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The Power Savings Possibilities by Light in the Smart Home Care

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ABSTRACT

When designing a visualisation environment for controlling the building service system in Smart Home Care in order to meet the needs of seniors, emphasis is placed not only on the ease of operation and safety of the elderly, but also on possible cost savings in the operation of the Smart Home Care system. The article describes a study design of potential savings of electrical energy using software developed for the efficient control of lighting to a constant level with the KNX bus system or with the use of the wireless xComfort system.

Indexing terms/Keywords

Smart Home Care, dimming, savings, lighting systems

Academic Discipline And Sub-Disciplines

Engineering; Healthcare science; Health informatics;

SUBJECT CLASSIFICATION

Home automation for the elderly and disabled; Energy savings; Light control

TYPE (METHOD/APPROACH)

Design; Experiment

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1. INTRODUCTION

The emphasis on cost savings leads to a reduction in electricity consumption. To reduce power consumption, it is also possible to focus on indoor lighting in intelligent buildings with elderly assistance service. Illumination of the interior of intelligent buildings with elderly assistance service is increasingly designed as a combination of daylight and artificial light, whereby an artificial lighting system supplies only the difference between the daylight levels and the levels required by norms using information from illuminance sensors. Current lighting technology allows one to regulate the level of luminous flux to a constant level of illumination through an independent wireless auto-dimming system without a substantial increase in costs. By employing daylight, such lighting systems can therefore bring considerable savings in electrical energy.

Modelling of potential savings should be based on the level of intensity of external illumination which, however, is a significantly variable value. Currently, calculations of the daylight factor use a model of uniformly overcast sky with light intensity 5 kilolux or 20 kilolux. We designed a dynamic model based on a uniformly overcast sky with variable illuminance during the day. This model can be used throughout the year for the calculation of illuminance from daylight in an indoor environment without having to know which directions the windows face.

2. Design of visualization environment for comfortable remote control in Smart Home Care system

Continuous regulation of lighting to a constant value uses the KNX bus system. Comfortable remote control of a building service system in smart home care taking into account the needs of seniors uses a visualisation environment with the wireless xComfort system (Fig. 1). The designed visualisation environment with a wireless system can also be used for continuous regulation of light in a room to a constant level.

