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Fuzzy control for the illumination and temperature comfort in a test chamber

Mateja Trobec Lah[a], Borut Zupančič[b], Aleš Krainer[a,*]

[a]Faculty of Civil and Geodetic Engineering, University of Ljubljana, Jamova cesta 2, 1000 Ljubljana, Slovenia
[b]Faculty of Electrical Engineering, University of Ljubljana, Tržaška 25, 1000 Ljubljana, Slovenia

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Abstract

The paper deals with the controlled dynamic thermal and illumination response of human-built environment in real-time conditions. The aim is to harmonize the thermal and optical behavior of a building with regulated energy flows through the envelope. A control system with fuzzy elements for changeable transparent elements of the building envelope was developed. For this purpose a test chamber with an opening on the south aside was built. Energy flows through the envelope are controlled with changeable geometry of the window, realized with the external roller blind, which is automatically positioned. The fuzzy controller for the corresponding positioning of the roller blind in a given combination of outside conditions as external disturbances is the subject of this paper.

1. Introduction

Energy flows through the building envelope are present all the time. The properties of the building envelope have significant influence on the interaction between the inner and the outer energy conditions in the sense of thermal and lighting flows [19,24]. Optical and thermal responses of the building correspond mostly to the solar radiation and the outside temperature. The development of the technology increases the positive aspect of thermal and illuminance energy flow [21,23] through the building envelope with its automatically active response [16–18]. In our case this is realized as a roller blind position adaptable to outside weather conditions.

The real model of the building—physical test chamber properly equipped—was built for the development of the whole fuzzy control system for changeable window geometry, which allows the investigation and experimentation in illumination, heating and cooling area and enables one to study the influences of movable shades interventions [12,15,20].

A controlled external roller blind on the window is supposed to harmonize the thermal and illumination response in the test chamber. The proper position of the roller blind as the resulting response on the given outside weather conditions is the condition to improve the indoor thermal and lighting comfort, taking into account predefined control parameters with selected properties.

The control algorithm for the movable roller blind is very complex. The design of the system for managing the movable roller blind is based on the alternative control approach. It contains two basic control loops for thermal and for lighting regulation. Each loop contains a cascade control with a fuzzy and conventional proportional, integral, derivative (PID) controller. The main fuzzy controller is linked with an auxiliary conventional PID controller.

*Corresponding author. Tel.: +386 01 4768 609;
fax: +386 01 4250 688.
E-mail addresses: mlah@kske.fgg.uni-lj.si (M.T. Lah), borut.zupancic@fe.uni-lj.si (B. Zupančič), AKrainer@kske.fgg.uni-lj.si (A. Krainer).

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The condition for real-time harmonization of the available daylight potential and thermal flows, as well as optimal thermal response of transparent and opaque parts of the envelope in the sphere of openings, is properly designed, and adjusted by fuzzy controllers.

2. Test chamber and the measuring equipment

The fuzzy system for managing and controlling the light–thermal process in buildings with automated reaction of a movable roller blind is realized in the test chamber. The test chamber is equipped with all the needed sensors to measure outdoor and indoor conditions: inside and outside temperature, solar direct and reflected radiation, inside illumination and current roller blind position, and with the necessary control equipment.

The test chamber (Fig. 1) was built on the roof of the Faculty of Civil Engineering, UL, Ljubljana (46.0° latitude, 300 m altitude). The test chamber has dimensions $1\,m \times 1\,m \times 1\,m$ and is designed especially for control design purposes. The cell is shifted off the ground and the roof is ventilated in order to avoid the influence of overheating caused by direct radiation on the roof. Walls, floor and ceiling are built of lightweight brick blocks. Material properties are shown in Table 1.

Fig. 1. Test model chamber.

The south wall is completely glazed with double glazing composed of two layers of standard clear glass and air fill, and the thickness of the wooden frame is 5 cm. The alternating geometry of the window is made with the automatically moveable roller blind. The roller blind is an external PVC blind and the alternating position is managed with the aid of the industrial programmable logical controller—PLC. The control algorithms, which include also fuzzy logic, were designed in program package IDR BLOK, which enables PLC to perform, besides traditional sequence control, also more sophisticated and more demanding digital feedback control.

To achieve indoor real-time harmonization of the available daylight potential and thermal flows with proper reaction of the movable roller blind, several measured values are necessary. The measured values for outdoor and indoor conditions are:

- direct and reflected solar radiation with pyranomether CM-B (Kipp & Zonnen delft BV),
- outdoor and indoor air temperature with thermocouples type T, and
- indoor illumination with luxmeter LUX cells.

The transparent area surface size of the envelope depends on the temporary roller blind position, expressed in the percentage of shaded area with regard to the whole glazing area. The displacement sensor measures the exact roll position.

3. Control system

The objective is to design and implement efficient fuzzy control system for the positioning of movable shade—roller blind, for the harmonization of thermal and optical flows in order to assure rational use of energy together with comfortable living and working conditions [25]. The developed and realized control system includes fuzzy logic controllers. They enable a high level of the system's adaptability to local specifics. Their functioning is transparent; they are adjustable to

Table 1
Material properties of the test chamber envelope

Walls, ceiling, floor	Thermal conductivity k (W/mK)	Density ρ (kg/m^3)	Specific heat c (W s/kg K)	Thickness d (m)	Absorption coefficient
Lightweight brick block	0.270	500	0.270	0.010	0.45

the manner of human thinking and perception processes. The design and tuning of fuzzy controllers consist of setting up linguistic model and free fuzzy parameters. The approach is based mostly on experimentation, on real trial error experiments.

3.1. Fundamentals of control strategy

The designed control algorithm enables harmonized alternating geometry of the window with proper position of the roller blind in real time. The role of the control algorithm is to produce appropriate signals for a roller blind positioning, based on outdoor weather conditions, to harmonize the indoor thermal and lighting energy conditions.

The control algorithm is complex. It consists of thermal and lighting parts, each one containing conventional and fuzzy controllers. The algorithm was developed progressively during the research procedure. The design of the light control loop for the roller blind alternation was based on experimentation. The design of the visual control part was designed exclusively on approximately 50 sets of experiments at the test chamber. The thermal control part is developed with the aid of the previously developed theoretical mathematical model. In previous work [1–4,14] a theoretical mathematical thermal model based on energy balance equations was developed and validated. According to many phenomena the experimentation was necessary to complete the thermal controller design. Different control strategies were taken into account, from feed forward control schemes to closed loop control using conventional PID controllers and fuzzy control algorithms.

Proper functioning of the control algorithm is of essential importance for the adequate adjustment and velocity of alternations of the roller blind with regard to the external conditions, i.e. weather disturbances. The assessment, how good the controlling algorithm is, is subjective. Through several experiments the control algorithm was optimized using observations of alternations of window geometry and corresponding internal lighting and thermal conditions. We observed, how the alternation of the window geometry—roller blind positioning—influences the internal lighting and thermal conditions with respect to the given external conditions.

