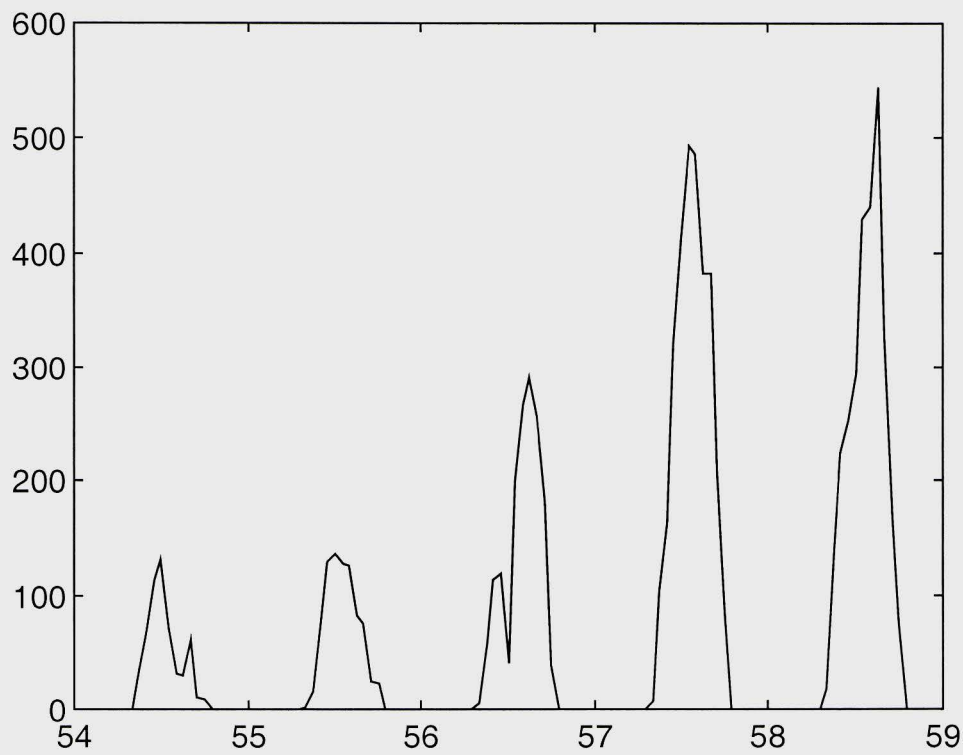
g=0.70;
ga=0.20;
Uv=3;
R=0.16;

num=u(1)-ga*g*u(2)+Uv/(1+R*Uv)*(u(3)-u(4));
den=g*(1-ga)*u(2)-(Uv-Uv/(1+R*Uv))*(u(3)-u(4));
if (den~=0) alpha=num/den; else alpha=0.5; end
if (alpha>1) alpha=1; elseif (alpha<0) alpha=0; end
```

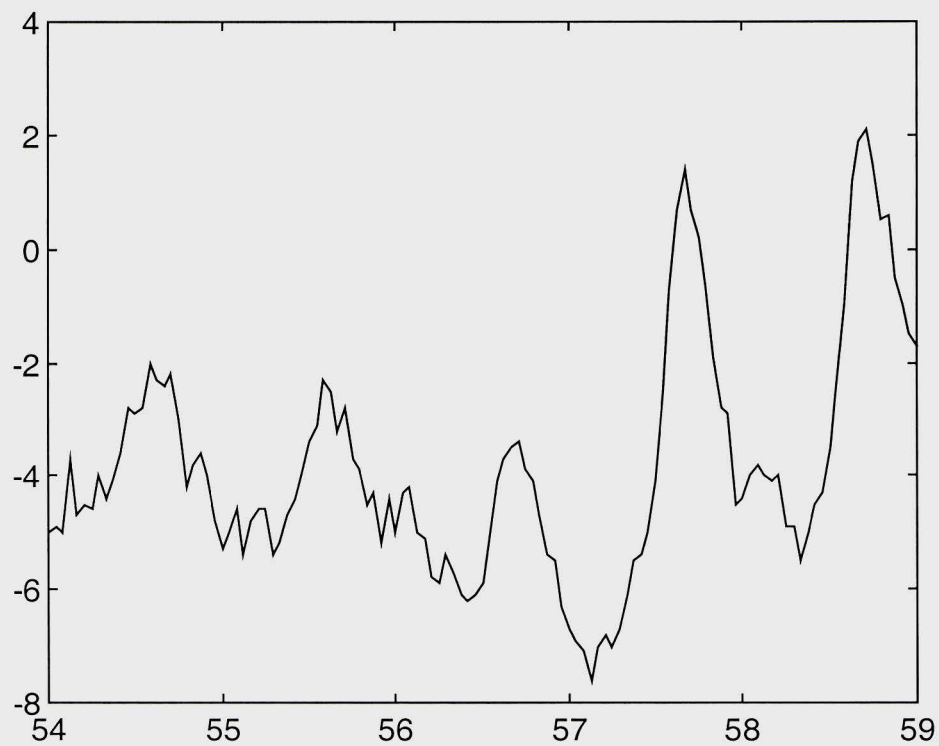


## Appendix F: Weather conditions (first study)

Global horizontal illuminance [ $\text{W/m}^2$ ]

