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Research paper



Close Loop Control of Daylight - Artificial Light Integrated System

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Abstract

The paper proposes a system to achieve optimal lighting level in a given workspace where the user can define the amount of lux level required on the workplane. A hardware-software interface model is developed with close loop control mechanism to maintain the user-defined lux level, this is achieved by continuous monitoring of the light level and dynamic control of window blinds and dimming of artificial light system. Since illuminance level in the space is influenced by daylight and artificial light, a lighting fixture with CFL connected to 1-10V dimmable HF electronic ballast and window blinds controlled by servo motor are incorporated in the workspace. Based on the feedback obtained by the LDR sensor module placed on the floor of the workspace, PID control algorithm programmed in LabVIEW actuates the servo motor and the ballast. NI-LabVIEW along with NI-USB6008DAQ card is used to monitor and control lighting.

Keywords: *Closed loop control; Daylight Integrated lighting system; Energy conservation; National Instruments LabVIEW; USB 6008 DAQ*

1. Introduction

In an energy deficient world, it is imperative to be able to utilize the available resources optimally. As per the report by Bureau of Energy Efficiency (Ministry of Power, Govt. of India) lighting loads alone consume around 28% of the total residential energy consumption. Daylight integrated with an artificial lighting system enables us to utilize the available natural light thereby reducing the amount of electrical energy consumption. Existing technologies with open loop control of blinds integrated with artificial light have been accomplished.

Harnessing renewable natural resources from the environment is attractive from the efficiency point of view, and also provides additional flexibility in system design [1]. The proposed system by Ashish Pandharipande et al.[1] operates using light and motion sensors to track illuminance and occupancy respectively along with a controller to determine and control the dimming levels of the luminaires such that the desired set-point is achieved at the light sensors.

Lighting control includes light sensors for the feedback to monitor light and meet the desired set point. In [2], a protocol is designed where dual use of LED is made first as a sensor and second act as a luminaire avoiding the use of dedicated sensor further reducing cost. The system also uses a microcontroller to output PWM pulses depending on feedback light to drive LED array to meet the desired light output.

Paper [3]-[5] addresses different control strategy MIMO (multi-input multi output), Proportional-Integral-Derivative (PID) controller optimization in greenhouse lighting control system, fuzzy based adaptive controller respectively to minimize the amount of energy usage by the lighting system. Approach is made in [6] to develop a solution of automated street light using Internet of Things (IoT) where entire system can be monitored and controlled by a central system through a web interface.

Light emitting diodes (LEDs), with their ability to produce tunable light spectrums, present a significant opportunity to improve on existing lighting systems [7], a novel algorithm for a closed-loop control with feedback from a spectral sensor, which allows the light output spectrum to converge toward the desired spectrum is implemented. Traditional street lamps often use high-pressure sodium vapor lamp [8]. Design is made to replace these traditional lamps with series of white LED lamps by controlling ON and OFF using PWM signals, also integrated with control of brightness and key lock function.

An interior lighting control system adopted could be an effective solution to reduce the amount of the electrical energy used for the medium and large tertiary and commercial buildings. L. Parise et.al, in [9], discussed a case study of the interior lighting control system installed into a university classroom. The control system presented is equipped with illuminance sensors that detect the level of illuminance in the given area. The paper also presented a series of measurements conducted on the field and simulations by software with different lighting scenarios.

Adjusting the modulation of the flux emitted by the lamps was done in order to guarantee, in every scenario, the minimum average value of illuminance required by standards. This paper [10] proposes a decentralized system to control lighting fixtures which are spectrally tunable and are embedded with the multi-channel color sensor. The solution proposed determines the feedback gains automatically using individual sensor measurement units without the requirement of any communication between fixtures.

In [11], a LabVIEW-based DC servo motor control system is designed. System software is developed by using LabVIEW program. DC servo motor will rotate according to demand, by using NI Data Acquisition (DAQ) Board, LabVIEW Real -Time application software, and The PCI extensions for Instrumentation (PXI) platform for LabVIEW Real-Time. Codes are developed in the LabVIEW Real-Time Development System and real-time codes are downloaded to run embedded applications on a PXI. Servo systems are generally controlled by conventional PID controllers

Paper [12] proposes an automatic sliding window whose position depends on the light level present in the workspace. LDR is used to sense the light falling on the window, microcontroller receives

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the level of intensity from the LDR and sends an appropriate signal to the motor driver, which then steers the stepper motor to one of two desired states. The first state is achieved when ambient light is present at the face of the window and the blinds are fully open. The second state of the system is when the intensity of light drops below a certain value and the blinds are closed.