For adaptable window geometry, fuzzy logic is a system advantage in controlling, since the fuzzy controllers are capable of non-linear mapping between external weather conditions and the corresponding roller blind position. Fuzzy logic is included in the main fuzzy regulators. The conventional PID regulators are also included, but they are supplementary to the fuzzy regulators.

4. Fundamentals of fuzzy logic

Fuzzy logic [5–7] is a superset of Boolean—conventional logic that has been expanded to handle the concept of partial truth and truth-values between “completely true” and “completely false”. Fuzzy theory should be seen as methodology to generalize any specific theory from crisp to continuous. Fuzzy modeling opens the possibility for straightforward translation of the statements in natural language—verbal formulation of the observed problem—into a fuzzy system. Its functioning is based on mathematical tools. The basic elements are fuzzy subsets—μ_X, μ_Y or membership functions for each linguistic variable. In the defined numerical domain the linguistic variable is arranged with a proper set of membership functions. In fuzzy logic the arbitrary linguistic variable is represented by fuzzy set A composed of a collection of fuzzy subsets—$\mu_X, \mu_Y, \mu_Z \in A$ or membership functions. Each numerical value x_i is defined as a fuzzy element when it is expressed as a pair: numerical value $x_i \in X$ (in our case real time measured values) and the membership degree to some appropriate memberships functions or subsets $\mu_{xi} \in X$. Fuzzy set A (linguistic variable) is defined on a variable definition area by the arrangement of membership functions $\mu(X)$, $\mu(Y)$, $\mu(Z)$. Therefore, to each numerical value $x_i \in \mu_Z$ there belongs a suitable membership degree of some subset $\mu_{X,Y,Z} \ldots$

The linguistic rules are the basis of the fuzzy system and in the used Takagi–Sugeno type [5] they are in the following form:

$$R_i : \text{IF } x_1 \text{ is } A_i \text{ and (or) } x_2 \text{ is } B_i \text{ THEN } y = (x_1, x_2),$$

where x_1, x_2 are the input numerical values and y is output value. A_i, B_i are fuzzy sets characterized by their membership functions. IF-parts of the rules describe the fuzzy regions of the input variables and THEN-parts are functions of the inputs. In the IF–THEN rules of the fuzzy system, the fuzzy subsets and set are combined with logical fuzzy operations. The basic operations of the set theory are intersection, union and complement extended for the purpose of fuzzy logic. The standard logic operators are realized in fuzzy logic with extended set operations on membership functions as shown in Table 2.

The process is described by a fuzzy system, which contains the control rules directly derived from the

Table 2
Standard definitions in fuzzy logic—basic operations of set theory introduced in the framework of the set theory

Set definition	Fuzzy logic	Basic operation
Complement $1-A(x)$	Not (A)	$1.0-\mu_A(x)$
Intersection $A(x)\cap B(x)$	A and B	min ($\mu_A(x)$,$\mu_B(y)$)
Union $A(x)\cup B(x)$	A or B	max ($\mu_A(x)$,$\mu_B(y)$)

observed process. For fuzzy system realization many preliminary studies are necessary. It is necessary to collect the data of the measured input and control values, including the corresponding behavior of the process.

4.1. Fuzzy logic in control engineering

Among other possibilities preliminary studies indicated that only conventional control approaches for the window geometry alternation give inadequate results in extremely varying external conditions. Non-linear boundary conditions, time varying characteristics and a complex physical environment create many difficulties in designing a mathematical model (e.g. systems of differential equations). One method that simplifies the complex system and tolerates a reasonable amount of imprecision, vagueness and uncertainty during the modeling phase is fuzzy logic approach. Very different and unsettled weather regimes during the year challenged us to develop an alternative control algorithm with fuzzy logic approach. Such a fuzzy system could give a more appropriate solution and can be designed without a precise mathematical model. The fuzzy control system is derived from the knowledge of the real process and is developed with the aid of experiments of real processes at the test chamber. Designing a fuzzy control system is mostly a trial error experimentation approach with on-line optimization of the included fuzzy controllers. Many of our preliminary investigations confirmed that such an approach could represent an appropriate solution [8,9,12,13].

In fuzzy systems the advantage of reduced complexity is taken into account and it is achieved by subjective estimation of the used information. Numerical values are described with the help of the fuzzy sets, where numerical values are related to human reasoning. The quality of the fuzzy controller can be measured only with regard to criteria such as correctness, adequacy, efficiency and convenience in use.

Control algorithms with fuzzy controllers prove to offer better robustness and efficiency in the case of more complicated non-linear and time varying working conditions in comparison with conventional PID controllers. An important advantage of the fuzzy controller's design is the principle, which derives directly from human reasoning. It is based on a linguistic model, which is expressed with a set of conditional rules, IF-THEN statements.

Automatically adapted window-shading ratio appears as a great opportunity for indirect control of the indoor living space parameters according to the current external conditions. Fundamental fuzzy approach in designing the fuzzy controller is closely related to human reasoning [7]. We want the movable shadow device to be alternating, as if it was adapted manually to the internal demands and external conditions.

We have to find a linguistic model for the part of the process as a basis for the fuzzy model that is expressed with a set of fuzzy rules, i.e. IF–THEN statements. With a defined set of IF-THEN rules and parameters, the input and output relations for each fuzzy controller are determined. In our case the inputs are on-line measured external and internal conditions and the output is an appropriate roller blind position. The designer must select appropriate fuzzy sets with membership functions for all the input and output variables. The input and output numerical values must belong to appropriate membership functions, which are with the aid of logically fuzzy operators correlated and combined in IF–THEN statements. One fuzzy system as fuzzy controller in the loop is used for describing one part of the process. With the aid of the linguistic terms the measured values are described as sets of ordered pairs: numerical values and degrees of memberships to fuzzy subsets. The correlation, non-linear mapping between two inputs and one output, is graphically represented with a specific 3D shape as shown in Fig. 2. The actual numerical output value, the current position of the roller blind, is located on the 3D shape, depending on the inputs—ambient conditions values and on the designed fuzzy system.

4.2. Fuzzy logic in the control algorithm for a movable roller blind

Three fuzzy controllers are included with the aim of obtaining a good control system for managing the movable shade as an impact part on the thermal-lighting process. They must be tuned with regard to the thermal–optical demands in the given weather conditions.