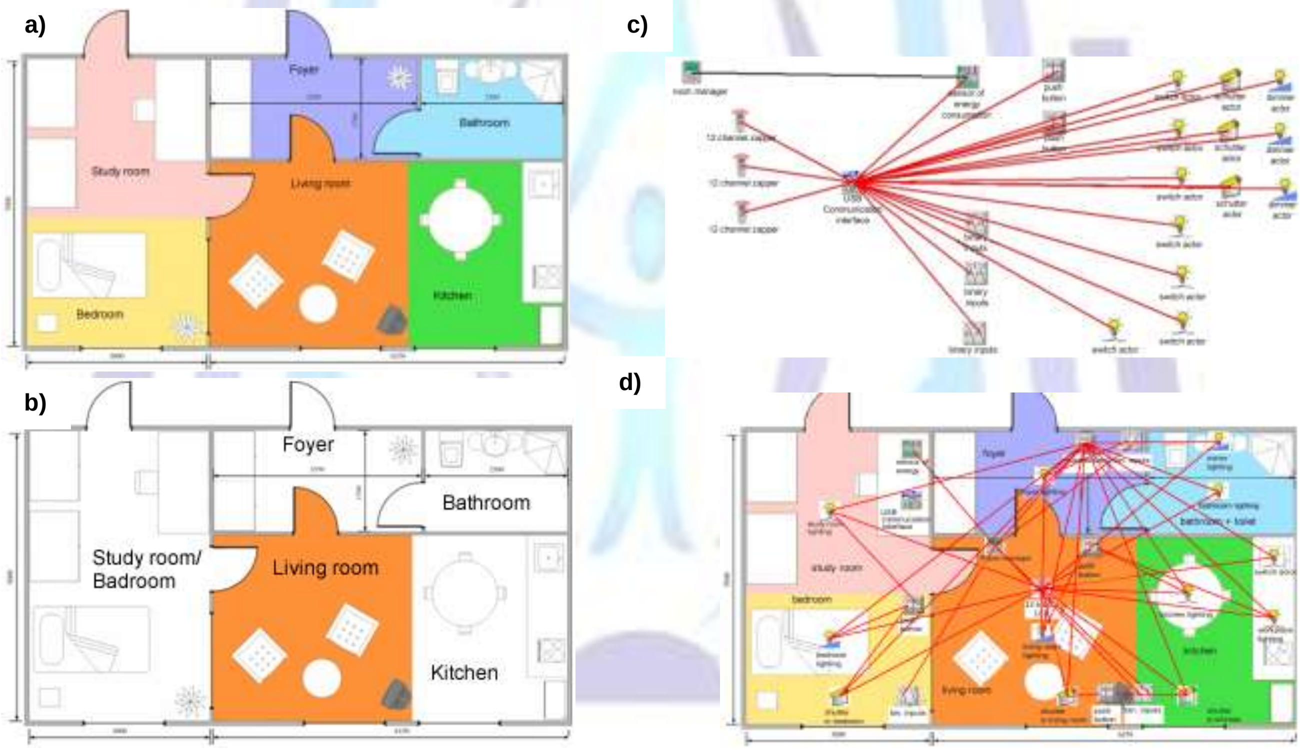

Fig. 1. Design of a visualisation environment for comfortable control of a building service system in Smart Home Care with components of the wireless xComfort system. a) floor projection; b) floor projection – change of colours in visualization environment by moving of the PC mouse; c) wireless conection design; d) floor projection with wireless components [2].

When designing an intelligent building for senior care, Infrastructure Mediated Sensing (IMS) [1] of monitored values is preferred, while focusing on:

1. comfort in controlling the building service-system,
2. management of energies,
3. safety functions,
4. monitoring of the seniors' vital activities.

Comfort during control of the building service system (lighting, heating, ventilation, air conditioning, blinds, energy monitoring, security functions - burglar alarm/fire protection) will be provided using the following elements (Fig. 2):

- wireless buttons in suitably located areas (e.g. near the bed),
- remote radiofrequency control unit,
- the designed visualisation environment,
- mobile phone,
- internet,
- voice commands.

Within the energy management we can monitor energy consumption with the possibility of monitoring the frequency of switching of lights, heating and blinds control. As regards safety functions, it is possible to use a detector of water overflow, smoke detector, detector of open/closed doors and windows, detector of open/closed refrigerator or a motion sensor.

