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Automated Lighting Control System in Building

Srishti Singh[1*], Neeta Mishra[2]
[1]U.G. Student, Amity School of Architecture & Planning, Amity University, Raipur, India
[2]Associate Professor, Amity School of Architecture & Planning, Amity University, Raipur, India

***Abstract*: Automated lighting control systems are critical to enhancing energy efficiency and user comfort in modern buildings. This paper offers an in-depth examination of these systems' features, benefits, and potential future designs. By investigating the integration of modern technologies including daylight harvesting, motion sensors, and occupancy sensors. The research classifies several kinds of automated lighting control systems and looks at their implementation methodologies, emphasizing best practices for an effective rollout in a range of building contexts. This covers hybrid strategies that incorporate aspects of both decentralized and centralized systems. Exploring new developments in automated lighting control technologies, such as the increasing popularity of wireless connectivity, machine learning algorithms for predictive control, and interaction with other building management systems, is a major goal of the research. The study also looks into how these new technologies might affect building settings in the future.**

***Keywords*: Automation, Energy Efficient, Lighting Control, Smart Control, PIR Detector, Smart Building.**

1. Introduction

To increase energy efficiency and sustainability, intelligent lighting systems that use presence control must be developed before an automatic lighting control system is implemented in a building. By using advanced sensors, such as infrared modules, these systems can identify the presence of people and adjust the illumination appropriately. Energy consumption is controlled and building occupants enjoy a more comfortable and efficient indoor environment with the introduction of intelligent lighting control systems.

A. Background

The concept of Building Automation Systems (BAS) revolves around the application of machines to tasks once performed by people. These systems take care of process execution using programmed commands with automatic feedback control to ensure that the commands are executed correctly. An automated building lighting control system is a modern solution that enhances energy efficiency, safety, and user comfort. It replaces traditional manual control systems with intelligent technology that adapts to different scenarios. By automatically adjusting light levels based on presence and external light sources, the system optimizes energy consumption and creates a comfortable environment for users.

B. Importance

An automatic lighting control system is a highly versatile solution that can be used in buildings. First, these systems significantly improve energy efficiency by adjusting lighting levels based on occupancy and available daylight, resulting in significant savings on utility bills. Second, they play a key role in creating security by integrating them with motion sensors and detecting intruders, and ensuring passenger safety. In addition, automated lighting systems improve user comfort and productivity by creating an optimal visual environment for various tasks.

C. Origin and History of Building Automation System

The first Building Automation System (BAS) were simple and crude, representing an important innovation in building technology. The BAS concept can be traced back to the 1600s, with Cornelius Drebbel's invention of an incubator thermostat, which laid the foundation for modern building controls. Over time, BAS evolved rapidly, from the 1950s to the 1990s, transitioning from pneumatics to electronics and eventually to open protocols like BACnet.

2. Literature Study

A. How does building automation system works?

Building automation systems (BAS) are responsible for overseeing all on-site electrical, mechanical, and electrical systems. Motion sensors, RFID scanners, presence sensors, and other smart components provide information that is used to automatically change functions, improving performance and reducing energy waste.

The following are the primary building systems that building automation systems control:

- Electrical: Features like energy management and utility monitoring help the building systems run as efficiently as possible.
- Lighting: The building's lighting systems are turned on and off based on occupancy sensors and scheduling features.
- Temperature: HVAC systems are used to control temperature. This lets building owners maintain cost-effectiveness while maintaining comfort.
- Security: The building and its residents, a building automation system combines access control

*Corresponding author: singhsrishti1024@gmail.com

(elevators, escalators, entrances), CCTV cameras, and CCTV recording systems.

B. The Components of a Building Automation System

BAS is a structural system and generally consists of five parts: sensors, controllers, printing devices, communication protocols and a terminal or user interface.

1. Sensors: These devices monitor temperature, humidity, number of people in the room, light level and other values. Sensors transmit this information to centralized controllers.
2. Controllers: Act as the "brain" of the BAS. They collect data from sensors and send commands to operating systems such as HVAC equipment, building lighting systems and other connected components.
3. Output Devices: When the controller sends a command, actuators and relays are activated to fulfill the requirements. For example, dim the lights in unused offices or turn on the air conditioning before people come to work.
4. Communication protocols: BAS uses a specific language. That the individual components of the system understand how to change settings or execute commands.
5. Terminal Interface: Facilities and property managers interact with the BAS through a terminal or user interface. It presents the information in a way that allows the user to monitor the health of the building and select settings manually.

