IEA Solar Heating & Cooling Programme
Task 31: Daylighting Buildings in the 21st Century

DAYLIGHT AND ELECTRIC LIGHTING CONTROL SYSTEMS DESIGN GUIDE

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1. INTRODUCTION

The goal of an automatic control system for daylighting and electric lighting devices is double:

1. Optimize the user's comfort inside the room;
2. Minimize the energy used for allowing a good inside comfort.

The control system must provide, even before tuning or adaptation, a good comfort to the users. This comfort is not limited to visual comfort, but also includes thermal and air quality comforts.

Actually, an automatic system must not only fulfill these requirements, it must also be well accepted by the users; otherwise, the users will complain and get unsatisfied, or the automatic control system will be disconnected, causing higher energy consumption and potentially uncomfortable situations.

The requirements listed in the next section concerns advanced control systems. Some of the requirements may be only partially fulfilled for other control systems, especially for commercially available control systems.

This document, after the guidelines themselves, lists a number of research projects as illustration to one or several points of the guidelines.

It should be also noted that advanced control systems should go a step further than daylight responsive control systems for electric lighting devices, which have been already treated in detail in IEA Task 21 (Daylight in Buildings). For further reference, please consult the Source Book produced by the Task 21, especially section 5 (Daylight Responsive Controls).

Target audience

This report is aimed at persons, companies or organizations dealing with the design of control systems. It is also aimed at the professionals, such as specialized engineers, responsible for integrating control systems in buildings.

Therefore, some knowledge of the field is required for a fruitful reading. In particular, this guide is hardly adequate for building owners or building designers, except for those persons having enough familiarity with the control concepts.

State of the art

Commercial control systems are usually not fulfilling all the requirements which are explained in sections 2 to 4. Nevertheless, some of them include advanced characteristics, like self-commissioning or the careful consideration of the environmental situation thanks to several sensors. The automatic adaptation to user preferences is in general not yet available in these systems.

In order to get an idea of what could be the future in control systems, several research projects are discussed in details in section 5. This will hopefully allow to fuel the progress in the field of design by control manufacturers and specialized engineers. Each of these research projects provides also a list of scientific references for further investigations.

2. REQUIREMENTS CONCERNING CONTROL ALGORITHMS

2.1 Integration

Daylighting considerations are not independent from thermal and air quality considerations. On the contrary, all these aspects are tightly interacting together. For instance, controlling the daylighting quantity also controls the passive solar gains, and the user's requirements may depend on the season perceived by the user (in summer, some people cut more daylighting because they feel cooler with a darker ambience).

Therefore, a daylighting control which does not include thermal and air quality considerations (and of course artificial lighting considerations) will not allow a complete optimization of user's comfort and energy saving. The best solution is to integrate the control of all relevant building services (heating, cooling, ventilation, artificial lighting, daylighting) into one single controller. Such an integration allows to go one step further than simple daylight responsive control systems for artificial lighting.

2.2 Priority of user preferences

In general, the users should be given the absolute priority when they want to get another setting than the one provided by the automatic control. A control system which obstinately resets the user wishes after some seconds is highly irritating and must be absolutely avoided. Therefore, when a user has overrided the automatic control system, the system should both adapts its characteristics to new setpoints (adaptivity to user preferences, see section 2.4) and wait for a reasonable time before getting back the hand (i.e. typically one or two hours), except if one of the situations below occurs:

1. the room is no more occupied;
2. security reasons apply, for instance rolling up external blinds when the wind velocity is too high and would possibly damage them, or closing the windows in case of rain if the window opening is controlled by the system.

Nevertheless, user preferences need to be taken into account in a different way for spaces with a lot of people (conference rooms, open space offices, public spaces with a lot of circulation, etc) and for spaces used by a small number of persons (for instance office rooms with maximum 2 or 3 persons, or dwellings). In the first case, the adaptivity to user preferences should be somehow limited to avoid too much disturbances for all the other persons. On the contrary, "private" spaces, shared by a limited number of persons, may use fully user-adaptive control systems.

2.3 User disturbances

A control system should not cause a too high level of disturbances for the user. For instance, if the blind movements are rather noisy, the system should avoid to move them too often. The issue is especially critical with devices that need to be changed by steps and which cannot be ignored by the users, like on/off control of artificial lighting or blinds going up or down.

2.4 Adaptivity

The adaptivity issue includes two aspects: adaptivity to user preferences and adaptivity to boundary conditions.

2.4.1 Adaptivity to user preferences

An automatic control system for building services aims primarily at providing an optimal comfort for the users. An "intelligent" control system may include very refined algorithms, providing a very good comfort level for all situations likely to be encountered, for an average user. Nevertheless, users exhibit a rather large spread of individual preferences: some people like very bright ambiences, some prefer dark ambiences; some people prefer warm situations while some others like cold; etc.

Therefore, an good control system should adapt to the personal wishes of the users. The issue is crucial: even a control system providing very good inside comfort for an average user could be rejected by the actual users because the setpoints are not tailored to their particular wishes. It should be also reminded that building services that cannot be adjusted freely by the users (for instance: a fixed temperature setpoint, windows which cannot be opened, an air conditioning system which provide too cold air, etc) are a primary cause of the well-known "sick building syndrome".

2.4.2 Adaptivity to boundary conditions

In general, a control system has to be adapted to the particular conditions it will have to operate. Typically, the factors which should be taken into consideration are the local climate, the building use, and the building characteristics. At the commissioning, the engineers have to adjust the control system in order to allow an optimal inside comfort while minimizing the energy consumption, taking into account all the relevant factors.

Although that adjustment is very important for the user’s satisfaction and energy saving, and because that work may be time consuming and expensive, it happens very often that the commissioning of control system is done in a very crude way, or even "forgotten". Therefore, control systems which would adapt themselves to the building characteristics and local climate are quite interesting.

2.5 Sensors and redundancy

In order to use refined control algorithms, the control system must be able to acquire a complete image of the surrounding conditions. This includes the weather situation (typically the outside air temperature and the solar radiation), but also sensors for the evaluation of the inside conditions (visual, thermal, air quality, room occupancy, energy consumption, etc).

Some of the sensors may provide a certain redundancy. If the investment cost issue has the absolute priority over any other considerations, a minimum set of sensors may be used (for instance, outside temperature and solar radiation are correlated, and only one sensor could possibly be used), but in general redundancy is desirable since it allows the operation of the control system even with some broken sensors, although with a light degradation of the control quality.

2.6 Control system reliability

In a close relationship with the sensor redundancy, the requirement of control system reliability is of prime importance.

2.7 Providing the optimal comfort and understanding the physiological discomfort mechanisms

The primary aim of the building services and their control systems is to provide an optimal comfort to the building users. In general, the comfort of the users (typically, visual, thermal and air quality) is more important than any other consideration.

In order to elaborate adequate control algorithms for building services, the physiological discomfort mechanisms have to be correctly understood. For thermal comfort, a rather well-accepted and well-proofed formalism, basically developed by P.O. Fanger and based on the observation of a large sample of persons, is available. For visual comfort, the situation is more difficult and several comfort indexes are used through the world, none of them being widely adopted by the scientific community.

A pre-requisite for the improvement of control algorithms would be a better understanding of the factors having an influence on the comfort level. Currently, already rather sophisticated comfort models do exist, and they should be used whenever possible when designing control algorithms.

2.8 Energy considerations

Normally, energy considerations are secondary when compared with inside comfort, because even a small increase of comfort can pay for a large quantity of energy consumption. Nevertheless, if the same comfort can be reached by different algorithms corresponding to rather different energy consumption, the best one should of course be chosen.

When tariffs are modulated in function of the current hour in the day (typically for electricity), an energy optimization should also include an optimal distribution of energy consumption over the whole day.

2.9 Practical design of an advanced control system

The design of an advanced control algorithm may include two steps:

1. The elaboration of a rule base gathering the expert and "common sense" knowledge about the building services to be controlled and the user's comfort, taking into account the elements in sections 2.6 and 2.7;

2. The test of the elaborated system by simulation, and/or possibly by monitoring of a real implementation in an inhabited building or building room.

3. ADVICES CONCERNING THE IMPLEMENTATION

3.1 Building management bus

The use of a building management bus allow an easy access to all sensors and actuators, and the sharing of the available information between all the partial control systems, making the integration of all controllers easier (see section 2.1). Several building buses types are available. Choosing a well-supported standard (for instance, European Installation Bus or LonWorks bus) gives a much wider choice of sensors and actuators from various manufacturers, which should be freely interoperable. The development work can be focused on the controller itself, instead of re-developing sensors and actuators which are already available on the market.

A building management bus also makes smaller the cabling work between sensors, actuators and controller.

3.2 Reliability and serviceabiliby

The long-term reliability of the control system is important. At a research level, some minor bugs in the control system may be acceptable, but for a commercial system the reliability needs to be maximal. For instance, the reliability of the overall system can be improved by:

1. the redundancy of sensors (see section 2.5);
2. the use of a stable real-time system for the controller (avoid Microsoft Windows when using a PC controller…);
3. a battery backup of the controller;
4. the designation of a well-trained responsible person for checking the correct operation of the system permanently.

Serviceability is influenced by the use of a good user interface between the controller and the maintenance engineers.