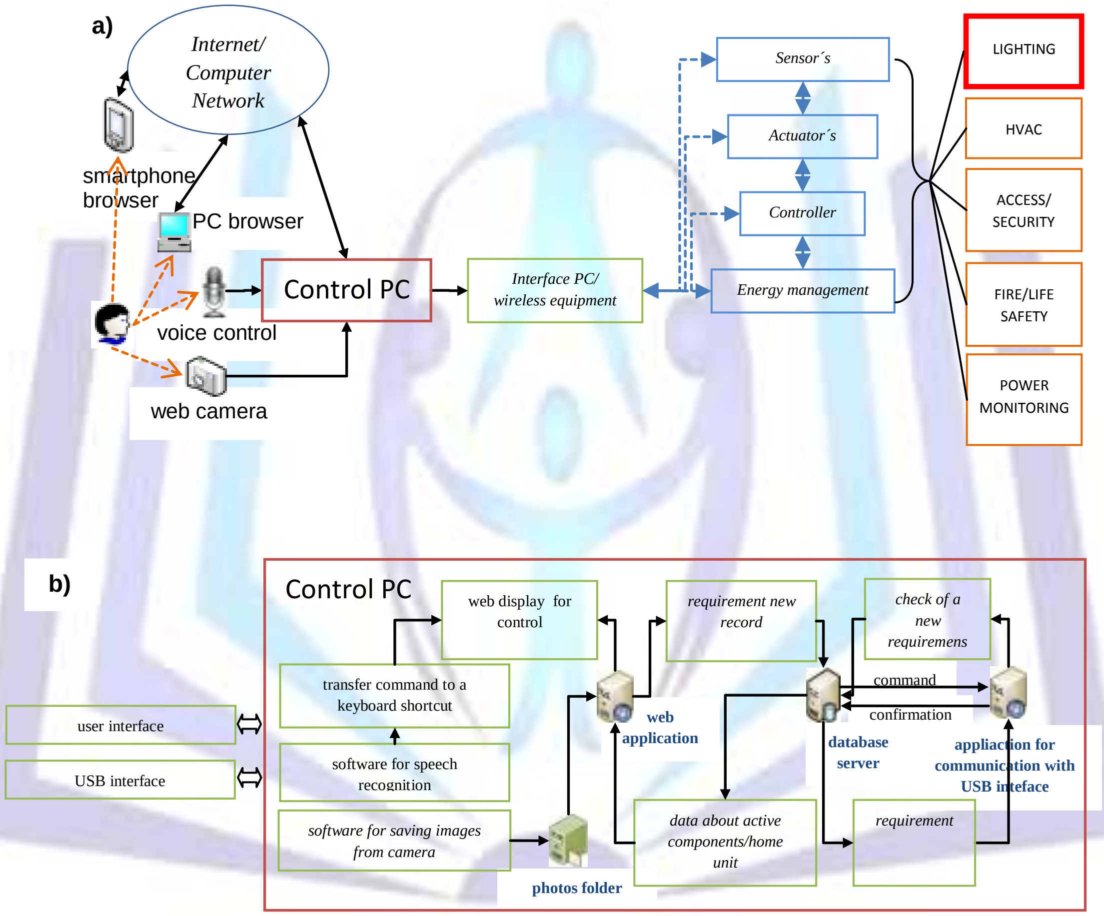

Fig. 2. Block diagram of the designed remote control of the building service system functions in Smart Home Care using a wireless system a) users´ interface, b) control PC [2].

Monitoring of energy consumption and security can be included in monitoring of the seniors' vital activities. When designing an intelligent building with senior assistance service, the Distributed Direct Sensing system can be used, e.g. a camera. With regard to the seniors' needs (respecting their privacy), a camera should be activated based on evaluation of a pre-defined unexpected event (water overflow, detection of smoke, etc.). The senior can therefore decide when the camera should be activated. It is obvious that modern technologies have only a supporting function in the comprehensive design of a Smart Home Care system with regard to seniors' needs. Needs such as preventing loneliness, human contact, acceptance, cleaning, cooking, laundry, taking medicines, movement, washing, minor repairs in the household, can only be provided by the personal action of family members with the use of professional assistance care in combination with modern technology in Smart Home Care.

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2.1 Light dimming using a wireless system

The principle of light dimming to constant lighting using the wireless xComfort system is shown in Figure 3.

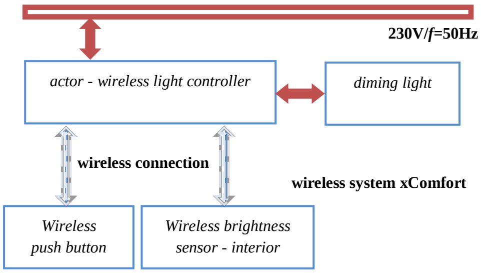

Fig. 3. Description of the principle of light regulation using the wireless xComfort system.

2.2 Dimming via the KNX bus system

Dimming of lights to a constant value using the KNX bus system with KNX/DALI Gateway and KNX/DALI light controller are shown in Figure 4.

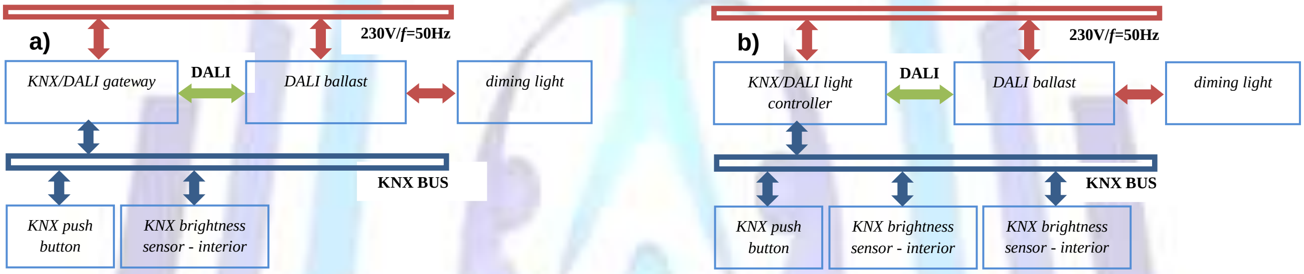

Fig. 4. Description of the principles´ of light regulation using the KNX bus system with a) KNX/DALI Gateway and with b) KNX/DALI controller.