C. Introduction to Automated Lighting Control System

Automated lighting control systems are advanced solutions that include electronic communication between various system inputs and outputs, enabling the right amount of light at the right time. These systems are widely used in commercial, industrial and residential settings for energy savings, comfort and safety. The goal of lighting control systems is to increase energy efficiency of lighting systems, comply with building codes and/or comply with energy conservation and environmentally friendly building programs. For example, activate exterior and interior door lighting from the car's security remote control, schedule lighting to automatically turn on and off so that the home looks occupied on vacation, and automatically activate lighting. Light the way away from home in an emergency.

1) Types of Automated Lighting System

Here are some types of automated lighting systems for buildings:

Occupancy sensors:

These are easy to install and can be used to make light fixtures more energy efficient. Passive infrared sensors (PIR) are triggered by heat-emitting bodies moving through their field of view. Wall-box type PIR occupancy sensors are good for small, enclosed spaces like private offices.

Smart down-lights:

These allow you to control lighting across multiple floors and fixtures, and you can program preset scenes.

Assisted lighting controls:

You can integrate voice-controlled assistive technology like Amazon Alexa and Google Home into your lighting scheme to turn lights on with voice commands.

Addressable controls:

These use an interface to control lighting, and typically separate cabling connects the light fixture to the control unit. Addressable controls are the most flexible type of lighting control system, but they require the help of an electrician.

Distributed controls:

A building automation system (BAS) is an example of a distributed control system. This is a computerized network of electronic devices that monitor and control the lighting, electronics, and mechanical systems in a building.

DALI lighting control:

Digital Addressable Lighting Interface (DALI) is a technical standard for network-based lighting control systems. It's commonly used in building automation and is the international standard for the network-based interface.

Bluetooth connected smart lights:

Qualified Bluetooth Mesh technology is part of the smart control system in new buildings that works with other devices. This allows lighting controls to work with sensors to monitor occupancy and daylight, and to adjust lighting levels in real time.

D. System Function and System Structure

1) System Function

To provide a solution for an intelligent automatic lighting system that could be used in our normal and residential life, as well as applications in public lighting, even industrial lighting with some necessary modulation. This system builds four functions which are listed in detail below:

- Turn lights on and off automatically: A thermal infrared sensor allows this system to gather data about insider performances and activities. It can determine if someone is in the room by examining and comparing the signals it has received.
- Two adjustable lighting solution: The lighting solutions in this study have been divided into two categories: High and Low. According to this rule, lux values between 300 and 750 represent the "High" level, while lux values between 0 and 300 represent the "Low" level.
- Two different ways to control the system: Additionally, the system offers a combination of human and automatic controller lighting control. Users can program the automated switching between two modes.
- LCD 1602 monitor with display: The introduction to the 1602 LCD display function is also included in this document. Its goal is to display the lighting system's present working conditions, such as the control mode, lighting illumination level, etc., making it easier for users to monitor.

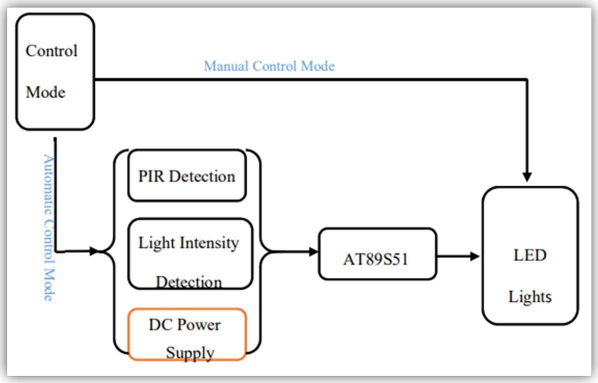

Fig. 1. Functional block diagram

2) System Structure

For the purpose of achieving a more detailed look at this smart automatic control lighting system, it is going to be disintegrated into several modules. The given figure represent the block illustration of system structure in order to show the sequence about how to realize its function.

The entire system comprises seven modules on the aggregate: central processing module, PIR detection module, light intensity module, 1602 display monitor module, LED lights module, control modes switching module and central unit power supply module.

