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Integrating Thermal and Digital Imaging Occupancy Detection to Achieve Daylight Harvesting

Praveen Kumar Sharma,
Assistant Professor,
Department of Electronics and Communication,
B. K. Birla Institute of Engineering & Technology,
Pilani, Rajasthan, India

Mridul Bansal,
Student (BE),
Department of Electronics and Communication Engineering,
B. K. Birla Institute of Engineering & Technology,
Pilani, Rajasthan, India

Rohan Sheoran,
Student (BE),
Department of Electronics and Communication Engineering,
B. K. Birla Institute of Engineering & Technology,
Pilani, Rajasthan, India

Abstract: **- Lighting is the largest consumable form of energy commercially. This paper presents a smart automatic light control system using thermal camera and high dynamic range CMOS sensor for daylight harvesting. This system overcomes the drawback of earlier systems that sense occupancy only on basis of motion by using combine approach of thermal camera and digital camera to detect human presence. The system algorithm involves calibration in three phases: 1) image capturing, 2) occupancy module and 3) DALI communication module. The system captures images using thermal cameras for use in occupancy module; an occupancy module involves calibration of human presence and daylight estimation using least square technique. Then, DALI communication module is involved to make the region of presence of human have targeted light level. Drawback of earlier system and technological challenges of this system are addressed in the paper.**

Keywords:**-Digital Addressable Lightning Interface (DALI), Occupancy sensors, Photo sensors, Thermal sensors, Thermal imaging.**

I. INTRODUCTION

In rapidly changing world, technology is involved so close in our life that it has now become a necessity like light, home appliances, personal computers, television, mobile phones and so many. Increase in the use of these things has in turn led to greater consumption of energy which is depleting the reserved resources at much faster than the technological development. At this rate in about 30 years or so from now on the reserved resources will vanishes. The scientists have moved to the use of renewable energy resources like solar energy, wind etc., but still the use of these resources has not penetrated much in the life of human. Energy saving by its efficient use is another way to harvest and save energy. Whether it's human carelessness or child's innocence at home, much of the time energy is wasted. Hence, there is a need of efficient control on regulation of energy.

A research has shown that lighting consumes 20-14% of total power in commercial buildings [1], and in the building sector, energy consumption is likely to increase in the coming future. Automatic lightning system can reduce the use of light significantly, upto 50% in existing building by using electronic ballasts lighting system [2]. As the demand for artificial lighting is growing, Daylight harvesting system provides a control over lighting by reducing artificial lighting when sunlight is in abundance.

A yearlong use of such technique has revealed that due to this technique 30% of the power has been saved in an office [3]. Conventional lighting control systems due to their technological drawbacks have been less used. Many systems that overcome the drawback of conventional lighting control system have been proposed earlier [4][5]. This paper proposes a system that senses the occupancy of a human and the daylight and then glows the electronic system as per requirement. The glare of this electronic lighting can be adjusted (dimmer or more) as per the daylight.

This system works in three phases, first occupancy of human is sensed, secondly according to his space of working the daylight is calibrated by estimating luminance from digital images using daylight estimating algorithm. In the last phase the lighting system is illuminated as per need.

These systems not only save energy but also have other benefits; as a research has shown that natural light is more comfortable than artificial light which helps in an increase in employee productivity [6].

II. BACKGROUND

A. Occupancy sensors and their Limitations

Conventionally, occupancy sensors used in commercial applications were Infra-red Sensors or Ultrasonic Motion Sensors. These sensors have a limitation of calibration, as the sensitivity of device to room or environment once set can't be adjusted, this makes the system less efficient in the real world situations. It has been viewed that the activity level of every person is different than other, the time delay of such sensor can't be adjusted which makes such occupancy sensor less adaptable, that's why such occupancy sensor were less popular and used less in occupancy detection.

Also, thermal sensors were used for occupancy detections like PIR sensor. These sensors have limited applicability as these sensors can detect the thermal presence of objects when they are in motion only not of still objects. So, are less reliable.

B. Lighting Control using Photo Sensor and their Limitations

The control of lighting system by sensing through Photo sensor provides a much less area to be sensed and moreover the photo sensors also depend on the position of installation of the sensor in the room. The calibration and estimation of daylight is not easy in these sensors and thus making them limitedly used in commercial applications.
Introduction of Digital Addressable Lighting Interface (DALI) [7] provides precise control over lighting system, by adjusting the luminance of electronic ballast, dimmer to various levels as needed.

Dimming of individual electronic lighting allows a development of precise energy saving system at the required region in space. The utilization of DALI based electronic lighting is difficult to implement using photo sensors and requires a need of more reliable sensing technology.