3.3 User interface

With complex control systems, the user interface plays a very important role: at the same time it must be simple to understand and not ambiguous, even for users having no knowledge in building physics, and it must explain the behaviour of the controller when actuator commands are not intuitive, using adequate indexes.

A well-design user interface will also allow a better adaptation to user's wishes, by preventing wrong reactions from the user.

3.4 Structure of the control system

Designing separately the different levels of the control algorithms can help to keep a well-organized control structure. Cascaded control algorithms are advisable for a complex system, because they allow to divide the system into several levels. For instance, the arrangement given below can be used:

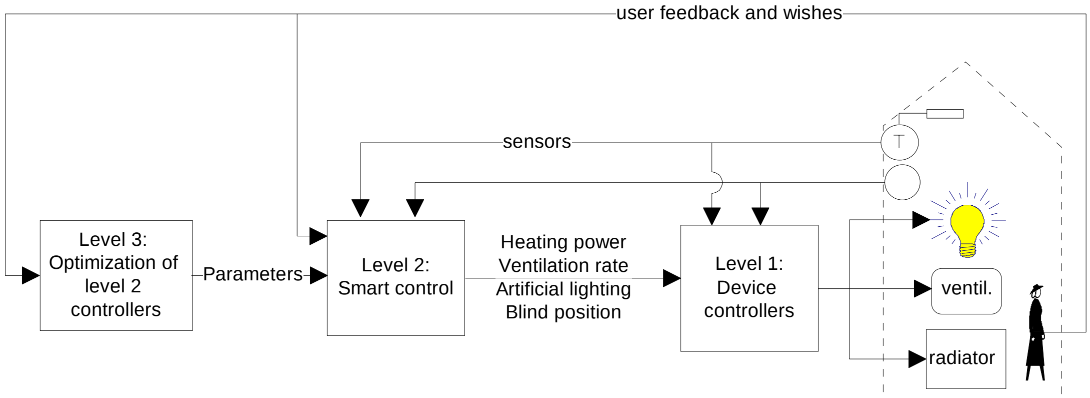

Figure 3.1: Cascaded control loops diagram.

In this figure, three levels are considered for the control algorithm:

1. The level-1 control block allows to control directly the technical devices provided in the particular case, translating the physical variable at the input (for instance, a blind position) into actuators commands (for instance in the same case, a command "blind up" or "blind down");

2. The level-2 control block includes the knowledge base, and provides the desired setpoint for the building devices taking into account the information given by the sensors and the predicted future behaviour of the whole system.

3. Finally, the level-3 control loop allows a continuous adaptation of the control parameters for the lower loop controllers, taking into account both an overall "cost function" (which represents the penalty for energy used and thermal, visual and air quality discomfort level), and reactions of the user.

4. CONCLUSION AND GENERAL CONSIDERATIONS

4.1 Bio-inspiration

Several of the requirements in section 2 can be summarized by the term "bio-inspiration". Advanced control systems may be considered in a similar way as a living being: although the environmental situation (i.e. the climate conditions) and the activity (i.e. the building use) may vary significantly, the control system allows to provide permanently the optimal conditions. In order to reach that goal, in both cases the controller needs many information from the surrounding world and from the object itself using sensors, and acts to keep the optimal conditions using actuators.

4.2 Adaptivity and self-commissioning

In particular, the adaptivity is an essential characteristics of advanced control systems. It is the next important step after the elaboration of "intelligent" control systems for building services. It allows both to design control systems well-accepted by the users and to make the commissioning of the controller easier.

4.3 Conformance with the proposed guidelines

The present report does not give mandatory standards or conditions which have to be absolutely respected: on the opposite, the guidelines are only here to make control system design easier. Therefore, the reader should not expect a strict conformance to all the advice. The control system will have the better performance when more of these advices are respected.

For instance, the implementation advices will allow an easier and more reliable operation, but it is possible to build a very performant control system without respecting them.

APPENDIX: PRACTICAL EXAMPLES FROM RESEARCH PROJECTS

The examples below show some possibilities for the design of an efficient control system. Since they were elaborated in the framework of research projects, the emphasis is put on the algorithms and not on the practical implementation.

It should be mentioned that some of the projects are not corresponding to today's state of the art and are only mentioned for a pedagogical goal. These algorithms would not conform to several of the guidelines mentioned in this report. For instance, the DELTA project was terminated in 1996, and the resulting algorithm does not take into account either the adaptivity (to building characteristics and to user preferences), nor the integration of various comfort aspects (at least visual and thermal), nor the principle of user priority.

APPENDIX A1: RESEARCH PROJECT DELTA

1. Summary

A control algorithm for a roll-down blind using fuzzy logic has been elaborated and tested experimentally at LESO-PB/EPFL. No adaptation was performed by the controller: although the user could override the blind position generated by the controller, the latter took back the hand after a predetermined time interval (typically one hour), and the characteristics of the controller were not changed as a result of the user's wishes.

Duration, partners and funding of the project: 1994-1996; LESO-PB/EPFL, Lausanne (CH), coordinator of the project (funding by Federal Office of Energy, Switzerland); Technical University of Vienna (A); Zumtobel Licht, Dornbirn (A); Landis & Gyr, Zug (CH).

Results: The DELTA algorithm allows an improvement of the thermal (overheating) and visual (glare reduction) comforts, together with a reduction of energy consumption (heating and lighting) of up to more than 50 % when compared to unfavourable (but unfortunately rather frequent) manual control strategies. The final report is available for downloading (web site lesowww.epfl.ch).

2. Algorithm description

The DELTA algorithm is based on following basic assumptions:

- the strategy used by the controller depends on the room occupancy;
- when the room is occupied, visual comfort has the priority and a fuzzy logic rule base is used to provide an optimal visual comfort, on a similar way a real user would do (i.e. adjusting the blinds in a way depending on the solar radiation and the sun position in the sky relative to the window, and possibly completing the inside illuminance by artificial lighting);
- when the room is not occupied, the controller's goal is to save thermal energy, by helping the heating/cooling system in its operation with an adequate position of the blind;
- the user can always override the system: if he is not satisfied, he can set the blind position and the artificial lighting level manually; after a predetermined time (normally 30 or 60 minutes), the automatic system gets back the hand for controlling the blind position and the artificial lighting.

A. "User present" strategy

The fuzzy variables used for the controller are the direct illuminance on the façade surface, the diffuse illuminance on an horizontal surface, and the incidence angle of the direct solar radiation (see figures 1, 2 and 3 below).

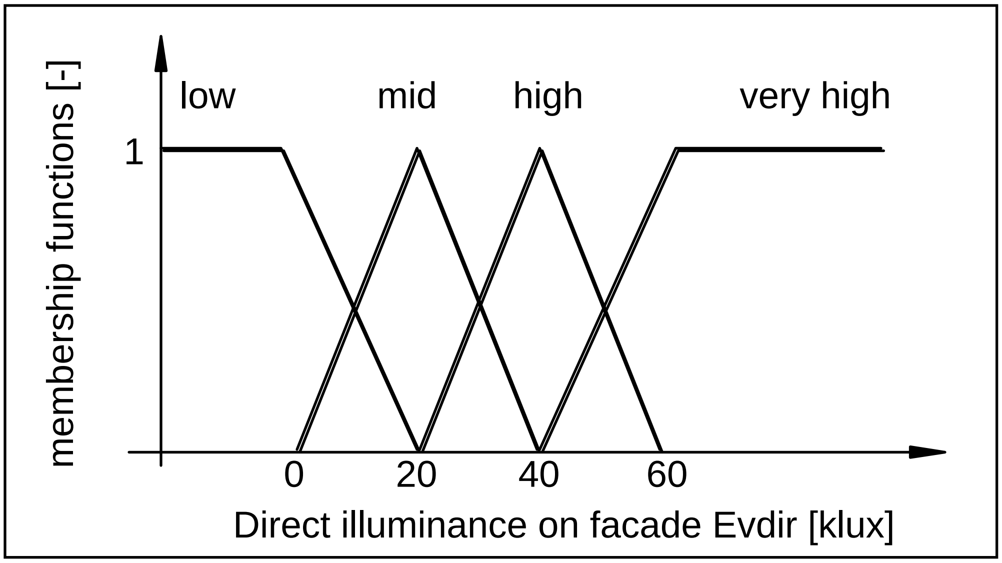

Figure 1: Fuzzy logic variable "Evdir" (direct illuminance on facade)