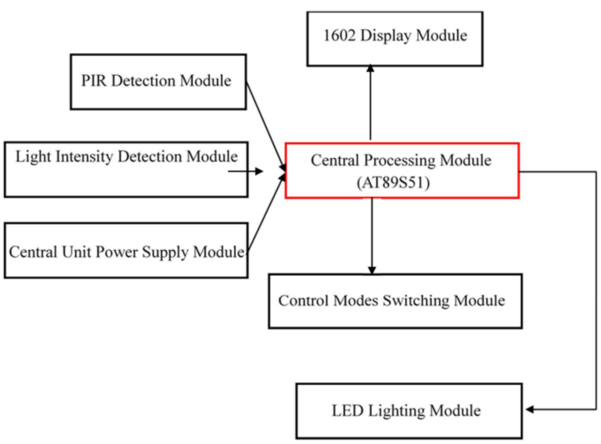

Fig. 2. The block diagram of system structure

E. System Structure Hardware Implementation

1) Central Processing Module

- The core of the central processing module is AT89S51 that is a microcontroller of MCS-51 architecture.
- The minimal system was designed including AT89S51, power supply circuit, clock reset circuit, and crystal oscillator circuit. The minimal system has been presented in Figure.
- The AT89S51 is a low-power, high-performance microcontroller from Microchip Technology.

a) Power Supply Circuit

- Each electronic device is required to be driven by a power supply, so does microcontroller.
- On the whole, there are two power supply systems for microcontroller: 5V and 3.3V. AT89S51 is associated *with 5V system.*

b) Clock Reset Circuit

- When a microcontroller is powered up, then, prior to its reach to the ultimate phase of supply voltage, it passes across the voltage ranges, whereby the gadget doesn’t guarantee to function.
- With this method, we are capable of making sure that microcontroller functions at a steady condition all the time in addition to reducing the system cost and increasing system reliability.
- In general, there are three different reset sources: Power-on Reset Circuit, Manual Reset and Internal Watchdog Reset.

c) Crystal Oscillator Circuit

- Clock pulses are required for the synchronization of the operations between various peripherals of the MCU.
- Crystal oscillators are meant to deliver stable clock pulses to the digital circuit. A clock pulse (CP) is a string of alternating 0’s and 1’s.

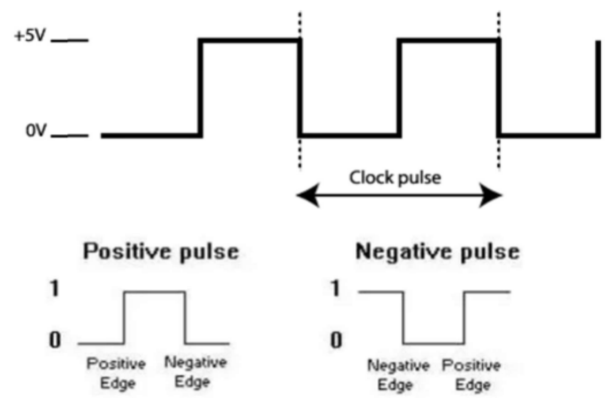

Fig. 3. Clock pulse definition

2) PIR Detection Module

a) PIR Sensor

- PIR sensor features two balanced sensors inside it whereby both of them are made of a specific material, responsive to IR, in addition to having a detection area.
- As soon as a warm physic, for instance a human or an animal walks nearby, it, firstly, develops interception of one half of the PIR sensor that gives birth to a positive differential variation between the 2 halves.
- As soon as the temperate body goes away from the sensing field, the opposite takes place and the sensor brings forth an adverse differential variation.

b) PIR Sensor Structure

- Because of the weaknesses of the output signal from PIR sensor, for instance the insensitive signal differential, the small amplitude (less than 1 mV), signal is required to be adjusted with a processing module before it heads towards controlling the lighting system.

- This signal processing circuit transforms the output from PIR sensor into a digital signal, which is appropriate for microcontroller.

Below, block diagram of a PIR detection system shows the floating consequence of the PIR detection module.

Fig. 4. Block diagram of a PIR detection system

3) Light intensity detection module

- Photo resistor and Light Intensity Sensor

a) Photo resistor

- Photo resistor (or light-dependent resistor, LDR, or photocell) poses to be a light controlled variable resistor.
- The resistance of photo resistor varies on the bases of the changes of incident light intensity, leading to the change of the voltage on itself.
- In accordance with the different light intensities, the input voltage on the positive terminal of voltage comparator positive is expected to change.

b) Light intensity sensor

- Light intensity sensor converts optical signal into current, and then transforms current into voltage output with ADC or DAC.
- Light intensity sensor is capable of converting the analog input into digital output that can connect to the microcontroller in a direct manner.
- It can make our system easier to build as well as maintain.

4. LCD 1602 Display

- This module was designed in order to exhibit the findings on current working status of system, including the lighting on/off, the mode (Auto or Manual), lighting level (High Illumination or Low Illumination).

a) LCD 1602

- The LCD-1602 is a low power 16 characters by 2-line liquid crystal display, with serial interface. It can display two rows with up to 16 characters on each row.