2. Proposed System

The objective of the paper is to present the developed close loop controlled hardware-software interface model to maintain user-defined lux level in a given workspace by an integrated system of daylight and artificial light. NI LabVIEW along with NI – USB 6008 DAQ card is used to monitor and control the lighting system. This is integrated with blind control to regulate the amount of daylight.
To get an insight of daylight-artificial light integrated system, closed-loop control of standalone artificial lighting system and standalone daylighting system was initially realized.

2.1. Block diagram

Standalone system of closed loop artificial light control system and daylight control system is quiet easy to realize.

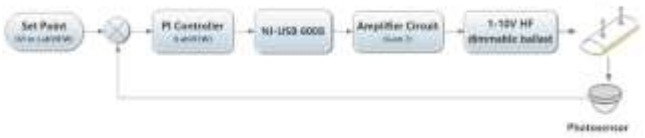

Fig. 1(a): Closed loop artificial light control system

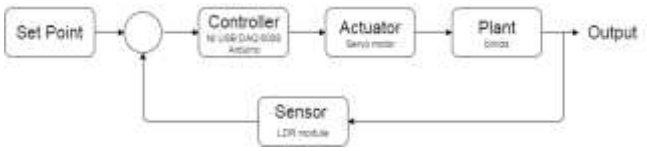

Fig. 1(b): Closed loop daylight control system

From Figure 1(a) and 1(b), it must be noted that both closed loop systems consider light output as a process variable. The controller in a closed loop control system computes the actuating signal to reduce the error between the set point and plant output. Amplifier circuit and actuator in artificial light control system and daylight control system respectively, play a very important role. They ensure that the controller output suitably influences the plant output, i.e., light. During the development of the integrating system, the controller algorithm should give priority to daylight harvesting.

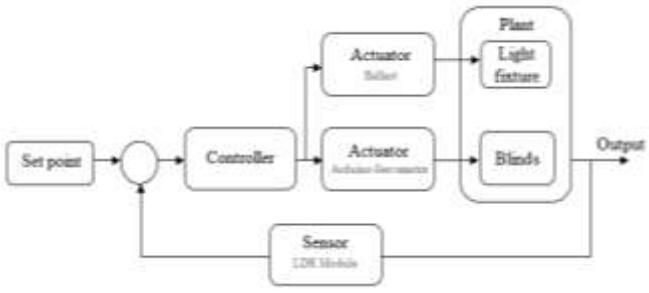

Fig. 2: Proposed integrated lighting system

Figure 2 gives a bird's view of the proposed integrated system. A sensor is used to detect the lux level in the workspace which is compared with the user-defined lux level which is the setpoint. The obtained error signal is given to the controller. The controller output signal is given to the actuator and amplifier circuit that drives the servomotor and ballast respectively, thereby controlling the light fixture and blinds correspondingly to achieve the set point.

3. Hardware Implementation

The setup comprises of a 1m (L) x 1m (W) x 1.25m (H) wooden box which serves as the workspace. The lighting fixture with CFLs connected to 1-10V dimmable HF electronic ballast is mounted on the ceiling of the box, and its brightness is controlled by the DC input to the ballast. A metal halide lamp is used to replicate daylight. The blinds are mounted on one side of the box. The movement of the blinds is controlled by the servo motor which is coupled to the shaft of the blinds. The sensor module is placed on the center of the floor inside the box. The sensor continuously monitors the light level inside the box whose output is the process variable and the feedback to the system. Based on the feedback obtained by the sensors and set point, PID control algorithm programmed in LABVIEW generates the control output signals. NI USB 6008 DAQ is used to interface NI-LabVIEW and the actuators of the plant. This algorithm gives first priority to harness daylight to achieve the desired set value of lux level. Second priority will be with the dimming of artificial light along with daylight and then with artificial light alone.

3.1. Workspace

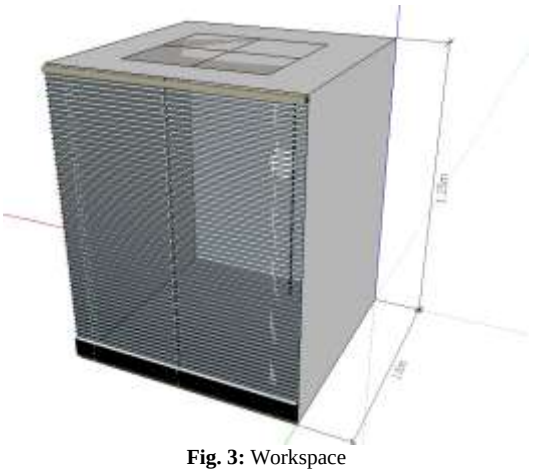

Fig. 3: Workspace

The dimensions of the plywood box are 1m (L) x 1m (W) x 1.25m (H) as shown in Figure 3. One side of the box is kept open to mount the blinds. The fixture is mounted on the ceiling, and the sensor is placed on the floor of the box.