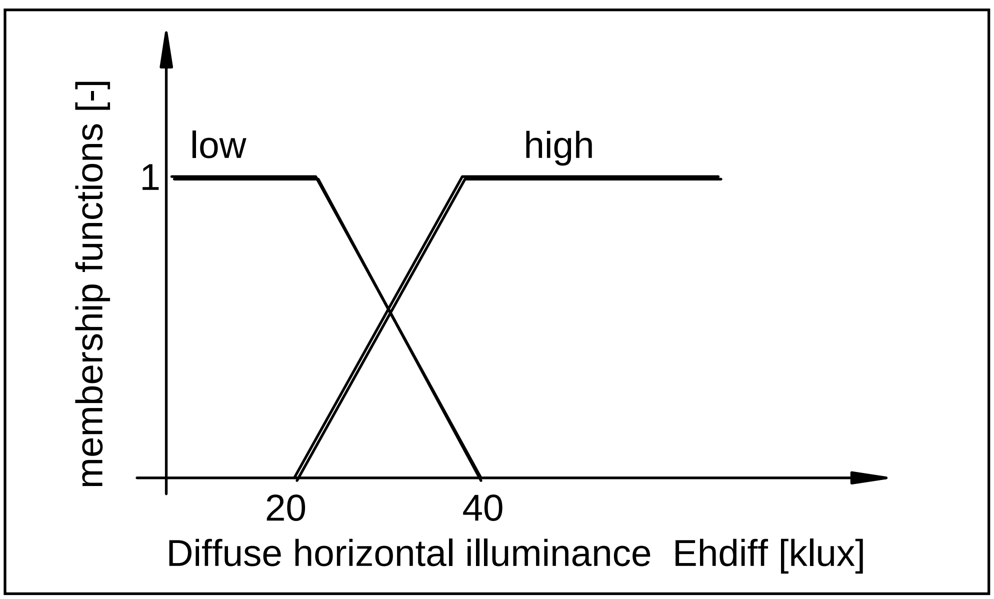

Figure 2: Fuzzy logic variable "Ehdiff" (diffuse illuminance on a horizontal surface)

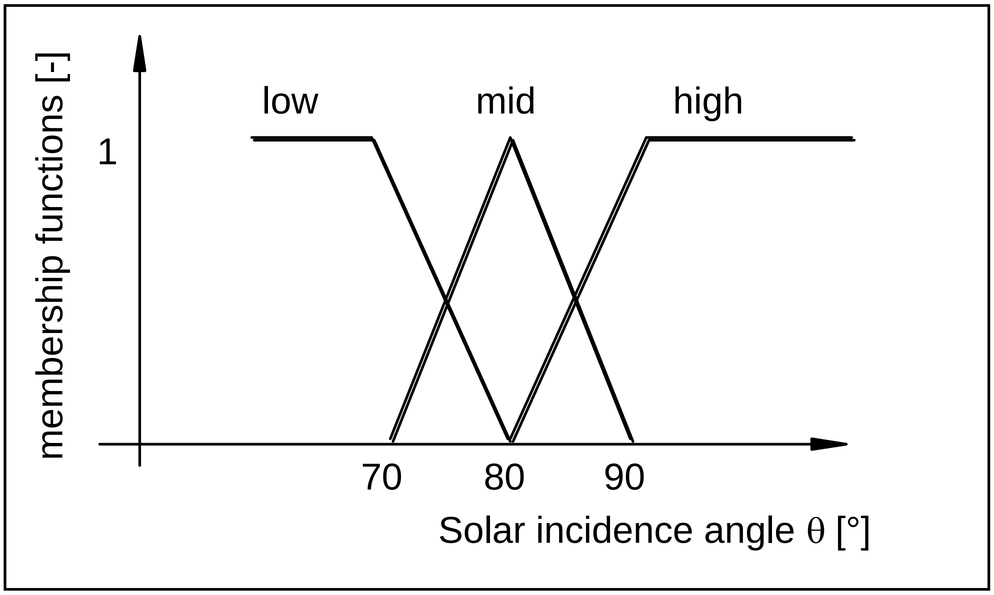

Figure 3: Fuzzy logic variable "theta" (incidence angle of the direct solar radiation on the window)

The rule base, providing the blind position as a fuzzy variable, is given by the table below.

Ehdiff	low				High			
Evdir	low	mid	high	very high	low	mid	high	very high
theta=low	open	half closed	closed	closed	half closed	half closed	closed	closed
theta=mid	open	half open	half closed	half closed	half closed	half closed	half closed	half closed
theta=high	open	open	open	open	half closed	half closed	half closed	half closed

B. "User not present" strategy

The window, equipped with its blind, is considered as a "heat source" controllable by the blind position. A simple thermal model for the window + blind system has been used in the controller, giving the heat power per unit area of window by the following formula:

$$Ps = Gv \bullet g \bullet \alpha + Gv \bullet g \bullet g\alpha \bullet (1-\alpha) - U'' \bullet (Ti-Te)$$

where α = blind position ($0 \le \alpha \le 1$, 0=closed, 1=open)
Gv = global vertical radiation [W/m2]
g = transmission coefficient of window glazing

$g\alpha$ = transmission coefficient of blind material
$U'' = \alpha \bullet U + (1-\alpha) \bullet U/(1+R\bullet U)$
U = heat loss coefficient of the window without blind [W/m2K]
R = thermal insulation coefficient of the blind [m2K/W]

In the above equation, the first term represents the solar gains through the window part not covered by the blind, the second term the solar gains through the window part covered by the blind, and the third term the heat loss from inside to outside (since we are interested to the heat provided to the room, we need thus a negative sign).

The fuzzy logic variables used in the controller are the season (derived from the outside temperature) and the heating/cooling power. They are represented in the figures 4 and 5 below.

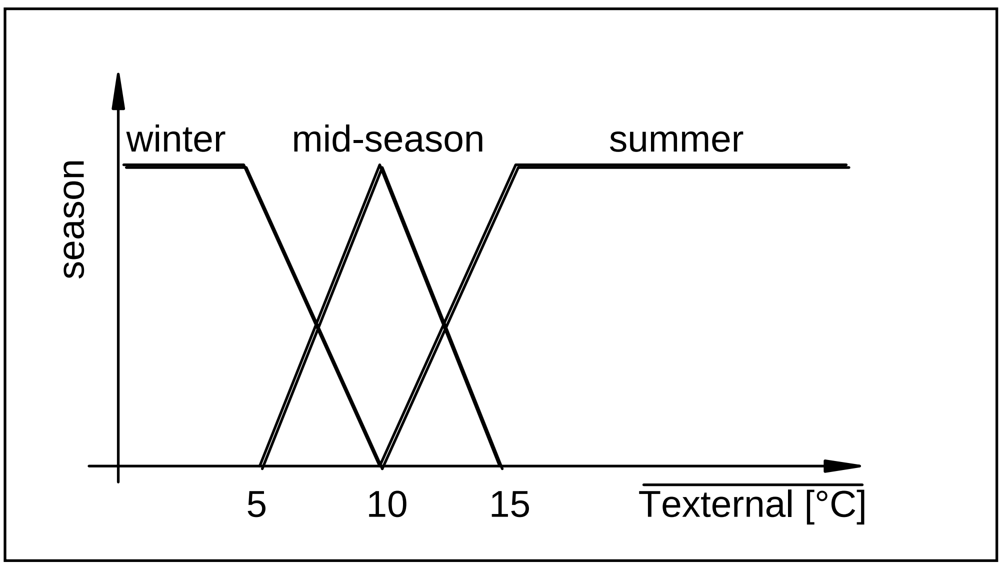

Figure 4: Fuzzy logic variable "season" (Texternal is the average outside temperature during the last 24 hours)

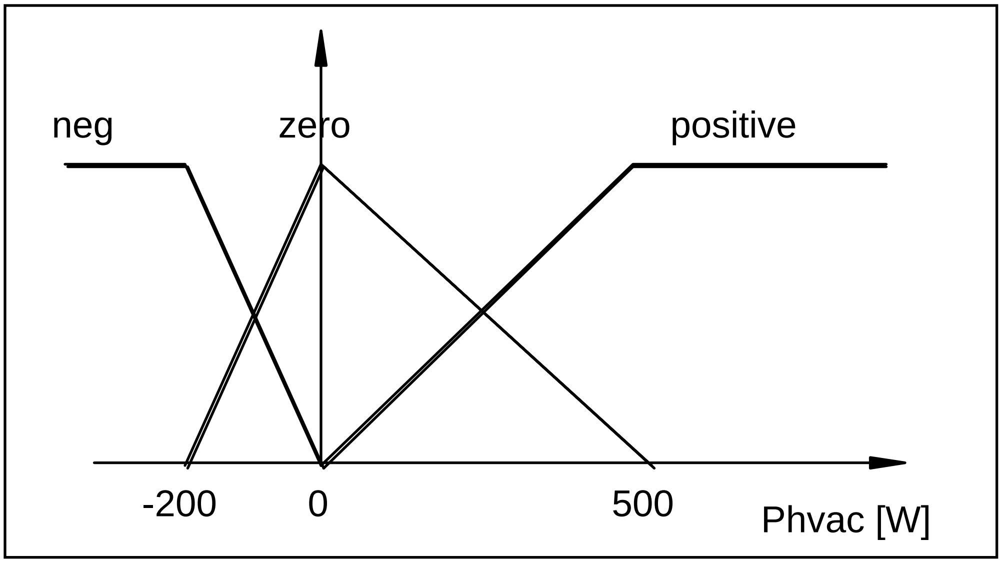

Figure 5: Fuzzy logic variable Phvac (heating/cooling power; positive=heating, negative=cooling)

The rule base for the case where no user is present is very simple, and is represented by the table below. It gives the desired window heat balance Psw. (The two cases noted with an (*) should normally not occur for an energy efficient heating/cooling system.)

Heating power	negative	zero	positive
Season=winter	negative (*)	positive	positive_high
Season=mid-season	negative	positive_low	positive
Season=summer	negative	zero	positive_low (*)

Then, from the desired window heat balance Psw, the inverse formula of the one giving Ps in function of α (the blind opening fraction) is used to derive the most adequate α value, within the allowable physical limits ($0 \leq \alpha \leq 1$).