Modern technologies can be useful in protecting persons or objects against burglary or fire. Modern technologies can also provide a great potential in reducing building operating costs by decreasing the energy demand. The following part describes a method of realizing of electrical energy saving possibilities by continuous intelligent lighting control using designed calculation software which compares the actual measured light data with the calculated data in the designing procedure.

3. The procedure for predicting energy savings

This part of the article describes dynamic modelling of daylight as the basis for calculating the regulation level of artificial lighting systems and subsequent quantification of energy savings potential. In dynamic modelling, a number of aspects occur which need to be taken into account. The basis for dynamic modelling of daylight illuminance contributions is the use of the above-mentioned uniformly overcast sky. When doing the calculation, this allows one to eliminate the impact of which way the building faces on the location of windows. The calculation includes not only the model of uniformly overcast sky, but also the impact of the Sun declination changing throughout the year.

To demonstrate the calculation of the daylight factor (percentage expression of daylight presence in the room), a model room was chosen which is located on the 3rd floor of a building (shade from the surrounding buildings and trees is taken into account for the calculation) (Fig. 5).

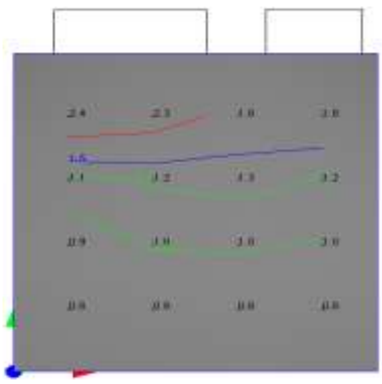

Fig. 5. Calculation of the daylight factor in the model room.

Its dimensions are 4300x5000 mm and its height is 2670 mm. The shorter wall has the following windows: The first triple window with dimensions of 1400x1800mm at a height of 1030mm above the floor, at a distance of 480mm from the wall. The second double window with dimensions of 1400x1140mm at a height of 1030mm above the floor, at a distance of 180mm from the wall. The distance between the windows is 700mm. In calculations of a model room, the daylight factor should be determined, which is calculated using the WDLS software (Fig. 5).

Figure 6 shows the contribution of the daylight illuminance in lux without the contribution of artificial lighting systems if the outside illuminance of unshaded surface is 20 klx.

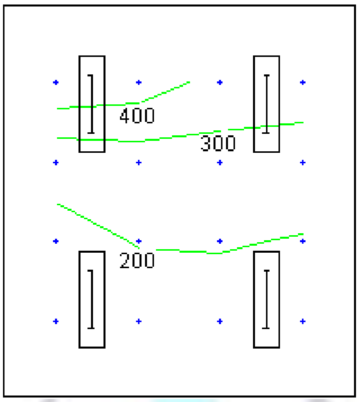

Fig. 6. Daylight illuminance without the contribution of artificial components.

To continue the calculation of energy savings potential, an artificial lighting system should be designed for our room. It is a model office (Fig. 7), for which the norm (EN 12464-1) requires maintaining illuminance of 500 lux.

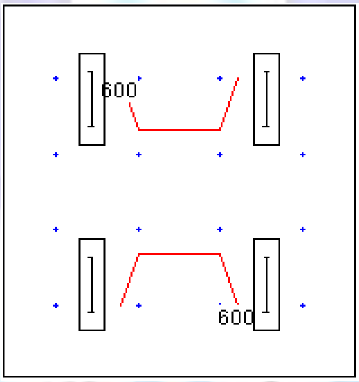

Fig. 7. Design of artificial lighting in a model room.

As no specific location of the visual task was specified in the selected room, the calculation was performed to meet the required 500 lux value at each calculated point. The design of the artificial lighting system was performed using the WILS program. The room is fitted with four surface-mounted fluorescent luminaires THORN - QUATTROC BODY 2x36W TC-L HFI WL6 L840.