3.2. NI USB 6008 DAQ card

The DAQ card is capable of acquiring and generating signals of 0-5V via LabVIEW interface. It acquires signal from the sensor module which is an input to the PID controller. The output of the PID controller is given to the actuators via the DAQ card thereby actuating servo motor and the ballast.

3.3. LDR sensor module

This module uses sensor LM393. It senses the light level in the workspace and gives the corresponding output in terms of voltage. The voltage signal generated by the sensor is inversely proportional to the intensity of light.

3.4. Servo motor

The venetian blind is selected for this hardware setup, as it was found relatively easier to control. MG 946R servo motor is used to control the position of the blind. This motor needs to be rotated in two directions, i.e., 0 to 90 degree (opening of the blinds) and -90 to 0 degree (closing of blinds). The servomotor operates on PWM signals which are generated by an Arduino based on the control output obtained from the LabVIEW.

3.5. Light Fixture

To incorporate the artificial light in the box, a twin CFL light fixture is used. The light fixture has 1-10V dimmable HF electronic ballast connected to it. Using this ballast, the light output of the fixture is controlled. The DAQ card has to send the actuating signals to the ballast of the CFL fixture.

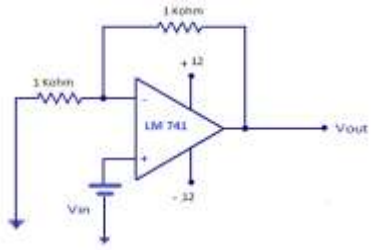

Fig. 4: Non-inverting amplifier circuit

But the NI-USB 6008 DAQ card is capable of generating 0-5V and the operating range of dimmable ballast of the CFL fixture is 1-10V. So a non-inverting amplifier circuit is designed with a gain of 2 as shown in Figure 4. The amplifier circuit amplifies the DAQ input by a factor of 2 which is given as input to the 1-10V HF dimmable ballast.

3.6. LabVIEW virtual instrument

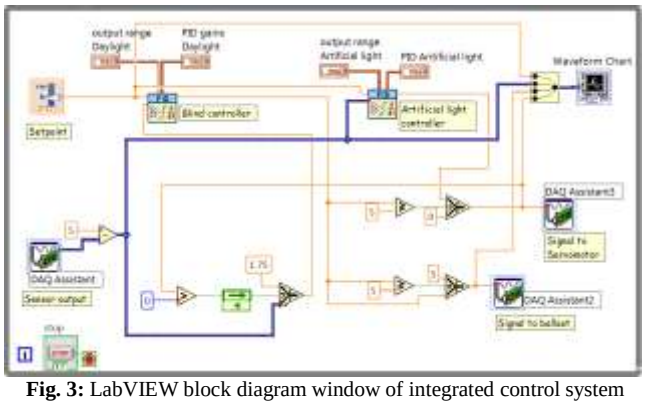

Fig. 3: LabVIEW block diagram window of integrated control system

The VI developed in LabVIEW has two PID blocks as shown in Figure 3. The first PID block is for blind control and the second PID block is for the artificial light control. The user can define a desired light level in the room by entering a corresponding voltage level from 0-5V. This is the set point. For both the PID blocks, the set point is the same and the process variable is the sensor output i.e., actual lighting level in the work plane.

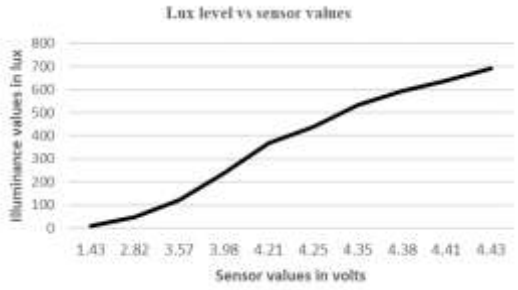

Fig. 4: Lux level versus sensor output

The voltage value corresponding to the process variable generated by the sensor is inversely proportional to amount of light falling on the sensor. This makes computation of actuating signal tedious using PID algorithm in LabVIEW. The issue is addressed by subtracting sensor output value from the maximum sensor output value (5V), which will result in direct relation between light output and sensor output as shown in Figure 4.