APPENDIX A2: RESEARCH PROJECT ADCONTROL

1. Summary

The project AdControl ("Adaptive Control: Bio-Mimetic Building Control Strategy Using Genetic Algorithms to Account for Human Wishes"), carried out at LESO-PB/EPFL, Switzerland, was aimed at the investigation of control algorithms adaptation to human wishes, by the way of genetic algorithms. It was started in January 2002, and terminated in December 2003.

Bio-mimetic control strategies of building services (heating, cooling, ventilation, and lighting) have been recently subject to significant advances, using algorithms such as fuzzy logic or artificial neural networks. The AdControl research project builds on this knowledge to investigate the use of another novel approach to implement the adaptability of building services control algorithms: the genetic algorithms. Its capabilities, regarding the optimisation of energy consumption and human comfort, were examined more deeply in relation with:

- the adaptation to the human wishes;
- the adaptation to the changing building characteristics and building use.

In particular, the adaptation to human wishes needed to be investigated in a new way. Not every user has the same requirements for the building equipment operational point, regarding for instance the lighting conditions, the inside temperature or the indoor air quality. Control systems which do not adapt their operation to the user behaviour, even if they take into account several factors and apply smart strategies, have an important drawback: the users may either switch off the control system because they are not satisfied with it, with a very high risk to get uncomfortable situations when they forget to interact with the system and to cause an increased energy consumption (for instance, to forget the artificial lighting on when leaving the room); or, especially if they have no access to the system control, they become unsatisfied and frustrated. (A very common cause of the "sick building syndrome" is the fact that the user cannot adjust his/her environment, like changing set-point temperatures, moving the blinds, opening the windows, etc.)

Therefore, the utilisation of control strategies which allow an adaptation to the human wishes is the next important step, after the elaboration of smart control strategies for building services. Following the results of previous research projects, it was proposed to provide this adaptive characteristics through the use of genetic algorithms.

Duration, partners and funding of the project: 2002-2003; LESO-PB/EPFL; ISR-EAST/EPFL (Institute of Robotic Systems); funding by EPFL. The project has just been started in January 2002, but preliminary work has been already carried out in the framework of the EDIFICIO project, especially concerning adaptation to the changing building characteristics and building use.

Results: The comparison between a manual control, an automatic control without adaptation to user preferences, and an automatic control with adaptation to user preferences, has shown that the energy saving due to the use of a smart control algorithm when compared to a manual control, is preserved by the user-adaptive control algorithm but with much less rejection rate and with an improved indoor comfort. (See more details in the section below.)

2. Algorithm description - Rule base and models

The control algorithms already elaborated by our laboratory through several other projects are using artificial neural networks and fuzzy logic, which are convenient for describing the control rules and the various models (building, building services) to be considered. The first part of the project was devoted to the elaboration of adaptive rules, which would be adapted to the individual user preferences by the way of Genetic Algorithms.

2.1 Basic Principles

Integrating all the different controllers in one unique system would have been very difficult and inefficient if there were no underlying principles. This section describes the basic principles used for the whole control system. It also explains how some additional physical data are prepared.

2.1.1 Integration Aspects

Three different device categories are considered for the control: the heating/cooling system, the blinds (shading devices) and the electric lighting. Ventilation was not taken into account since the LESO building (in which the experiments have been undertaken) has no mechanical ventilation system installed. Nevertheless, the chosen controller architecture allows implementing easily additional control devices4. The integrated system is built on the principle of three nested control loop levels (see Figure 2.1).

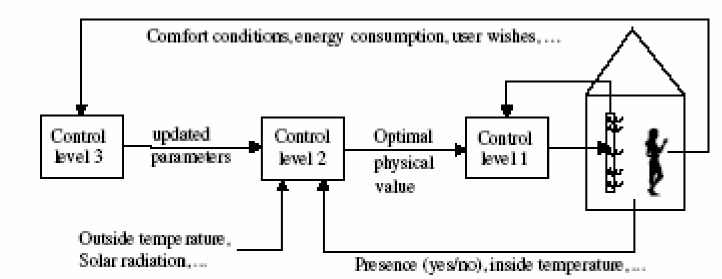

Figure 2.1: Principle block diagram of the three nested control loop levels

1 Level 1 performs the translation from physical values (heating power, blind position, etc.) into electrical signals for field actuators (to modify the heating system valve position, to raise or lower the blind, etc.). In our case, we use an

EIB building bus for the data transmission between the computer and the actuators and sensors, and the level 1 software modules have to take it into account.

2 Level 2 control loop includes the domain knowledge. It is based on expert fuzzy inference systems and uses adaptive models for thermal and lighting aspects in order to produce an efficient global control strategy. The different fuzzy controllers are described later in this chapter. The outputs of this level are the physical values that are the inputs of the level 1 control loop.

3 Level 3 ensures the long-term adaptation of the level 2 algorithms. The adaptation is performed in a continuous way to take into account all the long-term changes of the building and device characteristics (see Section 3.4). Moreover, an adaptation task using Genetic Algorithms is undertaken in order to optimize the system from both user and energy efficiency points of view (see section 3).

The level 1 is specific to each building but both levels 2 and 3 are very easily adjustable to any kind of controller device. The self-adaptation of the systemleads to simplified commissioning and efficient working without complicated parameter adjustment.

The system provides also an interface that allows the user to change set-points or other operative conditions (see Section 3.1). This gives the maximum flexibility to the system, user actions always keeping the first priority over the automatic control.

2.1.2 Data Handling

The control system requires some variable that are not directly available through the sensors, but that have to be generated by preprocessing blocks described in the figure 2.2.

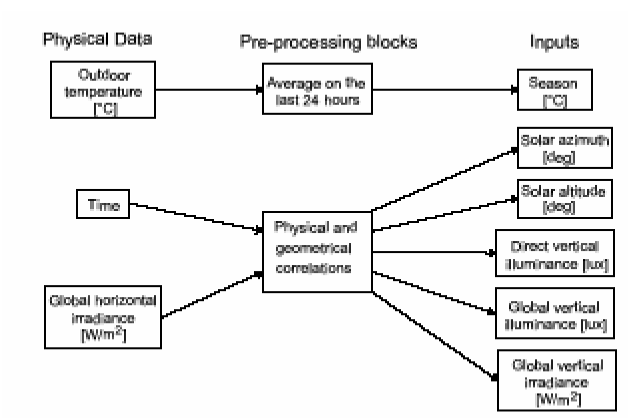

Figure 2.2: Preprocessing phase

The first block provides the average outdoor temperature during the last 24 hours, including the current outdoor temperature. It is used essentially to derive the current season as a fuzzy variable.

The second block provides all the needed illuminances for the controllers and provides also the solar altitude and solar azimuth relative to the facade. Its inputs are the time and the global horizontal radiation. Furthermore, four parameters are needed for the block calculations. The longitude λ, the latitude ϕ, the time zone Tz of the building location and the facade orientation a0.

The calculations are not detailed here to avoid a rather long description. Their principle is very well known and can be found in any good textbook on solar energy. Moreover, they can be find in the PhD thesis of Antoine Guillemin […].

2.2 Controllers

Three controllers are considered in this work: a shading device controller, an electric lighting controller and a heating controller. Each one is integrated in the whole system via the nested loops architecture (see Section 2.1). The present section deals only with the level 2 of the different controllers.

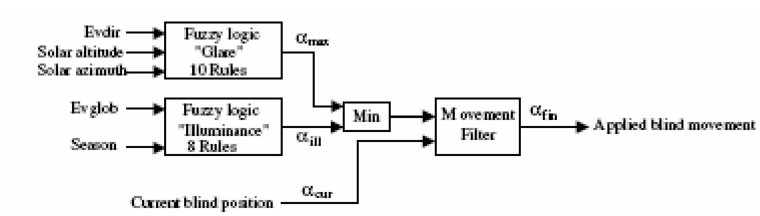

Figure 2.3: Overall diagram of the blinds controller operation

2.2.1 Shading Device

The shading device control system described here deals only with fabric blinds, since the available blinds in the LESO building are of this type. Nevertheless, a controller for venetian blinds was developed in another project (with both vertical position of the blind and slats angle regulated).

In this section, the fabric blind control system is presented: first the controller for the case where the user is present, and then the controller for the case where the user is absent.

2.2.1.1 User Present

From the preliminary study, the main criteria of a blind controller in the visual case have been established:

1 Priority is to avoid glare.

2 Thermal aspects should also be considered.

3 Both solar altitude and azimuth should be used to be able to provide different control

4 strategy for different user positions in the room.

5 There should not be a closed-loop control with indoor illuminance measurement.

Figure 2.3 shows the overall diagram of the blinds controller and the different included function blocks.

First, a maximum value alpha_max for the blind position is calculated through a fuzzy rule base in order to avoid glare. At the same time, a blind position depending on the illuminance setpoint alpha_ill is also determined. This last calculation is achieved using fuzzy logic inference systems. Then, the final value for the blind position alpha_fin is determined: it corresponds to the minimum value of the two blind positions alpha_max and alpha_ill. A blind movement filter depending on the current position of blind alpha_cur prevents from moving the blinds too often, which could irritate the user.

The final controller architecture has been chosen for the following reasons:

1 It is a simple and flexible system, containing only few rules, and therefore only few parameters have to be tuned by the adaptation process (see section 3).