Based on knowledge of the daylight factor and artificial lighting level in the room, we can calculate a combination of daylight and artificial light. An example of calculating a combination of daylight and artificial lighting for one specific moment of the year is shown in the following Figure 8.

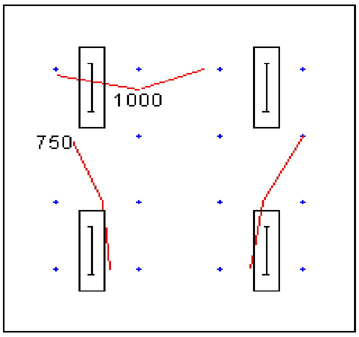

Fig. 8. Sum of artificial (100%) and natural light for one specific moment.

After performing the basic calculation of the lighting systems (daylight and artificial lighting), it is possible to use a modified version of the WILS program to calculate regulation of the potential of each entered artificial illumination system (Fig. 9).

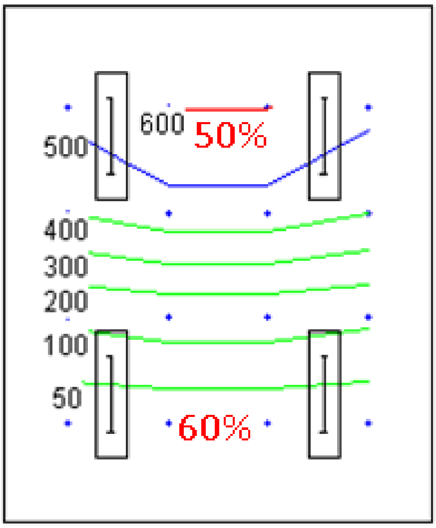

Fig. 9. An example of artificial lighting system control for the situation illustrated in Figure 8.

The regulation of the lighting systems is calculated in 10% increments ranging from 0% to 100%. For this example, the linear relationship between luminous flux and wattage was used. When the required luminous flux provided by the lighting system is lower than 10%, the system is virtually disconnected by the program.

For practical calculations of lighting system savings, it is advantageous to use no more than 4 independently controlled light-lines. The use of more regulated lighting systems would lead to a significant increase in the calculation duration.

Table 1 provides the values of the regulation level of two lighting systems, R_1 and R_2, at different intensities of light on an outdoor unshaded surface.

Table 1. Control of lighting systems.

Reference room		
E [lx]	R_1 [-]	R_2 [-]
1000	0.80	0.70
5000	0.80	0.60
7000	0.70	0.60
10000	0.70	0.50
20000	0.50	0.40
25000	0.50	0.30

For example, when the value of the horizontal illuminance on the outdoor unshaded surface is 20 klx, the first line of the artificial lighting system will provide 50 % of light and the second line will provide 60 % of light. (Fig. 9).

Table 2 compares the values which were calculated using the developed software against the genuially measured values in the model room.

Table 2. Comparison of measured and calculated values.

Date	Total power input [kWh]	Regulated values by software [kWh]	Measurement values [kWh]
30.1.	2,59	1,81	1,23
31.1.	2,59	1,81	1,02
1.2.	2,59	1,8	0,86
2.2.	2,59	1,79	1,55
3.2.	2,59	1,79	1,41
4.2.	2,59	1,76	1,17
5.2.	2,59	1,76	1,42
6.2.	2,59	1,76	1,26
7.2.	2,59	1,76	1,30
8.2.	2,59	1,76	1,18
9.2.	2,59	1,74	1,41
10.2.	2,59	1,74	1,29
11.2.	2,59	1,74	0,89
12.2.	2,59	1,74	1,22
13.2.	2,59	1,7	1,39
18.2	2,59	1,69	1,53

The values are within the time range from 7:00 a.m. to 3:30 p.m. and are provided for the months of January and February. The first column illustrates the total power consumption of the artificial lighting system, which is 2.59 kWh/ measured time interval. The second column includes the values of calculation for uniformly overcast sky. The third column shows actual measured values during the period from 30th January to 18th February for all weather conditions.