The developed algorithm, the scheme is shown in Fig. 3, contains an ‘‘illumination’’ fuzzy controller for managing the roller blind position with the aim to assure the internal illumination level corresponding to the external conditions. The two thermal fuzzy controllers, ‘‘winter thermal’’ fuzzy controller and ‘‘summer ther-

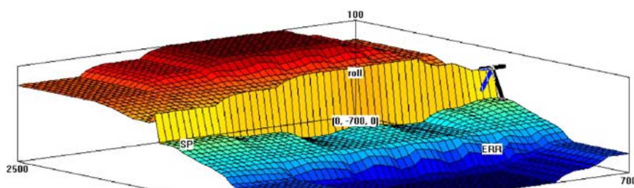

Fig. 2. Example of 3D surface for non-linear mapping between inputs and output as fuzzy model implemented in illumination fuzzy controller.

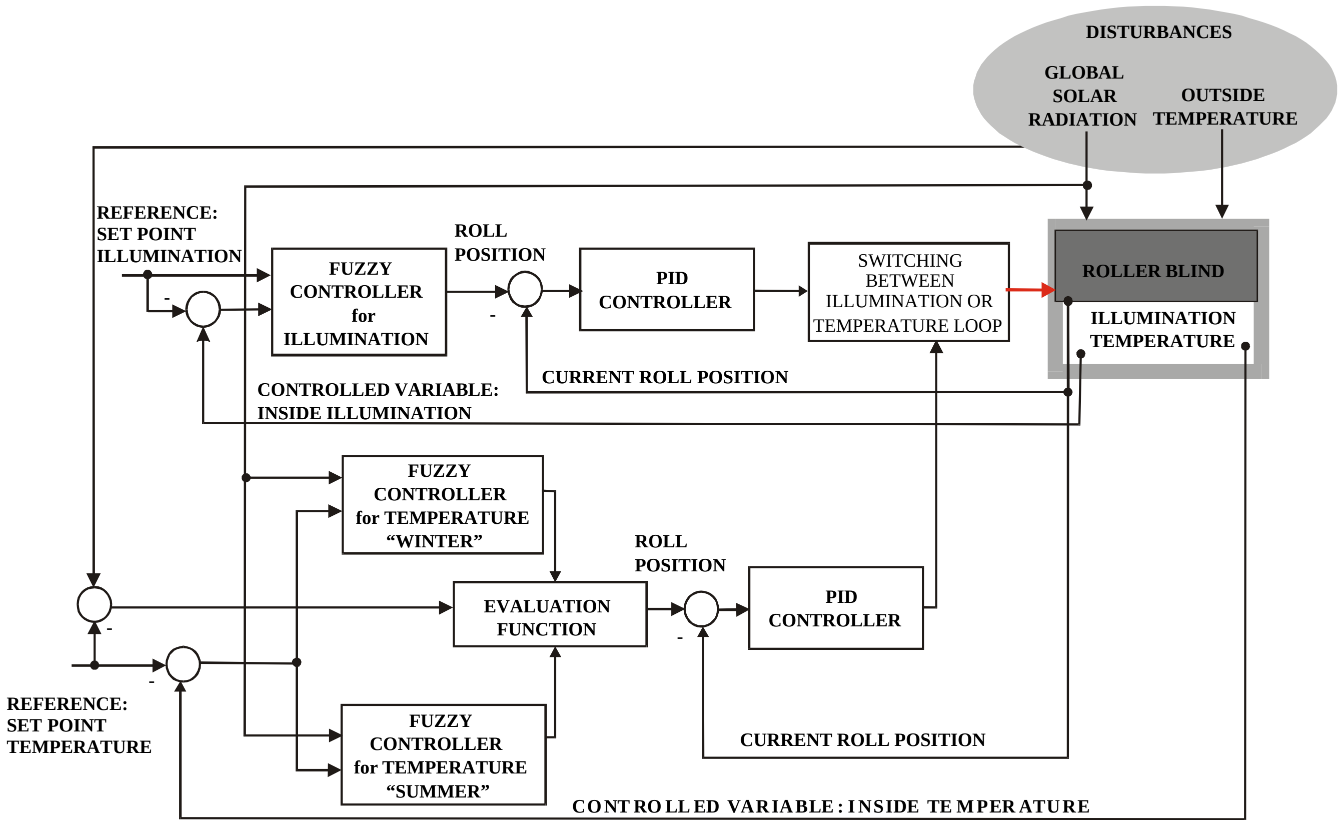

Fig. 3. Control scheme for illumination and temperature.

mal'' fuzzy controller, are also included for inside thermal control with the aid of the roller blind alteration.

The design and setting of the fuzzy controllers consist of defining the following free parameters:

- Defining the domain for the input and output linguistic variables for each fuzzy controller.
- Defining the set and the type of membership function for each linguistic value—input of every fuzzy controller. The relations between inputs and outputs of linguistic values must be provided in the form of fuzzy rules, which represent logical inference.
- Defining the fuzzy logic operators for each IF-THEN sentence, as a base of the final inference.

5. Description of the implemented control algorithm

An effective control algorithm, in our case designed in IDR BLOK environment [10], is necessary to manage and control the changeable geometry of the window as a response to temporary outside conditions—variable weather conditions as disturbances. This enables the optimal use of the renewable energy. Roller blind alternation represents window geometry adjustment. The demanded more or less constant internal thermal and lighting conditions regarding the outside weather conditions are to be achieved by following the set-point profile of illumination or temperature.

IDR BLOCK is an environment for designing control schemes for different areas where time constants are not too short (e.g. thermal process, chemical process, etc.). It is a programming language that allows the implementation of control techniques, such as feedforward, cascade, ratio control, as well more traditional ones, such as fuzzy control, PID control etc. Placing and interconnecting various blocks define the IDR application scheme. To each block a subprogram, which performs the necessary operation to input data, is assigned. Blocks are grouped into block groups, called loops.

The algorithm composed of two general loops is shown in Fig. 3. Each loop can act independently or they can be linked together to work simultaneously. One loop is an ''illumination'' loop and comprises all elements or blocks that make possible the alternation of the roller blind to follow the inside set-point illumination profile considering only the illumination with daylight. The other controlling loop is a ''thermal'' loop and is analogically composed of blocks that enable the window geometry alternation following the inside set-point temperature in variable weather conditions.

By setting the collection of several IF–THEN rules with suitable semantic and proper free fuzzy parameters as a fuzzy system for each fuzzy controller, the fuzzy blocks are prepared to be linked with other blocks in the control algorithm. Some other parameters, such as parameters of the PID controllers, filter times constants, sampling times and priorities of the loops in the control scheme, were adapted with the aim to optimize the control system. The priority of the optimization is tuning up the fuzzy controllers.