2 The glare aspect is very important: a dedicated fuzzy inference system ("Glare") is used to deal with this problem.

3 Providing a perfect illuminance is not aimed, because human eyes have a very low sensitivity towards the variation of illuminance. Moreover, the "Illuminance" fuzzy inference system allows finding a compromise between the illuminance and the thermal impact of solar gains. For instance, opening the blinds wider in winter in order to increase solar gains is quite acceptable for the user, as long as no glare occurs.

4 The vertical direct illuminance Evdir on the facade is more relevant than the horizontal one to address glare problems.

In addition, the fuzzy membership function mid-season is removed in the final controller in order to optimize it on the thermal aspects. In fact, the preliminary study has shown the necessity of providing an accurate value for the non-heating temperature in order to make the controller very energy efficient. Since this value is provided by the adaptive heating system, thermal optimization consists simply in deciding to maximize (in winter) or reject (in summer) solar gains. The fuzzy transition between winter and summer is probably sufficient to deal with mid-season. Thus, it has been decided to remove rules related to the mid-season, even it makes the control system less flexible for this period.

The fuzzy rule bases are discussed more in detail below.

Fuzzy logic "Glare", user present

The innovative idea to take into account not only the incidence angle of the solar radiation on the facade but the exact position of the sun relatively to the facade. It is depicted on Figure 2.4 below. This allows having different behaviours for different kind of direct sun penetration. In particular, it gives the opportunity to adapt the system (through the user wishes) depending on the user position in the room.

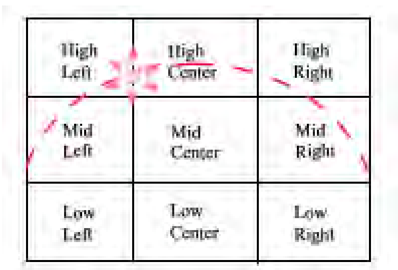

Figure 2.4: Sun position relatively to the façade

Inputs (fuzzy values):
1 Direct vertical illuminance (Evdir)
2 Solar altitude (Altitude)
3 Solar azimuth (relative to the facade orientation) (Azimuth)

Output (crisp value):
1 Maximum blind position (alpha_max)

Complete rule base (10 rules):
2 If "Evdir is high" and "Altitude is low" and "Azimuth is right" then "alpha_max = 0.4"
3 If "Evdir is high" and "Altitude is low" and "Azimuth is center" then "alpha_max = 0.4"
4 If "Evdir is high" and "Altitude is low" and "Azimuth is left" then "alpha_max = 0.4"
5 If "Evdir is high" and "Altitude is mid" and "Azimuth is right" then "alpha_max = 0.6"
6 If "Evdir is high" and "Altitude is mid" and "Azimuth is center" then "alpha_max = 0.6"
7 If "Evdir is high" and "Altitude is mid" and "Azimuth is left" then "alpha_max = 0.6"
8 If "Evdir is high" and "Altitude is high" and "Azimuth is right" then "alpha_max = 0.8"
9 If "Evdir is high" and "Altitude is high" and "Azimuth is center" then "alpha_max = 0.8"
10 If "Evdir is high" and "Altitude is high" and "Azimuth is left" then "alpha_max = 0.8"

11 If “Evdir is low” then “alpha_max = 1”

Fuzzy input variables are depicted on Figures 2.5 to 2.7.

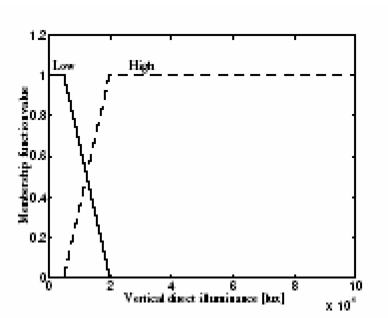

Figure 2.5: Fuzzy variable Evdir

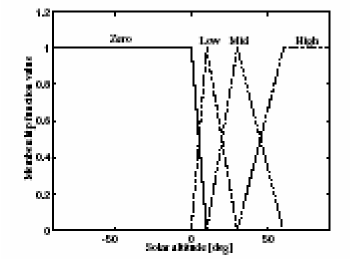

Figure 2.6: Fuzzy variable Altitude

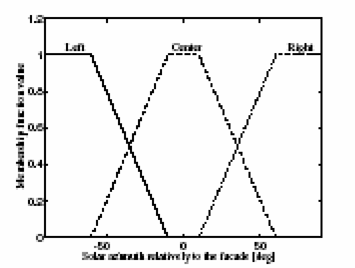

Figure 2.7: Fuzzy variable Azimuth

<u>Fuzzy logic rule base “Illuminance”, user present</u>

Inputs (fuzzy values):
12 Global vertical illuminance (Evglob)
13 Outdoor average temperature on the last 24 hours (Season)

Output (crisp value):
1 Maximum blind position (alpha_ill)

Complete rule base (8 rules):

2 If “Season is winter” and “Evglob is night” then “alpha_ill = 1”
3 If “Season is winter” and “Evglob is high” then “alpha_ill = 0.6”
4 If “Season is winter” and “Evglob is mid” then “alpha_ill = 0.8”
5 If “Season is winter” and “Evglob is low” then “alpha_ill = 1”
6 If “Season is summer” and “Evglob is night” then “alpha_ill = 1”
7 If “Season is summer” and “Evglob is high” then “alpha_ill = 0.3”
8 If “Season is summer” and “Evglob is mid” then “ alpha_ill = 0.5”
9 If “Season is summer” and “Evglob is low” then “alpha_ill = 0.7”

Fuzzy variables are depicted on figures 2.8 and 2.9.

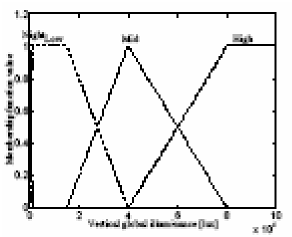

Figure 2.8: Fuzzy variable Evglob

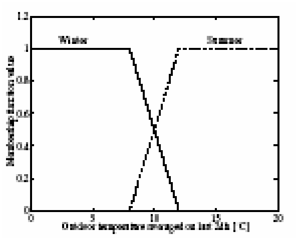

Figure 2.9: Fuzzy variable Season

<u>*Genetic Algorithms encoding*</u>

In the rule bases, the consequent value a of the output (“If … then x = a”) is only given as a starting point. We will see in the section 3 that the Genetic Algorithms are used to “tune” this value from user preferences, expressed through the manual change of the blind position.

The encoding of the two fuzzy rule bases for the cases where the user is present is realized by regrouping the two fuzzy rule bases in one individual, whose genes are representing variations of the crisp output values. An individual (chromosome) is built as follows:

“Glare” fuzzy rule number										“Illuminance” fuzzy rule number							
1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8

Fig 2.10: Gene encoding

2.2.1.2 User Absent

The preliminary study has shown two interesting facts about the thermal blind controller.

1 Energy efficiency of the blind controller largely depends on the use of the variable season.

2 Providing a positive window heat balance in mid-season is the most efficient strategy.

The final controller for the user absent case takes into account the current season (which is defined through the average of the outdoor temperature on the last 24 hours) to determine the blind position.

The basic idea is to use the window and blind system as a control of the incoming solar gains, which have to be minimized in summer and maximized in winter. The critical point is to have an accurate value of the temperature that delimits the heating season and the non-heating season. Thus, this value is adapted every month to the latest measurements.

The controller has been slightly improved to avoid overheating or overcooling with an extreme blind position. Briefly, the blind controller tries to cool (reject solar gains, increase thermal losses through window) in summer and to heat (maximize solar gains, decrease thermal losses through window) in winter. But when the indoor temperature is really too low or too high compared to the temperature setpoint, the controller takes temporarily the opposite behaviour in order to attenuate the overheating or overcooling.

The fuzzy rule base is given below.

Inputs (fuzzy values):
1 Outdoor average temperature on the last 24 hours (Season)
2 Horizontal global solar radiation (Qhglob)
3 Difference between current room temperature and setpoint temperature (Tdiff)

Output (crisp value):
1 Blind position (alpha)

Complete rule base:
2 If “Season is winter” and “Qhglob is night” and “Tdiff is zero” then “alpha = 0”
3 If “Season is winter” and “Qhglob is shinyday” and “Tdiff is zero” then “alpha = 1”
4 If “Season is summer” and “Qhglob is night” and “Tdiff is zero” then “alpha = 1”
5 If “Season is summer” and “Qhglob is shinyday” and “Tdiff is zero” then “alpha = 0”

6 If “Qhglob is night” and “Tdiff is too cold” then “alpha = 0”
7 If “Qhglob is night” and “Tdiff is too hot” then “alpha = 1”
8 If “Qhglob is shinyday” and “Tdiff is too cold” then “alpha = 1”
9 If “Qhglob is shinyday” and “Tdiff is too hot” then “alpha = 0”
10 If “Qhglob is darkday” then “alpha = 1”

The last rule is not quite optimal for thermal aspects but it allows to illuminate corridors with daylight when office doors are open. It has been seen to reduce the use of electric lighting in corridors during dark day. Fuzzy variables are depicted on Figures 2.10 and 2.11. The fuzzy variable Tdiff is less severe with too high temperature than too low temperature. It is due to the fact that it is less energy consuming to cool an office in winter (i.e. opens the windows) if there is overheating than to heat an office in summer (i.e. applies heating power) if there is overcooling. It would not be the case if a cooling system was installed in the LESO-PB building.