There are three DAQ assistants in the VI. The first DAQ assistant acquires signal from the sensor. The second DAQ assistant gives actuating signals to the servo motor for blind control and the third DAQ assistant gives actuating signals to the ballast for artificial light control.

The controller algorithm set up in the block diagram window as shown in Figure 3 can be analysed using following cases:

- Case1: When user sets a desired light level, the output of the first PID block is compared with 5V, if it is less than 5V this means that the blinds alone are sufficient to achieve the set point. The output of the first PID block drives the servo motor to control the blinds. Artificial light control is not needed and input to the ballast is zero.
- Case 2: If the output of the first PID block is more than 5V, this means that the blinds alone are not sufficient to achieve the set point. Both natural light and artificial light source is required. The output of the first PID block drives the servo motor to open the blinds completely. Output of the second PID block is given as the input to the ballast. As the artificial light starts operating, the light level inside the workspace increases, as a result the sensor output changes. For the given set point, in order to keep blinds in constant open position, the sensor output (process variable) to the first PID block should not change. To implement the same as the input to the ballast becomes greater than zero, the process variable to the first PID block is kept constant.
- Case 3: After case 2, when the user reduces the set point to a value which is possible to achieve by dimming artificial lights, the process variable to the first PID block is unlatched and Case 1 is followed.

4. Result Analysis

The stand-alone artificial light control algorithm was first realized using LabVIEW and the hardware setup. The punctual working of the system confirmed the accuracy of the algorithm.

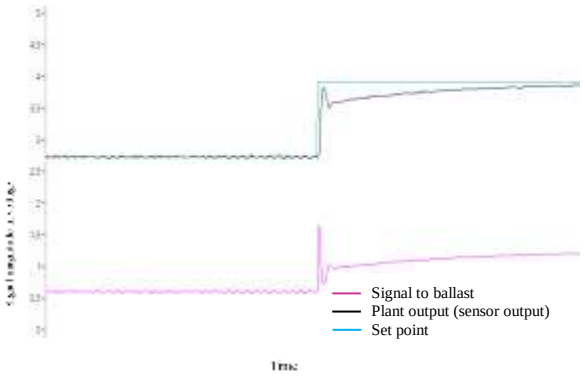

Fig. 5: Results of artificial light control system

It is observed from Figure 5 that as long as the set point is at fixed value of 2.75V, the plant output follows the set point satisfactorily. When the set point is changed from 2.75V to 4V, the signal to the ballast undergoes a transient and eventually settles with zero error.

Working of the prototype was analysed by considering three set point levels - low (~20 lux), medium (~200 lux) and high (~400 lux) by replicating cloudy daylight, sunny daylight and night scenario outside the plywood box. High intensity distribution (HID) metal halide lamp is positioned at a certain distance from the plywood box to replicate daylight influencing the workplane. By varying the distance between plywood box and HID lamp, illuminance on the workplane can be varied; thus replicating cloudy and sunny daylight conditions. The entire set up is kept in a dark room to avoid impact of actual daylight and artificial light outside the plywood box.

Table 1: Summary of blind position and dimming of artificial light source for different set points and daylight conditions

Type of the day	Set Point	Blinds position	Dimming of fixture
Sunny Day	Low	Completely closed	Maximum
	Medium	Partially open	Maximum
	High	Completely open	Maximum
Cloudy Day	Low	Completely closed	Maximum
	Medium	Completely open	Partial
	High	Completely open	Minimum
Night	Low	Completely open	Maximum
	Medium	Completely open	Partial
	High	Completely open	Minimum

As summarized in table 1, it was observed that, when the desired light level is low, blinds close completely and artificial light source is ON at maximum dimming (less light output from the fixture). During second case (medium set point) blinds partially open; thus giving priority to daylight for achieving desired lux level. For the third case (high set point) blinds fully open and artificial light source is also triggered to put out more light. However, when HID lamp is turned OFF (to replicate night) and set point is high, the desired light level is achieved by artificial light source alone and is at its maximum intensity. The different desired illuminance levels are achieved by varying the intensity of the light source alone.

User interface is created using LabVIEW to adjust set point and controller gains. A graph is added to dynamically visualise change in set point, actuating signals to blind and artificial light source along with sensor output.



