I dedicate this thesis to my father ***Late Bimal Kumar Majumdar*** and my family whose love, unselfish support and guidance enhance me to reach to the summit.

-*Pickon Majumdar*

AN INTRODUCTION OF IMAGE ANALYSIS SYSTEM FOR INTELLIGENT LIGHTING CONTROL

A thesis submitted toward partial fulfilment

of the requirements for the degree of

Master of Technology in

Illumination Technology and Design

Jadavpur University

Submitted by

PICKON MAJUMDAR

Examination Roll No.: M6ILT19019

Class Roll No. : 101531101003

Under the guidance of

Dr. KAMALIKA GHOSH
&
Mr. DEBSHIS RAUL

School of Illumination Science, Engineering and Design

Jadavpur University

Course affiliated to

Faculty of Engineering and Technology

Jadavpur University

Kolkata-700032

India

May, 2019

M.Tech. (Illumination Technology and Design)

Course affiliated to

Faculty of Engineering and Technology

Jadavpur University

Kolkata, India

CERTIFICATE OF RECOMMENDATION

This is to certify that the thesis entitled **"AN INTRODUCTION OF IMAGE ANALYSIS SYSTEM FOR INTELLIGENT LIGHTING CONTROL"** is a bonafide work carried out by **PICKON MAJUMDAR, Examination Roll No.: M6ILT19019, Class Roll No. : 101531101003,** under our supervision and guidance for partial fulfilment of the requirement of **M.Tech. (Illumination Technology and Design)** in School of Illumination Science, Engineering and Design, during the academic session 2018-2019.

THESIS ADVISOR

Dr. Kamalika Ghosh,

Assistant Professor,
SISED, Jadavpur University,

Kolkata-700 032

THESIS CO-ADVISOR

Mr. Debashis Raul

Faculty,
SISED, Jadavpur University

Kolkata-700 032

DIRECTOR

Dr. Kamalika Ghosh

School of Illumination Science, Engineering and Design,

Jadavpur University,

Kolkata-700 032.

DEAN –FISLM

Dr. Pankaj Kumar Roy

Jadavpur University,

Kolkata-700 032.

M.Tech. (Illumination Technology and Design)

Course affiliated to

Faculty of Engineering and Technology

Jadavpur University

Kolkata, India

CERTIFICATE OF APPROVAL

This foregoing thesis is hereby approved as a credible study of an engineering subject carried out and presented **PICKON MAJUMDAR, Examination Roll No.: M6ILT19019, Class Roll No. : 101531101003,** in a manner satisfactorily to warranty its acceptance as a prerequisite to the degree for which it has been submitted. It is understood that by this approval the undersigned do not endorse or approve any statement made or opinion expressed or conclusion drawn therein but approve the thesis only for purpose for which it has been submitted.

Committee of final examination for evaluation of Thesis

DECLARATION OF ORIGINALITY AND COMPLIANCE OF ACADEMIC ETHICS

I hereby declare that this thesis contains literature survey and original research work by the undersigned candidate, as part of his M.Tech**. (Illumination Technology and Design)** studies during academic session 2018-2019.

All information in this document has been obtained and presented in accordance with academic rules and ethical conduct.

I also declare that, as required by this rules and conduct, I have fully cited and referred all material and results that are not original to this work.

NAME: PICKON MAJUMDAR

EXAMINATION ROLL NUMBER: M6ILT19019

THESIS TITLE: AN INTRODUCTION OF IMAGE ANALYSIS SYSTEM FOR INTELLIGENT LIGHTING CONTROL

SIGNATURE: DATE:

ACKNOWLEDGEMENT

Foremost I would like to express my sincere, deep sense of gratitude and indebtedness to my project guide and advisor **Dr. Kamalika Ghosh, Assistant Professor of School of Illumination Science, Engineering and Design (SISED), Jadavpur University**, for the continuous support of my thesis work, for her patience, motivation, enthusiasm, invaluable guidance and supervision.

Besides my advisor, I am highly beholden to my superiors, **Mr. Debashis Raul, Faculty, SISED, Jadavpur University,** for their insightful advices, incomparable guidance, and supervision and for enlightening me the first glance of my thesis work.

I would like to acknowledge my sincere thanks to my friends Manjulika Bera, Nabayan Chaudhury and Sugata Bhattacharyya, Jadavpur University, for providing me the opportunity to carry out my thesis work in Jadavpur University.

Finally, this thesis would not have been possible without the confidence, endurance and support of my classmates with whom I share tons of fond memories. They are always been a source of inspiration and encouragement.

Date:

Place: (PICKON MAJUMDAR)

Contents

Page No.

Chapter 5: Methodology of Proposed Model

Chapter 8: Conclusion and Future Scope

References

Chapter 1:

Aims and Objectives

1.1 Aims and Objectives of study

Of late, as high-efficient, long-lifespan LED lightings were developed recently in combination with LED semiconductor and IT technologies for digital control, it has become possible to vary the lighting environments. As a result, lighting systems that maximize the functional features of space by controlling the optical characteristics of LED, such as illuminance and colour temperature, by using in wireless sensor networks.

With the variation of daylight, the artificial light may be controlled by capturing image through Web in real time. By Performing Image processing & histogram of image & finding RGB value of respective image and region of interest (ROI) how this system can control the artificial light in real time using wireless network that is described throughout the study. Artificial light control according to threshold value by ROI data analysis & occupant detection and recognition has been employed to achieve energy saving activity in this work.

On the other hand, that lighting systems are designed for the occupants' health and comfort as well as functional aspects of space. According to existing researches, changes in daily, monthly, and seasonal cycles in line with the earth's rotation and revolution around the sun create certain rhythms in living things including humans. As such, natural light is a crucial factor for living creatures and functions as an important environmental factor that affects humans' visual impact. Hence, to create a healthy and comfortable lighting environments in interior spaces, as well as for energy efficient purpose, it is necessary to represent daylight integrated artificial lighting methods. So, daylight linked control is required for commercial space which takes advantage of naturally available lights. The artificial electric lights can automatically be dimmed down by the controller or turned off when enough natural light is entering into the workspace. Occupant detection is occurred by using camera that eventually energy saving process which has been taken. It is also applicable for safety & security purpose for those interior workspace. In comparison with previous control techniques this proposed system can perform versatile activities and can take the decision automatically and respond accordingly.

Instead of photo sensor or daylight sensors or phototransistor or photo resistor, a camera is used as image sensor which can find the region of interest for particular work-plane and provide information of light level for this particular region of interest of that work-plane. The sensor used here also facilitates with temperature sensor and gas sensor to monitor the internal thermal and humidity data which is also useful to control both lighting and cooling loads according to set threshold value, if required. Using deep neural network (DNN), same camera is used for occupant detection. That camera can replace the installation of high cost occupancy sensor for energy saving.

Chapter 2:
Daylight Integration

2.1 Artificial Light as LED

In early days, artificial lights such as incandescent lamps, fluorescent lamps were used. But now a days, after invention of LED technology ,in most areas LEDs are used as they are having long life, energy efficient in comparison with other artificial lamps and compatible with dimming methods such as DALI(Digitally Addressable Lighting Interface) that is most popular method in this era, easy incorporation into electric systems and so many.

2.2 Daylight and Daylight Integration

Daylight is the combination of all direct and indirect sunlight during the daytime. This includes direct sunlight, diffuse sky radiation or both of these reflected by the earth and terrestrial objects, like buildings. Sunlight scattered or reflected by objects in outer space that is, beyond the earth and atmosphere is generally not considered daylight. Thus, daylight excludes moonlight, despite it being indirect sunlight. Daytime is the period of time each day when daylight occurs. Daylight occurs as earth rotates, and either side on which the Sun shines is considered daylight [25,26].

2.2.1 Daylighting

Daylighting is required to enlighten an indoor space with openings such as windows and skylights that allow daylight into the building. Artificial lighting energy use can be minimized by using daylighting with some procedures in indoors [25,26]. The amount of daylight received in an internal space can be analysed by measuring illuminance on a grid or undertaking a daylight factor in calculation. Computer programs such as Radiance allows us to quickly calculate benefits of a particular design.

2.2.2 Daylight Factor

The amount of daylight received into an indoor space or room is defined as a daylight factor, being the ratio between the measured internal (E_i) and external light (E_0) levels.

$$\%\, Daylight\ factor = \frac{E_i}{E_o} * 100$$

2.2.3 Daylight Integration with Artificial Light

Artificial lighting energy use can be reduced by simply installing fewer electric lights because daylight is present, or by dimming or switching electric lights automatically in response to the presence of daylight, a process known as daylight harvesting. To avoid over illumination, energy saving we use the integration of daylight with artificial lights as per requirement of recommended lux level into indoor space according to penetration of Useful Daylight Interface (UDI) into indoor space [25,26].

Chapter 3:
Existing and Proposed System

3.1 Literature Review

Some papers helped to develop the concept of daylight integration with artificial lights.

3.1.1 Earlier Studies-1

‘A smart lighting control to save energy’

-By Luigi Martinaro, University of Rome Sapienza, DIAEE, The 6 th IEEE International Conference on Intelligent Data Acquisition and Advanced Computing Systems, Technology and Application

- **Methodology Adopted:**

The paper concentrates on identifying the integrated lighting control strategy in working rooms, taking into consideration the available daylight and the actual occupancy of persons in each zone of the room.

- **Outcome:**

In Europe the amount of the electrical energy used in illuminating the interiors of medium and large buildings is considerable of about 40%. Energy saving actions are followed in two basic direction. These are: efficiency and effectiveness. Efficiency is done with performing equipment (lamps, control gear, etc.) and by utilization of improved lighting design practices (localised task lighting systems) and effectiveness is done by improvements in lighting control systems to avoid energy waste and by adopting a technical building management system (maintenance and metering). By controlling the lighting in such a way that the lighting level is always accurately matched to the actual need allows to save on the energy costs and to improve the human comfort and efficiency. Establishing an integrated lighting control concept is a very important part of the lighting design.

An area of further studies can be deliberated by taking into account the global and diffused efficacy of daylighting.

- **Area of Further Studies:**

Adapting smart lighting control systems allow to save the energy consumed for lighting up to 25% in industrial and commercial and up to 45% in tertiary and educational. This paper does not focus on methodology by which the further reduction of energy consumption is adapted.

3.1.2 Earlier Studies-2

'A statistical approach for the evaluation of thermal and visual comfort in free-running buildings'

-By Fabio Sicurella a, Gianpiero Evolaa, Etienne Wurtzb a, LEPMI – CNRS, 73376 Le Bourget-Du-Lac, France b LEB – CEA – INES, 73376 Le Bourget-Du-Lac, France, Energy and Buildings 47 (2012) 402–410.

- **Methodology Adopted:**

In the present work, an approach based on simple indicators calculated on a statistical basis will be presented; it can be useful for the simultaneous evaluation of the indoor thermal and visual comfort on a more comprehensive perspective, and it can be applied in any building energy analysis where a comparison between different solutions or strategies is required.

- **Conclusion and Area of Further Studies:**

In the present work an innovative statistical approach for the combined evaluation of thermal and visual comfort in buildings is presented with an approach is based on the introduction of simple indicators that account for both the duration and the intensity of the potential discomfort. The statistical indicators can be used either separately or properly combined in order to obtain useful information about simultaneous effects of building solution for visual and thermal comfort.

This simplified approach requires input data like, only the hourly operative temperature and the hourly average daylight illuminance to manage a visual and thermal comfort analysis. It may have a large application since it can be used whenever an effective and quick comparison among several technical solutions has to be made. This can happen during the design phase for both new and existing buildings.

- **Research Gap:**

If the research can be done further in small segment of time apart from hourly basis, the minute change can be reflected in statistical analysis.

3.1.3 Earlier Studies-3

'Building form and environmental performance: archetypes, analysis and an arid climate'

-By Carlo Ratti, Dana Raydan, Koen Steemers: Department of Architecture, The Martin Centre for Architectural and Urban Studies, University of Cambridge, 6 Chaucer Road, Cambridge CB2 2EB, UK, Energy and Buildings 35 (2003) 49–59

- **Methodology Adopted:**

They selected six simplified urban arrays based on archetypal building forms and image processing took place. Then they analysed and compared the archetypes in terms of built potential and day lighting criteria, eventually reaching the conclusion that courtyards perform best.

- **Conclusion and Area of Further Studies:**

As demonstrated in the above case study, the specification of the climatic zone within which any environmental research on urban form is taking place is fundamental in the analysis of results. The case study demonstrated that the courtyard configuration showed better response through the calculated environmental variables (surface to volume ratio, shadow density, daylight distribution, sky view factor).

- **Research Gap:**

The paper does not tell about the detailing of the sky condition.

3.1.4 Earlier Studies-4

'Predicting lighting energy use under daylight linked lighting controls'

-By Paul J. Littlefair, Building Research Establishment Ltd, Garston, Watford WD2 7JR, UK,Building Research & Information,ISSN: 0961-3218.

- **Methodology Adopted:**

I. Differential Switching Control

The differential control has two switching illuminances; one (E_{off}) at which the lights are switched off, and another, lower, illuminance (E_{on}) at which the lights are switched on. **Figure 3.1**illustrates the operation of the control in response to changing daylight illuminances. Before the lights can be switched on then off in succession, the daylight illuminance at the control point has to traverse the whole of the illuminance differential between E_{on}andE_{off}. Thus it is likely that annoying rapid switching on and off of the lights would be reduced. Another advantage claimed for the differential switching control is that it makes switching off less obtrusive, as it is performed when daylight represents a higher proportion of the illuminance to which the eye is adapted.

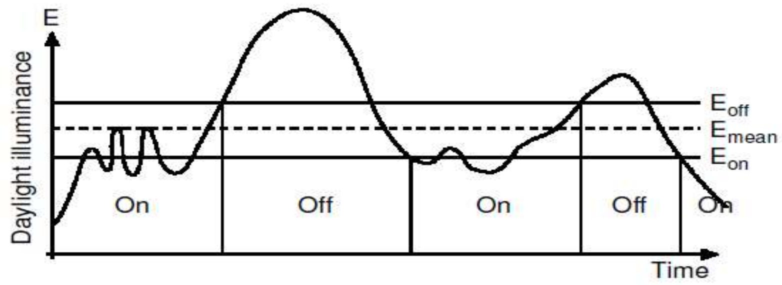


Figure-3.1: Operation of a Differential Switching Photo-electric Control as Daylight Illuminance at the Control Point Changes

This approach gives a close match to annual energy savings but can overestimate savings in the morning when illuminances are rising, and underestimate them in the afternoon when illuminances are dropping. Use the hourly average illuminances to simulate switching.

ii. Photoelectric Switching with Time Delay

Another way to reduce the frequency of switching operations is to introduce a time delay into the process. No delay in switching on is considered here because that could lead to illuminances falling well below desired levels. Of the two different control strategies, a daylight linked time delay (waiting for the daylight illuminance to exceed the target value for *n* minutes) gives significantly less switching. **Figure-3.2** which shows the number of switching operations when the variation of daylight under real skies shows smooth changes in illuminance interspersed with rapid fluctuations. Under these rapidly fluctuating conditions a daylight linked time delay would inhibit switching completely.

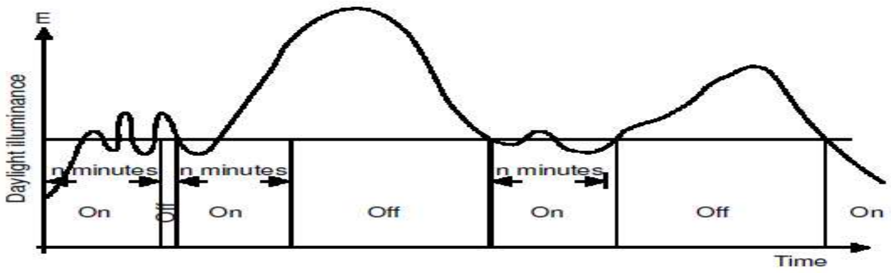


Figure-3.2: Operation of a Switching Linked Time Delay Photoelectric Control as Daylight Illumination at the Control Point Changes.

- **Conclusion and Area of Further Studies:**

  Here it was presented to quantify the savings of various kinds of photoelectric and manual controls. Sky condition and environmental condition in interior spaces for commercial building also affect. On the other hand, the dynamic variation of daylight throughout the day also vary the temperature. So heat balance is required to provide thermal comfort to occupants as for the change of solar radiation. Monitoring weather condition is necessitated as cloud condition sun position is changing. So controlling the electric light in presence or absence of daylight is the challenging attempt. On the other hand, internal illuminance may be varied based on the presence or absence of an occupant.

- **Research Gap:**

  The paper does not tell about the detailing of the hardware description.

3.2 Energy Saving Actions are required to Enhance Efficiency and Effectiveness

For illuminating the interiors of medium and large buildings, considerable amount of the electrical energy used. So, by installing more improved performing equipment (lamps, control gear, etc.) and by utilization of improved lighting design practices for localised task area. Some lighting control systems are installed to avoid energy waste. By controlling the lighting in such a way that the lighting level is always accurately matched to the actual need allows to save on the energy costs and to improve the human comfort and efficiency. Here a newly integrated lighting control concept is established which plays an important role in lighting design process. Directly controlling and managing energy consumption it is possible to reach high effectiveness in energy management.

Intelligent management of energy efficiency, optimizing of costs and quality, requires imagination that can reveal opportunities, expose risks and support strategic decision making.

To adopt smart lighting control systems allows to save the energy consumed for lighting up to 25% in industrial and commercial and up to 45% in tertiary and educational. The *effectiveness* could be improved by adopting lighting automatic control systems to avoid energy waste for unoccupied and daylight hours.

For a lighting system, the author suggests the following characterisations:

- **Control Techniques:** How the adjustment is made of luminous flux.
- **Control Actions:** How the control technique is implemented.
- **Control Modes:** How the control action works.
- **Control Strategies:** What purpose it must pursue the control system.

Here, the main strategies of the Smart Lighting Control could be classified in:

- **Zoning:** To subdivide the classroom in different zones with different uses (i.e. corridor zone, working zone, hardworking zone, etc.) and with different lux values.
- **Scheduling:** To schedule the general on/off switching by a remote controller using time signals.
- **Daylighting:** To regulate the electric lights according to the real available daylighting in the room.
- **Occupancy:** To switch on/off automatically the lights according to the real presence of persons.
- **Luminance control:** To regulate the electric lights in order to guarantee continuously a prospected illuminance value on the task plane, compensating for light losses due to lumen depreciation.
- **Remoting:** To monitor and control the lighting system by remote supervisory system.
- **Integrating:** To integrate the lighting control system with HVAC (heating, ventilation, air conditioned) control and with solar blinds.
- **Metering:** To meter continuously energy consumptions.

Taking into account the BMS (BACS and TBM). By adopting electronic control gear and dimming mode, useful for new installations or deep restorations. The control could be organized according to the HBES standards (EN 50110) adopting a KNX system. HBES systems are with "distributed intelligence" as each device is properly programmed, it has an "address" unique in the whole system needed to be recognized as the recipient of the message, scheduled to make an accurate function, according to an expected mode, with another component of the system established by the program. The system will consist of Power supply KNX system and other KNX devices, input devices as interfaces of sensors and KNX system and output device (actuators) to switch the luminaries; occupancy sensors and daylighting sensors interfaced with the KNX system using the input devices. The line between KNX devices is provided by a simple twisted pair cable.