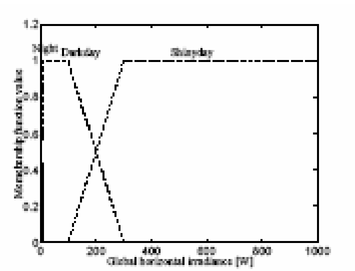

Figure 2.10: Fuzzy variable Qhglob

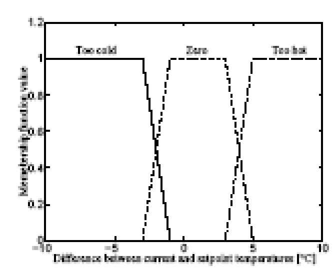

Figure 2.11: Fuzzy variable Tdiff

2.2.1.3 Movement filter

For the case of user present, the “Movement filter” is made of two consecutive filters: a time dependent filter and a minimum step filter.

The time filter prevents too frequent blind movements by forbidding a blind movement when the precedent one has been applied less than 15 minutes ago. The time elapsed is reset to 0 even when the blinds do not move but would have moved towards down if the minimum step filter was not applied. This is done to prevent the blinds moving periodically (each time the 15 minutes pause is ended) during a day with an intermediate sky (sunny-cloudy). Moreover, the movements that lower the blinds are not concerned by the time filter, in order to avoid glare problems during these sunny-cloudy days. A blind position slightly too low is thus preferred to a position slightly too high.

When the blind movement is accepted by the time filter, it enters the minimum step filter: the movement is applied only if it is larger than a fixed minimum value delta_alpha (in our case, delta_alpha = 0.3, i.e. 30% of the movement between totally closed and totally open). This value is reduced by half when there is a risk of glare (i.e. when alpha_max < alpha_cur).

The control algorithm presented here deals only with one blind but in the LESO building there are two blinds to control per room. The idea is to control independently the two blinds with two similar algorithms. The unique difference is in the fuzzy rule base “Illuminance” of the lower blind. A minimal opening of 0.4 is kept in order to allow visual contact with the outdoor environment, which has been clearly shown as an important criteria for user acceptance [Elder and Tibbott, 1981].

In the case of user absent, two steps have been taken to minimize the number of movements (and prevents early mechanical wear). The first reduction of the number of blind movements is realized with a minimum step filter (similar to the one used in the user present case) that allows moving blind only if the movement is large enough (larger than 40% of the movement between totally closed and totally open). The other reduction is done through the use of the two blinds (in the case of the LESO building) in a sequential way, that means to consider the two blinds as only one larger blind. In the LESO building, one blind is above the other and a sequential control seems to be a natural solution.

The idea is to use a parameter called Bi that describes the importance of blinds regarding the illuminance provided.

0 < Bi < 1

Using Bi and the alpha value given by the controller, the blind position of the upper blind alpha_1 and the lower blind alpha_2 are calculated as follows:

If alpha >= Bi then:

1 alpha_1 = (alpha-Bi)/(1-Bi) and alpha_2 = 1 (completely open)

If alpha <= Bi then:

2 alpha_1 = 0 (completely closed) and alpha_2 = alpha/Bi

The Bi parameter is continuously adapted together with the RI model adaptation (described in a further section).

2.2.2 Electric Lighting System

The electric lighting is used as a complement of the indoor illuminance Eind (provided by the RI model, see Section 2.4.2) in order to reach the illuminance setpoint Eset. An hysteresis control is applied to avoid too frequent switches on or off:

1 If $Eind/Eset < 0.75$ the electric lighting system is switched on.
2 If $Eind/Eset > 1.0$ the electric lighting system is switched off.

But prior to switching on, the system tries to raise the blinds, as far as the user has not interacted with them. Thus, only in very special cases the electric lighting may be switched on with blinds being closed at the same time.

The calculation of the exact power fraction (Pal, included in the interval [0,1]) applied to the dimming control is performed using the electric lighting model described in Section 3.4.3 and the difference between the indoor illuminance and the illuminance setpoint:

$$a \cdot Pal^4 + b \cdot Pal^3 + c \cdot Pal^2 + d \cdot Pal + Eset - Eind = 0$$

where a, b, c and d are the parameters of the electric lighting model.

The electric lighting power is the root of this equation. It has to be noted that the solution Pal may be negative or higher than 1 but in the controller non-physical values are rejected and replaced by the nearest physical value.

In a post-occupancy evaluation of seven energy efficient buildings in USA, Heerwagen and Diamond had shown that users did not like the automatic daylight and electric light controls because they were distracting and disturbing [Heerwagen and Diamond, 1992]. Therefore, an electric lighting "smoother" have been developed and implemented. It varies the electric lighting power by maximum steps of 2% that are not noticed by occupants. Each time an event occurs and the main control module is called, a variation step of electric lighting is done, if needed, in the latest calculated direction (increasing or decreasing power).

Figure 2.12 shows the effect of the "smoother" compared to a lighting control strategy without the smoothing feature during a measurement day in January. The time range depicted corresponds to about one hour and a half. First, it prevents the frequent and very disturbing switching on or off as it occurred at time 30.34. Second, it avoids sudden large variations of electric lighting power as it occurred around times 30.37 and 30.38. Larger steps of variation are permitted when users enters or leaves the room and if the current electric lighting power is really too low compared to the calculated power (difference larger than 50% of maximum power).

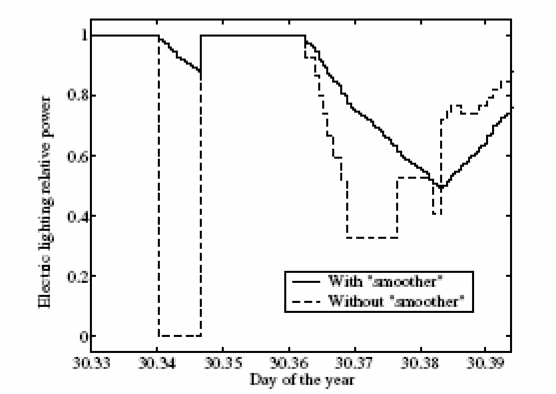

Figure 2.12: Effect of the "smoother" feature on the electric lighting control

2.2.3 Heating System

An efficient heating controller should have predictive and adaptive features. Unfortunately, available controllers such as NEUROBAT [Krauss et al., 1998] consume too much computational time. Indeed, optimization of a cost function (grouping discomfort and energy consumption) is unsuited to our experiments with 15 office rooms and 15 heating controllers to run. Thus, a simpler empirical heating controller has been developed, that nevertheless has both predictive and adaptive features.

Since the present report is not focused on heating device control, the algorithm is not describe here. The reader interested in this subject should refer to the PhD thesis of Antoine Guillemin […].

2.3 AdaptiveModels

The different controllers being defined, the adaptive models used by them are described in the present section. All these models are adapting at a room level. Only the weather data prediction model is achieved at the building level.

2.3.1 Weather Data Prediction Model

The vector of solar irradiance predicted over the six next hours on the horizontal plane is needed by the control system. Such data could have been provided by public weather forecast service but in this case the information supplied is often averaged over several hours and is not directly usable for a six hours ahead prediction. Moreover, the necessary solar radiation sensor is already available in our system because it is required for the lighting and thermal controllers. Thus, a solar irradiance predictor is used within this work. The approach used was developed and verified in the NEUROBAT project [Krauss et al., 1998, Morel et al., 2001]. It was there shown that artificial neural networks (see the book of Haykin [Haykin, 1999] for comprehensive explanations of ANNs) are the most effective method for the prediction of the horizontal global solar irradiance8. A new version of a similar feed-forward network has been re-developed.

The same structure with one hidden layer of four neurons has been taken. Due to its convergence capabilities, the Levenberg-Marquart training algorithm was used. For the activation function of the neurons, the tangent hyperbolic was chosen due to its non-linearity, continuity and derivability. The training data were relative values because they were divided by the theoretical maximum solar irradiance, i.e. the solar irradiance with an atmospheric transmission factor of 1.0.

The Artificial Neural Network (ANN) used for the solar radiation predictor has four normalized inputs:

1. Grel(k): Relative solar irradiance at current time k
2. Grel(k − 1): Relative solar irradiance at time k − 1 (one hour ago)
3. Grel(k + 6 − 24): Relative solar irradiance 24 hours before the time of prediction
4. Gmax(k + 6): Computed maximum solar irradiance at the time of prediction

and one normalized output:

1. Grel(k + 6): Relative solar radiation at the time of prediction

The newly developed predictor (called "new ANN") is compared with the one used in the NEUROBAT project, with a reference model that uses the current measurement of the relative solar irradiance as the prediction value and with a more recent meteorological physical model (MRM) developed by Muneer et al. [Muneer et al., 1998]. Weather data used for the comparison are synthetic values generated by the METEONORM program [MeteoTest, 1996] (except the results of the Muneer model that have been obtained with real weather data). Training is performed on the six first months of the year, and evaluation is performed on the last six months. Results are given in table of figure 2.13. Both ANN models give better results than the reference one, which shows that it is worth using ANN for prediction. The accuracy of the new ANN model is confirmed by its results quite similar to the NEUROBAT ones. Moreover, results of ANN models are even better than the ones of MRM. But it should be mentioned that the latter come from real weather data, which is maybe detrimental.