C. Image Sensor

Image sensors are CMOS sensors. Unlike, photo sensors that give single luminance signal; a CMOS sensor provides luminance as well as colour information at various points in space.
Traditionally, imaging was done using CCD technology which has limited dynamic range. Introduction of CMOS sensors has made the digital imaging more reliable because of their high dynamic range. Not only high dynamic range but a continuous interaction of image acquisition and image processing modules for motion (occupancy) detection [8], this system can further be modified for daylight estimation and control.

Thermal Imaging creates images whose pixel values represent thermal values. A thermal Imaging sensor does not give us the information of intensity. So, the alone use of thermal sensors is less convenient in automatic controlling lightning system but researches have shown its reliable use in occupancy detection [9].

III. DESCRIPTION AND DESIGN APPROACH

The approach behind the paper is to propose a daylight harvesting and automatic lighting control system, which is more versatile in use and has a better control over daylight harvesting irrespective of any illumination environment.
Our approach is to overcome the drawback occurred in earlier research [4]. The earlier system has used only CMOS sensor for occupancy detection by detecting motion of the object [4][8] or the occupancy detection using thermal cameras [9]. But both of them have some limitations and hence, limited applicability. Combining these two methods will eliminate the drawbacks of these two methods and the new approach will show more efficiency in real time systems for occupancy detection.

A. DESIGN IMPLEMENTATION

Phase 1: Image Capturing
Initially, the thermal images are captured using thermal cameras periodically. The image capturing is performed in continuous loop sequence and these captured images, are continuously sent to occupancy module. This image capturing module shall be developed in C++, interfacing the thermal camera and the occupancy module [4].

Phase 2: Occupancy module
In the received thermal images, using (thermal occupancy algorithm) background subtraction and comparing the human thermal intensity the human detection in space of vision of camera is monitored [9][10]. If the human interaction, is found then(otherwise not) the digital images using CMOS sensor are taken for detection of space of working of human, computing the difference between the last and the current frame, difference in chromatic component in terms of pixel difference and spatial difference motion is detected (motion occupancy algorithm).
After the occupancy detection in region of space the daylight is estimated using those images that are used for motion detection by luminance checking algorithm (using least square technique) [4][8]. The whole occupancy module and daylight sensing shall be developed using MATLAB [4].

Phase 3: DALI communication module
Estimating the daylight, the amount of artificial light needed is calculated using luminance checking algorithm and the electronic ballast based on DALI is communicated accordingly. This DALI communication module shall be developed in C[4]. If the need of lighting is not there or there is no human interaction the DALI system is in standby mode.

B. Advantages Of Proposed System Over Others

- The proposed approach is capable of detecting small movements of human as well as when object is still.
- Combined approach of human thermal sensing and motion detection will make the system use versatile; from office, laboratories where may a process be going on but no human presence is there, home interior where room heater may be in use but human is not

there so turning off the lighting system; only switching on when someone moves into the room.

- Comparing to conventional photo sensor and thermal sensor, the system is more versatile.

IV. IMPLEMENTATION ISSUES

- Design of minimum delay system is complex as each system thermal camera, digital sensor, DALI communication and occupancy sensor module algorithm can have some delay in real time, which in turn slows down the performance of the system.
- Need a fast and simpler algorithm for the whole system and parallel computation algorithm for motion occupancy algorithm and luminance checking algorithm to reduce the system response time.
- Use of thermal as well as CMOS digital camera has made the system an expensive measure of daylight harvesting.

V. APPLICATION AREAS

- System is helpful in making energy efficient area with less manual need.
- It's a versatile and robust system, it can be used in offices, home, school and colleges, libraries, hospitals, and laboratories.
- Commercial utilization of system apart from automatic lighting control system can be modified for other appliances control.

VI. FUTURE WORK

- An Embedded approach to proposed system can make the system compact on single hardware.
- Integration of thermal and Digital imaging into one CMOS camera can be made for cost reduction and hardware reduction of the system.
- Increasing the efficiency of the system by reducing delay time of each individual algorithm and sensor is foreseen.
- Development of software of converting RGB digital image into thermal image can further reduce the cost and enhance system response.
- Development of more inexpensive and with less user intervention and standalone system with this approach.

VII. CONCLUSION

This paper presents an approach for integrated daylight harvesting and automatic light control system with overcoming drawback in occupancy detection in earlier systems using thermal imaging with the motion detection in the system. The paper also, outlines possible application areas and design implementation issues of this system. Cost effectiveness and reducing design complexity of the system to make it more reliable commercially will be its future prime concern.

However, there is no yet development of this system, some more design complications are still not understood well. A much more research and analysis is needed for this technique to reach higher level of usefulness.

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