The illuminance level in a room or in a zone of a room can be controlled by one or a combination of the following control techniques:

- **Switching Mode:** The light output of an installation can be adjusted step-by-step to the required level. The control could be arranged by switching of single luminaires, group of luminaire, or individual lamps in a multi-lamp luminaire. Switching individual lamps by remotely interruption of hot conductors (by switch, relays or BUS actuators), could have the consequence to complicate excessively the wiring and the components.
- **Dimming Mode:** The light output is continuously variable. Present-day dimmers use phase-control circuits to vary the conducting period of each half-cycle of lamp current. Such circuits are virtually free from power losses.

3.3 Lighting Design Parameters

- The parameters are Lighting Level, Luminance Distribution, Uniformity, Direction of incidence of Light and Shadow Effect, Correlated Colour temperature, Glare and Colour Rendering Index, considered as generalised Lighting Design Parameters for any kind of indoor based design.
- **a) Lighting Level ($\overline{E_m}$):** The lighting level generated by a lighting installation is usually qualified by the illuminance produced on specific working plane. The lighting level is termed as Illuminance and the illuminance is supposed to fall by an installation, which effects the performance of the tasks and the colour appearance of the working plane. It is measured in Lux or lx.
- **b) Luminance Distribution:** The luminance distribution should be regarded as complementary to the design on the illuminance in the Educational Facility interior. The luminance distribution in the field of view controls the adaptation level of the eyes, which is related to task visibility. Luminance distribution should be taken into account by avoiding the glare.
- **c) Uniformity (U_o):** The term uniformity for indoor Educational Facility lighting design defines the ratio of minimum illuminance value measured under the different grid points. According to the standards the task shall be illuminated as uniformly as possible. The uniformity of the task area and the immediate surrounding areas shall not be less than the specified values as per EN 12464-1:2002 (E), shown in **Table-3.1.**It is the ratio of minimum illuminance level ($\overline{E_{min}}$) to average illuminance level ($\overline{E_m}$).

Table-3.1: Recommended Uniformity as per EN 12464-1:2002(E)

Task Illuminance(Lux)	Illuminance of Immediate Surrounding Area (Lux)
≥750	500
500	300
300	200
≤200	E_{task}
Uniformity: ≥ 0.7	Uniformity: ≥ 0.5

3.4 Proposed System

For visual adaptivity ,energy savings, maintaining recommended illuminance in interior spaces during daylight hours, here, a different daylight integrated lighting control strategy were adopted based on image processing. After real time experimental studies in different interior spaces this approach is presented that provides a level of internal illumination during daytime as well as glare control using intelligent lighting system. Using Wi-Fi linked wireless image processing we can achieve & analyse daylight parameter data and eventually control the whole system automatically. Daylight linked control is a key energy-saving strategy for commercial space which takes advantage of naturally available lights. The artificial electric lights can automatically be dimmed down or turned off when enough natural light is entering into the workspace. By using occupant detection eventually energy saving process has been taken. It is also applicable for safety & security purpose for those interior workspace. In comparison with previous control techniques this proposed system can perform versatile activities and can take the decision automatically and respond accordingly.

Instead of photo sensor or daylight sensors or phototransistor or photo resistor, a camera is used as image sensor which can find the region of interest for particular work-plane and provide information of light level for this particular region of interest of that work-plane. The sensor used here also facilitates with temperature sensor and gas sensor to monitor the internal thermal and environmental data which is also useful to control both lighting and cooling loads according to set threshold value, if required. Using deep neural network (DNN), same camera is used for occupant detection. That camera can replace the installation of high cost occupancy sensor for energy saving.

Chapter 4:
Wireless Image Processing

4.1 Image Processing

4.1.1 Human Vision & Machine Vision

Human beings are primarily ocular creatures. We rely greatly on our vision to make sense of the world around us. We not only look at things to detect and categorize them. Humans have evolved very precise visual skills to detect faces, humans, objects instantaneously; we can discriminate colours; we can practice a bulky sum of visual information very speedily and can find the change its appearance depending on the time of day (day or night); amount of sunlight (clear or cloudy), or various shadows falling upon it [30,31,32].

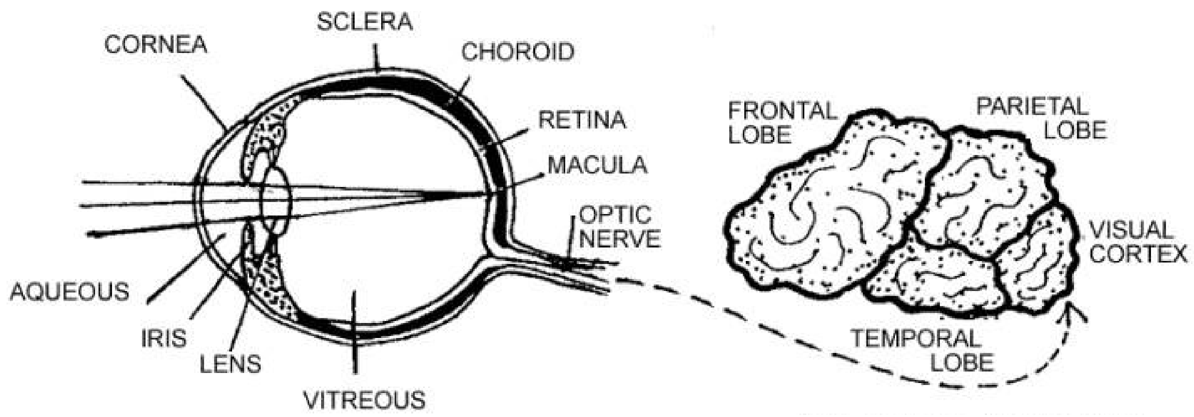


Figure-4.1: Biological Human Vision System

Like visual and perceptual system of human being shown in **Figure-4.1**, the technology is incorporated in this project to identify colours, luminance, and illuminance and object recognition by computer vision application using deep learning methods. Image processing involves changing the nature of an image in order to either improve its pictorial information for human interpretation, render it more suitable for autonomous machine perception.

Before discussing the research methodology admitted for this project work, here, it is required to discuss about the types of image and key levels while it is processed and analysed through electronic components or machine. Much of image processing is concerned with making an image appear better to human beings. We should therefore be aware of the limitations of the human visual system [30, 31, 32].

4.1.2 Necessary Steps for Image Perception

- Capturing the image with the eye or by the camera.
- Recognising and interpreting the image with the visual cortex in the brain or by the help of computer.

Categorically, the image types are talked about here in few words.

4.1.3 Types of Digital Images

We shall consider here three basic types of images.

a) Binary: Each pixel is just black or white. Since there are only two possible values for each pixel, i.e. 0 or 1 bit per pixel. In the case studies, the captured RGB image is converted to Binary image having binary, we have only two colours: white for the edges, and black for the background.

b) Greyscale: Each pixel is a shade of grey, normally from (black) to white. This range means that each pixel can be represented by eight bits or precisely one byte. This is a very natural range for image handling. Different grey levels are sufficient for the recognition of most natural objects.

c) True colour or RGB: Here each pixel has a particular colour; that colour is described by the amount of red, green and blue in it depicted in **Figure-4.2**.

Example:

49	55	56	57	52	53
58	60	60	58	55	57
58	58	54	53	55	56
83	78	72	69	68	69
88	91	91	84	83	82
69	76	83	78	76	75
61	69	73	78	76	76

Red

64	76	82	79	78	78
93	93	91	91	86	86
88	82	88	90	88	89
125	119	113	108	111	110
137	136	132	128	126	120
105	108	114	114	118	113
96	103	112	108	111	107

Green

66	80	77	80	87	77
81	93	96	99	86	85
83	83	91	94	92	88
135	128	126	112	107	106
141	129	129	117	115	101
95	99	109	108	112	109
84	93	107	101	105	102

Blue

Figure-4.2: A Pixel having R-channel, G-channel and B-channel of an Image[30,31,32].

4.1.4 Challenges of Image Acquisition before Machine Vision Application

Following points are the challenge of the study:

1. Removing noise from an image is very necessary Noise is the random errors in the image and very common problem in data transmission.
2. Removing motion blur from an image. Motion blur may occur when the shutter speed of the camera is too long for the speed of the object.

For a black and white image, lots of shades of grey in this photo so no colour. As the image as being a two dimensional function, where the function values give the brightness of the image at any given point. We may assume that in such an image brightness values can be any real numbers in the range black to white. A digital image differs from a photo that values are all discrete. Usually they take on only integer values ranging from 1 to 256 each, and the brightness values also ranging from 0 (black) to 255 (white). A digital image can be considered as a large array of discrete dots, each of which has a brightness associated with it. These dots are called picture elements, or more simply pixels. The pixels surrounding a given pixel constitute its neighbourhood.A neighbourhood can be characterized by its shape in the same way as a matrix in **Figure-4.3**.

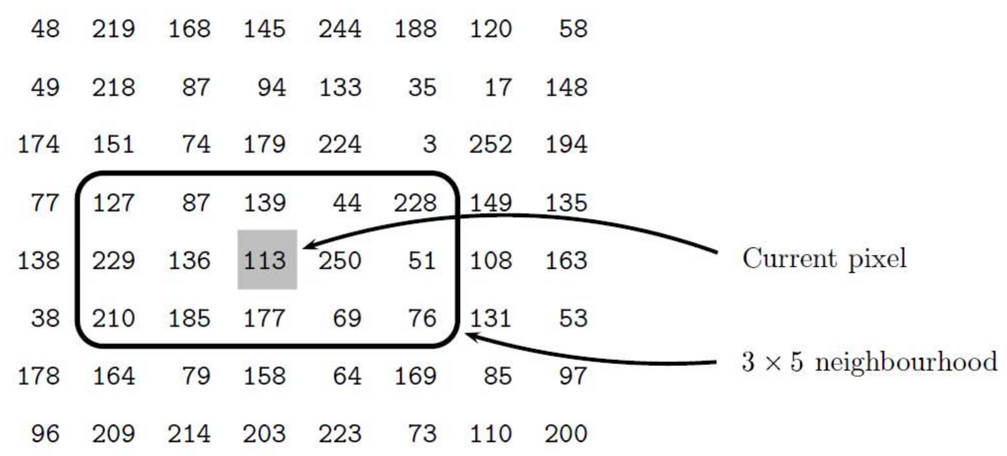


Figure-4.3: Current Pixel and its Neighbourhood of the Matrix of an Image[30,31,32].

Like human vision, machine can also understand the level of illuminance by capturing image and using it as training set to predict the level of illuminance. Before application of image processing technique for finding the illumination & luminance level of a particular region in interior spaces, the key stages of image processing are discussed below [30, 31, 32]. .

4.1.5 Key Stages of Digital Image Processing

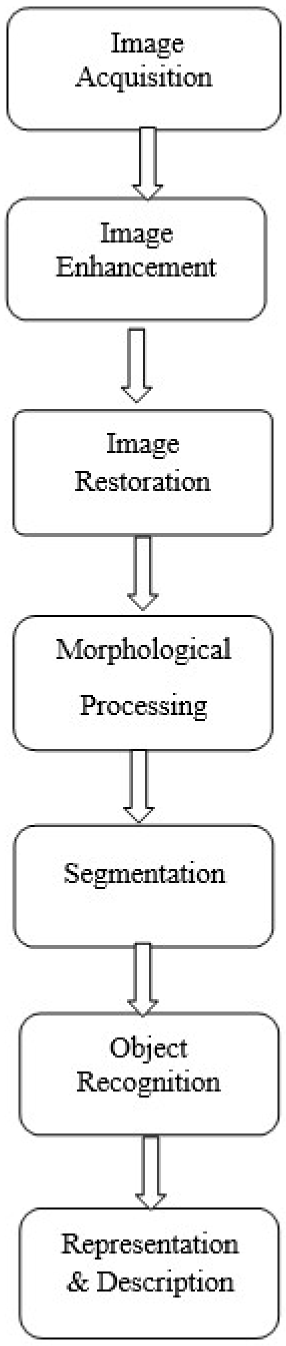


Figure-4.4: Flowchart of Digital Image Processing

- Input: Attributes/Features
- Output : Understanding /Classification

4.1.6 Key Areas of Image Processing Steps

Main areas of image processing stages are shown in **Figure-4.4**

- **Image Enhancement:** This refers to processing an image so that the result is more suitable for a particular application. Example includes sharpening or de-blurring an out of focus image, highlighting edges, improving image contrast, or brightening an image, removing noise.

- **Image Restoration:** This may be considered as reversing the damage done to an image by a known cause, for example: removing of blur caused by linear motion, removal of optical distortions, removing periodic interference.

- **Image Segmentation:** This involves subdividing an image into constituent parts, or isolating certain aspects of an image: finding lines, circles, or particular shapes in an image, in an aerial photograph, identifying cars, trees, buildings, or roads.

4.1.7 Spatial Filtering

An image can be modified by applying a particular function to each pixel value. Spatial filtering may be considered as an extension of this, where applying a function
to a neighbourhood of each pixel. The idea is to move a mask: a rectangle (usually with sides of odd length) or other shape over the given image [30, 31, 32].

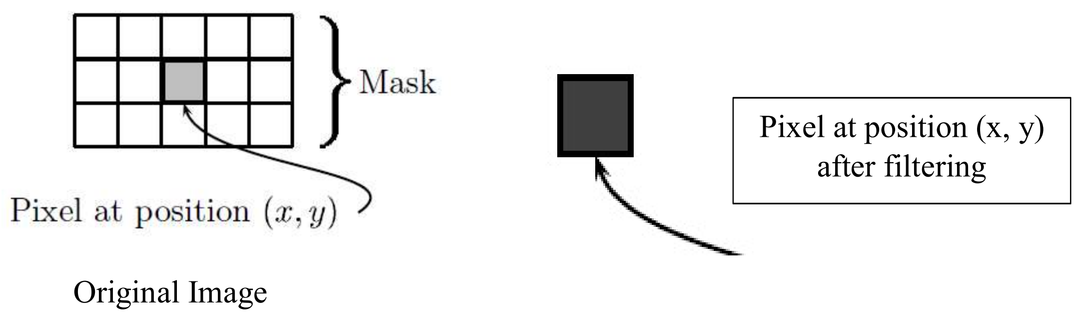


Figure- 4.5: Filtering on an Image

Spatial filtering is an image processing technique for changing the intensities of a pixel according to the intensities of the neighbouring pixels. Using spatial filtering, the image is transformed (convoluted) based on a kernel H which has certain height and width (x, y), defining both the area and the weight of the pixels within the initial image that will replace the value of the image. The corresponding process is to convolve the input image I(i,j) with the filter function H(x,y), to produce the new filtered image explained in **Figure- 4.5.**

$$I'(i,j)=I(i,j)\odot H(x,y).$$

The mathematical operation is a multiplication in the frequency space. The spatial filtering can be characterized as a "shift-and-multiply" operation: the kernel shifts over the initial image producing a mask and multiplies its value with the corresponding pixel values of the image. The result is a new value that replaces the central value of the mask in the new image. 'ʘ' is the convolution operator.

4.2 Machine Intelligence

The human brain is the most complicated organ in the universe and a new frontier yet to be explored by an interdisciplinary approach. In this project, the attempts for object recognition tasks are done by developing logical and cognitive models of the virtual brain of machine by using cognitive informatics and formal methodologies. This project adopts a memory-based approach to explore the functionality of computer vision approach and to demonstrate the foundation based on artificial intelligence.

4.2.1 Artificial Intelligence

The prospect of creating intelligent computers has fascinated many people for as long as computers have been around and, as we shall see in the historic overview. Precisely saying, this is an area of study in the field of computer science and it is concerned with the development of computers able to engage in human-like thought processes such as learning, reasoning, and self-correction.

The concept that machines can be improved to assume some capabilities normally thought to be like human intelligence such as learning, adapting, self-correction, etc. In a restricted sense, the study of techniques to use computers more effectively by improved programming technique. For some time now, the Artificial Intelligence era has been trying to imitate intelligent behaviour with computer programs. This is not an easy task because a computer program must be able to do many different things in order to be called intelligent. Instead of looking at a general definition of Artificial Intelligence, one can also restrict oneself to the definition of artificially intelligent systems.

There are many definitions around, but most of them can be classified into the following four categories:

- Systems that think like humans
- Systems that act like humans
- Systems that think rationally

- Systems that act rationally

The Turing Test where Turing has proposed a game that can be played in order to answer the question "Can a machine think?" This imitation game is now known as the Turing test that gives the very initial idea on Artificial Intelligence. To pass the Turing test, a computer would need machine learning skills.

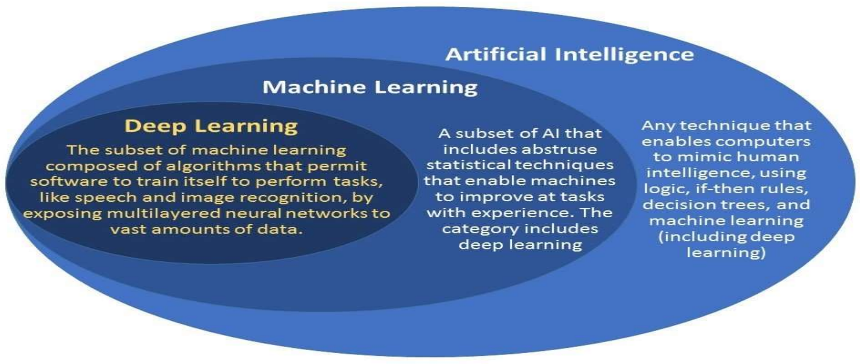


Figure- 4.6: Layers of Machine Learning [11]

4.2.2 Machine Learning

Machine learning is an application of artificial intelligence (AI) that provides systems the ability to automatically learn and improve from experience without being explicitly programmed. Machine learning as shown in **Figure- 4.6** focuses on the development of computer programs that can access data and use it learn for themselves.

The process of learning begins with observations or data, such as examples, direct experience, or instruction, in order to look for patterns in data and make better decisions in the future based on the examples that we provide. The primary aim is to allow the computers learn automatically without human intervention or assistance and adjust actions accordingly.

