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Intelligent System for Lighting Control in Smart Buildings

Mariana FRATU
Transilvania University of Brasov, Romania, mariana.fratu@unitbv.ro

Abstract
This paper presents an adaptive architecture that centralizes the control of buildings' lighting and intelligent management to economize lighting and maintain maximum visual comfort in illuminated areas. To carry out this management, the architecture merges various techniques of artificial intelligence. It achieves optimization in terms of both energy consumption and cost by using a modular architecture and is fully adaptable to current lighting systems. The architecture was successfully tested and validated and continues to be in development at Aula building of our university. The author expect this research to extend the study and adaptability of computer technique in design of Smart Buildings.

Keywords
intelligent systems, smart buildings, light sensors, autonomous control

1. Introduction

Smart buildings can be systemically classified by the information and control services that serve the needs and expectations of the occupants. The specially designed controlling software and actual electronic hardware and devices installed within the structure that manipulate the telecommunications and building automation functions are necessary to create such a facility.

Necessarily, buildings consume the energy to provide their occupants with services, including thermal and visual comfort, access to water, and power for electronic devices. As a result, understanding the relationship between buildings and their occupants is central to designing buildings that enhance occupant well-being, improve service delivery, and reduce energy usage. Since such building services are usually delivered to provide occupants with satisfactory indoor conditions, it is important to accurately determine the occupancy of building spaces in real time as an input to optimal control.

The occupancy of building spaces is a complex interaction between buildings and humans, depending occupant presence and they behavior, depending even the interaction with lighting systems.

2. Smart Buildings

Designers need to ensure that the building owner receives the best product possible. Concerning the smart buildings, the designers are in face of the exciting new innovative technologies.

The design of smart building starts with monitoring and controlling information services known as Building Automation System (BAS). This can be achieved by using computers, together with function distribution control techniques, to optimize the usage of various pieces of equipment within the building such as the electrical lighting facilities, the air-conditioning systems, fire-prevention equipment and security devices.

BAS comprises of electronic equipment that automatically performs specific facility functions. The commonly accepted definition of a BAS includes the comprehensive automatic control of one or more major building system functions required in a facility, such as heating, ventilating, and air conditioning system, lighting, power, lifts, security and more. BAS includes a collection of sensors that determine the condition or status of parameters to be controlled. BAS and Local Area Network (LAN) provide the lowest level network structure interconnecting various controllers for electrical system. Building designers and managers are increasingly utilizing sensors and the data they collect to make decisions about how buildings are designed, built, and operated [1]. These sensors measure properties such as lighting levels, and energy use. The information about the state of occupancy in buildings - the presence or absence of occupants as well as their activities - can be useful both for efficient control of lighting buildings and for improved space planning of future buildings.

2.1. Data-driven and occupant-driven energy efficiency

Over recent years, the analysis of building energy data with statistical and data mining techniques has been shown to be helpful in improving energy efficient management of building systems. Within buildings, researchers have worked toward achieving a condition in which building systems-such as lighting, heating, and cooling-are provided only as much as they are needed, and only where and when they are needed. Matching these building systems with occupancy information has been shown to lead to significant energy savings [2].

Recently in commercial buildings, energy use data collected through power floor covering installed at the individual outlet level have been used for multiple approaches to save energy in buildings: to show that energy is wasted due to inefficient occupant behavior, such as leaving lights or other systems on during non-occupied hours ; to calibrate and improve the accuracy of building energy models in conjunction with other building data sources ; and to describe the behavior of occupants and improve program modeling in buildings.

Many studies have noted the high impact occupant presence and behavior has on building energy use has noted that occupant behavior (as distinct from occupancy) relates to more than just the presence or absence of occupants in buildings - that is the activities of occupants within the building have a large impact on building energy performance. However, this human element, which is responsible for much of building energy use, is often difficult to characterize. One reason is because it is multidimensional, requiring a fundamental understanding of spatial, temporal, and social dimensions of occupant behavior [3].

Understanding each of these dimensions and reconciling their effects on occupant behavior is critical to gaining a broad understanding of occupant behavior and its impact on building energy use. Furthermore, the structure and type of the social network of occupants has been shown to be highly influential when it comes to how occupants behave and adapt to information in buildings. Researchers have shown that providing the right information to occupants can lead to changes in behavior that reduce buildings' energy consumption [4].

Due to the impact on energy consumption, when designing spaces there remains a pressing need to better understand the behavior of the occupants of the building.

3. Control of Building's lighting

Along with other data streams specific to each building system, the detection of occupant activities has been shown to be significant in addressing electrical energy use in buildings for lighting control: for example, a lighting sensor may provide feedback to lighting controls that can dim the overhead lighting if the building is receiving enough light from outdoors.

An intelligent lighting instrumentation and automation system is presented as the objective of achieving high energy-efficiency in greenhouse supplemental lighting based on the Internet of Things (IoT) technology [5].