Both control loops are defined as cascade controllers. The fuzzy regulator is used as the main regulator and PID as the auxiliary one. This means that the main fuzzy regulators, considering the measured external and internal conditions and set-point values as inputs, determine the set-point position of the roller blind as output. PID controllers are of the PID/V type, which means that they execute the velocity PID algorithm and the output value defines the amount for which the actuator must change its current position. In our case this means the alternation of the roller blind position. The input values for PID/V are:

- the desired position of the roller blind, which is defined as output signal of the main fuzzy controllers, and
- the temporary measured position of the roller blind.

The output signal of the block PID/V as a classical PID regulator is calculated from the current difference between the desired and the measured roller blind position. Then the output signal provokes an appropriate movement of the actuator, i.e. roller blind.

Fuzzy controllers for roller blind positioning in the controlling scheme are:

- Illumination fuzzy logic controller: for roller blind positioning the illumination set-point profile is considered. The input variables are set-point inside illumination and the difference between the inside illumination and the set point illumination.
- Winter thermal fuzzy logic controller: for roller blind positioning the thermal conditions for the wintertime season are considered. The input variables are global solar radiation and the temperature difference between the set point temperature and the measured inside temperature.
- Summer thermal fuzzy logic controller: for roller blind positioning the thermal conditions for the summertime season are considered. The input variables are the same: global solar radiation and the temperature difference between the set-point temperature and the measured inside temperature.

The following to the desired inside thermal profile is closer when both thermal fuzzy controllers (winter and summer) are used to regulate the roller blind instead of just one with a wider range of impact. Each of them is setting well for the foreseen thermal interval. Depending on the outside temperatures, the roller blind is regulated with a winter or summer fuzzy regulator or with a combined functioning of both. With roller blind positioning, only smaller inside air temperature corrections are possible. The capability to follow the inside set-point temperature profile with roller blind positioning depends on direct solar radiation on the window. The higher the solar radiation on the window, the more important the window geometry alternation to protect the inside overheating (summertime) or for inside heat gain (wintertime).

5.1. Illumination control loop

The roller blind is controlled with the aim to follow the set-point internal illumination profile, which is a function of the measured conditions [22]. A decisive factor for the window geometry alternations has the formed "illumination" fuzzy controller with proper semantic background, and it is also important to set other appropriate parameters in the algorithm: parameters of the PID controllers, filter time constants, sampling times and priorities of the loops. Possible illumination oscillations are in the range of 1000–5000 lx or even more in short time periods. Therefore, considering the daylight regulation, it is more difficult than in the thermal control loop to find a well-defined collection of IF-THEN statements and free parameters. The illumination loop is shown in Fig. 4 and contains the main illumination fuzzy controller and PID controller as the auxiliary one. The two filters realized in filter blocks are included to damp the possible too fast and frequent oscillations of roller blind movements caused when the external solar radiation is extremely changeable. Proper setting of the filter time constants means smoother roller blind alternation. We want to exclude too frequent roller blind moving, since it is annoying to occupants.

5.2. Thermal control loop

When the roller blind is managed only on the basis of thermal conditions, to follow the internal set-point temperature as much as possible, the design and setting of the free parameters in the control scheme are not so demanding as in the case of illumination. The temperature changes are slow and more predictable compared to daylight changes. The current position of the roller blind is defined with the aid of two main thermal fuzzy controllers—winter and summer. The output of each fuzzy thermal controller contributes its part to the final

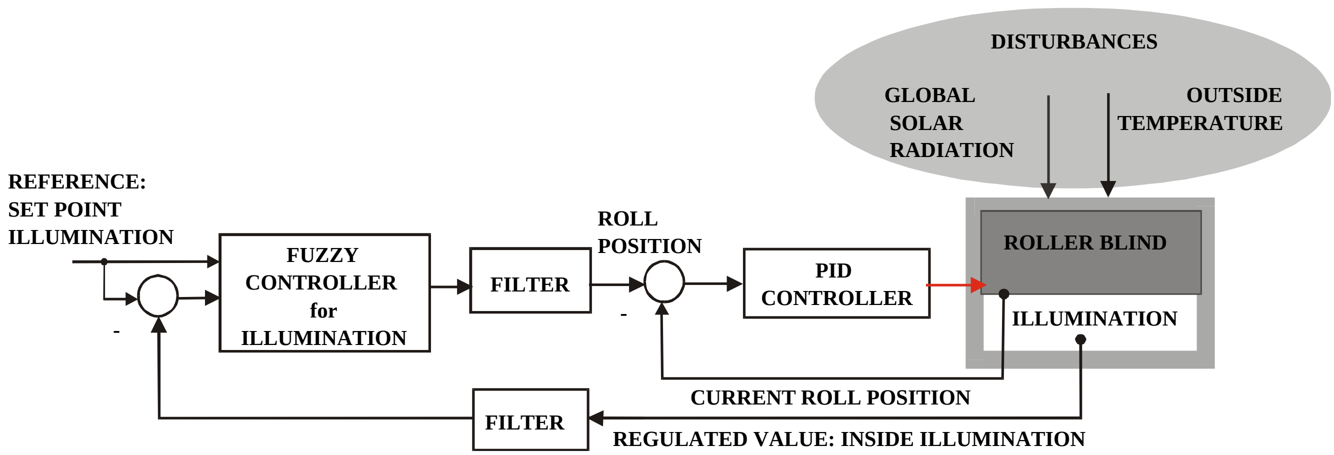

Fig. 4. More detailed scheme of the illumination control loop.

decision that determines the set-point roller blind position. The contributed part of each regulator depends on the temperature difference between the internal and the external air. The fuzzy outputs influence the auxiliary PID controller through the evaluation function, which defines the contributed parts of the winter and summer. Contributed parts are:

- External temperature is lower than the internal set-point temperature: only the ‘‘winter thermal’’ fuzzy controller determines the decision of the roller blind position.
- External temperature is higher than the internal set-point temperature: both thermal fuzzy controllers contribute to the current roll position. Fuzzy outputs are combined with the evaluation function to determine the signal for the actuator—to track the roll. The evaluation function defines the final output signal:

$$\text{Output\_signl} = (\text{fuzzy\_roll\_summer}/100 * \text{T\_error} * 0.5) + (\text{fuzzy\_roll\_winter}/100 * (100 - \text{T\_error} * 0.5),$$

where the fuzzy_roll_summer (winter) is the output signal of the adequate fuzzy regulator. T_error is the temperature difference between the external and the internal set-point value.

The thermal loop is shown in Fig. 5. Three filter blocks are included in order to eliminate higher frequency disturbances from measured signals, and proper setting of the filter time constants means smoother roller blind movements.