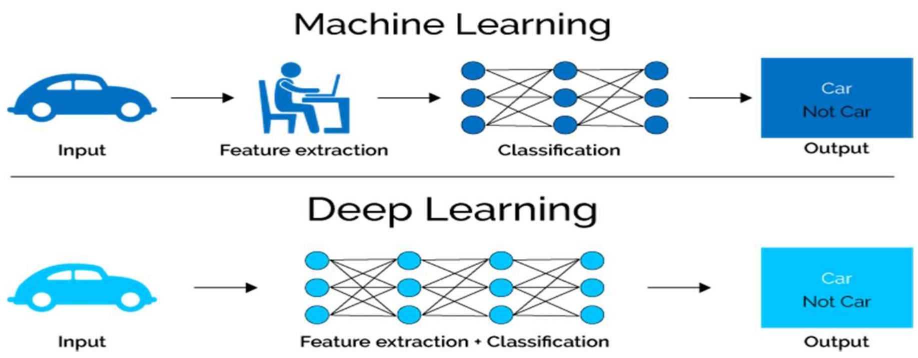


Figure-4.7: Machine learning (ML) vs Deep learning (DL)[12]

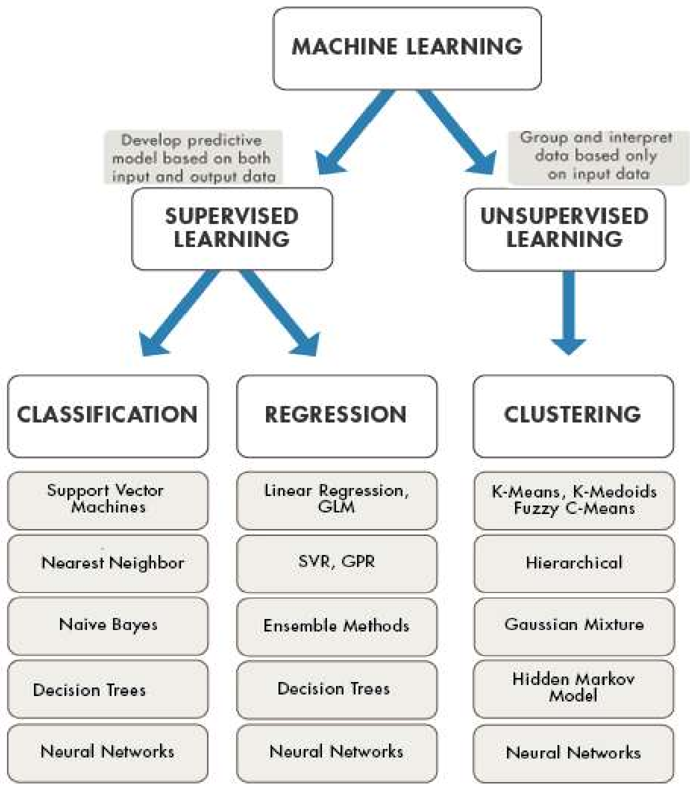


Figure- 4.8: Machine Learning (ML) Process Categorization

4.2.2.1 Classification of Machine Learning

Machine learning implementations are classified into three major categories, depending on the nature of the learning "signal" or "response" available to a learning system which are as follows:-

- **Supervised Learning:** When an algorithm learns from example data and associated target responses that can consist of numeric values or string labels, such as classes or tags, in order to later predict the correct response when posed with new examples comes under the category of supervised learning.
- **Unsupervised Learning:** Whereas when an algorithm learns from plain examples without any associated response, leaving to the algorithm to determine the data patterns on its own. This type of algorithm tends to restructure the data into something else, such as new features that may represent a class or a new series of un-correlated values. They are quite useful in providing humans with insights into the meaning of data and new useful inputs to supervised machine learning algorithms. As a kind of learning, it resembles the methods humans use to figure out that certain objects or events are from the same class, such as by observing the degree of similarity between objects.

- **Reinforcement Learning:** When an algorithm is presented with examples that lack labels, as in unsupervised learning. However, you can accompany an example with positive or negative feedback according to the solution the algorithm proposes comes under the category of Reinforcement learning, which is connected to applications for which the algorithm must make decisions (so the product is prescriptive, not just descriptive, as in unsupervised learning), and the decisions bear consequences. In the human world, it is just like learning by trial and error. Errors help in learning because they have a penalty added (cost, loss of time, regret, pain, and so on), teaching you that a certain course of action is less likely to succeed than others. An interesting example of reinforcement learning occurs when computers learn to play video games by themselves.

- **Semi-supervised Learning:** where an incomplete training signal is given: a training set with some (often many) of the target outputs missing. There is a special case of this principle known as Transduction where the entire set of problem instances is known at learning time, except that part of the targets are missing.

4.2.2.2 Categorizing on the Basis of Required Output by Machine Learning Method

Another categorization of machine learning tasks arises when one considers the desired output of a machine-learned system:

- **Classification:** When inputs are divided into two or more classes, and the learner must produce a model that assigns unseen inputs to one or more (multi-label classification) of these classes. This is typically tackled in a supervised way.

- **Regression:** Which is also a supervised problem, A case when the outputs are continuous rather than discrete.

- **Clustering:** When a set of inputs is to be divided into groups. Unlike in classification, the groups are not known beforehand, making this typically an unsupervised task.

4.2.2.3 Data

It can be any unprocessed fact, value, text, sound or picture that is not being interpreted and analysed. Data is the most important part of all Data Analytics, Machine Learning, and Artificial Intelligence. Without data, we can’t train any model and all modern research and automation will go vain.

- **Information:** Data that has been interpreted and manipulated and has now some meaningful inference for the users.
- **Knowledge:** Combination of inferred information, experiences, learning and insights. Results in awareness or concept building for an individual or organization.

Splitting of data in Machine Learning follows:

- **Training Data:** The part of data we use to train our model. This is the data which your model actually sees (both input and output) and learn from.

- **Validation Data:** The part of data which is used to do a frequent evaluation of model, fit on training dataset along with improving involved hyper parameters (initially set parameters before the model begins learning). This data plays its part when the model is actually training.

- **Testing Data:** Once our model is completely trained, testing data provides the unbiased evaluation. When we feed in the inputs of testing data, our model will predict some values (without seeing actual output). After prediction, we evaluate our model by comparing it with actual output present in the testing data. This is how we evaluate and see how much our model has learned from the experiences feed in as training data, set at the time of training.

4.3 Deep Learning

Deep learning (also known as deep structured learning or hierarchical learning) is part of a broader family of neural network methods based on artificial neural networks. Learning can be supervised, semi-supervised or unsupervised. Deep learning architectures such as deep neural networks, deep belief networks, recurrent neural networks and convolutional neural networks have been applied to fields including computer vision, speech recognition, natural language processing, audio recognition, social network filtering, machine translation, bioinformatics, drug design, medical image analysis, material inspection and board game programs, where they have produced results comparable to and in some cases superior to human experts [34,35,36].

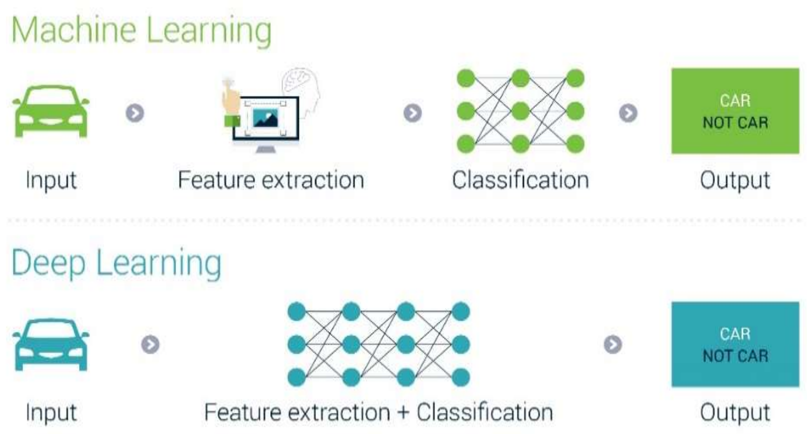


Figure-4.9: Deep learning (DL) with Increased Number of Hidden Layers [13]

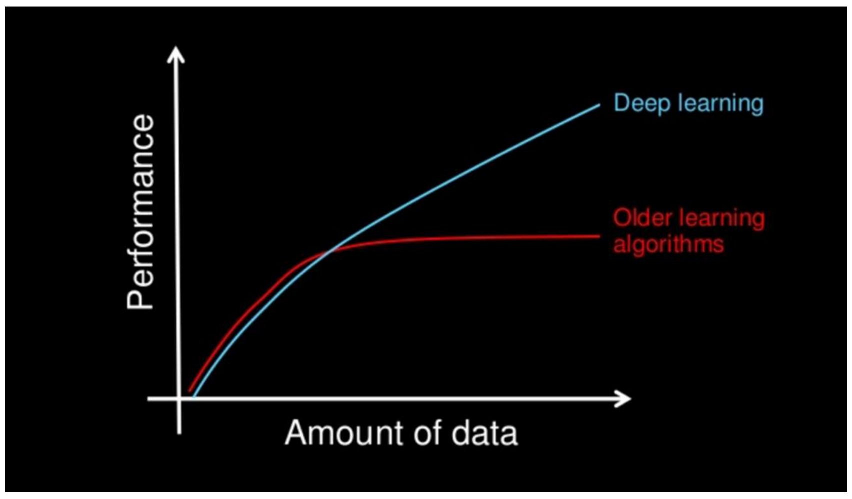


Figure-4.10: Deep Learning (DL) with Performance Curve [14]

4.3.1 Convolution Neural Network (CNN)

In neural networks, Convolutional neural network (ConvNets or CNNs) is one of the main categories to do images recognition, images classifications. Objects detections, recognition faces etc., are some of the areas where CNNs are widely used. CNN image classifications takes an input image, process it and classify it under certain categories (Eg., Dog, Cat, Tiger, Lion). Computers sees an input image as array of pixels and it depends on the image resolution. Based on the image resolution, it will see h x w x d(h = Height, w = Width, d = Dimension). Eg., An image of 6 x 6 x 3 array of matrix of RGB (3 refers to RGB values) in fig 4.3.3 and an image of 4 x 4 x 1 array of matrix of grayscale image.

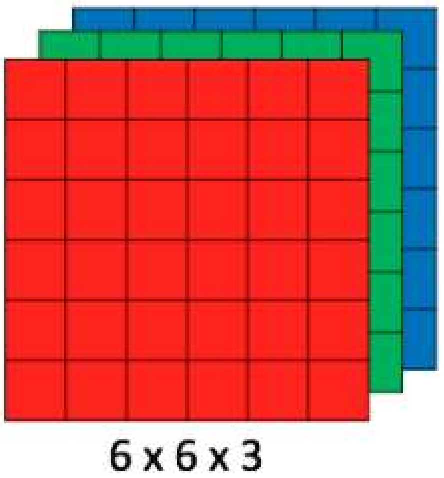


Figure-4.11: Three Layers of R-G-B or True Colour Image

Technically, deep learning CNN models to train and test, each input image will pass it through a series of convolution layers with filters (Kernels), Pooling, fully connected layers (FC) and apply Softmax function to classify an object with probabilistic values between 0 and 1. The below figure 4.3.4 is a complete flow of CNN to process an input image and classifies the objects based on values.

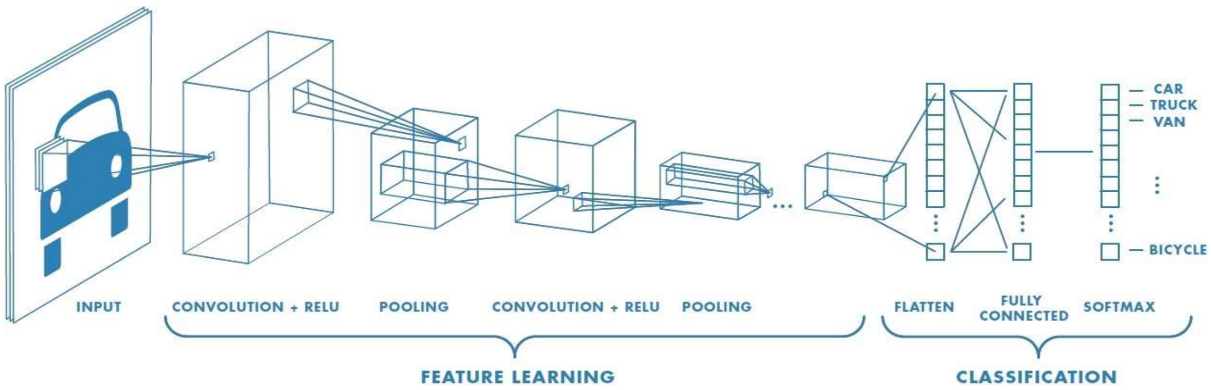


Figure-4.12: Neural Network with Many Convolutional Layers [15]

4.3.2 Convolution Layer

Convolution is the first layer to extract features from an input image. Convolution preserves the relationship between pixels by learning image features using small squares of input data. It is a mathematical operation that takes two inputs such as image matrix and a filter or kernel convolve together [17,18,19,20].

- An image matrix (volume) of dimension **(h x w x d)**
- A filter **(f_h x f_w x d)**
- Outputs a volume dimension **(h - f_h + 1) x (w - f_w + 1) x 1**

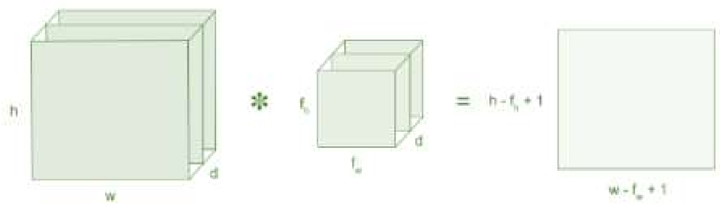


Figure-4.13: Image Matrix Multiplies Kernel or Filter Matrix

Consider a 5 x 5 whose image pixel values are 0, 1 and filter matrix 3 x 3 as shown in below

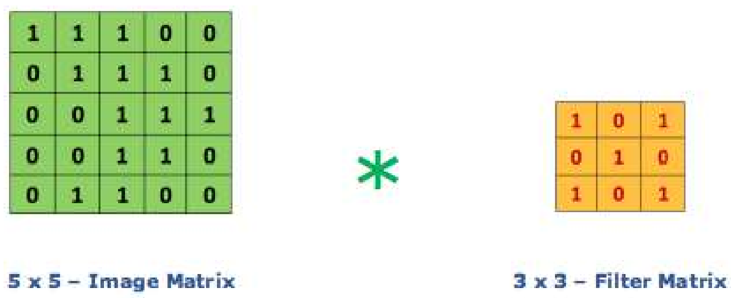


Figure-4.13: Image Matrix Multiplies Kernel or Filter Matrix

Then the convolution of 5 x 5 image matrix multiplies with 3 x 3 filter matrix which is called **“Feature Map”** as output shown in below

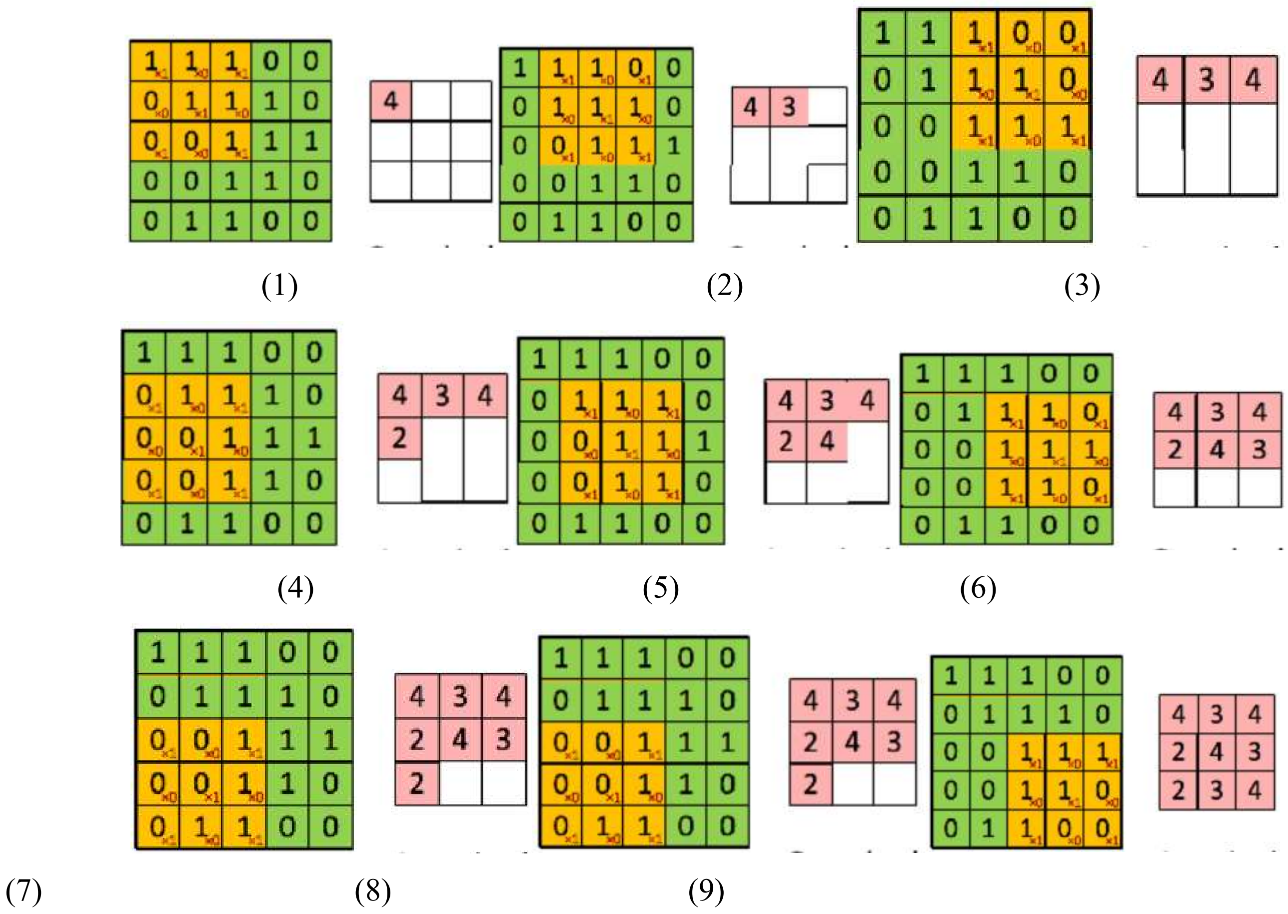


Figure-4.13: Convolution of 5 x 5 Image Matrix Multiplies with 3 x 3 Filter Matrix [20]

The image is nothing but a matrix.After creating kernel or filter, it is convolve with the image matrix which produces low dimensional image after feature reduction.The kernel will work on each pixel producing new pixel value after convolution and that pixel operation will work
Convolution of an image with different filters can perform operations such as edge detection, blur and sharpen by applying filters.

4.4 IoT (Internet of Things)

The Internet of things (IoT) is the extension of Internet connectivity into physical devices and everyday objects. Embedded with electronics, Internet connectivity, and other forms of hardware (such as sensors), these devices can communicate and interact with others over the Internet, and they can be remotely monitored and controlled.

4.4.1 Benefits of IoT Technology

The internet of things offers a number of benefits:

- Monitor their overall business processes
- Improve the customer experience
- Save time and money
- Enhance employee productivity
- Integrate and adapt business models
- Make better business decisions
- Generate more revenue.

4.4.2 IoT Security and Privacy Issues

The internet of things [21] connects billions of devices to the internet and involves the use of billions of data points, all of which need to be secured. Due to its expanded attack surface, IoT security and IoT privacy are cited as major concerns.

4.4.3 Why IoT Matters

When something is connected to the internet that means that it can send information or receive information, or both. This ability to send and/or receive information makes things smart and smart is good.

To be smart, a thing doesn't need to have super storage or a super computer inside of it. All a thing has to do is connect to super storage or to a super computer. Being connected is awesome.

In the Internet of Things, all the things that are being connected to the internet can be put into three categories:

- Things that collect information and then send it.
- Things that receive information and then act on it.
- Things that do both

4.5 XAMPP as Web Server

XAMPP is a free and open-source cross-platform web server solution stack package developed by Apache Friends, consisting mainly of the Apache HTTP Server, Maria DB database, and interpreters for scripts written in the PHP and Perl programming languages. Here XAMPP is used as an actual web server deployments, it makes transitioning from a local test server to a live server possible.The term XAMPP is an apparent acronym. However, there is no official acronym expansion specified on the Apache Friends website. Their homepage header reads "XAMPP Apache + Maria DB + PHP + Perl", indicating that this abbreviation is an acronym. The term can be unofficially broken down as follows at Table-4.5.1[22]

Letter	Meaning
X	as an ideographic letter referring to cross-platform
A	Apacheor its expanded form, Apache HTTP Server
M	MariaDB (formerly: MySQL)
P	PHP
P	PERL

So, XAMPP stands for Cross-Platform (X), Apache (A), MySQL (M), PHP (P) and Perl (P). It is a simple, lightweight Apache distribution that makes it extremely easy for developers to create a local web server for testing purposes. Everything you need to set up a web server – server application (Apache), database (MySQL), and scripting language (PHP) – is included in a simple extractable file.

