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# Implementation of Smart LED Lighting and Efficient Data Management System for Buildings

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**Abstract**

Recent studies have shown that energy-efficient smart LED lighting systems provide a better visual comfort-working environment at a reduced energy consumption compared to existing lighting systems. Present daylighting systems are able to regulate the light intensities via communication technologies utilizing smart sensors. This paper presents implementation of a smart LED lighting system utilizing different energy-efficient techniques without compromising the visual comfort of occupants. The proposed lighting system uses ZigBee and Wi-Fi communication protocols to control the lights of commercial/residential buildings according to natural daylight, occupancy or as per the requirements of the inhabitants of the building. The lighting system can be operated in three different modes: *Manual*, *Auto*, and *Hybrid* to account for various applications. A wireless sensor and actuator network (WSAN) is used to collect available data, regarding the usage of personalised smart LED lights by occupants in the building. A complete design and implementation of the smart lighting system are presented in the paper. The paper also presents the detailed test-bed implementation of the proposed smart lighting technique and data management system to illustrate the impact of the proposed lighting system on energy consumption and occupants' visual satisfaction. The proposed lighting system aims to reduce energy consumption by 60-70% compared to the existing lighting system while satisfying the visual comfort of the occupants. The proposed work also suggests the guidelines to incorporate intelligence into the system such that it can automatically predict the occupant preferences in a decentralized framework for better visual comfort and improved energy utilization in existing buildings.


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*Keywords:* visual comfort; wireless sensor and actuator network; database management system; personal and automatic control

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## 1. Introduction

The automation of devices and systems are changing the lives of ordinary people gradually. Smart devices and systems are gaining popularity due to the introduction of Internet of Things (IoT). As present devices and systems are smarter than their previous counterparts, nowadays smart buildings [1, 2] employ the recent advancement of modern technologies. In a smart building, devices are controlled automatically and intelligently as per the occupant's preference. A smart lighting system is an essential part of a smart building. The smart lighting system [3] employs techniques to control the lights automatically or semi-automatically and to adjust the light intensities based on occupant's visual comfort. The smart lighting system may also comprise of heterogeneous lights and can be controlled using the same unified controlling system. Harnessing daylight makes a lighting system more energy-efficient. The main goal of a smart lighting system is to achieve energy efficiency without sacrificing the visual comfort of the occupants. A smart lighting system considers several parameters, including natural daylight available in the building, user preferences, user movement, and occupancy in the building to control illuminance.

The proposed smart lighting system comprises of designing a Wireless Sensor Actuator Network (WSAN) [4, 5] involving ZigBee wireless communication between sensors and actuators. Personal agents are used by occupants to vary the light illuminance based on individual preferences and are connected to the network through Wi-Fi [6]. A Graphical User Interface (GUI); an android app; runs on personal agents, by which occupants can input their preferences into the system. The proposed lighting system is a decentralized system. Occupants have individual control of their surrounding environment while the central server can override the user commands, if any conditions are violated like overuse of energy at peak times. The central server collects sensor values via coordinator and user preferences values from personal agents. A JAVA agent runs on the central server to store the collected information in structured formation into a database. The data collection is carried out over a period of time. An intelligent tool is used to derive predicted actuator values to automatically control light intensities for better visual comfort. With the use of these advanced technologies, in this research work, a novel framework is presented to control lights within a smart building based on individual occupant preferences and natural daylight available.

Conventionally, the mechanically-conditioned spaces [7, 8] are designed and operated to provide a visually comfortable environment to a maximum number of people. Visual comfort is not only dependent on the environmental factors, but also on factors such as the user's requirements and expectations [9, 10]. With the paradigm shift from a uniform lighting environment for all occupants to an individual preference based visual comfort system, there is a need to conduct large-scale experiments in the field to establish new user-centric models and their applications.

## 2. Smart Lighting System

The proposed framework enables changing the brightness of lights to provide satisfactory visual comfort to the users at a lesser energy cost. In addition, the framework provides the methodology to integrate visual comfort devices with WSAN in the built environment. A schematic of the proposed WSAN framework is shown in Fig. 1 (a). To account for different types of experiments (both with personal control and centralized control), the framework is designed to operate in three different modes; *Manual Mode* - the users can interact with the lights according to their preference. *Auto Mode* - the lights are actuated according to a model-based or data-driven control based on the sensor measurements. *Hybrid Mode* - the lights can be actuated automatically but the users can interact with the device in case they feel discomfort.

Modern bidirectional communication networks can control sensor activities and put them into SLEEP state after receiving data from them. Therefore, the smart lighting system is designed using the WSAN. The WSAN is widely used in many applications to analyze physical and environmental parameters. The structure of the WSAN comprises of nodes where each node represents an autonomous entity in the network. The sensor network in this system comprises of sensor nodes, which transmit measured sensor values to the coordinator. A Gateway node facilitates connectivity of the WSAN with the other nodes involved within it. Actuation nodes work based on the instructions from the coordinator. The lighting system implements the proposed actions. A Personal Agent enables external preferences of the individual users to control the system. The architecture of a sensor node is illustrated in Fig. 1 (b).