5.3. Coupling of illumination and thermal controlling loop

Thermal and lighting energy are inseparable, but the lighting energy demands are in contradiction to the thermal ones. Our target is to attain the harmonization of light and thermal flows [11,13]. For this purpose both control loops can be connected. The changeable geometry of the window is regulated with simultaneous functioning of both control loops. We gave the illumination control loop a priority. Lighting is a quantity that is more difficult to control, because the inside illumination alternation is based on daylight, which is in direct connection with the solar radiation alternation dependent on momentary sky conditions. The roller blind is managed with the illumination loop and when the desired internal illumination level is achieved, the thermal loop takes over the control of the roller blind positioning. In admissible internal set-point illumination tolerance, the roller blind is influenced with thermal loop to follow as much as possible the set-point temperature profile. The admissible internal illumination tolerance is the error between the reference (set-point illumination profile) and the measured internal illumination. The error is defined as deviation from the set-point illumination value in percentage. The allowed error in our experiments was 2%.

6. Experiments

To find out the impact on thermal–light behavior of the test chamber with automatically adaptable window geometry, several experiments were carried out. Some examples are presented in the paper. The experiments were made in different seasons of the year with different control strategies. In Figs. 6–10 the thermal and illumination response of the test chamber is shown. The time-dependent outside conditions as external system disturbances, the air temperatures and the solar radiation oscillation are also included as input data.

In Figs. 6 and 7 the experiments in September are shown with illumination control. From Fig. 6 it is evident that the fuzzy controller for illumination is well

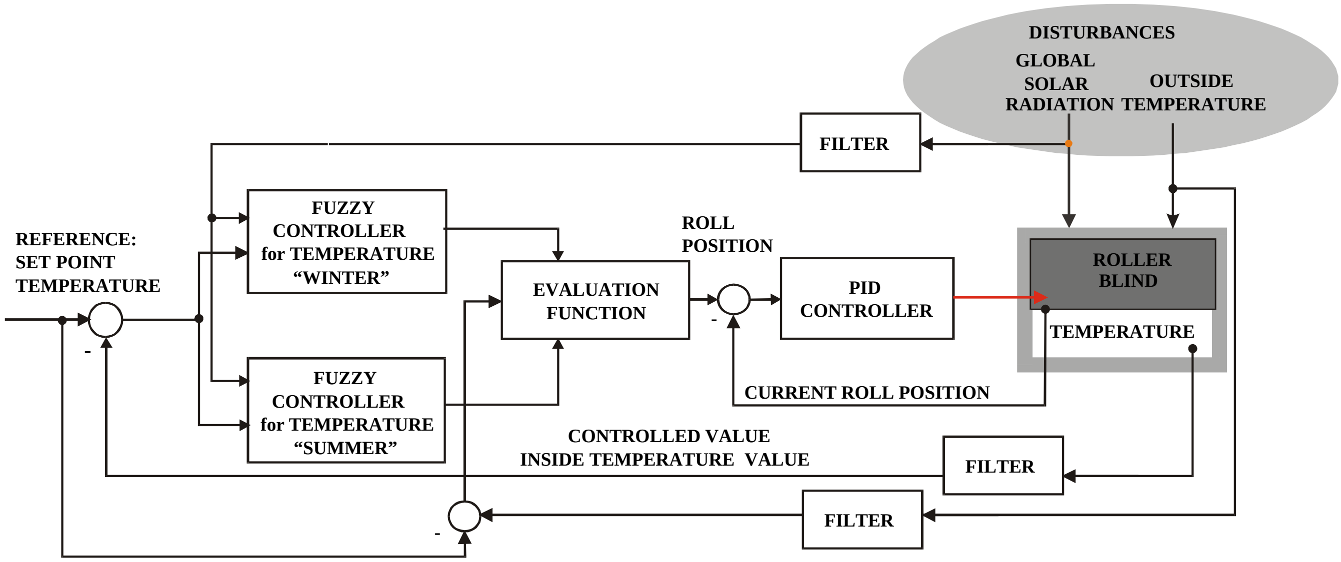

Fig. 5. More detailed scheme of the thermal control loop.

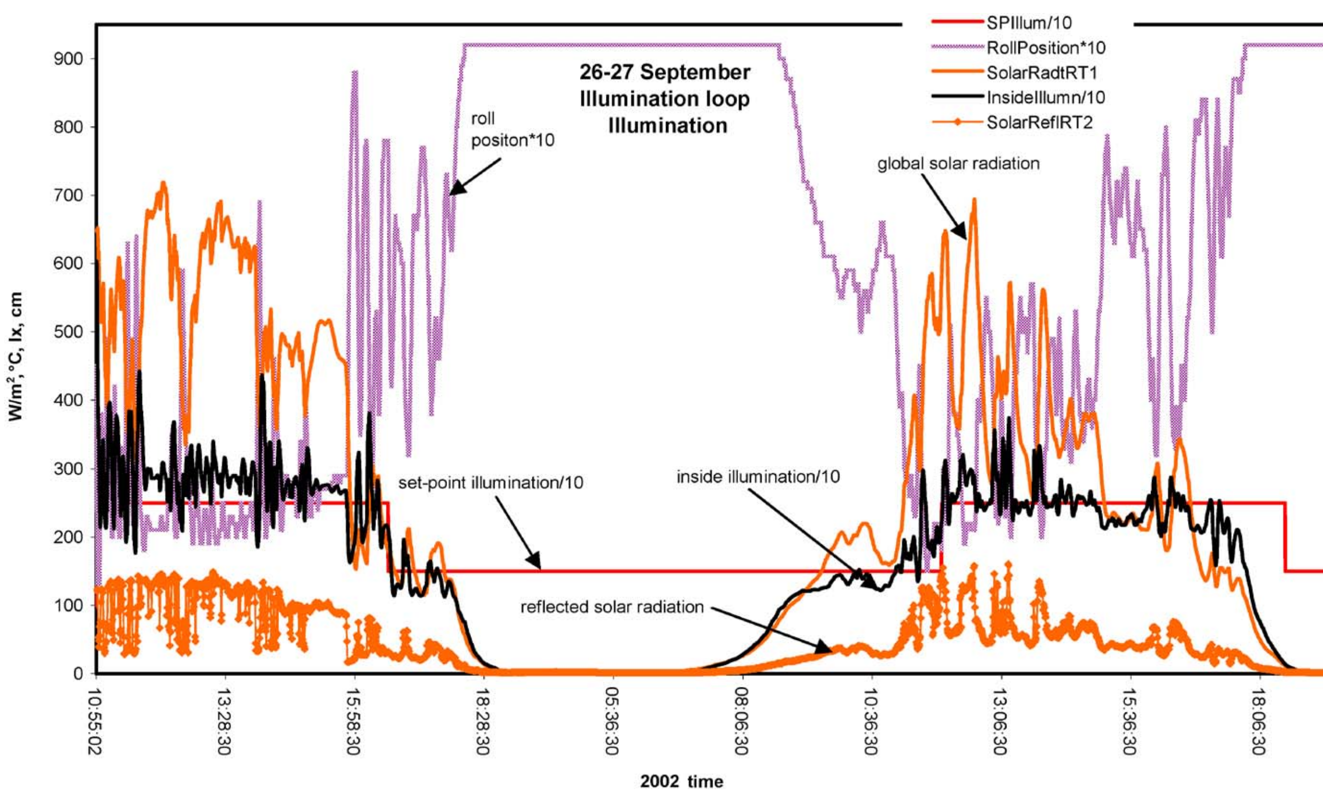

Fig. 6. Inside daylight illumination when the roller blind positioning was managed with the illumination loop. The system was influenced by the set-point illumination step changes and by the global solar radiation and outside air temperature disturbances.

designed and adjusted, and enables the inside daylight illumination level with moderate continuous movement of the roller blind in the area, where the desired value deviates up to ± 200 lx. The largest deviations are caused by very changeable solar radiation in short time periods and by changes in the set-point illumination profile.