4.6 Components of XAMPP

XAMPP has four primary components [22]. These are:

a) XAMPP Apache b) MySQL c) PHP d) Perl

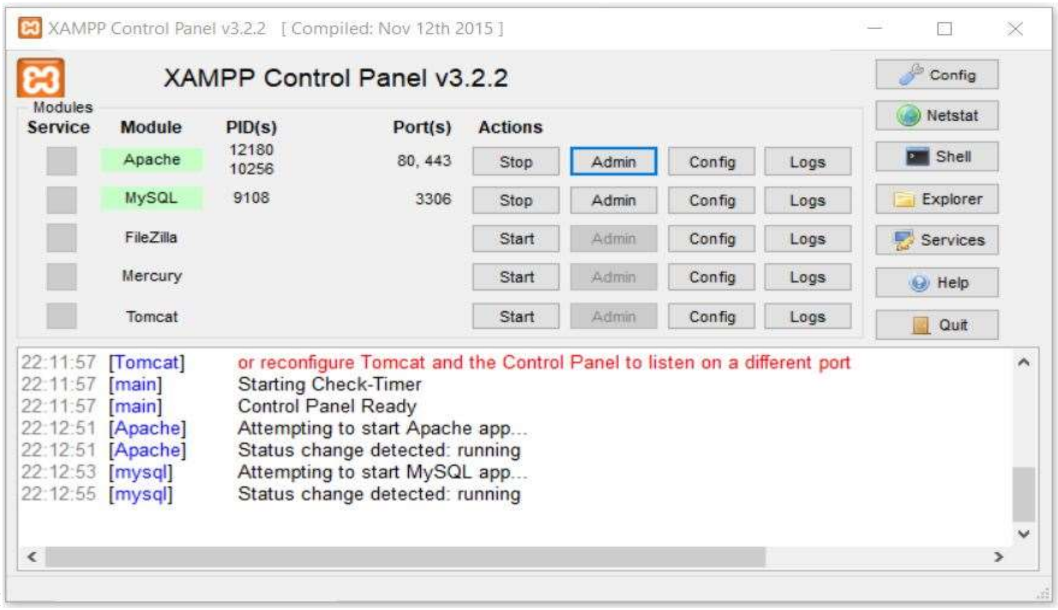
a) XAMPP Apache: Apache is the actual web server application that processes and delivers web content to a computer. Apache is the most popular web server online, powering nearly 54% of all websites.

b) MySQL: Every web application, howsoever simple or complicated, requires a database for storing collected data. MySQL, which is open source, is the world's most popular database management system.

c) PHP: PHP stands for Hypertext Pre-processor. It is a server-side scripting. It is open source, relatively easy to learn, and works perfectly with MySQL, making it a popular choice for web developers.

d) Perl: Perl is a high-level, dynamic programming language used extensively in network programming, system admin, etc. Although less popular for web development purposes, Perl has a lot of niche applications.

Different versions of XAMPP may have additional components such as phpMyAdmin, OpenSSL, etc. to create full-fledged web servers.



:

Figure-4.14: XAMPP Control Panel (as software simulation)

4.6 Database Management System (DBMS)

Database is a collection of related data and data is a collection of facts and figures that can be processed to produce information. Mostly data represents recordable facts. Data aids in producing information, which is based on facts. A database management system stores data in such a way that it becomes easier to retrieve, manipulate, and produce information [23].

4.6.1 Characteristics of DBMS

Traditionally, data was organized in file formats. A modern DBMS has the following characteristics:

- **Real-world entity:** A modern DBMS is more realistic and uses real-world entities to design its architecture. It uses the behaviour and attributes too. For example, a school database may use students as an entity and their age as an attribute.

- **Relation-based tables:** DBMS allows entities and relations among them to form tables. A user can understand the architecture of a database just by looking at the table names.

- **Isolation of data and application:** A database system is entirely different than its data. A database is an active entity, whereas data is said to be passive, on which the database works and organizes. DBMS also stores metadata, which is data about data, to ease its own process. • Less redundancy: DBMS follows the rules of normalization, which splits a relation when any of its attributes is having redundancy in values. Normalization is a mathematically rich and scientific process that reduces data redundancy.

- **Consistency:** Consistency is a state where every relation in a database remains consistent. There exist methods and techniques, which can detect attempt of leaving database in inconsistent state. A DBMS can provide greater consistency as compared to earlier forms of data storing applications like file-processing systems.

- **Query Language:** DBMS is equipped with query language, which makes it more efficient to retrieve and manipulate data. A user can apply as many and as different filtering options as required to retrieve a set of 1. OVERVIEW DBMS 2 data. Traditionally it was not possible where file-processing system was used.

- **ACID Properties:** DBMS follows the concepts of Atomicity, Consistency, Isolation, and Durability (normally shortened as ACID). These concepts are applied on transactions, which manipulate data in a database. ACID properties help the database stay healthy in multi-transactional environments and in case of failure.

• **Multiuser and Concurrent Access:** DBMS supports multi-user environment and allows them to access and manipulate data in parallel. Though there are restrictions on transactions when users attempt to handle the same data item, but users are always unaware of them.

• **Multiple Views:** DBMS offers multiple views for different users. A user who is in the Sales department will have a different view of database than a person working in the Production department. This feature enables the users to have a concentrate view of the database according to their requirements.

• **Security:** Features like multiple views offer security to some extent where users are unable to access data of other users and departments. DBMS offers methods to impose constraints while entering data into the database and retrieving the same at a later stage. DBMS offers many different levels of security features, which enables multiple users to have different views with different features. For example, a user in the Sales department cannot see the data that belongs to the Purchase department. Additionally, it can also be managed how much data of the Sales department should be displayed to the user. Since a DBMS is not saved on the disk as traditional file systems, it is very hard for miscreants to break the code.

4.6.2 Users

A typical DBMS has users with different rights and permissions who use it for different purposes. Some users retrieve data and some back it up. The users of a DBMS can be broadly categorized as follows:

•**Administrators:** Administrators maintain the DBMS and are responsible for administrating the database. They are responsible to look after its usage and by whom it should be used. They create access profiles for users and apply limitations to maintain isolation and force security. Administrators also look after DBMS resources like system license, required tools, and other software and hardware related maintenance.

• **Designers:** Designers are the group of people who actually work on the designing part of the database. They keep a close watch on what data should be kept and in what format. They identify and design the whole set of entities, relations, constraints, and views.

• **End Users:** End users are those who actually reap the benefits of having a DBMS. End users can range from simple viewers who pay attention to the logs or market rates to sophisticated users such as business analysts.

Figure-4.15: DBMS User

phpMyAdmin is one of the most popular applications for MySQL database management. It is a free tool written in PHP. Through this software you can create, alter, drop, delete, import and export MySQL database tables. You can run MySQL queries, optimize, repair and check tables, change collation and execute other database management commands.

An administrator's tool of sorts, phpMyAdmin is a PHP script meant for giving users the ability to interact with their MySQL databases. A "raw" view of the data, tables and fields stored in the MySQL database is accessible through phpMyAdmin.

The main phpMyAdmin features are:

- Intuitive web interface
- Support for most MySQL features:
- browse and drop databases, tables, views, fields and indexes
- create, copy, drop, rename and alter databases, tables, fields and indexes
- maintenance server, databases and tables, with proposals on server configuration
- execute, edit and bookmark any SQL-statement, even batch-queries
- manage stored procedures and triggers
- Import data from CSV and SQL
- Export data to various formats: CSV, SQL, XML, PDF, ISO/IEC 26300 - OpenDocument Text and Spreadsheet, Word, $\LaTeX$ and others
- Creating complex queries using Query-by-example (QBE)
- Searching globally in a database or a subset of it
- Transforming stored data into any format using a set of predefined functions, like displaying BLOB-data as image or download-link.

Figure-4.16: phpMyAdmin Welcome box

4.7 Cloud Computing Methodology

Cloud computing is a kind of outsourcing of computer programs. Using cloud computing, users are able to access software and applications from wherever they are; the computer programs are being hosted by an outside party and reside in the cloud. This means that users do not have to worry about things such as storage and power, they can simply enjoy the end result.

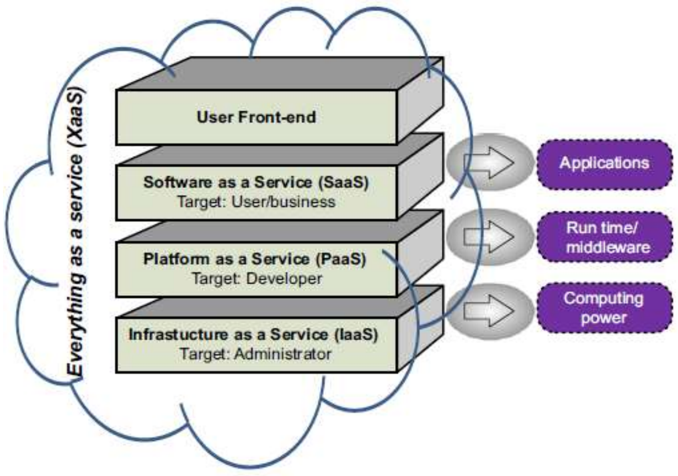


Figure- 4.17: Cloud Computing Everything is a Service

With cloud computing, users eliminate problems with storing their own data, and users not managing hardware and software that becomes the responsibility of an experienced vendor or provider. The shared infrastructure means it works like a utility where users only pay for what they need, upgrades are automatic, and scaling up or down is easy.

Cloud-based apps can be up and running in days or weeks, and they cost less. With a cloud app, users can just open a browser, log in, customize the app, and start using it.

In Cloud computing, everything is treated as a service (i.e. XaaS), e.g. SaaS (Software as a Service), PaaS (Platform as a Service) and IaaS (Infrastructure as a Service).These services define a layered system structure for cloud computing.

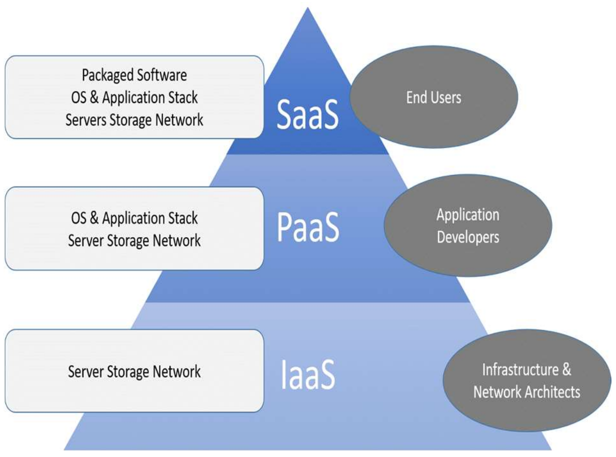


Figure-4.18: Cloud Service Model

At the Infrastructure layer, processing, storage, networks, and other fundamental computing resources are defined as standardized services over the network. Cloud providers' clients can deploy and run operating systems. The middle layer, i.e. PaaS provides abstractions and services for developing, testing, deploying, hosting, and maintaining applications in the integrated development environment. The application layer provides a complete application set of SaaS. The user interface layer at the top enables seamless interaction with all the underlying XaaS layers.

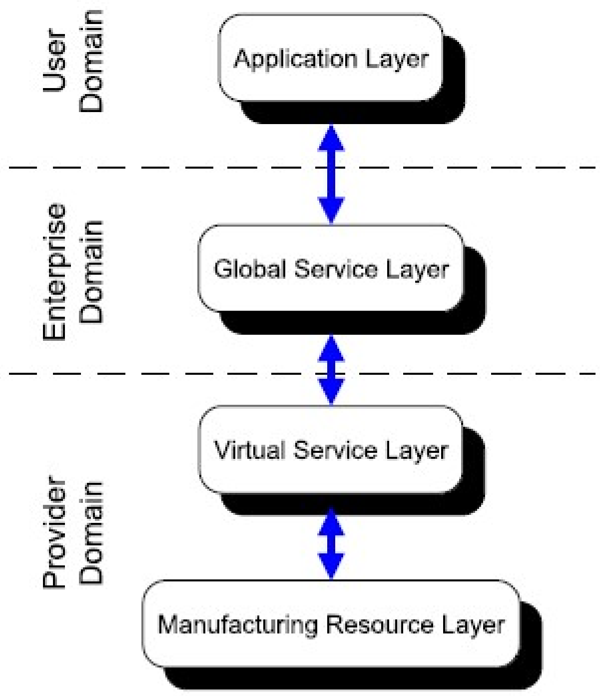


Figure-4.19: Layered Architecture of Cloud Manufacturing System

Chapter 5:
Methodology of Proposed Model

5.1 Methodology Adopted

A digital single camera interfaced with microcontroller has the potential to replace the multiple sensors required by conventional systems for daylight controlling, shading control, and occupancy sensing. The illuminance can be calculated by the camera's with digital RGB output values by using the exposure value. Intake of daylight is mainly through windows. It is necessary to study the condition of daylight in existing interior spaces. A detailed study needs to be undertaken to analyse the effect of the various percentage of opening, dimensions, etc. of windows on the daylighting. The research deals with quantitative analysis of daylight through windows. The issues identified in each case are discussed further in the research. Recommendations are given based on the case studies and simulations undertaken to tackle the issues and thus help in optimizing daylight in a workspace. After approximate simulation by DIALux for the particular workspace and after measurement of lux level using luxmeter, it is required to compare the proposed system. After image acquisition by picamera throughout the daytime, using python and Matlab programming image processing is done on those images. Initially, the images has been read and processed by the machine and next these are converted to a binary and grayscale image. After histogram pixel intensity or the frequency of each pixel values are found. Based on the threshold point set by the programmer, the machine arises the output. If pixel intensity is more beyond this threshold value system understood that the brightness value is more for the workplace. So accordingly it is required to dim the light level after a specified delay. Sudden and frequent dimming are avoided providing inevitable time delay as visual adaptivity may hamper for this consequence. Unobtrusive light during daytime as well as artificial lights are turned on during day hours may create glare. So, by this approach, glare control may happen. For accurate analysis of an image or getting an improved result, it is required to find dark patches, deblur the image & filtering process, image enhancement & enhancement of contrast are required. Another important aspect of this approach is that human & face detection by computer vision techniques for occupant detection for energy saving purpose. Occupant detection is also considered when no light is there for safety & security purposes. The issues identified in each case are discussed later.

Recommendations are followed based on the case studies and simulations undertaken to tackle the issues and thus help in 'optimizing daylight in workspace'. By image processing, finding R-G-B information from each pixel value, and from here, it is required to achieve lux value.

5.2 Flowchart of Proposed Model

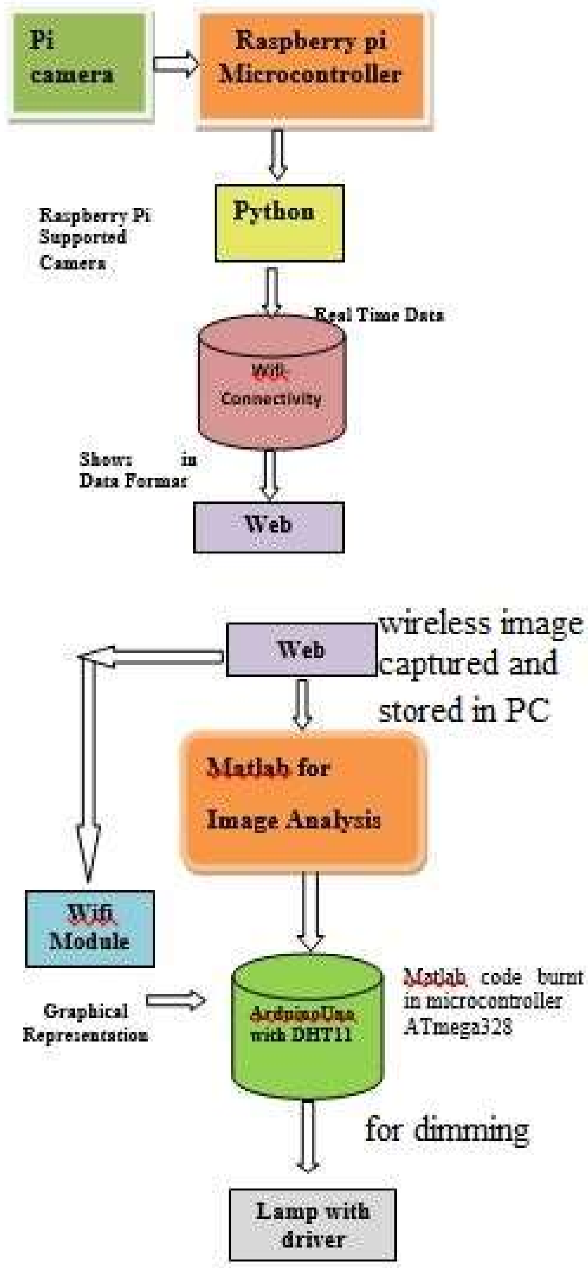


Figure-5.1 : Architecture of Sensor Based Microcontroller System

At first a connection with picamera and Raspberry pi microcontroller is established to capture real time images provided that the environment should have Wi-Fi connectivity. Now, the real time data chunk is accumulated in the web either in cloud or local server.The database of sensor and image data can be stored in the database.The user after Sign up can view the data when required.The images via wireless communication were stored in the machine. Then the MATLAB coding is needed to view real data graphically. A connection is set among Wi-Fi module, Arduino Uno with DHT11 and MATLAB coding for image analysis and temperature monitoring purpose. Lastly, it is sequenced with lamp.

5.3 Process Description Step by Step

a) Establishing connection with camera and Raspberry Pi 3B.

b) Capturing real time image and process it through Wi-Fi.

c) Wireless connectivity.

d) Viewing real data graphically through MATLAB.

e) Storing in MySQL Database.

f)Viewing captured image through Web in real time.

g)Performing Image processing and histogram of image.

h)Finding RGB value of respective image and region of interest (ROI).

i) Artificial light control according to threshold value by ROI data analysis.

j)Occupant detection and recognition for serving energy saving activity.

5.4 Introduction of MobileNet

Convolutional neural networks have become ubiquitous in computer vision application. The general trend has been to make deeper and more complicated networks to achieve higher accuracy .Convolution of an image with different filters can perform operations such as edge detection, blur and sharpen by applying filters. Here, MobileNet architecture is used based on the convolution layer which is the set of convolution of an image and convolved features [17, 18, 19, 20].

MobileNet is an architecture which is more suitable for mobile and embedded based vision applications where there is a lack of computing power. MobileNet has convolutional layers, which are essential to computer vision tasks but are quite expensive to compute, can be replaced by so-called **depthwise separable** convolutions.MobileNets primarily focus on optimising for latency but also yield small networks. The job of the convolution layer is split into two subtasks: first, there is a depth wise convolution layer that filters the input, followed by a 1×1 (or pointwise) convolution layer that combines these filtered values to create new features. Here, it is introduce two simple global hyper-parameters that efficiently trade-off between latency and accuracy. These hyper-parameters allow the model builder to choose the right sized model for their application based on the constraints of the problem. Here it is demonstrated the effectiveness of MobileNets across a wide range of applications and use cases including object detection, face attributes and many more.