Model	Mean error [W/m^2]	Standard deviation [W/m^2]
Reference[a]	72.8	160.6
ANN NEUROBAT[a]	-6.7	82.6
New ANN	-9.1	80.9
MRM[b]	12 - 54	39 - 112

[a] values coming from the NEUROBAT final report [Krauss et al., 1998]

[b] values from [Muneer et al., 1998] in lux translated in W/m² with the Winkelmann and Selkowitz correlations [Winkelmann and Selkowitz, 1985]

Figure 2.13: Mean values and standard deviations of the 6-hours prediction error of the horizontal global solar radiation for different models

Even with ANN models, standard deviation is quite large, which attests to the diffi- culty of solar radiation prediction. Qualitative results of the prediction with the new ANN model are depicted on Figure 2.14. They are sufficiently accurate to provide valuable information to the heating system about future solar gains.

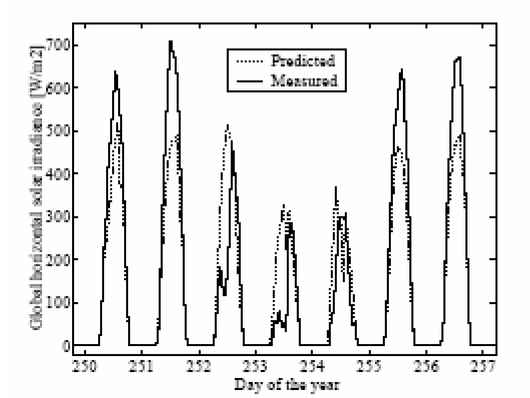

Figure 2.14: Comparison of measured and predicted value of horizontal solar irradiance

2.3.2 Illuminance Ratio Model

The RI model calculates the horizontal indoor illuminance on the workplane from the measurement of the vertical outdoor illuminance. Some experiments have shown that the use of the vertical outdoor illuminance gives better and more consistent results than the standard use of the horizontal outdoor illuminance (equal to a *daylight factor* for overcast sky) when comparing with horizontal indoor illuminance for different blind positions (both upper and lower blinds are moved together). Figures 2.15 and 2.16 show the results for both cases. The case with vertical outdoor illuminance (RI model) clearly leads to less scattered results than the case with horizontal outdoor illuminance ("Extended daylight factor"). Hence, the RI model will give better results for different sky conditions. Note that sensors for indoor illuminance measurements were protected from direct solar radiation.

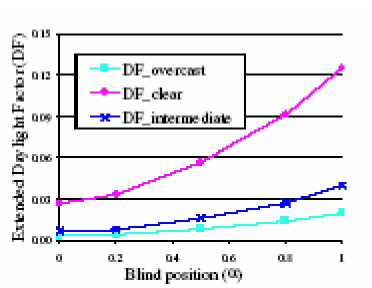

Figure 2.15: "Extended daylight factor" (horizontal indoor / horizontal outdoor illuminances) measured for three sky conditions

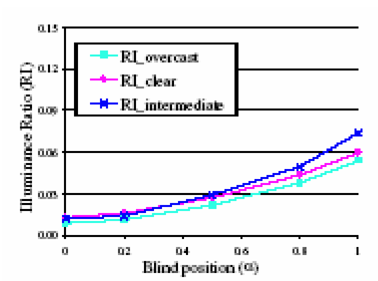

Figure 2.16: Illuminance ratio (horizontal indoor / vertical outdoor illuminances) measured for three sky conditions

Three RI models have been compared. First, a simple exponential that was shown to be better suited than a linear model, then an artificial neural network model and finally a model that mixes the exponential and the ANN models. The latter model first fits the data with an exponential model and then tries to fit the remaining error ΔE via an ANN model.

Ehind = a · exp(b · alpha) · Evout (model 1)

Ehind = a · exp(b · alpha) · Evout + ΔE (model 3)

where Ehind is the indoor horizontal illuminance, Evout the outdoor vertical illuminance, alpha the blind position and a, b the model parameters.

The fit of the exponential model is performed using the nonlinear least-squares Gauss-Newton method (MATLAB toolbox). The ANN models are feed-forward networks with six neurons in the hidden layer and with the same two inputs: the blind position _ and the outdoor vertical illuminance Evout.

The three models are fitted (trained on 100 epochs for the ANN) on experimental measurements of the whole month of August and evaluated on the measurements of the month of September, provided that there were no electric lighting and no saturation of the indoor illuminance sensor (values below 3500 lux). The results are given in table of figure 2.17. The two models with the exponential characteristic are clearly giving more accurate results than the simple ANN model. The combination of the two models gives similar results to the simple exponential model in accuracy but it necessitates much more computational time. The corresponding ANN model does not improve the exponential model and requires too much computational time for a real implementation. Thus, the chosen RI model is the exponential model.

Model	Standard deviation	CPU time [s]
Exponential model	416	3
ANN model	494*	110*
Exponential + ANN model	417*	99*

*average value out of ten runs

Figure 2.17: RI models comparison

The RI model is continuously adapted to the new monitored data of the day via the same procedure described above. It allows to take into account changes in the environment (trees in their winter dress, new building in the vicinity, etc.). So, every night the two parameters of the RI model and the Bi parameter (for the two blinds case) are fitted on the measurements of the indoor and outdoor illuminances during the last 15 days.

An additional feature related to the RI model is the shading mask detection. Indeed, shading from neighboring buildings and trees may largely affect the indoor illuminance. Thus, the system tries to detect shading cases in a room by calculating the indoor illuminance using the diffuse component of the vertical outdoor illuminance instead of the global one in the RI model. If the result is closer to the indoor illuminance measurement without the direct component, it is assumed that there is actually shading on the windows of the room and that it is better to only use the diffuse component. Figure 2.18 shows the RI model results during a sunny morning in January compared to the measurements. Thanks to the shading mask detection, the model provides good values even when direct solar radiation is cut by obstacles. At time about 7:42, there is no more shading and the RI model goes properly back to the no shading mask mode.

In addition, if a shading mask is detected, the calculated value of the vertical direct outdoor illuminance (see Section 2.2.2) is set to zero. This has repercussions on the blind and electric lighting controls, which need either RI model calculations or vertical illuminance data.

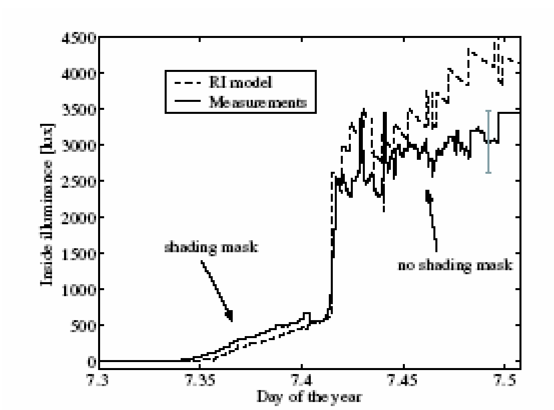

Figure 2.18: Effect of the shading mask detection in the RI model - measurements have a relative error of 15%

2.3.3 Electric Lighting Model

This model relates the illuminance provided by the electric lighting system to the electrical power applied. The variables to consider are the electrical power fraction (of the maximum power) applied to the electric lighting system (Pal, included in the interval [0,1]), and the corresponding provided illuminance Eal ([lux]).

Every night during the user's absence, illuminances are measured for five different power fractions (0.2, 0.4, 0.6, 0.8 and 1). In order to reduce the impact of an adaptation with wrong measurements, they are averaged with the old ones. And if the values are clearly too low (monitored illuminance is lower than 50 lux with electric lighting power at full power), which could occur if a paper is on sensor or in case of sensor failure, the adaptation is postponed.

A fourth order polynomial is fitted to the five measurements, using the nonlinear least squares Gauss-Newton method. This model forces to give a zero value of illuminance when no electric lighting power is applied.

A fourth order model was chosen because it properly describes the typical characteristic of the electric lighting with only four parameters, as shown by the example depicted on Figure 2.19 (measurement values have a relative error of 15%).

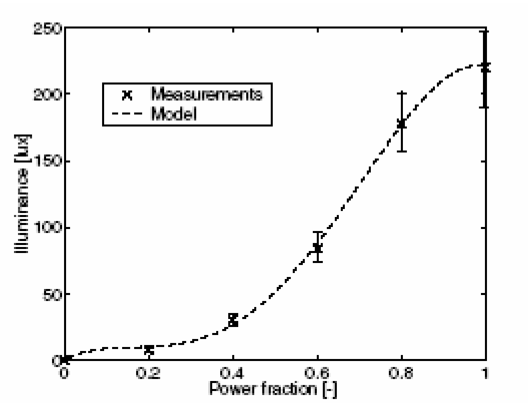

Figure 2.19: Electric lighting model compared to measurements

2.3.4 Room Thermal Model

A physical model (2-nodes) of the room has been developed. It is not reported here, since the focus of this description is essentially on lighting controller (shading and electric lighting).

2.3.5 User Presence Prediction Model

The heating controller needs the prediction of the user presence, in one hour and in six hours. At the beginning of the project, no set of presence data was available to develop and test a reliable predictor (using Artificial Network, for instance). Only fragmented data from two office rooms were recorded during the EDIFICIO European research project [Priolo et al., 2001].