Fig. 7 shows the same experiment as Fig. 6. The inside temperature profile is observed when the roller blind is regulated with an illumination loop. Roller blind

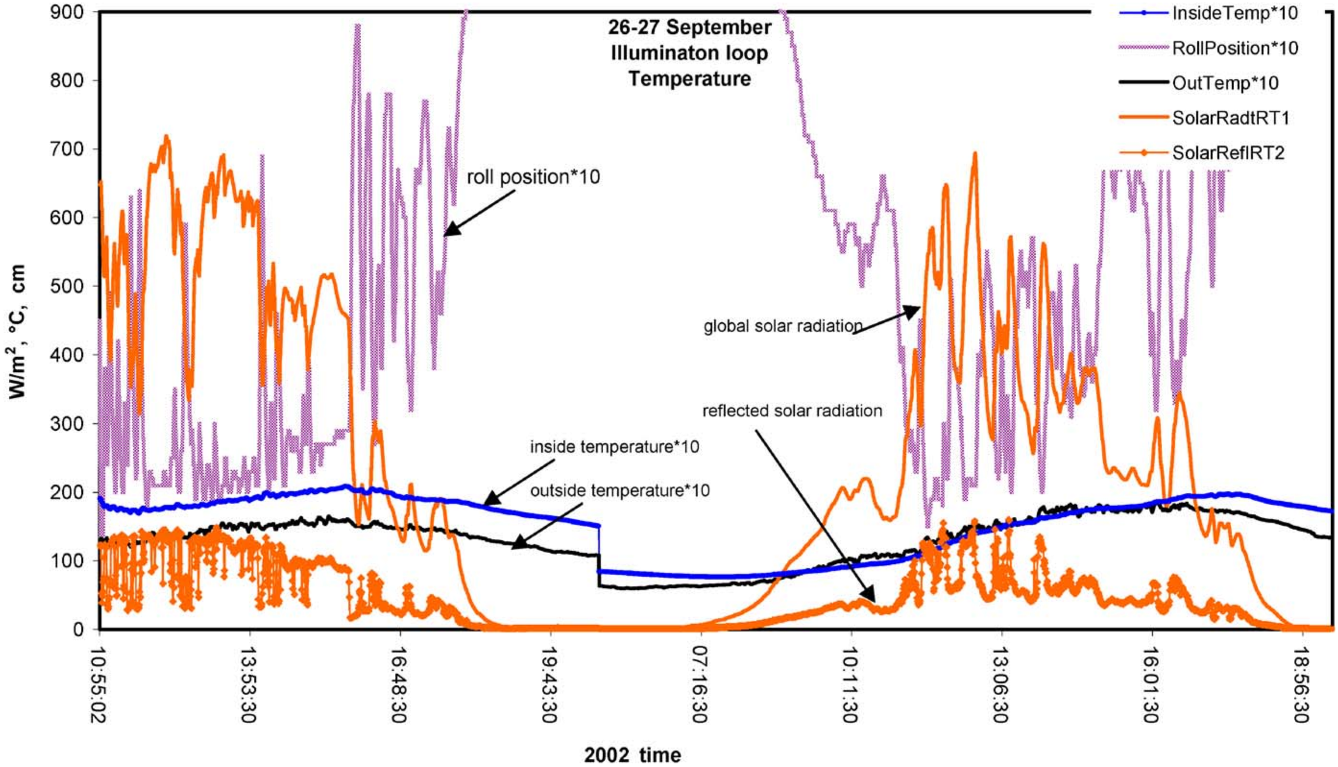

Fig. 7. Inside temperature when the roller blind positioning was managed with the illumination loop. The system was influenced by the set-point illumination step changes and by the global solar radiation and outside air temperature disturbances.