5.4.1 The Architectural Steps [17, 18, 19, 20]

- The standard convolution is replaced by **depthwise convolution followed by pointwise convolution** which is called as **depthwise separable convolution**.

- This architecture uses **depthwise separable convolutions** which significantly **reduces the number of parameters** when compared to the network with regular convolutions with the **same depth** in the networks. This results in lightweight deep neural networks (L-DNN).

- This results in the reduction of the number of parameters significantly and thereby **reduces the total number of floating point multiplication operation** which is **favourable in mobile and embedded vision applications** with less compute power.

- By **using depthwise separable convolutions**, there is some **sacrifice of accuracy** for **low complexity deep neural network**.

The flowchart of Mobilenet SSD is shown in the **Figure-5.2** in paragraph under 5.5.1

5.4.2 Train MobileNet SSD to Detect the Object or the Occupant Using Convolution Neural Network

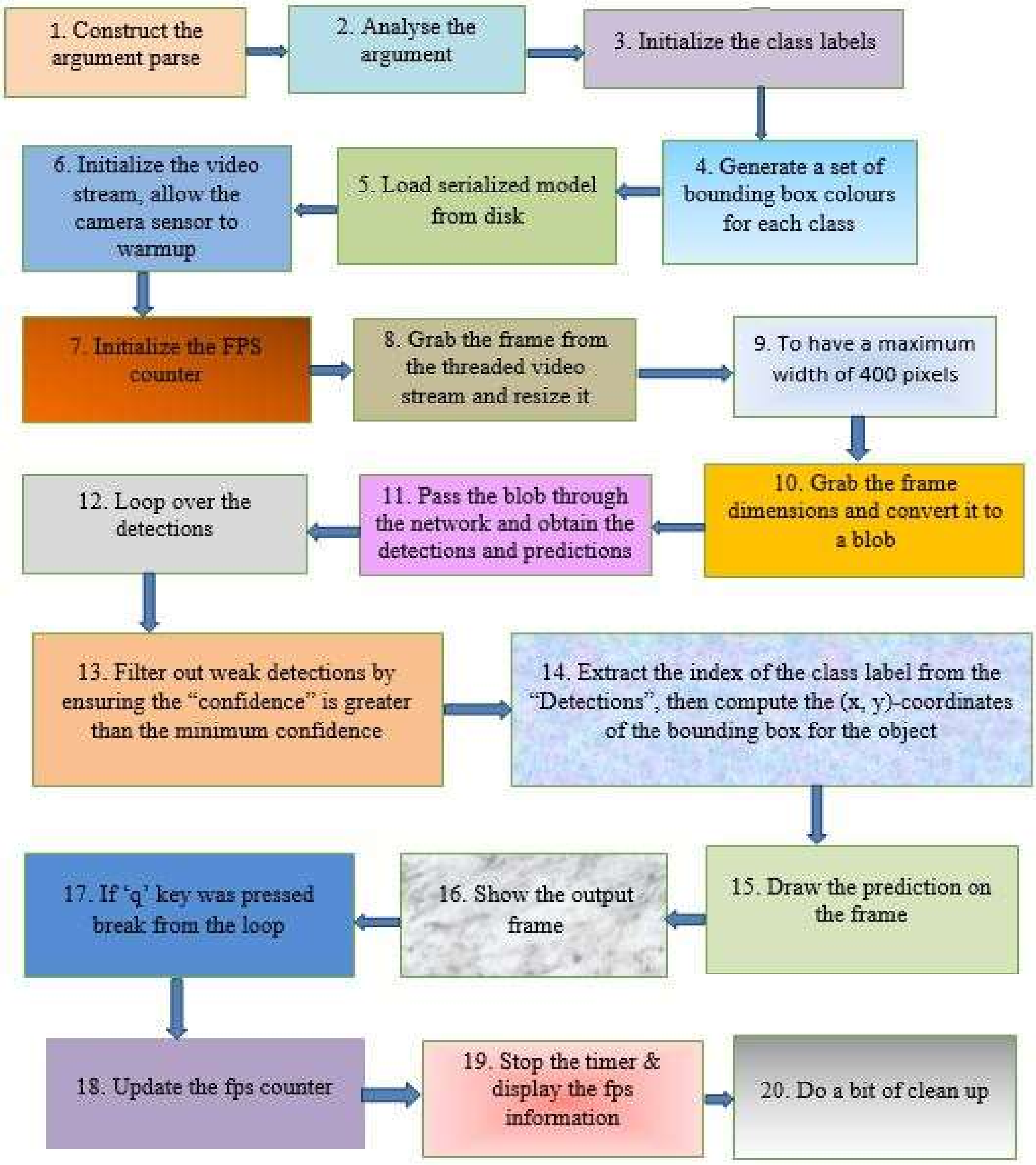


Figure- 5.2: Flowchart of Mobile Net for Detection and Recognition

In above **Figure 5.2**,the MobileNet architecture and two hyper-parameters width multiplier and resolution multiplier to define smaller and more efficient MobileNets which is built on which are depthwise separable filters that gives the descriptions of the two model shrinking hyper-parameters width multiplier and resolution multiplier.

5.4.3 Depthwise Separable Convolution of Deep Neural Network (DNN)[19,20]

The MobileNet model is based on depthwise separable convolutions which are a form of factorized convolutions which factorize a standard convolution into a depthwise convolution and a 1×1 convolution called a pointwise convolution. For MobileNets the depthwise convolution applies a single filter to each input channel. The pointwise convolution then applies a 1×1 convolution to combine the outputs the depthwise convolution. A standard convolution both filters and combines inputs into a new set of outputs in one step. The depthwise separable convolution splits this into two layers, a separate layer for filtering and a separate layer for combining. This factorization has the effect of drastically reducing computation and model size. Figure 5.3 shows how a standard convolution (a) is factorized into a depthwise convolution (b) and a 1 × 1 pointwise convolution.

5.4.4 Network Structure and Training

The MobileNet structure is built on depthwise separable convolutions as mentioned in the previous section except for the first layer which is a full convolution. By defining the network in such simple terms we are able to easily explore network topologies to find a good network. All layers are followed by a batchnorm and ReLU nonlinearity with the exception of the final fully connected layer which has no nonlinearity and feeds into a softmax layer for classification.

A layer with regular convolutions, batchnorm and ReLU nonlinearity to the factorized layer with depthwise convolution, 1 × 1 pointwise convolution as well as batchnorm and ReLU after each convolutional layer. Down sampling is handled with strided convolution in the depthwise convolutions as well as in the first layer. A final average pooling reduces the spatial resolution to 1 before the fully connected layer. Counting depthwise and pointwise convolutions as separate layers, MobileNet layers are determined.

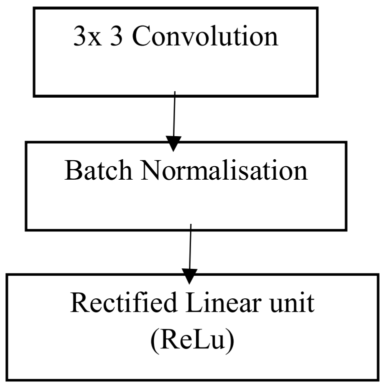


Figure- 5.3 a):3× 3 Depthwise Convolution

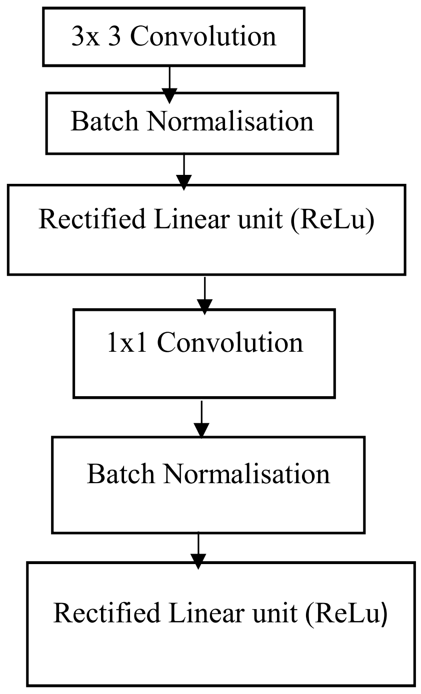


Figure 5.3 b): 1 × 1 Pointwise Convolution

Chapter 6:

Experimental Setup Details

6.1 Introduction to Hardware Description of Proposed Model

Image analysis has played an essential role in this project. Centralising the idea, here, all the hardware were stitched together in such a way that it can fulfil the objectives and finally gives the outcome. Due to the development in embedded technology, an attempt was taken to introduce an intelligent lighting control system that can able to perform multidisciplinary activities in illumination point of view as well as reduced overall cost in comparison with another conventional system.

6.1.1 Raspberry Pi 3 model B

The suggested system is implemented using a Raspberry Pi 3 Model B, shown in Figure 6.1. Raspberry Pi is an economical, small size computer. It has the facility to connect to a computer monitor and uses a standard mouse and keyboard for visualising the system program.

Figure 6.1: Raspberry Pi 3B

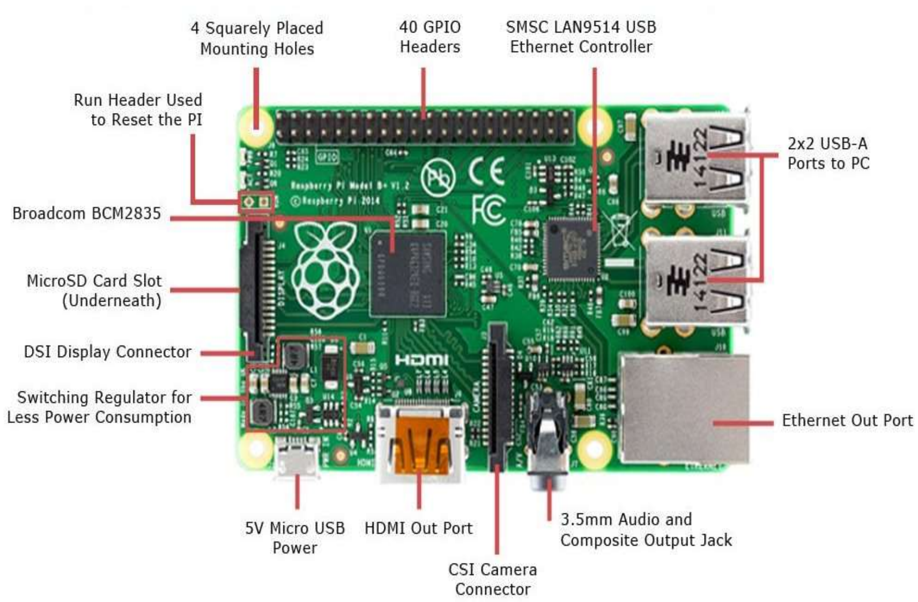


Figure 6.2: Raspberry Pi 3B pinout

It has the latest Broadcom 2837 ARMv8 64bit processor the Raspberry Pi 3 model B is faster and more prevailing than its previous versions. It has improved power management to support more powerful external USB devices and now arises with built-in wireless and Bluetooth connectivity. A 2.5A adapter is a prerequisite for improved power management on the Raspberry Pi 3 that provides support for even more powerful devices connected with the USB ports. It has CPU core Quad-core ARM Cortex-A53, clock speed 1.2 GHz, RAM 1 GB, GPU 400 MHz Video Core IV, network connectivity 1 x 10 / 100 Ethernet (RJ45 Port) wireless connectivity 802.11n wireless LAN (Wi-Fi) and Bluetooth 4.1, GPIO 2*20 Pin Header ,camera interface CSI ,Display interface DSI 15 Pin / HDMI Out / Composite RCA [ ]. All the pinouts are depicted in Figure 6.2.

- Key Features of Raspberry Pi 3 model B
  - Broadcom BCM2837 64-bit ARMv8 Quad Core Processor
  - 1.2GHz speed
  - BCM43143 Wi-Fi with IEEE 802.11b/g/n support
  - Bluetooth
  - 1GB RAM
  - 40pin extended GPIO

6.1.2 Initialization of Raspberry Pi 3B

Execution process began with primarily booting up the Raspberry Pi. A 32 GB micro SD card is given a proper format using SD Formatter and setup with latest Raspbian operating system (Raspbian Stretch).The Raspbian Operating System (OS) was downloaded from Raspberry Pi's official website in Zip file format. The downloaded files were then extracted to the micro SD card, after which it was inserted into the SD card slot on the Raspberry Pi 3B.The image of Operating System (OS) was downloaded and installed in SD card by using Win32DiskImager utility. As the system provides Linux based platform therefore it is programmed in Python, which is a dominant yet easy-to-use programming language that allows connecting the system to the real world. The Raspberry Pi was then plugged into a monitor or laptop via HDMI adaptor cable; input connections like keyboard and mouse were properly established and powered up using USB power supply or an equivalent battery pack. Once the Raspbian operating system was installed, the initial boot completed and it was ready for working condition [27].

6.1.3. Raspberry Pi camera

The Raspberry Pi 3 board (Rpi3B), after prepared for practice condition, Raspberry Pi NoIR (No Infra-Red) camera V2 module has required to integrate with the system. This is the primary component for acquiring an image in system execution. The Raspberry Pi board itself is miniature, at around 300mm*16, and it has CSI camera connector port shown in Figure 6.2.The neck width of the camera module is 6mm; this highlight making it seamless for image capturing applications where small size and better image quality are essential.

The camera itself, shown in **Figure 6.3,** has an instinctive resolution of 8 megapixels, and has a fixed focus lens onboard. In terms of still images, the camera is capable of $2592 * 1944$ pixel static images, and also supports 1080p30, 720p60 and it makes nice frames in 640 * 480 at 90 frames per second. The camera's fps measures the display device performance. It consists of the number of complete scans of the display screen that occur each second. This is the number of times the image on the screen is refreshed each second, or the rate at which an image device produces unique sequential images called frames. This camera module uses the dedicated CSI interface, which was designed especially for interfacing to cameras. The CSI bus is capable of extremely high data rates, and it completely brings pixel data. The camera is supported in the latest version of Raspbian, Raspberry Pi's preferred operating system.

Figure 6.3: Raspberry Pi 3B supported picamera

6.1.4 Raspberry Pi 3B with picamera

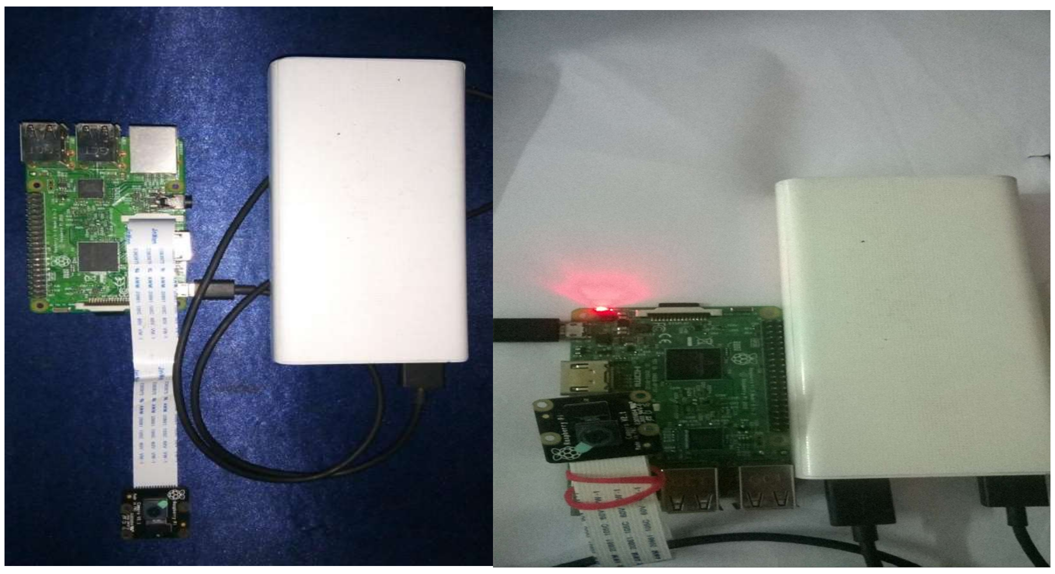


Figure-6.4 : Raspberry pi 3B connected with picamera power supplied by battery

The camera was connected to the BCM2835/BCM2836 processor on the Raspberry Pi microcontroller via the CSI (camera serial interface) bus, a higher bandwidth link which carries pixel data from the camera back to the processor in **Figure 6.4**. This CSI bus travels along the ribbon cable that accords the camera board to the Raspberry Pi microcontroller. From Raspberry Pi microcontroller, the data was directed to personal computer away from the actual field for further application. The Picamera was connected to the Raspberry Pi 3 board and powered up. It was then enabled on Raspberry Pi GUI (graphical user interface). Once this is done, the Pi camera delivers high-quality imaging when instructed. And being a night vision camera, it is also impeccable for low light taking pictures in Figure 6.4. For image processing and occupant detection, Raspberry Pi supported camera was then connected to the internet over LAN (local area network)/WLAN (wireless local area network) and Pi's IP address was fetched and eventually wireless camera interface was prepared. The configuration (raspi-config) program should automatically come up. After putting Raspberry Pi on the network, enable SSH to allow another computer to connect to the Raspberry Pi over the Wi-Fi network [28,29].

6.1.5 Arduino UNO Microcontroller

Arduino is an open-source platform used for building digital devices and interactive objects that can sense and control physical devices. Arduino consists of both a physical programmable circuit board (often referred to as a microcontroller) and a piece of software, or IDE (Integrated Development Environment) that runs on PC / Laptop, used to write and upload computer code to the physical board.Arduino UNO is a microcontroller board, based on ATMega328. It consists of 14 digital I/O (input/output) pins in which PWM (pulse width modulation) pin count is 6. For analog inputs, there are 6 analog pins. Also, it contains 16 MHz quartz crystal, a USB connection, a power jack and a reset button, shown in **Figure 6.5** [33]

Figure 6.5: Arduino UNO board

IoT (Internet of Things) refers to the networked interconnection with objects which are often equipped with ubiquitous intelligence. IoT will increase the ubiquity of the Internet by integrating object for interaction via embedded system like Arduino, which leads to a highly distributed network of devices communicating with human beings as well as other.

6.1.6 ESP8266

The ESP8266 **ESP-01** shown in **Figure 6.6** Arduino compatible module is a very low-cost Wi-Fi chip detail in **Table 6.1** with full TCP/IP capability [ ] for communicating over the internet and this has a MCU (Micro Controller Unit) integrated which gives the possibility to control I/O digital pins via simple programming language. Using the Arduino IDE web server is developed to control an LED remotely.