Thus, a simple occupancy schedule has been used for the presence prediction: rooms are supposed to be occupied from 8 am to 18 pm during weekdays.

However, recent work [Scherz, 2003] shows that presence prediction using ANNs outperforms schedule prediction and may lead to large improvements for both comfort and heating energy consumption. Thus, a further improvement of the heating controller used in this work would be to develop and implement an advanced presence predictor.

2.4 Lighting Self-Commissioning

Each time a new automatic controller is applied in a room, a self-commissioning for lighting aspects is carried out. The goal of this procedure is to provide reasonable starting values for the parameters of the different adaptive models used by the controllers. It concerns the RI model, the electric lighting model and the blinds controller. This commissioning is only run when the global irradiance is higher than 50 W/m2.

The procedure is described more in details in the PhD thesis of Antoine Guillemin.

No commissioning is carried out regarding the heating, because a correct adjustment of parameters needs data on several days (to deal with inertial aspects of room characteristics) and these data are not always available.

3. Algorithm description – Adaptation to user preferences with Genetic Algorithms

(to be completed !!!)

4. Experimental results

In a second phase, measurements have been done on the LESO experimental building, involving 14 occupied office rooms (mostly with one or two persons in each room), during 9 months. The monitoring results have proved the interest of the new user-adaptive algorithms. These results can be summarized by the table below.

Controller type	Energy savings (base: manual)	Thermal comfort satisfaction	Visual comfort satisfaction	Rejection rate after 4 weeks
Manual	-	84 %	86 %	-
automatic, <u>without</u> adaptation to user's preferences	-26 %	84 %	88 %	25 %
automatic, <u>with</u> adaptation to user's preferences	-26 %	86 %	89 %	5 %

The table shows clearly that the significant energy savings due to the automatic controller were not altered by the introduction of the adaptation to the user's preferences, and that at the same time the rejection rate after 4 weeks was reduced considerably from 25 % to only 5 %.

APPENDIX A3: RESEARCH PROJECT ECCO-BUILD

1. Summary

The objective of the project ECCO-BUILD is to develop a new generation of control devices for solar shading systems, glare control systems, electric lighting and HVAC systems for the simultaneous optimisation of building energy consumption and comfort. Another important goal of the project is the development of glare criteria for windows and daylighting systems, which can be used for control purposes, and the development of a new device for luminance measurements.

The project is split into 7 work packages:

1. Coordination
2. User assessment: Develop new criteria for glare rating to be used as input for building management systems. The basis for the criteria are user acceptance studies in different countries.
3. Measurement facility: Design and construct a device for luminance measurements.Characterise different facade systems.
4. Control device: Develop new control algorithms and construct a prototype controller.
5. Design tool: Develop an information package for building planners and scientific software tools to predict the energy impact of different control strategies for glare protection and solar shading devices.
6. Pilot buildings: Test the algorithms developed in WP4 in an occupied multiroom building and other pilot buildings.
7. Dissemination: Disseminate results to scientists, standardisation bodies, component and facade manufacturers, architects and building planners and set up a project Internet service.

Duration, partners and funding of the project: The project has been started in November 2002. Its planned duration is 3 years, i.e. until October 2005. The partners are: Fraunhofer Institute for Solar Energy Systems (D, coordinator), Danish Building and Urban Research (DK), Ingélux S.a.r.l.(F), LESO-PB/Swiss Federal Institute of Technology, Lausanne (CH), Hüppe Form (D), TechnoTeam (D), Bug-AluTechnic AG (A), and Servodan S/A (DK).

Work in progress and main results already achieved: The work packages 2 and 4 have been allocated the most significant part of the work. For WP 2 (main contributors DBUR and ISE), some preliminary results show that the illuminance in the vertical place oriented in the same direction as the view of the user might represent a good index for visual comfort, together with the usual horizontal workplane illuminance. For the WP 4 (main contributors are LESO-PB/EPFL and ISE), an exploration work has been done, considering an original control algorithm for venetian blinds using a Bayesian algorithm, and different variants for the solar shading transmission function. For the WP 6 (main contributors are also LESO-PB/EPFL and ISE), only the preparation work has been done, but no measurement is yet available.

Concerning the control algorithm, we have started from the knowledge acquired during the preceding projects carried at LESO-PB/EPFL, especially the project AdControl funded by EPFL and devoted to the elaboration and the experimental test of a user-adaptive control algorithm for blinds (fabric roll-down), electric lighting and heating. Since more complex shading systems are considered in the ECCO-BUILD project (essentially venetian blinds), the control algorithm has to be re-elaborated in order to be able to handle a more complex light transmission function.

More information is available on the Ecco-Build public web site:
http://www.ingelux.com/ecco_build

Additionally, internal technical reports have been written and distributed among the partners. With a confidentiality clause, some of them may possibly be distributed to IEA Task 31 participants.

2. Algorithm description

(to be completed !!!)

INTERNATIONAL ENERGY AGENCY
Solar Heating & Cooling Programme

IEA Solar Heating and Cooling Programme

The International Energy Agency (IEA) was established in 1974 as an autonomous agency within the framework of the Economic Cooperation and Development (OECD) to carry out a comprehensive program of energy cooperation among its 25 member countries and the Commission of the European Communities.

An important part of the Agency's program involves collaboration in the research, development and demonstration of new energy technologies to reduce excessive reliance on imported oil, increase long-term energy security and reduce greenhouse gas emissions. The IEA's R&D activities are headed by the Committee on Energy Research and Technology (CERT) and supported by a small Secretariat staff, headquartered in Paris. In addition, three Working Parties are charged with monitoring the various collaborative energy agreements, identifying new areas for cooperation and advising the CERT on policy matters.

Collaborative programs in the various energy technology areas are conducted under Implementing Agreements, which are signed by contracting parties (government agencies or entities designated by them). There are currently 42 Implementing Agreements covering fossil fuel technologies, renewable energy technologies, efficient energy end-use technologies, nuclear fusion science and technology, and energy technology information centers.

The Solar Heating and Cooling Programme was one of the first IEA Implementing Agreements to be established. Since 1977, its 20 members have been collaborating to advance active solar, passive solar and photovoltaic technologies and their application in buildings.

Australia	Finland	Portugal
Austria	France	Spain
Belgium	Italy	Sweden
Canada	Mexico	Switzerland
Denmark	Netherlands	United Kingdom
European Commission	New Zealand	United States
Germany	Norway	

A total of 35 Tasks have been initiated, 25 of which have been completed. Each Task is managed by an Operating Agent from one of the participating countries. Overall control of the program rests with an Executive Committee comprised of one representative from each contracting party to the Implementing Agreement. In addition, a number of special ad hoc activities—working groups, conferences and workshops—have been organized.

The Tasks of the IEA Solar Heating and Cooling Programme, both completed and current, are as follows:

Completed Tasks:

Task 1	*Investigation of the Performance of Solar Heating and Cooling Systems*
Task 2	*Coordination of Solar Heating and Cooling R&D*
Task 3	*Performance Testing of Solar Collectors*
Task 4	*Development of an Insolation Handbook and Instrument Package*
Task 5	*Use of Existing Meteorological Information for Solar Energy Application*
Task 6	*Performance of Solar Systems Using Evacuated Collectors*
Task 7	*Central Solar Heating Plants with Seasonal Storage*
Task 8	*Passive and Hybrid Solar Low Energy Buildings*
Task 9	*Solar Radiation and Pyranometry Studies*
Task 10	*Solar Materials R&D*
Task 11	*Passive and Hybrid Solar Commercial Buildings*
Task 12	*Building Energy Analysis and Design Tools for Solar Applications*
Task 13	*Advance Solar Low Energy Buildings*
Task 14	*Advance Active Solar Energy Systems*
Task 16	*Photovoltaics in Buildings*
Task 17	*Measuring and Modeling Spectral Radiation*
Task 18	*Advanced Glazing and Associated Materials for Solar and Building Applications*
Task 19	*Solar Air Systems*
Task 20	*Solar Energy in Building Renovation*
Task 21	*Daylight in Buildings*
Task 23	*Optimization of Solar Energy Use in Large Buildings*
Task 22	*Building Energy Analysis Tools*
Task 24	*Solar Procurement*
Task 25	*Solar Assisted Air Conditioning of Buildings*
Task 26	*Solar Combisystems*

Completed Working Groups:

CSHPSS	*ISOLDE*
Materials in Solar Thermal Collectors	*Evaluation of Task 13 Houses*

Current Tasks:

Task 27	*Performance of Solar Facade Components*
Task 28	*Solar Sustainable Housing* ECBCS Annex 38
Task 29	*Solar Crop Drying*
Task 31	*Daylighting Buildings in the 21st Century*
Task 32	*Advanced Storage Concepts for Solar and Low Energy Buildings*
Task 33	*Solar Heat for Industrial Processes*

Task 34 *Testing and Validation of Building Energy Simulation Tools* ECBCS Annex 43
Task 35 *PV/Thermal Systems*

Task Defintion Phase:

Solar Resource Knowledge Management

To find `more IEA Solar Heating and Cooling Programme publications or learn about the Programme visit our Internet site at **www.iea-shc.org** or contact the SHC Executive Secretary, Pamela Murphy, e-mail: pmurphy@MorseAssociatesInc.com.