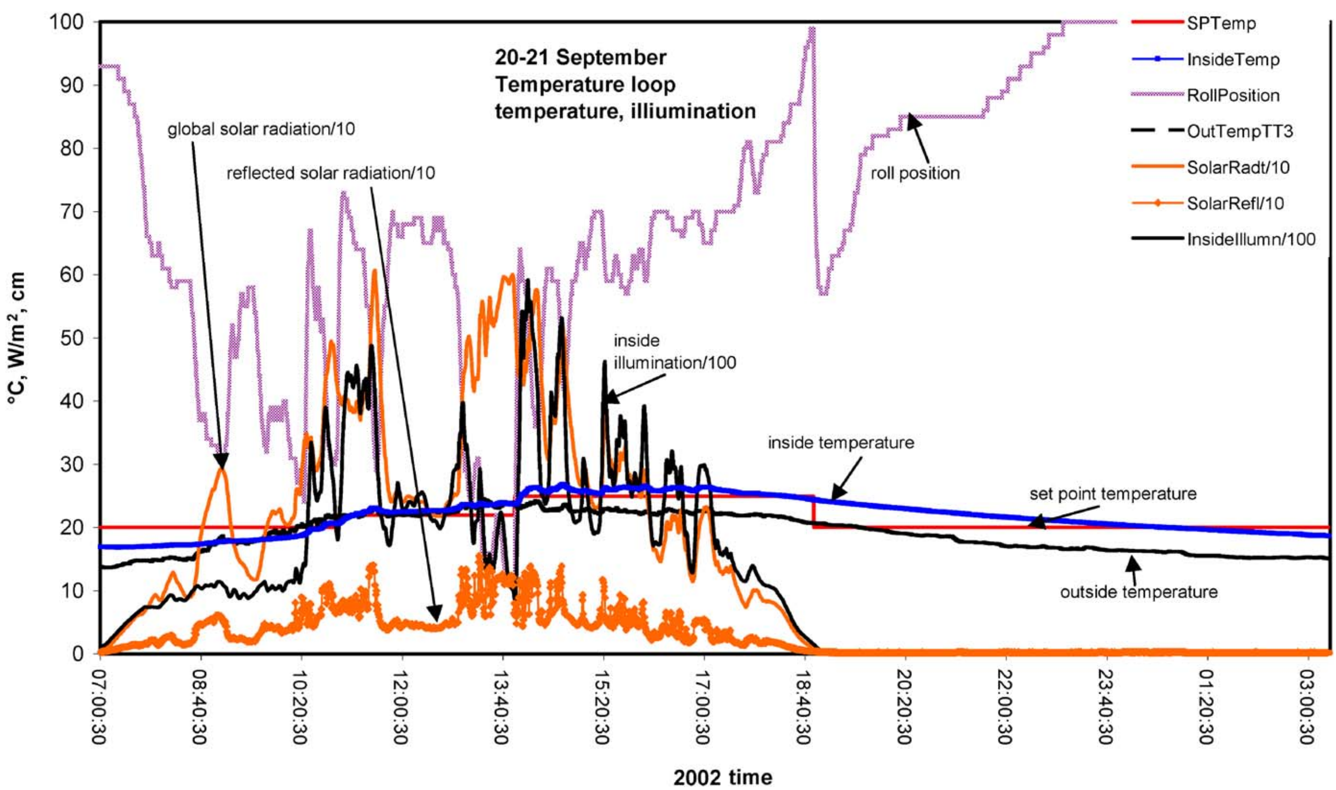

Fig. 8. Inside daylight illumination is the observed value and inside temperature is the controlled value. The roller blind was regulated with the thermal loop. The system was influenced by the set-point temperature step changes and by the global solar radiation and outside air temperature disturbances.

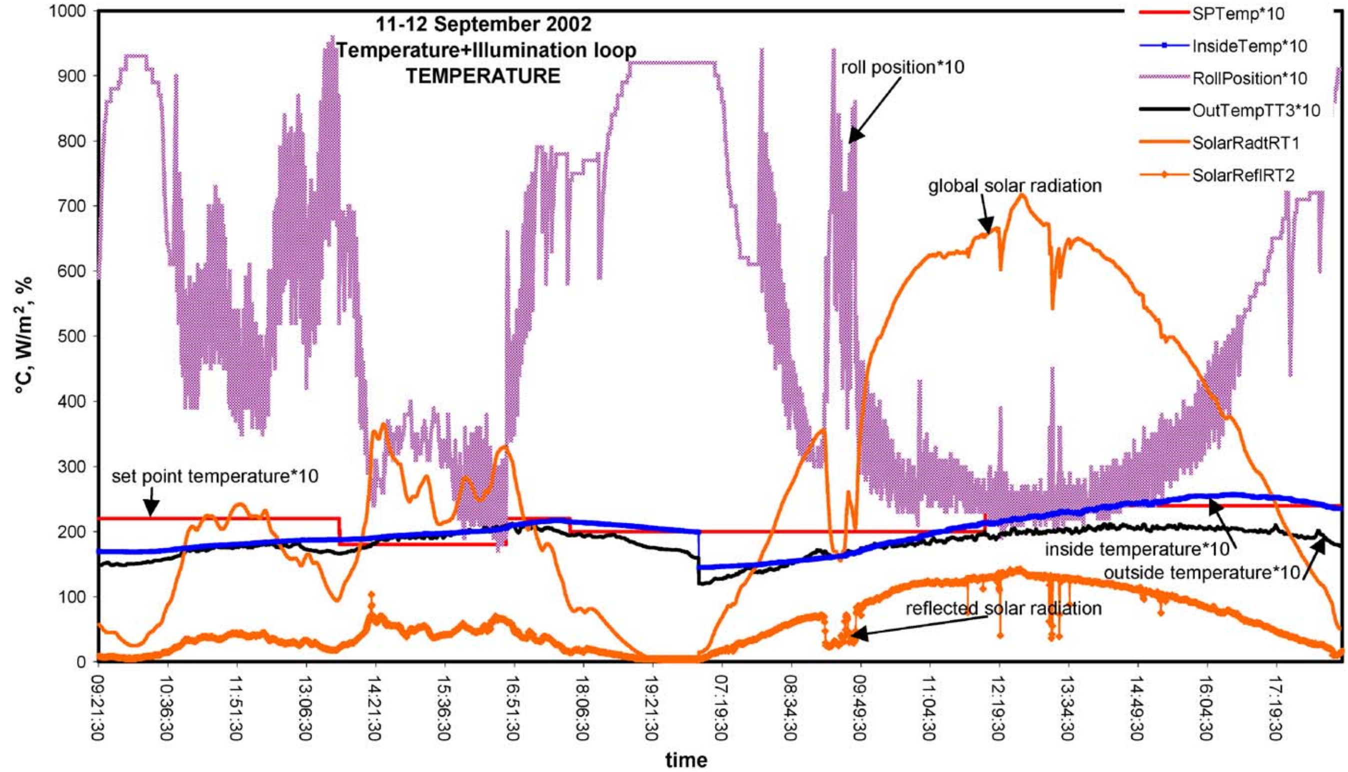

Fig. 9. Inside temperature when the roller blind positioning was managed with the illumination and thermal loop simultaneously. The system was influenced by the set-point illumination and thermal step changes and by the global solar radiation and outside air temperature disturbances.