Figure 6.6 : ESP-8266-01 for Wi-Fi connection

Table-6.1: ESP8266 specification details [33]

32-bit RISC CPU	Tensilica Xtensa LX106 running at 80 MHz
RAM	64 KiB of instruction RAM, 96 KiB of data RAM
External QSPI flash	512 KiB to 4 MiB
Wireless network products using the Wi-Fi	IEEE 802.11 b/g/n Wi-Fi
GPIO	16 GPIO pins

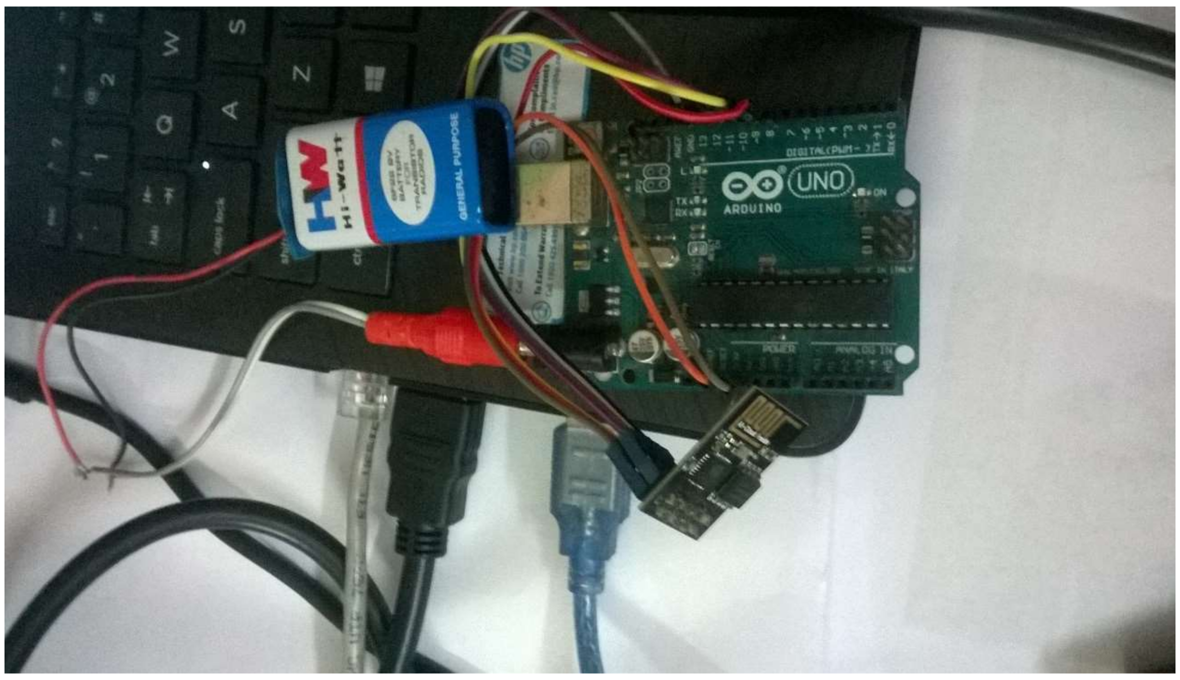


Figure 6.7: Arduino UNO board with Wifi ESP8266 module for wireless communication

ESP8266 Module is turned on by using Arduino Uno 3.3V DC Output Pin **Figure 6.7**. Arduino board is not delivering sufficient voltage to the ESP8266 module. It was required to use a 3.3 V to power this module. A voltage divider circuit is used to drop the Arduino 5V to ESP8266 3.3 V. After sending AT commands to ESP8266 Module that is connected to Arduino Board and eventually wireless data transfer was successful.

6.1.7 NodeMCU

NodeMCU is an open source IoT platform. It include firmware which runs on ESP8266 Wi-Fi System on Chip and hardware which is based on ESP-12 module. It is improved alternative of previous Arduino ESP8266 integrated model because of failure of continuous wireless connection in the **Figure 6.8** below.

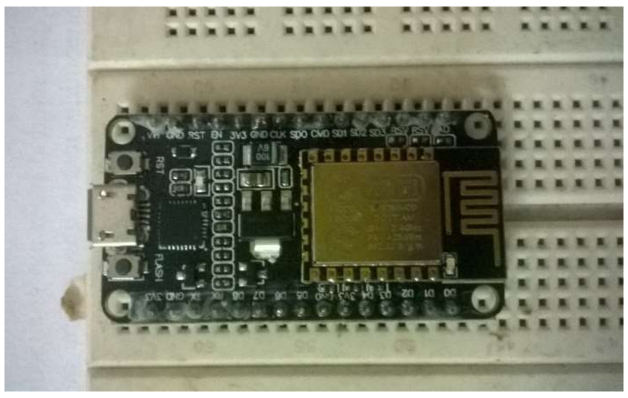


Figure 6.8: Node MCU instead of ESP8266-Arduino set up

6.1.7 Electronic Sugar Cube Relay

This is high-quality Single Pole - Double Throw (SPDT) sealed 9V Sugar Cube relays. It was used to switch high voltage (240AC), and/or high current devices (7A). This relay's coil is rated up to 14V, with a minimum switching voltage of 10V. The contacts are rated up to 7A at 250V AC and 7A at 24V DC. By using this it is integrated with artificial lighting loads and switched accordingly.

Figure- 6.9: Electronic Relay for Making Switching To Lighting Load

6.2 Wireless connectivity

Raspberry Pi NoIR camera V2 module is connected to the Raspberry Pi 3B through a CSI bus, which is the Camera Serial Interface. After interface the camera, it is required to collect images throughout the time and send it via wireless communication to the personal computer located remotely. After building up a Wi-Fi connection, the images are received. At receiving end, python programming is done. That python programming is so powerful to capture live or real-time video frame or images to a specific destination of a personal computer. After image acquisition image is stored, analysed and after processing gives a controlled output which leads to control the artificial light.

Figure-6.10: TP Link Router

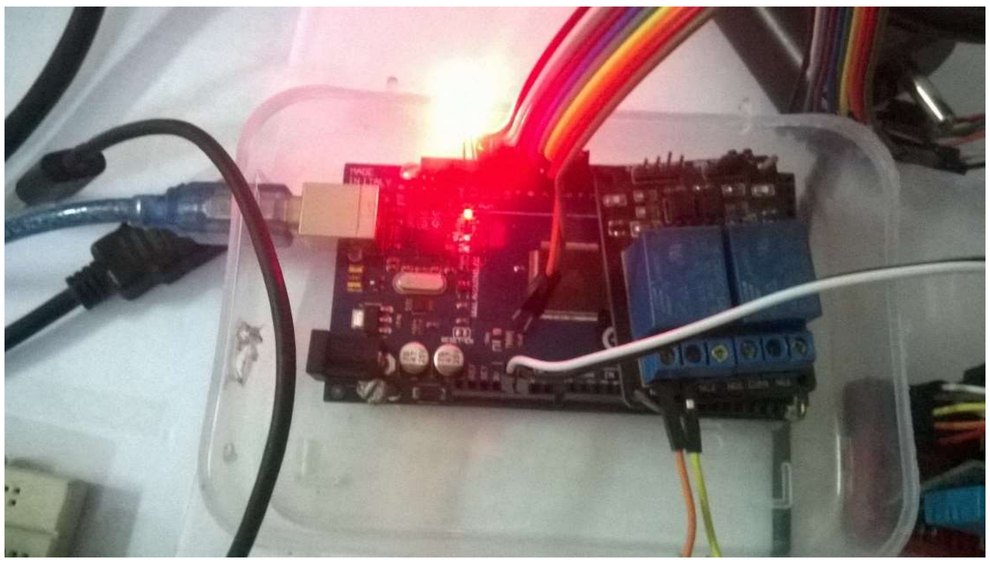


Figure-6.11: Arduino Mega with relay and LED connection

6.3 Whole Setup Pictures Step by Step

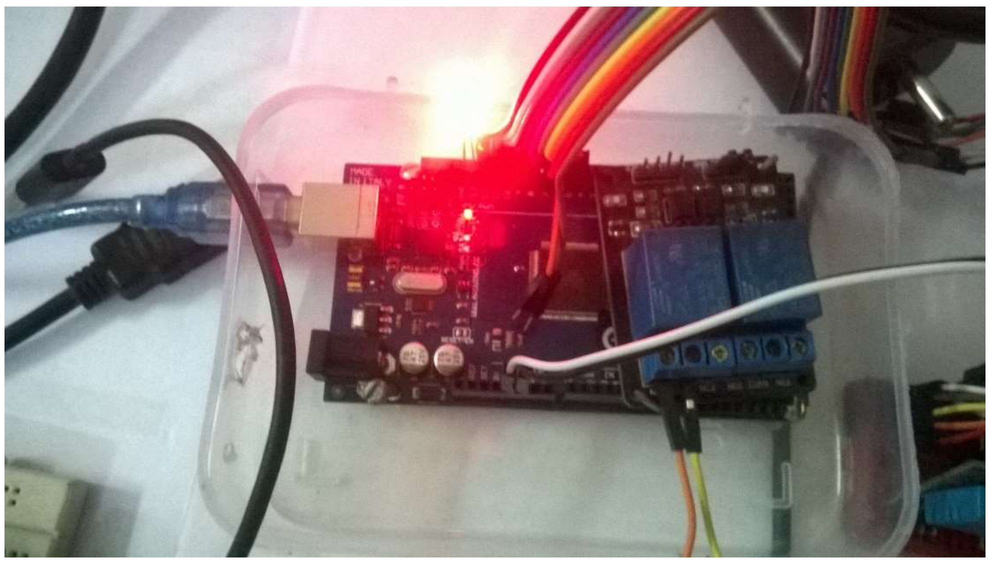


Figure- 6.12: Arduino Mega with Relay and LED Connection

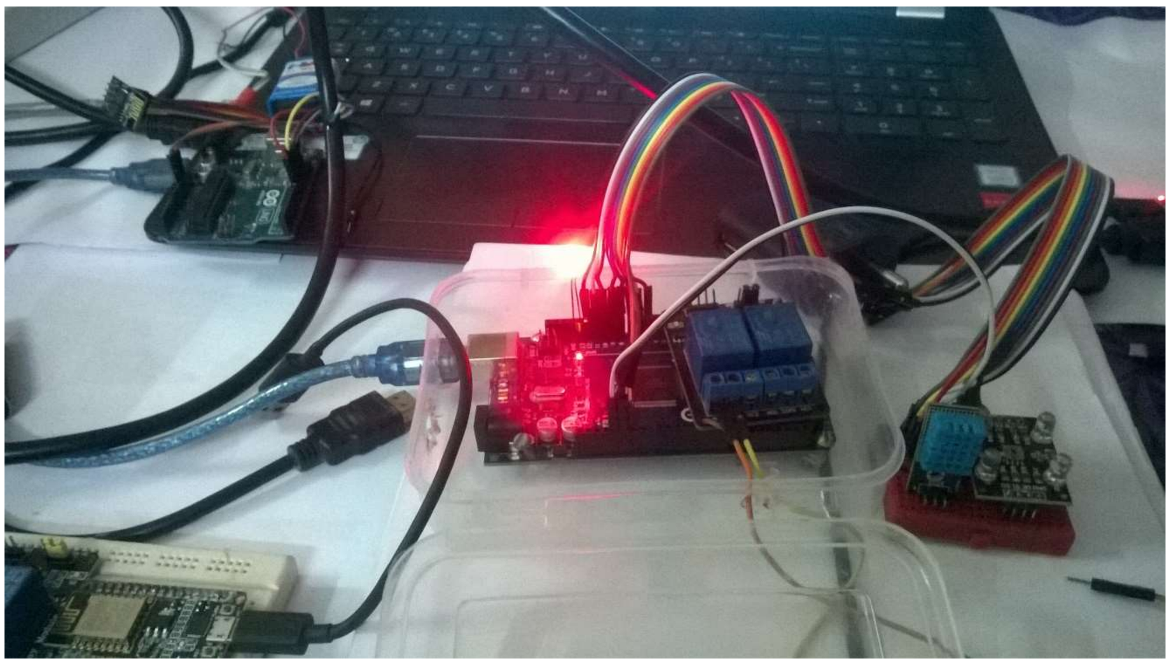


Figure- 6.13: Arduino Mega with Relay and LED Connection as well as Sensors for Monitoring the Internal Condition

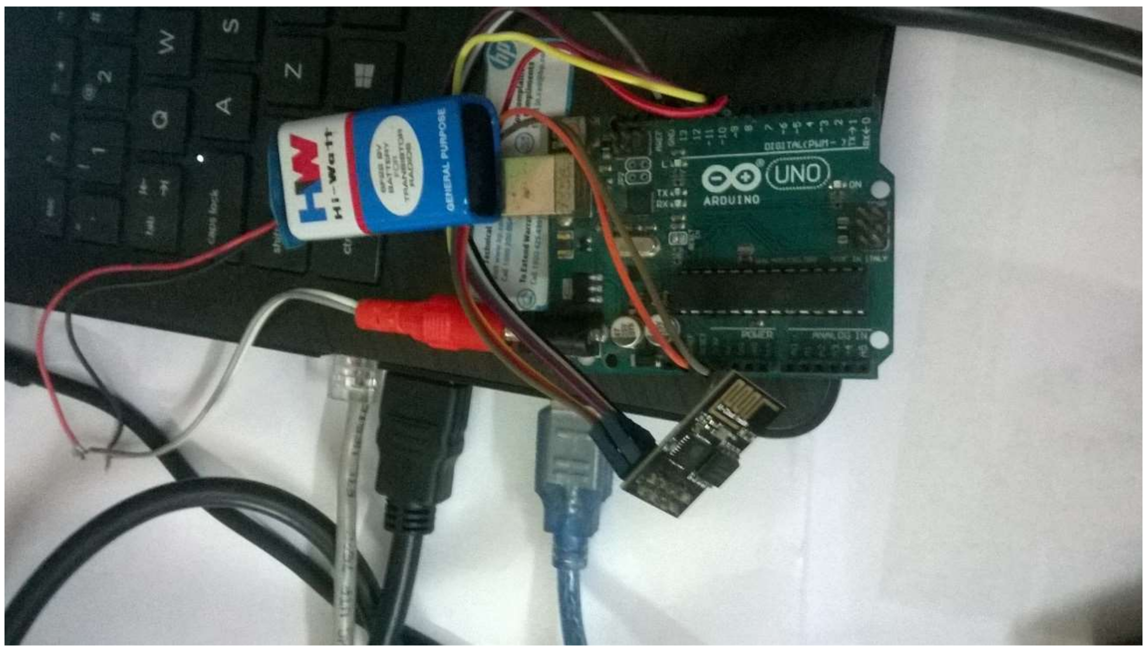


Figure-6.14: Arduino UNO Board with Wifi ESP8266 Module for Wireless Communication

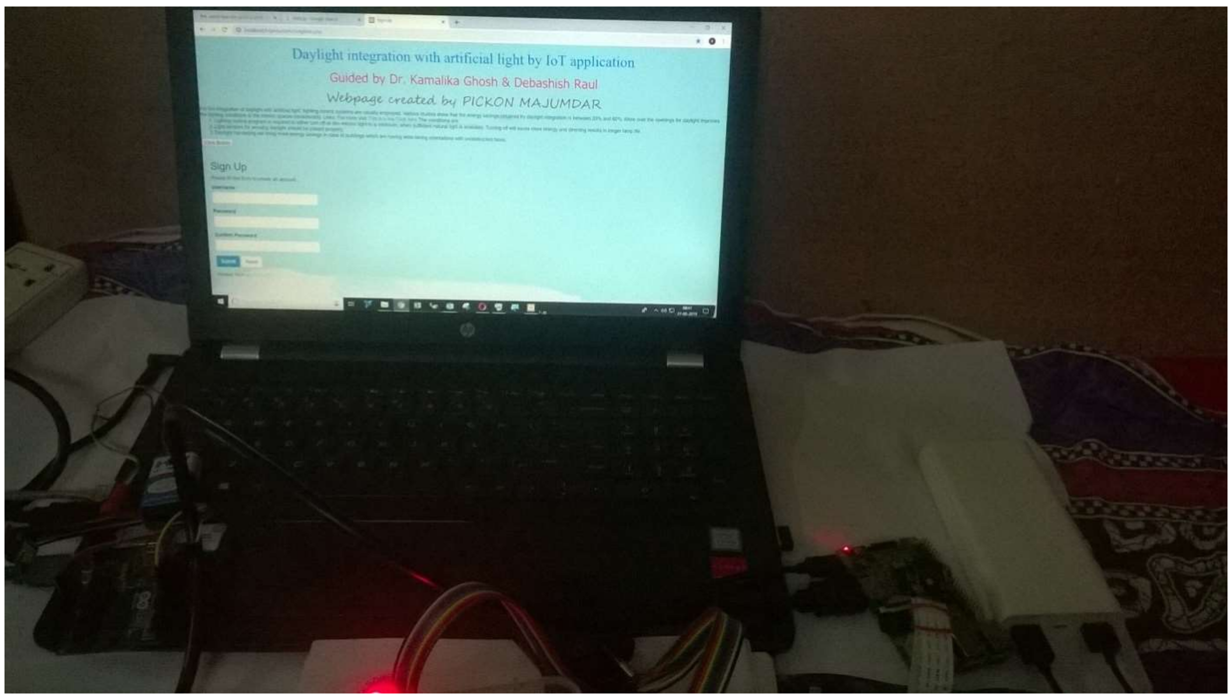


Figure-6.15: Register Page before Connecting to Cloud

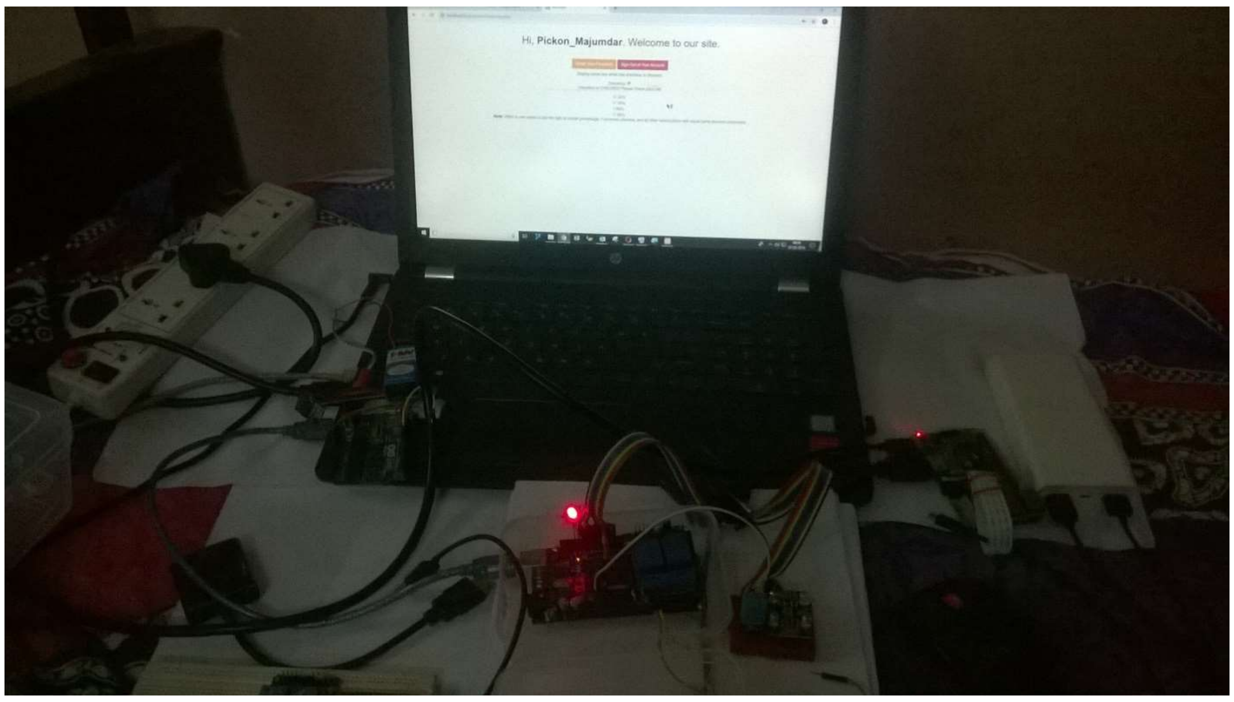


Figure-6.16: Welcome Page for Connecting to Cloud Platform

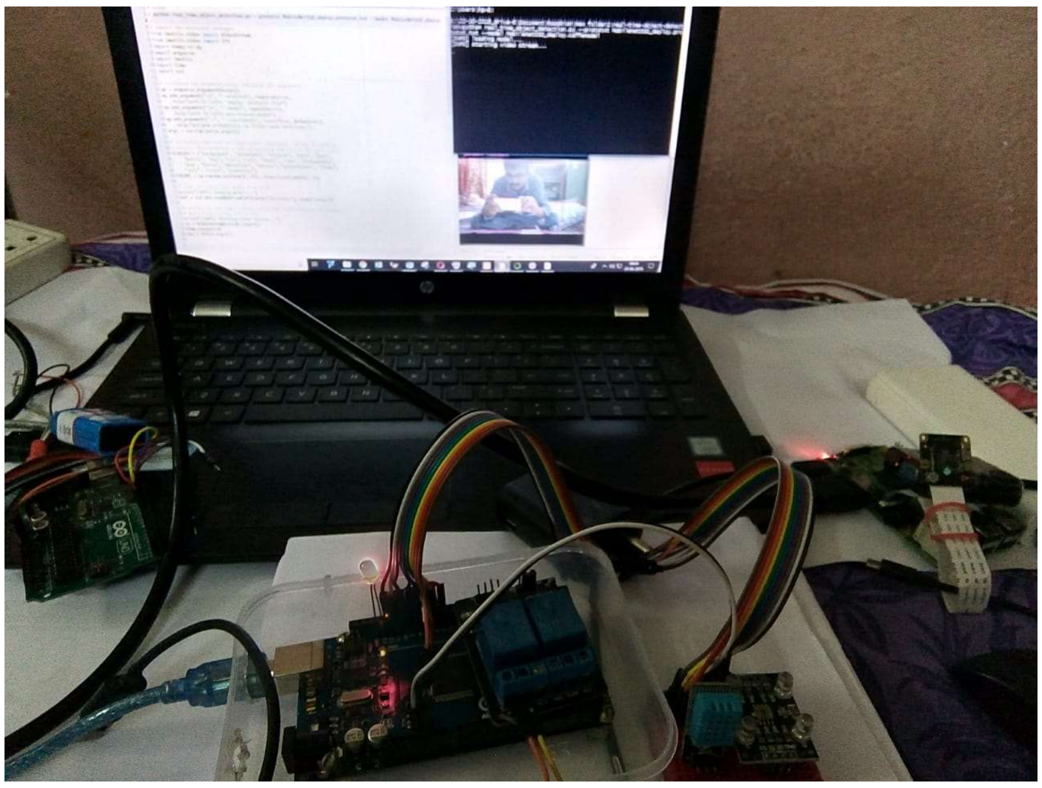


Figure-6.17: Whole Setup with Image Acquisition and Object Detection

6.4 Sensor Details

a) DHT 11 (Temperature and Humidity Sensor)

