Smart Staircase Lighting

Joel Kinny, Dylan Dias, Tanmay Malekar

Abstract— The Smart Staircase system is a lighting control system where the lights are automated according to presence of people using the staircase. It has been further extended with a user interface on mobile devices. This user interface, in the form of an Android Application will remotely monitor the status of the lights and also be able to modify the color and intensity of lights being used on the staircase. With this project, we will successfully create a system where lighting control will be purely based on human presence and hence eliminating the need for manual switching. In order to implement this technology, we first need to survey the various methods available for sensing data and controlling the lighting based on occupancy of the area. Furthermore, the various methods and their implementation has been discussed.

Keywords— Home Automation, Occupancy Sensors, Sensor Network, Wireless Communication, Android Application Connectivity

1 Introduction

Home Automation involves the control and automation of lighting, heating, ventilation and other systems. Home automation system achieved great popularity in the last decades and it increases the comfort and quality of life. Home devices when remotely monitored and controlled via the Internet, are an important constituent of Internet of Things. Modern systems generally consist of switches and sensors connected to a central hub sometimes called a "gateway" from which the system is controlled with a user interface that is interacted either with a wall-mounted terminal, mobile phone software, tablet computer or a web interface, often but not always via Internet cloud services. A lighting control system is an intelligent networ based lighting control solution that incorporates communication between various system inputs and outputs related to lighting control with the use of one or more central computing devices. Automatic Lighting Control uses the principles of Home Automation where an occupancy sensor collects data from the surrounding area and detects the presence of a person. This data is then used to determine the presence of a person with the help of a microcontroller and is interfaced with the light and turns it on. The major advantage of a lighting control system over stand-alone lighting controls or conventional manual switching is the ability to control individual lights or groups of lights from a single user interface device.[3] This ability to control multiple light sources from a user device allows complex lighting scenes to be created. A room may have multiple scenes pre-set, each one created for different activities in the room. A major benefit of lighting control systems is reduced energy consumption. Longer lamp life is also gained when dimming and switching off lights when not in use. Wireless lighting control systems provide additional benefits including reduced installation costs and increased flexibility over where switches and sensors may be placed.[2] In this paper, we will be studying the various methods available for sensing human presence in confined and closed areas using different types of sensors and categorizing the accuracy and the effectiveness of each sensor along with the various other methods for data classification. Once the sensor data is acquired, it is important to transform this data into a form where our device will be able to distinguish between the type of presence in the target area, by extracting features like distance from sensor, number of persons in the area, speed of the target persons. Etc. This will be made possible by accurate Sensing data and Efficient Machine Learning Algorithms.

2 Literature Survey

With the advancement of sensor technologies and sensor networks being implemented in IoT and Home Automation projects, it is advisable to learn the various types of sensors available and their classification. These sensors are used to sense indoor enviroments such as office spaces, rooms, staircases, hallways to detect the presence of objects, and also human beings. Such sensors can be used in synchronization to determine a person's location within room and be aware of the person's surroundings and adapt to it. Accordingly, indoor tracking and localization is one of the key technologies for providing activity-aware services in a smart environment. Occupancy/vacancy sensors, which can automatically turn lights on when you enter a room and off when you leave, are a smart and easy way to save energy in commercial applications. According to the U.S. Department of Energy, lighting accounts for an average of 38 percent of electricity used in commercial buildings—more than any other building system.[8] Utilizing occupancy/ vacancy sensors is a key strategy for saving lighting energy. In fact, occupancy sensors can typically save 30 percent—and up to 60 percent—of lighting energy in a building.

In addition, sensors add convenience by eliminating the need to manually turn lights on or off. And because occupancy sensors automatically turn lights on, a person never has to enter a dark room.[5]

A. Sensor types

a) PIR sensors: which work on heat difference detection, measuring infrared radiation. Inside the device is a pyroelectric sensor which can detect the sudden presence of objects (such as humans) who radiate a temperature different from the temperature of the background, such as the room temperature of a wall. Fig. 1 shows us the PIR sensor module used and the output singal measured from a PIR sensor.[5]