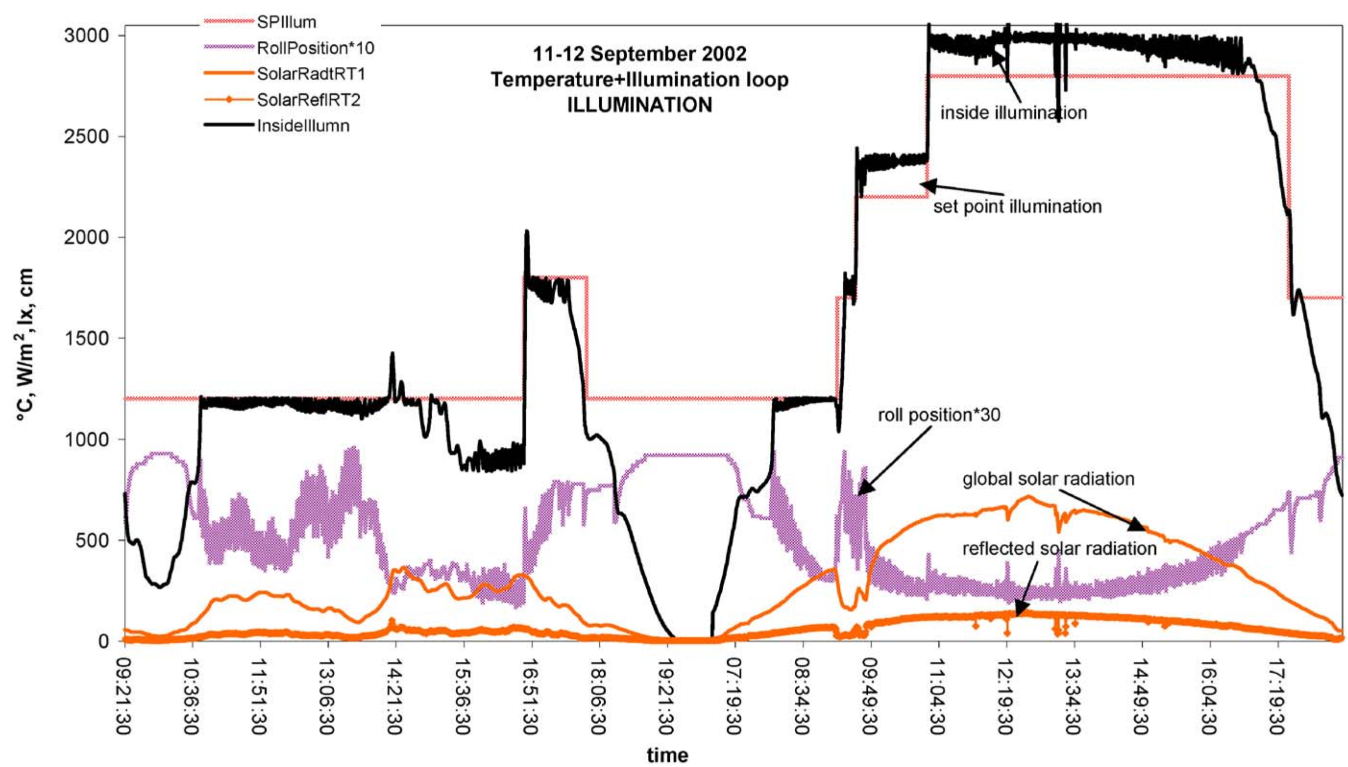

Fig. 10. Inside daylight illumination when the roller blind positioning was managed with the illumination and thermal loop simultaneously. The system was influenced by the set-point illumination and thermal step changes and by the global solar radiation and outside air temperature disturbances.

positioning with illumination control also prevents overheating. An unshaded window by solar radiations of above 700 W/m^2 means about 15–20 K higher inside than outside temperatures. Therefore, the controlled inside daylight illumination level also has direct influence on the inside thermal comfort. Inside the temperature is about 3 K higher than outside in the evenings and during the nights, which is the desired effect in the autumn. During the extreme solar radiation the temperature inside and outside is nearly equal.

In Fig. 8 the experiment in September is presented when the thermal control regulation for a movable roller blind is active. For following the desired inside thermal profile, only renewable sources of energy were used. This means that the set-point internal thermal profile is followed as much as possible only with adequate roller blind positioning, so this is the function of the outside temperature and the available solar radiation. With roller blind regulation, the inside overheating was prevented and inside temperatures during the night are only slightly higher than outside, about 1–3 K. High solar radiation causes no overheating inside, and the temperatures inside and outside are nearly equal. The inside illumination profile is an observed quantity and the values are up to 2–4 times higher compared to the inside admissible visual illuminance comfort values, which are around 1000–2000 lx.

Figs. 9 and 10 depict the experiment in September, when the illumination and thermal controlling loops were active simultaneously. The controlled values were internal illumination and temperature. With the roller blind positioning we try to follow, in the presence of the weather disturbances, the set-point illumination and temperature. Simultaneously the functioning of both loops provokes too many roller blind alternations. In further work we have to find more suitable coupling between both loops, which enables moderate shadow alternations.

From Fig. 9 it is evident that conducting the roller blind prevents the inside overheating during the highest solar radiation. The inside temperature is about 1–4 K higher than outside. In Fig. 10 the inside illumination is presented as a controlled variable. Roller blind alternations are very frequent, but the inside illumination follows the desired profile very closely. Deviations are smaller than 200 lx.

On the basis of the analyses of many experiments, parameters of the controllers were optimized.

7. Conclusion

With the proposed control scheme, the roller blind position is managed regarding the desired internal visual and thermal comfort. Window geometry automatically adjusted to the external weather conditions (disturbances) enables us to get closer to the desired inside temperature, illumination set-point values with the best possible exploitation of renewable energy. This contributes to lower consumption of conventional energy for lighting, heating and cooling and increases the cost-saving potential.

The system for managing the roller blind is designed with the cascade control approach, where fuzzy regulators as main regulators are connected in the control algorithm with auxiliary conventional PID regulators. Non-linear relations between external changeable conditions and the stiffness of the system—thermal part with large time constants and illumination part with short time constants—are the reasons why fuzzy logic is used in the control scheme. Fuzzy logic controllers enable us to use the non-linear experience about the problem and transfer it to an appropriate control action in such way that it is close to human thinking. Verbally expressed systems adapted to the implementation in fuzzy controllers represent a non-linear mapping between linguistic inputs, in our case changeable external solar radiation and the air temperature with outputs—appropriate roller blind position. Decisive influence on internal thermal and optical response of the test chamber or any arbitrary building as the result of controlled energy flows through the window is achieved with coordinated roller blind positioning.

Based on the experimentation the control algorithm was progressively adjusted and optimized, with emphasis on design and optimization of the fuzzy controllers. The illumination fuzzy system for the controller, which gives the best controlling performance, assures the inside daylight illumination with moderate continuous movement of the roller blind in the area, where the desired value deviates up to ± 200 lx. With regard to the moderate roller blind moving the internal daylight illumination is a quantity, which is more difficult to control with adjustable window geometry compared to the temperature. Fuzzy controllers are of essential importance in the system. They determine, based on the measured external conditions, i.e. solar radiation and its specific influences, the adequate current position of the roller blind.

Our design approach also has the goal to link the optical and thermal behavior of the building with the aid of new information and control strategies. The design and the tuning of the control scheme demand a lot of measurements and experiments to define the thermal-daylight co-ordination. The general tuning method is based on real trial error experimentation, where the iterative optimization is included.

There are three fuzzy logic controllers for roller blind positioning. The appropriate position of the roller is a decisive factor to assure the economic energy consumption. The output of each fuzzy controller is the anticipated roll position with regard to the controller domain. Finally the fuzzy outputs for the anticipated roll position are mutually combined or only one output is used on the actuator to track the roll.

To ascertain optimal values and setting of the fuzzy sets with rules is a very complex task, having in mind the thermal and illumination harmonization. When both requirements are present, the roller positioning is very volatile in short time periods. The tendency is harmonization and optimization of all of the free parameters in the control scheme, to get smooth roller blind movements, which enable the following to the desired set-point illumination and temperature profile and to eliminate as much as possible the external weather disturbances—external temperature and global solar radiation.

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