Figure 10 demonstrates the difference in the wattage of the lighting system without regulation, with regulation and the actual measured values in the room. When using four lights without regulation (operation during the measured time interval), the power consumption is about 2.59 kWh per measured time interval. The value with regulation shows that the level of regulation of the artificial lighting system in this month is low, which is given by the position and height of the Sun during the day. The measured values clearly demonstrate that the weather patterns vary, which determines the genuine overall power consumption.

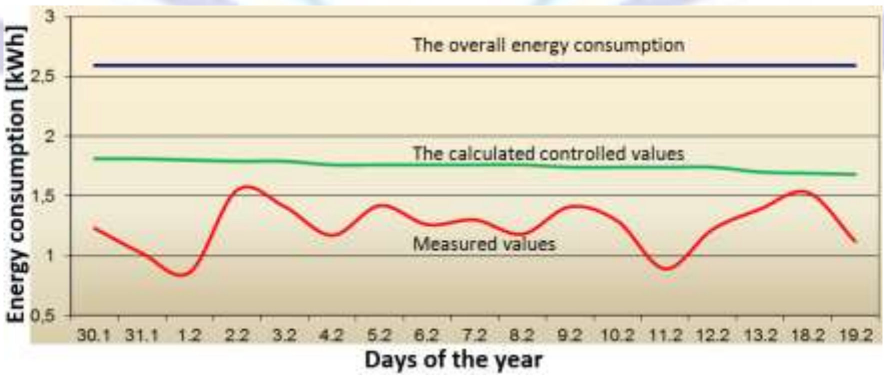

Fig. 10 Consumption of regulated and unregulated power and of the actual lighting system.

Figure 11 shows the patterns of the non-dimmable lighting system and dimmable lighting system designed by the software. The result shows that the savings calculated using the developed software are not as large as those achieved in real terms. This fact fits the expectation that calculation works with the worst weather conditonos (uniformly overcast sky). It can be said that the average power consumption is around 1.25 kWh.

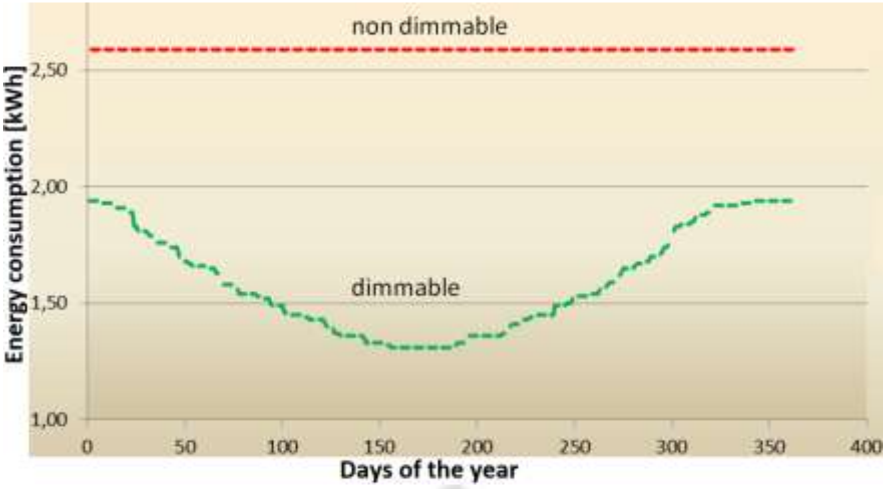

Fig. 11 Power consumption of the lighting system throughout the year.

CONCLUSION and FUTURE WORK

The first part of the article describes the design of a visualisation environment and the structure with a wireless system for comfortable control of a building service system in an intelligent building with the focus on the needs of seniors. It also illustrates the methods of regulating lighting to a constant level by the developed wireless system in an intelligent building with senior assistance using the KNX bus system. The next part of the article describes the results of modelling the savings potential of lighting systems by using natural light and their comparison with the actual measured values for continuous lighting control via the KNX bus system. These results suggest that considerable energy savings can be achieved by employing lighting control. After verifying the accuracy of the uniformly overcast sky model and after tuning the software, this method could be further utilised in the design and refurbishment of artificial lighting systems, energy audits of buildings and when preparing recommendations for reducing their energy consumption.

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