The operating system which interacts with wireless-enabled light emitting diode (LED) fixtures for plant growth, an online data server, and different light sensors including RGB sensors. The communication is achieved through communication protocol UART. The system is utilized to implement a feedback controller that automatically adjusts the light dimming levels and, in particular, the ratio of red and blue light intensities based on the plants' needs. A series of experiments involving plant growth were conducted which indicate that the proposed system can achieve energy-savings up to 34%, when compared to a conventional time scheduling scheme.

Additionally, the experiments demonstrate that the system can achieve a highly uniform light distribution under unpredictable natural lighting conditions while saving energy due to supplemental lighting.

3.1. Integrating Building Information Modelling (BIM) for real-time interactive architectural visualization

Building Information Modelling (BIM) is an emerging technology for building modelling, collaborative design, and integrated project delivery. The integration of BIM with design provides the underlying technology that enables the building representation to be communicated to a virtual environment. Current applications of computer in design visualization supports an innovative design process that allows designers to work in their own designed environments with the capability for simulations of physical dynamics and user activities.

The implementation of BIM provides a variety of connections among several fields including architecture, engineering, computer science and visualization. These connections bridge diverse areas such as building modelling, equipment simulation and visualization, character modelling and animation, materials and lighting, and interaction through controllers and user interfaces. In this section, the author describe the integrated design process and present a prototype of her approach. She examine recent personal results in architectural design, Figure 1, followed by BIM's application in design visualization for a multipurpose space [6].

Fig. 1. Virtual prototype of a multipurpose space equipped with a variety of lighting

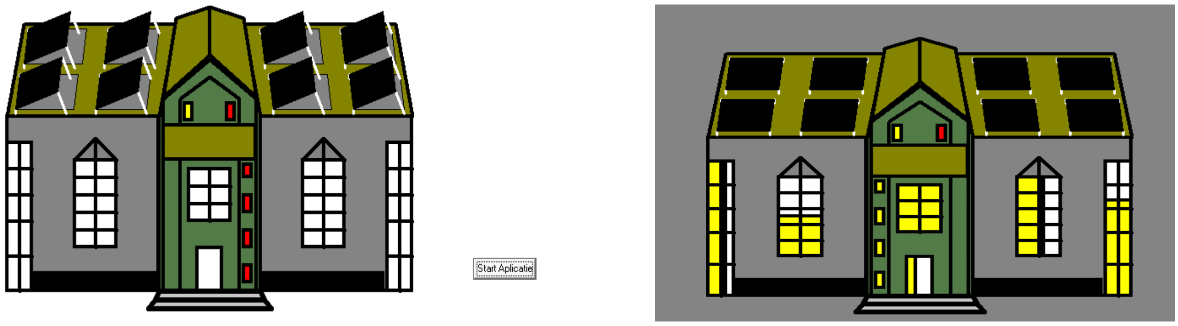
A multipurpose space that accommodates training, videos, events and presentations requires lighting that is flexible. So a variety of lighting: adjustable down lights, stage lights, ambient cove lighting and linear wall lights, all of which can be individually controlled for different situations. Also part of this project, an adjacent screening hall was designed as a black box with accent lighting in the bench risers and minimal down lights.

3.2. Intelligent Lighting and Control - case study of AULA building of Transilvania University

A small-scale indoor plant growth system was designed using LED supplemental lighting fixtures and other sensor modules. The system is equipped with different sensors such as RGB and camera. Other components of the system include a microcontroller unit, LED supplemental light fixtures, communication hardware, and a cloud data server. Designing with Microchip-based intelligent lighting solutions and control enables innovation that expands lighting product capabilities and provides product differentiation. Microchip can meet the technical needs of lighting engineers with its large array of 8-, 16-, 32-bit PIC® microcontrollers, analog, wireless, and human interface products. Light-emitting diode (LED) and fluorescent technologies are currently at the forefront of delivering the most efficient alternatives to incandescent lighting, as in Figure 2.

Although both pose technical challenges, they also offer significant advantages beyond simple incandescent light bulb replacement, including improved efficacy (lumens/watt), reduced energy consumption and the ability to add intelligence.

Microchip’s advanced lighting solutions offer the opportunity to incorporate non-traditional capabilities into lighting designs. Features such as predictive failure and maintenance, energy monitoring and remote communications and control are just some of the advanced capabilities that can make intelligent lighting solutions more attractive. These advanced capabilities - along with reduced operating, maintenance and energy costs - can quickly translate to significant savings, particularly for commercial facilities.



a) b)

Fig. 2. Image with autonom lighting electric system at AULA building of Transilvania University
a) Auto-oriented solar panels on AULA building; b) View of inside lighting of AULA building

4. Conclusion

In the presented system, the light designs can be set either manually or through a smart process. In the former case, the user is encouraged to plan the time slots (in hours) and the luminous flux of each time slot. In the second case, one proceed to the observation of different environmental factors that may be influential in determining adequate lighting for the particular area, such as flow or pedestrian traffic, or weather conditions, which influence the level of ambient light, especially near the hours of sunrise and sunset. One observes the procedures to use the lighting patterns according to ambient factors and different user preferences.

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