b)Gas Sensor

a) DHT 11 (Temperature and Humidity Sensor)

The DHT11 Temperature & Humidity Sensor consists of a temperature & humidity sensor which is calibrated against a digital signal output. The DHT11 ensures reliability, high efficiency and stability for a long time which is present with the help of this digital-signal-acquisition exclusive technique. This temperature and humidity sensor have an Negative Temperature Co-efficient (**NTC**) temperature component for measuring the temperature and a very high-performance 8-bit microcontroller connected for humidity, which is cost effective and provides an excellent quality and fast response ability with anti-interference[7,33].

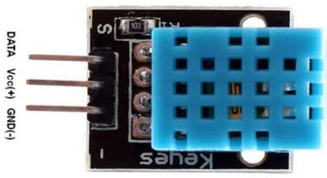


Figure- 6.18: DHT 11(Temperature and Humidity Sensor)

Table-6.1: Details of DHT 11(Temperature and Humidity Sensor

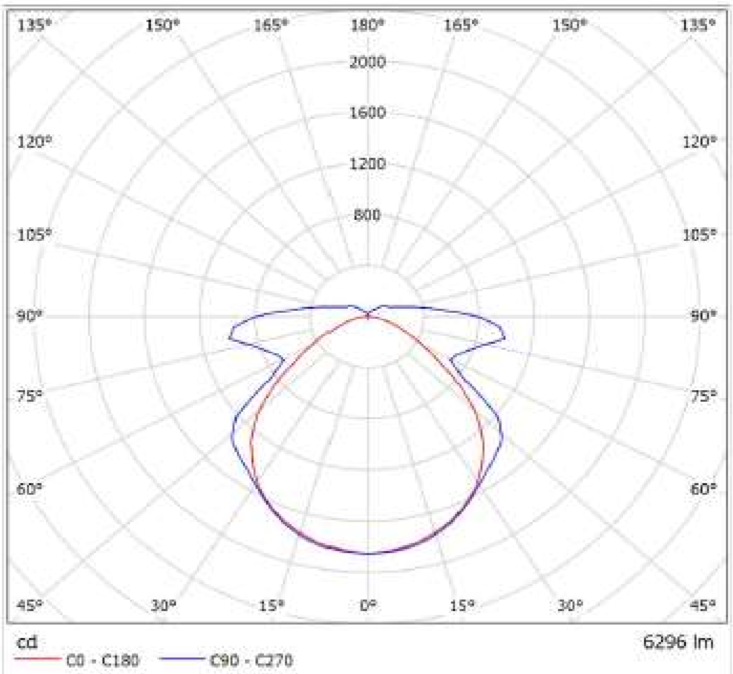
Item	DHT11
Measurement Range	20-90%RH 0-50 ℃
Humidity Accuracy	±5%RH
Temperature Accuracy	±2℃
Resolution	1
Package	3 Pin Single Row

6.5 Lamps and Luminaire Description

ECLIPSE Lighting 511-LED60-(2) EBU-WHT 49"L. X 11"W. X 4"H. LED FIXTURE PRISMATIC LENS / Luminaire Data Sheet

Figure-6.19: ECLIPSE LED Light

Luminous Emittance 1:



Glare Evaluation According to UGR

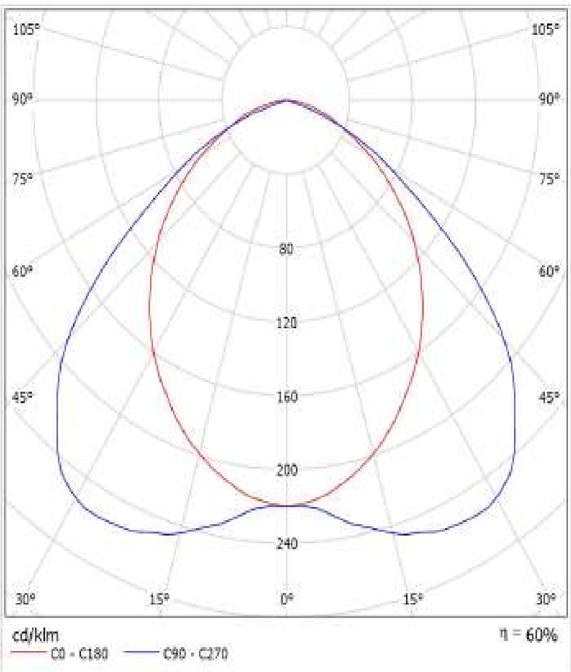
ρ Ceiling		70	70	50	50	30	70	70	50	50	30
ρ Walls		50	30	50	30	30	50	30	50	30	30
ρ Floor		20	20	20	20	20	20	20	20	20	20
Room Size X	Y	Viewing direction at right angles to lamp axis					Viewing direction parallel to lamp axis				
2H	2H	15.0	16.2	15.4	16.6	17.1	16.0	17.3	16.5	17.7	18.2
	3H	15.5	16.6	16.0	17.1	17.6	18.3	19.4	18.8	19.9	20.4
	4H	15.7	16.7	16.2	17.2	17.7	20.1	21.1	20.6	21.6	22.1
	6H	15.8	16.8	16.3	17.3	17.9	22.2	23.2	22.8	23.7	24.3
	8H	15.9	16.8	16.4	17.3	17.9	23.3	24.3	23.8	24.8	25.3
	12H	15.9	16.8	16.5	17.3	17.9	24.3	25.2	24.9	25.8	26.3
4H	2H	15.5	16.6	16.0	17.0	17.6	16.4	17.5	16.9	18.0	18.5
	3H	16.3	17.2	16.8	17.7	18.3	19.0	19.9	19.6	20.5	21.1
	4H	16.6	17.4	17.1	17.9	18.5	21.0	21.8	21.6	22.4	23.0
	6H	16.8	17.5	17.4	18.1	18.7	23.5	24.2	24.1	24.8	25.4
	8H	16.9	17.6	17.5	18.1	18.8	24.7	25.4	25.3	26.0	26.6
	12H	17.0	17.6	17.6	18.2	18.9	25.9	26.5	26.5	27.1	27.8
8H	4H	17.5	18.2	18.1	18.8	19.4	21.3	21.9	21.9	22.5	23.2
	6H	18.0	18.5	18.6	19.2	19.9	24.0	24.6	24.7	25.2	25.9
	8H	18.1	18.6	18.8	19.3	20.0	25.5	26.0	26.2	26.7	27.4
	12H	18.2	18.7	18.9	19.3	20.1	27.0	27.4	27.6	28.1	28.8
12H	4H	18.1	18.7	18.7	19.3	20.0	21.2	21.9	21.9	22.5	23.2
	6H	18.8	19.3	19.4	19.9	20.7	24.1	24.6	24.7	25.3	26.0
	8H	19.0	19.5	19.7	20.1	20.9	25.7	26.1	26.3	26.8	27.5
Variation of the observer position for the luminaire distances S											
S = 1.0H		+0.2 / -0.2					+0.2 / -0.1				
S = 1.5H		+0.4 / -0.7					+0.3 / -0.4				
S = 2.0H		+0.8 / -1.0					+0.3 / -0.6				
Standard table		BK05					---				
Correction Summand		1.2					---				
Corrected Glare Indices referring to 6296lm Total Luminous Flux											

Figure-6.20: Luminaire Description 1

Luminaire classification according to CIE: 88
CIE flux code: 45 73 87 88 100

PHILIPS TCS306/236 HF NORMAL / Luminaire Data Sheet

Figure-6.21: PHILIPS Fluroscent Lamp



Glare Evaluation According to UGR

ρ Ceiling		70	70	50	50	30	70	70	50	50	30
ρ Walls		50	30	50	30	30	50	30	50	30	30
ρ Floor		20	20	20	20	20	20	20	20	20	20
Room Size X	Y	Viewing direction at right angles to lamp axis					Viewing direction parallel to lamp axis				
2H	2H	18.7	19.9	19.0	20.1	20.3	19.9	21.1	20.2	21.3	21.6
	3H	19.5	20.5	19.8	20.8	21.1	20.3	21.4	20.7	21.7	21.9
	4H	19.7	20.8	20.1	21.0	21.3	20.3	21.3	20.7	21.6	21.9
	6H	20.0	20.9	20.3	21.2	21.5	20.3	21.2	20.6	21.5	21.8
	8H	20.0	20.9	20.4	21.2	21.6	20.2	21.1	20.6	21.4	21.8
	12H	20.1	20.9	20.4	21.3	21.6	20.2	21.1	20.6	21.4	21.7
4H	2H	19.2	20.2	19.5	20.5	20.8	20.2	21.2	20.5	21.5	21.8
	3H	20.1	21.0	20.5	21.3	21.6	20.8	21.6	21.1	21.9	22.3
	4H	20.5	21.3	20.9	21.6	22.0	20.8	21.5	21.2	21.9	22.2
	6H	20.8	21.5	21.2	21.9	22.2	20.7	21.4	21.2	21.8	22.2
	8H	20.9	21.5	21.4	21.9	22.3	20.7	21.3	21.2	21.7	22.1
	12H	21.0	21.6	21.5	22.0	22.4	20.7	21.2	21.1	21.6	22.1
8H	4H	20.6	21.2	21.0	21.6	22.0	20.8	21.4	21.3	21.8	22.2
	6H	21.0	21.5	21.4	21.9	22.4	20.8	21.3	21.3	21.8	22.2
	8H	21.2	21.6	21.6	22.0	22.5	20.8	21.3	21.3	21.7	22.2
	12H	21.3	21.7	21.8	22.1	22.6	20.8	21.2	21.3	21.7	22.2
12H	4H	20.6	21.1	21.0	21.5	21.9	20.8	21.4	21.3	21.8	22.2
	6H	21.0	21.4	21.5	21.9	22.3	20.9	21.3	21.3	21.7	22.2
	8H	21.2	21.5	21.7	22.0	22.5	20.9	21.2	21.3	21.7	22.2
Variation of the observer position for the luminaire distances S											
S = 1.0H		+0.3 / -0.4					+0.3 / -0.5				
S = 1.5H		+0.7 / -1.0					+1.0 / -1.5				
S = 2.0H		+1.0 / -1.8					+2.2 / -2.8				
Standard table		BK03					BK02				
Correction Summand		1.5					1.4				
Corrected Glare Indices referring to 6410lm Total Luminous Flux											

Figure-6.22: Luminaire Description 2

16 Pieces PHILIPS TCS306/236 HF NORMAL
Luminous flux of the lamps: 6410 lumen

Table-6.2: Luminaire Details

Sl. No.	Specification	Detailed values
1	Type of luminaires	LED
2	No. Of luminaires	16
3	Lumens of luminaires	3858 lumen
4	Wattage of luminaires	74W
5	Luminaire classification according to CIE	100

6.6 Measuring Instruments Required During Experiments

During Experiment, some measuring instruments are required. These are the followings.

- Lux meter
- Measuring tapes

Chapter 7:
Experimental Results and Analysis

7. Results and Discussion

The assessment of the level of illumination for particular indoor space and to achieve energy efficiency of lighting control systems, the proposed methodology is adopted. In the previous chapter [Chapter 6], the hardware and software description are explained. Here in this chapter, the consequence of control strategies will be expounded based on daylight availability and on room occupancy. All the results will be explained later with proper discussion.

7.1 Case Study 1

Here, the first experiment, based on this projected idea, is accomplished in a room of a house. The room is situated at Subhasgram near Kolkata having coordinates **22.4138° N**, **88.4342° E**. But, before experiment with the suggested plan, a simulation of a room is done using DIALux software considering overcast sky condition. The approximate design with general description of the room listed at **Table-7.1.** Here, initially, 16 florescent lamps were used after that12 LEDs luminaires re used. The dimming system was used for balance in quantity in illumination at the presence of daylight. The dimming system provides a reduction in electric energy consumption.

Table-7.1: General Description

Sl. No.	Dimension of the Room(in m)	10*8 (L=10m and B=8m)
1	**Area of the Room**	$80m^2$.
2	**Location**	Subhasgram,Kolkata
3	**Time of Use**	8 Hours (10 am to 5 pm)
4	**No. Of Luminaires**	16/12
5	**Type of Luminaires**	FTL / LED
6	**Wattage of Lamps**	70.5 W
7	**No. of Windows**	2
8	**Position of Windows**	At east
9	**Date, Time and Sky Condition During Simulation**	Overcast Sky

7.2 DIALux simulation result for Case Study 1

This simulation is done taking particular room dimension mention above **Table-7.1.** For allowing the daylight flux reaching to this interior space, two windows, having dimension $3.5m * 1.5\ m$, are placed considering typical environment where pollution factor 0.60,framing factor 0.85 and maintenance factor 0.85.

Figure- 7.1 : Switching Artificial Lights in absence of Daylight

Here, daylight is not coming through window as the simulated value shows the window portion looks black .Only artificial light is glowing and no daylight integration with artificial light in this case **Figure- 7.1**.The usual objects are present inside the room.

Figure- 7.2 : Daylight Entry through Window (having Certain Dimension) and no Integration of Artificial Light and No Object

7.2.1 Lighting Design of the Room without Objects shown in Figure- 7.2

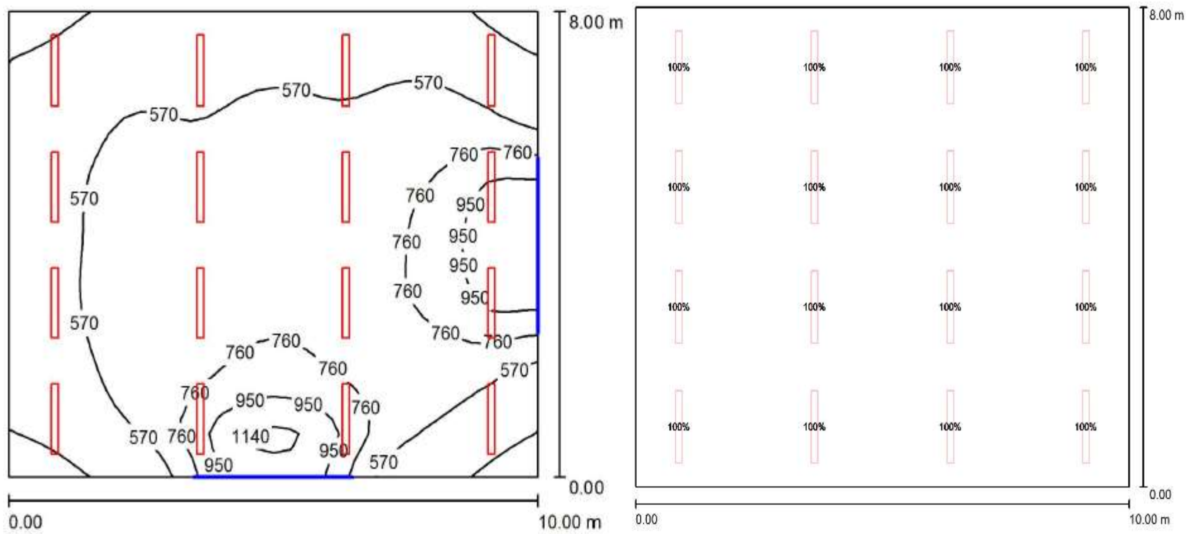


Figure-7.3: 2D View of the Case Study Room Geometry

2D View of the room without object while daylight is coming shown in **Figure-7.3** and the photometric result is shown at **Table-7.2**

Table-7.2: Photometric Results

Surface	Reflectance (Percentage) (% ρ)	Average Illumination (E_{avg}) lx	Minimum Illumination ($E_{\min}$) lx	Maximum Illumination (E_{max}) lx	Overall Uniformity (U_o)
Work-Plane	Ceiling-80/ Walls-50/ Floor-20	636	312	1235	0.492

The photometric result shown in Table-7.2 gives significant average illumination **(E_{avg})** 636 lx.

Table-7.3: Photometric Parameters According to Reflectance Values

Surface	Average illuminances [lx] direct	indirect	total	Reflection factor [%]	Average luminance [cd/m²]
Workplane	516	119	636	/	/
Floor	462	125	587	20	37
Ceiling	0.00	132	132	80	34
Wall 1	165	126	291	50	46
Wall 2	194	125	320	50	51
Wall 3	184	119	303	50	48
Wall 4	210	118	328	50	52

Table-7.4: Dimming Used in Different Light Scenes

Sl. No.	Control group (Luminaire)	Dimming Values (%)
1	Control group 1 (PHILIPS TCS306/236 HF NORMAL)	100

Here, Specific connected load is described as:

- Lighting Power Density (LPD) = 14.80 W/m²
- Normalized power density (NPD) = 2.33 W/m²/100 lx (Ground area: 80.00 m²)

Photometric parameters according to reflectance values shown in below **Table-7.3** and different light scenes with control group shown in above **Table-7.4**.