4) LED Lighting Module

- Contemporary LED bulbs are mandatorily required to transform the standard household supply into a DC supply at a lower voltage (typically 12V DC to 24V DC) in respect to the LED array. This is performed on a per bulb basis.

F. User Control for Automated Lighting System

1) Remote Control

- Automated lighting control systems allow users to control the lighting remotely, either from a wall switch, smartphone/tablet app, voice assistant, or dedicated remote control
- This provides convenient and flexible control over the lighting, enabling users to adjust lights without having to physically access the switches or fixtures.

2) Scheduling and Scenes

- Users can program the system to automatically turn lights on/off or adjust brightness based on schedules, occupancy, and time of day.
- They can also create custom lighting "scenes" for different activities or moods, allowing the system to set the appropriate lighting levels with a single command.

3) Dimming and Color Tuning:

- Many automated lighting systems allow users to dim the lights or adjust the color temperature to create the desired ambiance and support different tasks like reading, relaxing, or working.
- This level of granular control over light intensity and color helps optimize the visual environment for occupant comfort and productivity.

4) Voice Control

- Automated lighting can be integrated with voice control platforms like Alexa, Google Assistant, and Apple Home Kit, allowing users to control the lights using voice commands.
- This hands-free control further enhances the convenience and accessibility of the lighting system.

5) Centralized Management:

- Sophisticated building automation systems provide a centralized control interface to manage the lighting along with other building systems like HVAC, security, and energy monitoring.
- This unified control allows users to optimize the entire facility from a single platform.

6) Customization and Flexibility:

- Modern automated lighting systems are highly customizable, allowing users to tailor the lighting to their specific needs and preferences.
- The systems are also scalable and can be expanded over time as user requirements or the building's needs evolve.

G. Emerging Trends for Future

New developments in lighting control technology increase user comfort and energy savings potential. There are two ways to look at the current state of this field's advancement: the individual's development of lighting control technology and the establishment of networked management ecosystems. Research on technology advancements is yielding new approaches. As previously reported, researchers are concentrating on enhancing detection utilizing image systems and RFID, rather than depending on low-tech techniques like PIR and ultrasound for location. Researchers shouldn't place as much emphasis on developing sensor networks that use individual sensors to fix related faults as they should on developing individual technologies. In lighting control strategies, wireless sensor networks are becoming more and more popular. In these situations, the utilization of numerous sensors improves energy efficiency and customer satisfaction by providing cumulative information to detect usage instead of depending solely on data from a single sensor. Multiple low-cost network sensors can offer far better detection accuracy than a single expensive sensor, allowing for faster reference setup times and thus greater energy savings.

H. Advantages of Automated Lighting Control System

1) Less Wastage, Cost effective

Energy waste can be avoided by using automated lighting control systems, which adjust lights based on your demands.

These systems let building managers to find cost-saving opportunities and maximize the utilization of each area by tracking and monitoring occupancy levels, lighting usage, and other data points.

2) Enhanced Safety

The automated lighting control of lamps, ballasts, LEDs, etc., is a major contributor to added safety. For instance, in industrial units the motion-sensing lights are best suited to illuminate places with possible spillage as soon as technicians visit the site.

Other important uses are found in spaces like offices and workstations. By having brighter lights in areas dedicated to computer usage, you can help in preventing any visual strain.

3) Biological Benefits

Bio-adaptive lighting is a manifestation of lighting automation where light temperatures, intensities, etc., are changed according to the body clock.

Light in itself is a driver for biological processes, and when the artificial lighting around you emulates natural light, it tends to optimize physiological functioning too.

Hence, for such minute biological benefits, automated lighting systems are important, especially at work places where concentration is key.

4) Better Aesthetics

With the lighting control panel and the microcontrollers, users can choose the color, intensity, and temperature of lights that they wish for a particular space.

Moreover, by sensing changes in the ambient conditions, these systems will allow your lights to get dimmer or brighter, thereby preserving the aesthetics of your space at all times.

5) Convenience and Flexibility

With the help of voice commands, remote controls, or smartphones, users of automated lighting systems can change lighting settings remotely and from any location.

Users may manage their lighting surroundings with flexibility and ease thanks to this convenience and the ability to construct lighting schedules and scenes.

3. Case Studies

A. Intelligent Building Get Smart Lighting Controls

- Name: Van Andel Institute's (VAI)
- Area: 22,300 Sq.m.
- Building Typology: Institute
- Location: Grand Rapids, Michigan.

In April 2011, the Van Andel Institute's (VAI) earned LEED (Leadership in Energy and Environmental Design) Platinum status.

The center utilizes intelligent building controls to achieve energy and operational efficiency.