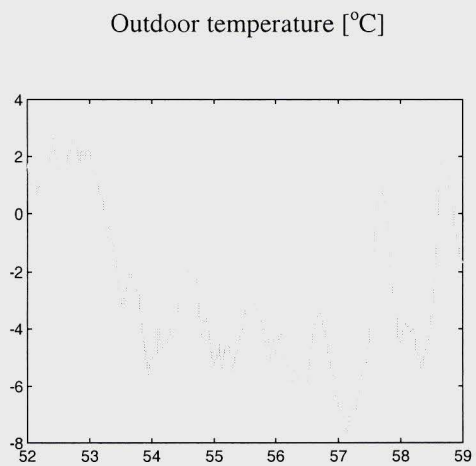
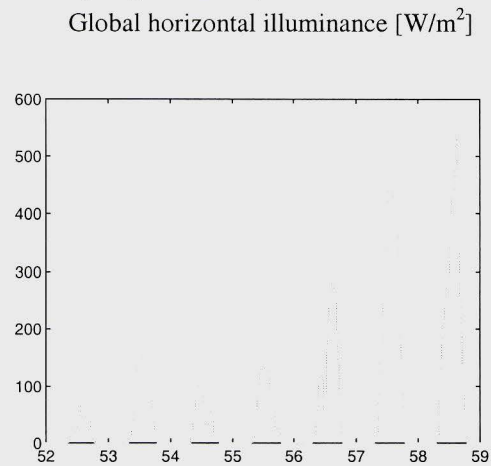


Outdoor temperature [ $^{\circ}\text{C}$ ]

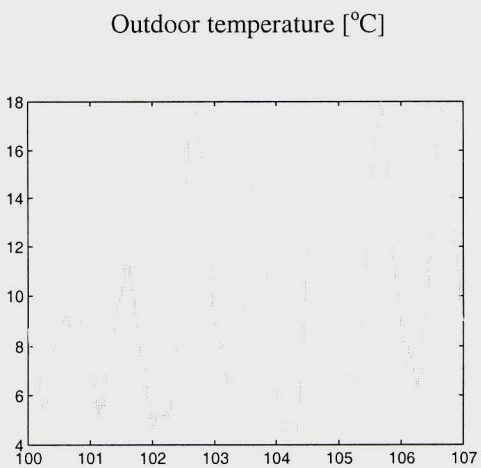
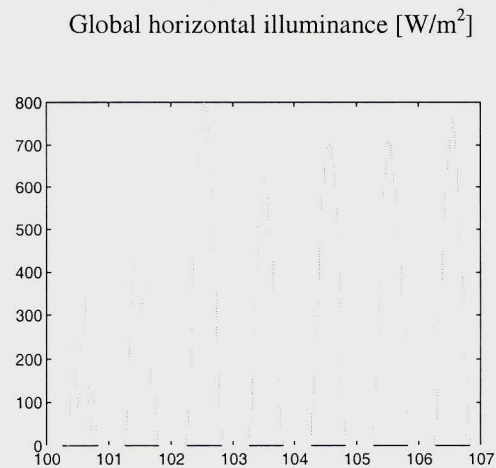


## Appendix G: weather conditions (second study)

### Winter (days 52-59)



### Mid-season (days 100-107)



### Summer (days 192-199)