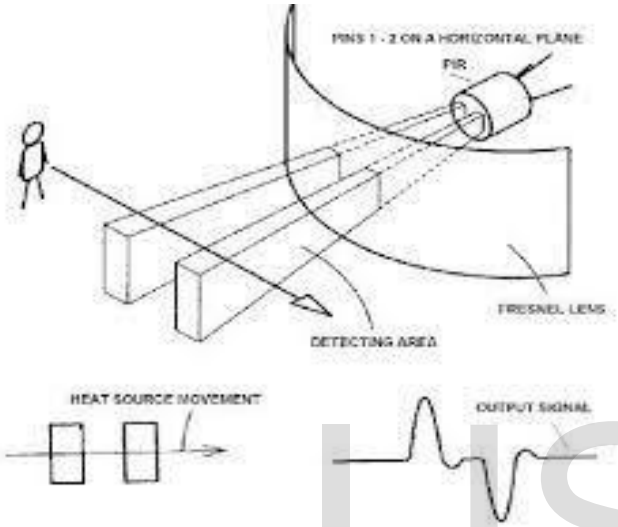

Fig.1

b) Environmental sensors: such as temperature, humidity and CO2 sensors, which detect the change in the environment due to the presence of a human being.[5]

c) IR proximity sensor: These sensors work on the principle of Time of flight and Doppler Shift for the determining the distance of an object from the sensor. The emited pulse bounces off the object and is picked up by the detector which then the predicts the distance based on preset values. Fig. 2 shows the principle behind IR sensing.[5]

If the reflected pattern is the same for a preset time then the sensor assumes there is no occupancy and the load is switched off. Fig. 3 below shows us the detection of objects using Ultrasonic sensors.[5]

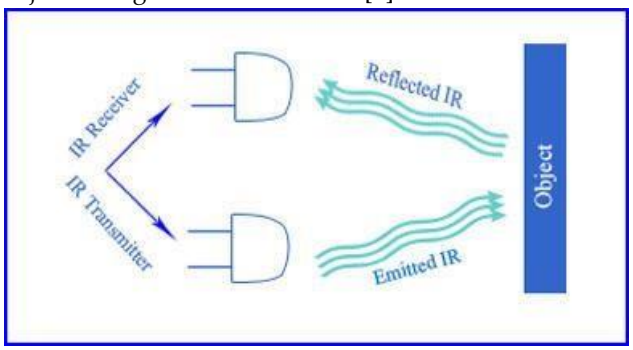

Fig.2

d) Ultrasonic sensors: similar to radar , they work on the doppler shift principle. An ultrasonic sensor will send high frequency sound waves in area and will check for their reflected patterns. If the reflected pattern is changing continuously then it assumes that there is occupancy and the lighting load connected is turned on.

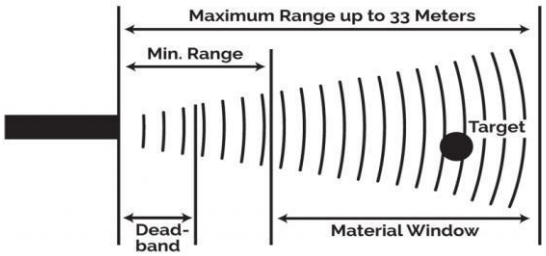

Fig.3

e) Microwave sensors: Similar to the ultrasonic sensor, a microwave sensor also works on the doppler shift principle. A microwave sensor will send high frequency microwaves in an area and will check for their reflected patterns. If the reflected pattern is changing continuously then it assumes that there is occupancy and the lighting load connected is turned on. If the reflected pattern is the same for a preset time then the sensor assumes there is no occupancy and the load is switched off. A microwave

sensor has high sensitivity as well as detection range compared to other types of sensors.

As we have seen in previous and other projects based on Automatic Light control, a wide variety of sensors can be used and it all comes down to the cost and reliability of each sensor and its implementation in the real world.

The table below shows us a few popular sensors being used in Lighting control projects:

Table.1

Type of Sensor	Range	Cost
Ultrasonic (HC-SR04)	2cm-400cm	200-300
PIR(HC-SR501)	Upto 10 meters	500
IR Proximity(GPY)	Upto 5 feet	1000
Microwave	Large	500-1000

B. Implementation using IR and PIR sensors

Pyroelectric infrared (PIR) sensors are well-known occupancy detectors. They have been widely employed for human tracking systems, due to their low cost and power consumption, small form factor and unobtrusive and privacy-preserving interaction. In particular, a dense array of PIR sensors having digital output and the modulated visibility of Fresnel lenses can provide capabilities for tracking human motion, idengifying walking subject and counting people entering or leaving the entrance of a room or building.[1]
However, the analog output signal of PIR sensors involves more aspects beyond simple people presence, including the distance of the body from the PIR sensor, the velocity of the movement (*i.e.*, direction and speed), body shape and gait (*i.e.*, a particular way or manner of walking). Thus, we can leverage discriminative features of the analog output signal of PIR sensors in order to develop various applications for indoor human tracking and localization. [1]In the paper by Jaeseok Yun et al. ,[1] PIR sensors have been used to detect the differential infrared radiation received on the receiver which is then converted into an analog voltage signal which gives us the characteristics such as distance, velocity of target. This output voltage is then classified using Bayes nets, and other machine learning classifiers to accurately determine the presence as well as the features of the person in the room. They have used an array of four PIR sensors in one module, which is then connected to a data logger to read the sensor data. Subsequently, three such modules are used in a hallway where two modules are placed on the wall facing each other and the third module is placed on the ceiling. Fig. 4 is given below which shows us the implementation of the project.