The glass roof of the eight-story building provides ample natural light throughout the facility, including the open laboratories.

Advanced lighting control systems played a role in meeting the LEED target.

Fig. 5. Van Andel Institute's (VAI)

A key consideration in selecting Watt Stopper (Company) controls was the availability of both open and closed loop photo-sensors for optimal daylight harvesting solutions in the many different types of day lit spaces throughout the facility.

According to the company, these controls can typically reduce lighting energy costs by up to 20-50 percent without compromising light quality.

The system is compatible with Tridium's Niagara framework (controls programming-based core data), which helps facilitate an open and interoperable approach to controls by allowing the IT enterprise, building automation control systems and underlying mechanical systems to work.

The controls platform supports peer-to-peer communication, which enables the system to initiate requests for data across different applications and subsystems.

B. Smart Lighting Solution at Cherry Hill Village Mall

- Name: Cherry hill Village Mall
- Area: 20000 SQ.M
- Building Typology: Retail
- Location: London, Canada

Cherry hill Village Mall offers a diverse array of stores and amenities to meet their needs. With the intention of upgrading their lighting system to improve energy efficiency and operational convenience.

Cherry hill Village Mall, the client wanted to improve its lighting system through smart controls so it could run more efficiently with less energy consumption. Centralized control of lights, grouping capabilities, and automate lighting schedules to match mall hours were the main.

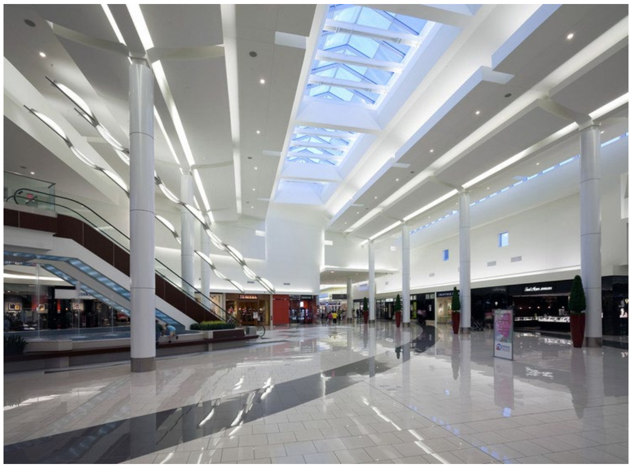

Fig. 6. Cherry hill village mall

The Radiar AF10 fixture controller, which has a 2-channel AC-powered 0-10V capacity and an inbuilt relay, was the cornerstone of the centralized control of lighting fixtures at Cherry Hill Village Mall. With this solution, the client could easily manage lighting groups and use automation through the desktop application, which was in line with their goal of centralized control.

In addition, integration with the mobile app increased the efficiency of remote control. Through the mobile app, the client was able to access various settings and control, providing them with flexibility and convenience for managing their fixtures from any location.

The Radiar AR10 is a fixture controller that can dim and tango fixtures in electrical junction boxes, providing dependable dual-channel functionality. It has two channels for both indoor and outdoor use. With this solution, lights were precisely regulated and toned down, improving the mall's atmosphere while also providing flexibility for controlling lighting.

The Enor E, a BLE-Wi-Fi gateway with real-time clock, enabled the smart lighting network to function through cloud connectivity. The RTC function enabled the gateway to maintain a precise time connection, even when there was no cloud connection or power outage, enabling automated lighting scheduling that accurately corresponds to the mall's time.

4. Conclusion

The review indicates that lighting control systems have the ability to offer considerable energy savings and lead to a decrease in the price of electricity. Reduced need for electricity also provides advantages environmental effects of a lower carbon footprint. However, every control technology has unique characteristics that impact how well they perform. The residents' pattern of behavior, the building's or room's geometric characteristics, the daylight entry, work done, etc., all have a significant impact on the lighting control systems, as evident from the comments in this paper.

Automated lighting control systems represent a significant advancement in building management since they integrate efficiency, adaptability, and sustainability. Strategic integration of sensors, control interfaces, and communication networks is required for their placement in order to optimize lighting based on occupancy, daylight, and preset schedules.

In addition to increasing energy efficiency, this integration lowers costs and lessens adverse environmental-effects.

There are numerous advantages to these systems. They increase building occupant productivity and comfort, save a significant amount of energy and money, and minimize maintenance costs by employing lighting efficiently. In addition to providing enhanced security and safety, these systems' remote-control features will be useful to building administrators and users. Systems for automated lighting control are crucial for promoting energy efficiency and a sustainable future as buildings adapt to meet contemporary needs.

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