Fig. 6(a): Image of the hardware setup showing fully opened blinds and partial dimming of artificial light source for cloudy day and medium set point

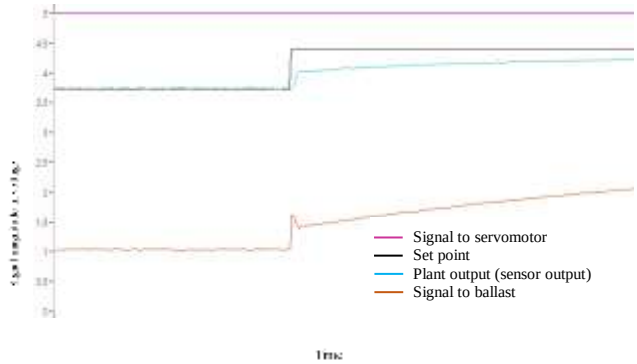

Fig. 6(b): Setpoint and sensor signals along with actuating signals of blind and artificial light source obtained from LabVIEW

Fig. 6(a) and Fig. 6(b) show hardware setup and various signal waveforms respectively, for cloudy day and medium set point.

It can be observed from Fig. 6(b) that the for the user's set point, opening the blinds completely did not achieve the desired lux level. Thus actuating signal of blinds gets saturated at value 5V, indicating the blinds are completely open. When a step change of the set-point to a higher value is triggered, PID controller accordingly increases the magnitude of the signal to the ballast to ensure process variable catches up the set point by gradually increasing the light output of the artificial fixture.

5. Conclusion

A prototype of closed loop controlled daylight - artificial light integrated system to maintain user-defined lux level in a given workspace was developed successfully with the help of NI LabVIEW and NI USB 6008 DAQ card. This concept of an automated lighting system having daylight integration not only boosts user comfort but also helps in minimizing electrical energy consumption hence contributing towards the economy of the establishment.

References

[1] Ashish Pandharipande and Shuai Li, *"Light Harvesting Wireless Sensors for Indoor Lighting Control"*, IEEE sensors Journal, Volume 13, No. 12, December 2013, p. no. 4599-4606

[2] Ashish Pandharipande and Shuai Li, *"Illumination and light sensing for daylight adaptation with an LED array: Proof-of-principle"*, IEEE sensors Journal, Volume 13, No. 12, December 2013, p. no. 6081-6086

[3] S. Attarchi, M. Moallem S, *"Set-point control of LED luminaires for daylight harvesting"*, 2017 5th International Conference on Control, Instrumentation, and Automation (ICCIA), p. no. 244-248

[4] Mehdi Mahdavian, Naremon Wattanapongsakorn, *"Optimizing PID controller tuning for greenhouse lighting control system by varying number of objectives"*, International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON), May 2014

[5] Bhavana Pillai, Krishnapriya T. Nair, *"Intelligent adaptive controller for DC servomotor position control in LabVIEW"*, International Conference on Intelligent Computing Instrumentation and Control Technologies (ICICICT), July 2017

[6] Fathima Dheena P. P, Greema S Raj, Gopika Dutt, Vinila Jinny S, *"IOT Based Smart Street Light Management System"*, Proceedings of IEEE International Conference on Circuits and Systems (ICCS 2017), December 2017

[7] Ivan Chew, Vineeth Kalavally, Chee Pin Tan, Jussi Parkkinen, *"A Spectrally Tunable Smart LED Lighting System With Closed-Loop Control"*, IEEE Sensors Journal, Vol. 16, No. 11, June 2016

[8] Su Zhihua, *"Design of White Light LED Lighting Control System"*, 2018 International Conference on Intelligent Transportation, Big Data & Smart City, Jan 2018

[9] L. Parise, F. Lamonaca, D. L. Carni, *"Interior lighting control system: a practical case using daylight harvesting control strategy"*, IEEE 15th International Conference on Environment and Electrical Engineering (EEEIC), June 2015

[10] Sina Afshari, Sandipan Mishra, *"A Plug-and-Play Realization of Decentralized Feedback Control for Smart Lighting Systems"*, IEEE Transactions on Control Systems Technology, Vol. 24, No. 4, July 2016

[11] Jianying Liu, Pengiu Zhang, Fei Wang, *"Real –Time DC Servo Motor Position Control by PID Controllers Using Labview"*, International Conference on Intelligent Human-Machine Systems and Cybernetics, China, August 2009, p. no. 206-209.

[12] Abhishek Jindal, Abhishek Kr. Pandey, Amit Kr. Chaturvedi, Manish Kr. Gupta, *"Automatic Room Light Intensity Based Window Blind Control System"*, International Journal of Engineering Research & Management Technology, Volume 1, Issue 2, 2014, p.no. 268-271.