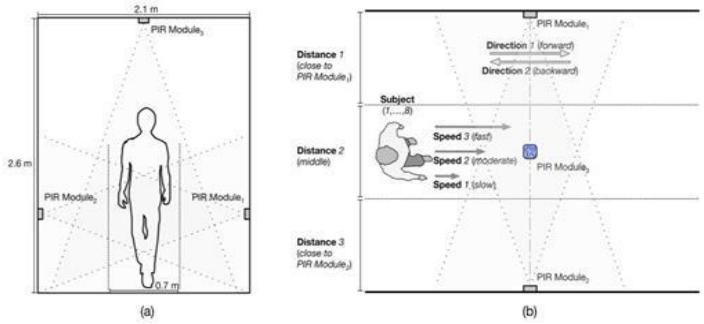

Fig.4

With this implementation, data is classified using Machine Learning algorithms and the location of the person as well as the motion of the person is determined. This method shows a 92% accuracy in successfully identifying movement and detection. It can be used to count the number of people present in the room, determine whether a person is entering or leaving a room.

The push for networking and device inter-connectivity in buildings is fueling the development of a new wave of smart devices with embedded electronics, sensors and wireless connectivity that can collect, process and exchange data. Commonly known as the Internet of Things (IoT), it encompasses, but is not limited to wireless sensor networks, home automation, mobile devices and lighting control systems. Smart lighting systems are of particular interest as they evolve from traditional lighting control by introducing autonomous control of light through feedback from integrated sensors, user data, cloud services and user input, bringing with it a host of benefits including increased energy savings, enhanced functionality, and user-centric lighting.

3 METHODOLOGY

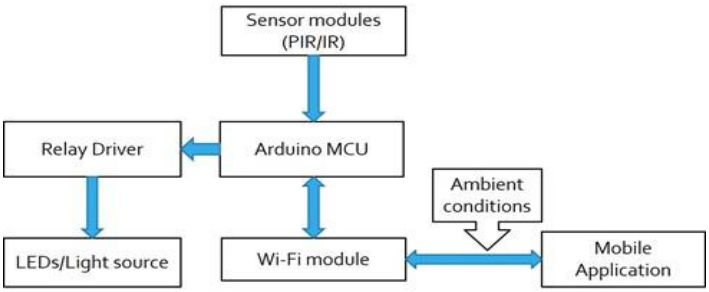

Fig.5

In Fig. 5, we see the basic block diagram of the Lighting Control system. On the input side, we have a sensor which helps us in detecting the presence of people. Such sensors are called as vacancy sensors which use various methods such as Ultrasonics, Microwave, Infrared detection which sends out waves or beams of light or sound in the surrounding area. Among the Infrared sensors, the IR proximity sensor (GP2Y0A02YK0F) by Sharp Electronics is the ideal sensor being used for this application. Doppler shift or Time of Flight which are Signal processing methods are used to determine the location of a person.

This data is then sent to the microcontroller or other embedded systems which help in processing the input data from sensors and helps us to detect a person. The Light load will turn ON when there is a person present in the respective range of the sensor. This project will be be cutting cost by using low power devices. Also, we will be implementing algorithms that detect human presence and determine whether the person is ascending or descending the flight of stairs. Sequentially turning the lights ON as the person climbs the stairs or descends. After a person steps away from a particular stair, the previous lights will fade away as the person walks away from the step. Also, the control of lighting can be implemented on any smart phone via a mobile Application which will remotely control the lighting, lighting conditions like ambient lighting and also be able to customize the light intensity, color.

4 Conclusion

This project would be implemented in a modern home automation system which would automatically control the Home Lighting system over a staircase. This project works on the principle of occupancy sensors where the Light turns ON with the presence of a person. It can save a lot of power by keeping the Lights OFF when there are no people present in the room. Also, with increasing demand of IoT systems at home and office, this project could be a great addition to existing IoT systems. Further, this project can be wirelessly connected to a central hub which would not require the use of wires between sensor and control unit. We could also achieve more than a 94% accuracy in classifying the direction, distance and speed and idengifying subjects using the features of the IR sensor. IoT is a interconnected network of home devices which include your sensors, control unit and can also be extended to a mobile or a Local Network. [6].

Also, the mobile Application can be developed using MIT App Inventor which makes it easier to interface the project to a cloud or mobile server. This extends the project to a mobile device and can alter its output based on external environmental conditions.

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