Table-7.5: Luminaire Parts List

Surface	Reflectance (Percentage) (% ρ)	Average Illumination (E_{avg})	Minimum Illumination (E_{min})	Maximum Illumination (E_{max})	Overall Uniformity (U_o)
1	16	PHILIPS TCS306/236 HF NORMAL	3858	6410	74
Total			61731	102560	1184.0

7.2.2 Lighting Design of the Room with Objects

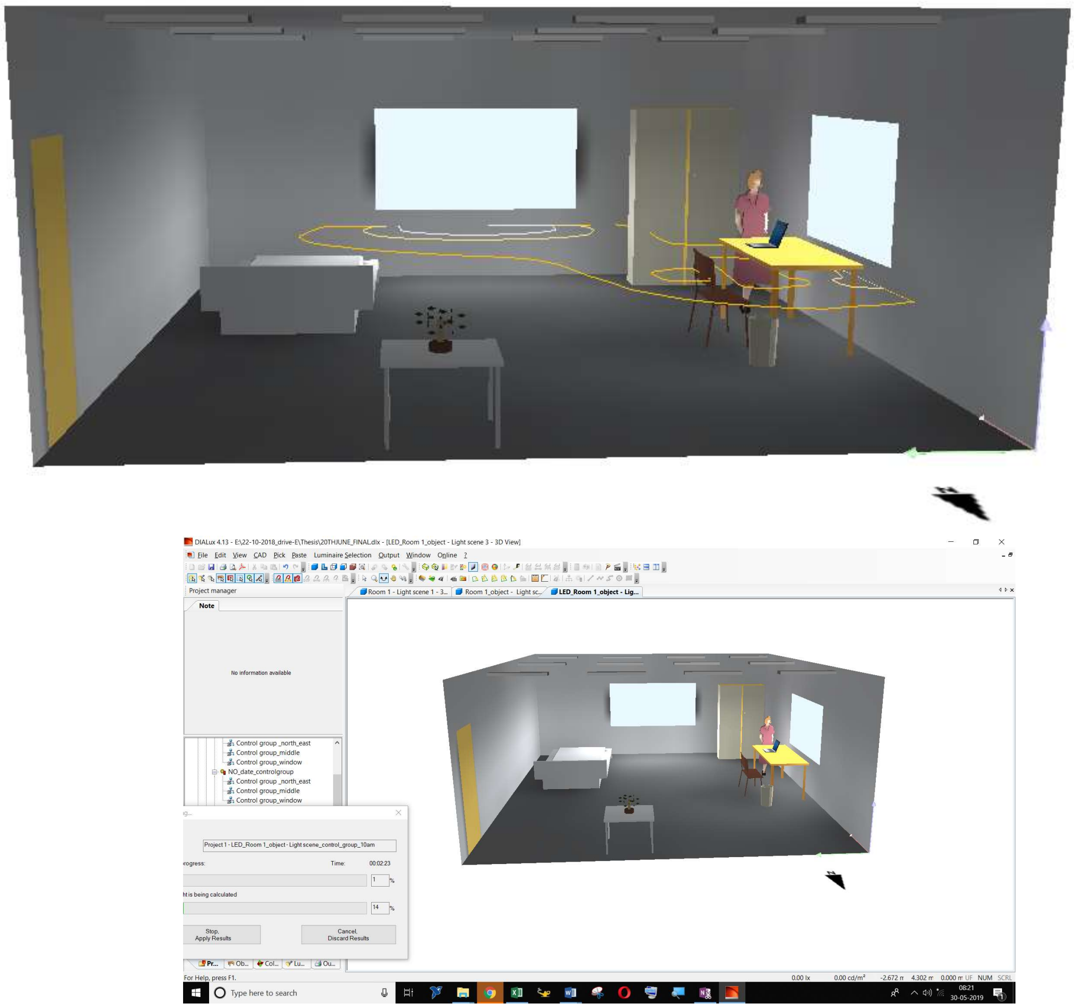


Figure- 7.4 (a) and (b): Daylight Entry through Window having Certain Dimension and no Integration of Artificial Light with objects.

Daylight is coming through window having certain dimension and no integration of artificial light but objects are present shown in **Figure- 7.4 (a) and (b)** DIALux simulation of the same room with Daylight Integration with artificial light is simulated with approximated design and depicted below at **Figure -7.5.**

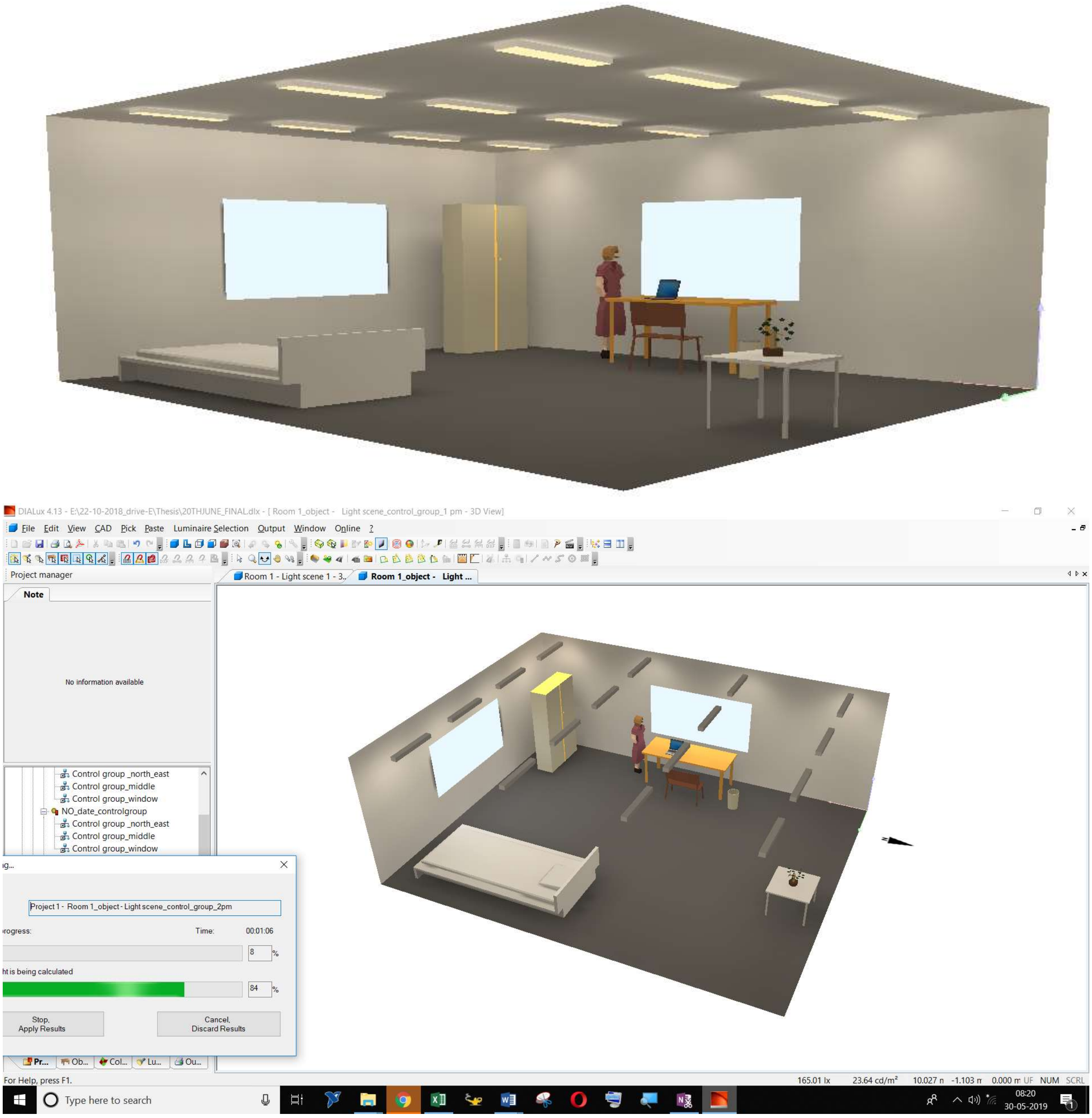


Figure -7.5 (a) and (b): DIALux Simulation of the above Room with Artificial Light (Approximate Design)

7.3 Luminaires Details

Table-7.6 gives the luminaire details where 16 Pieces PHILIPS TCS306/236 HF NORMAL. Luminous flux of the lamps are 6410 lumen.

Table-7.6: Luminaire Details

Sl. No.	Specification	Detailed values
1	**Type of luminaires**	PHILIPS TCS306/236 HF NORMAL
2	**No. of Luminaires**	16
3	**Lumens of Luminaires**	6410 lumen
4	**Wattage of Luminaires**	74W
5	**Luminaire Classification According to CIE**	100

7.4 Dimming Used in Different Light Scenes

As entry of daylight through windows during daytime the electrical energy is utilised for illumination can be saved through implementation of artificial lighting control system with dimming values.Luminiares with control groups are listed accordingly at **Table-7.5**

Table-7.5: Luminaire Parts List with Control Group

Sl. No.	Control group (Luminaire)	Dimming Values (%)
1	Control Group _Northeast (PHILIPS TCS306/236 HF NORMAL)	100
2	Control Group Middle (PHILIPS TCS306/236 HF NORMAL)	90
3	Control Group Window (PHILIPS TCS306/236 HF NORMAL)	85

7.5 Lighting Design of the Room with Objects

Now all the simulated result by fluorescent lamp installed at this room for daylight hours from 10 am to 5 pm is shown below. The light distribution of the room as well as light scene with particular control group mentioned above **Table-7.5** are shown in the approaching result. After that, the comparison table is shown to show performance characteristics.

7.6 Variation of average illumination during daytime after simulation

- Variation of average illumination, shown in **Figure-7.6.1**, designed by Fluorescent Lamp
- Variation of average illumination, shown in **Figure-7.6.2** ,designed by LED Lamp

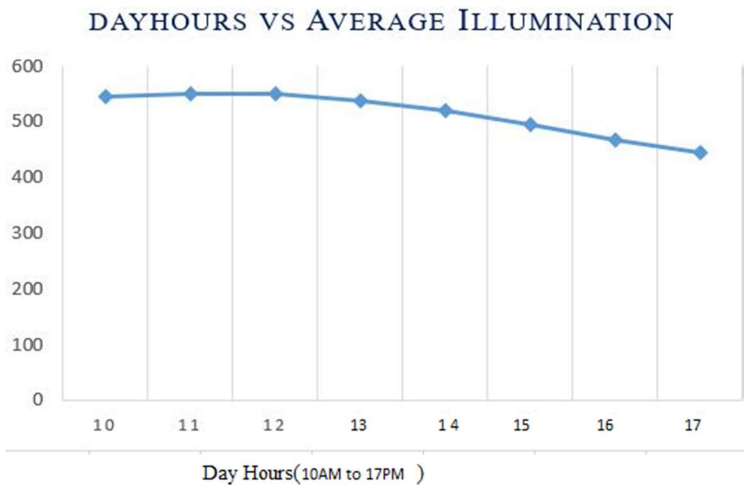


Figure-7.6.1 Average Illumination Plot while designed by Fluorescent Lamp

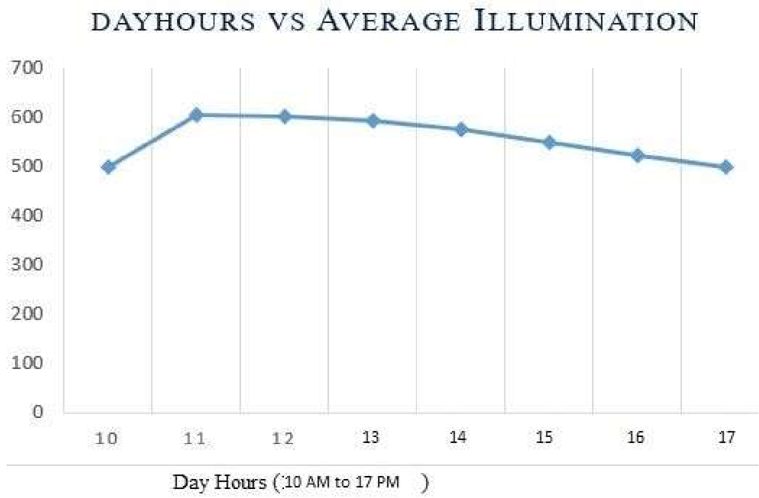


Figure-7.6.2 Average Illumination Plot while designed by LED Lamp

Table-7.5.1 Design by Fluorescent Lamp

Day Hours	10 AM	11 AM	12 PM	13 PM	14 PM	15 PM	16 PM	17 PM
Average Illumination (E_{avg}) (lx)	545	551	549	538	521	496	467	445

Table-7.5.2 Design by LED Lamp

Day Hours	10 AM	11 AM	12 PM	13 PM	14 PM	15 PM	16 PM	17 PM
Average Illumination (E_{avg}) (lx)	545	551	549	538	521	496	467	445

7.7 All simulated result at daylight hours for fluorescent and LED lamp mentioned below

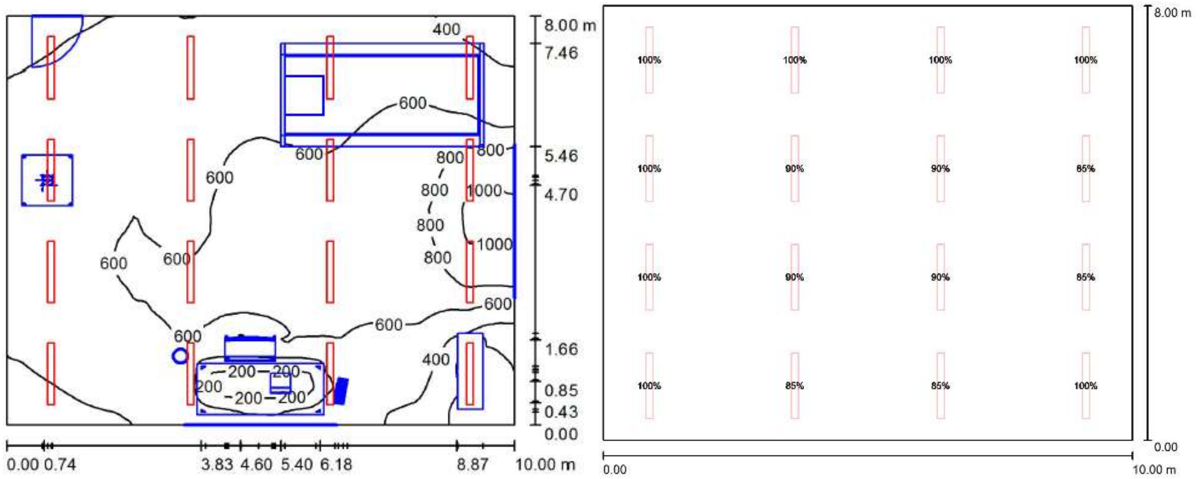


Figure-7.7: Lighting Distribution of the Room with Objects having Light Scene with Control Group at 10 AM

Table-7.6: Work Plane Details

Surface	Reflectance (Percentage) (% ρ)	Average Illumination (E_{avg})lx	Minimum Illumination $(E_{\min})$lx	Maximum Illumination (E_{max})lx	Overall Uniformity (U_o)
Work-Plane	Ceiling-80/ Walls-50/ Floor-20	545	71	1045	0.130

- **Luminaire Parts List**
  Specific connected load is described as:
  a) Lighting Power Density (LPD) = 14.80 W/m²
  b) Normalized power density (NPD) = 2.72 W/m²/100 lx (Ground area: 80.00 m²)

Photometric result:

Table -7.7: Photometric Design Parameters According to Reflectance Values

Surface	Average illuminances [lx] direct	indirect	total	Reflection factor [%]	Average luminance [cd/m²]
Workplane	437	107	545	/	/
Floor	330	96	426	20	27
Ceiling	0.00	127	127	80	32
Wall 1	133	102	235	50	37
Wall 2	168	115	284	50	45
Wall 3	174	116	290	50	46
Wall 4	202	107	309	50	49

Photometric parameters according to reflectance values shown in above **Table-7.6** and different light scenes with control group shown in above **Table-7.7**.

- **Room with objects having light scene with control group at 11 AM**

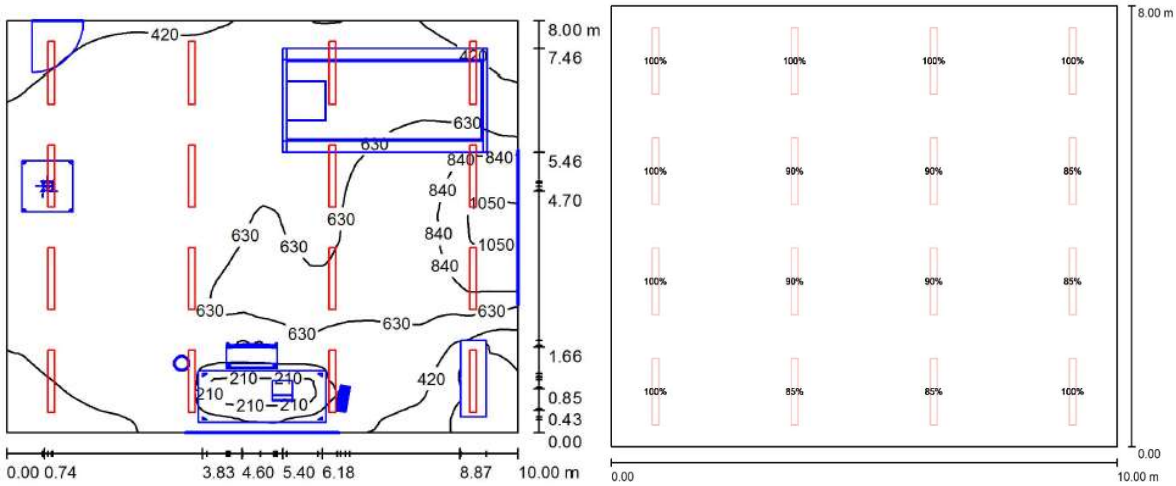


Figure-7.8: Lighting Distribution of the Room with Objects Having Light Scene with Control Group at 11 AM

Table-7.8: Work Plane Details

Surface	Reflectance (Percentage) (% ρ)	Average Illumination (E_{avg})	Minimum Illumination ($E_{\min}$)	Maximum Illumination (E_{max})	Overall Uniformity (U_o)
Work-Plane	Ceiling-80/ Walls-50/ Floor-20	551	75	1084	0.135

- **Luminaire Parts List**
  Specific connected load is described as:
  a) Lighting Power Density (LPD) = 14.80 W/m²
  b) Normalized power density (NPD) = 2.69 W/m²/100 lx (Ground area: 80.00 m²)

Table -7.9: Photometric Design Parameters According to Reflectance Values

Surface	Average illuminances [lx] direct	indirect	total	Reflection factor [%]	Average luminance [cd/m²]
Workplane	443	108	551	/	/
Floor	334	97	431	20	27
Ceiling	0.00	128	128	80	33
Wall 1	133	103	236	50	38
Wall 2	169	117	285	50	45
Wall 3	176	117	293	50	47
Wall 4	204	108	311	50	50

Photometric parameters according to reflectance values shown in above **Table-7.8** and different light scenes with control group shown in above **Table-7.9**.

- **Room with objects having light scene with control group at 12 PM**

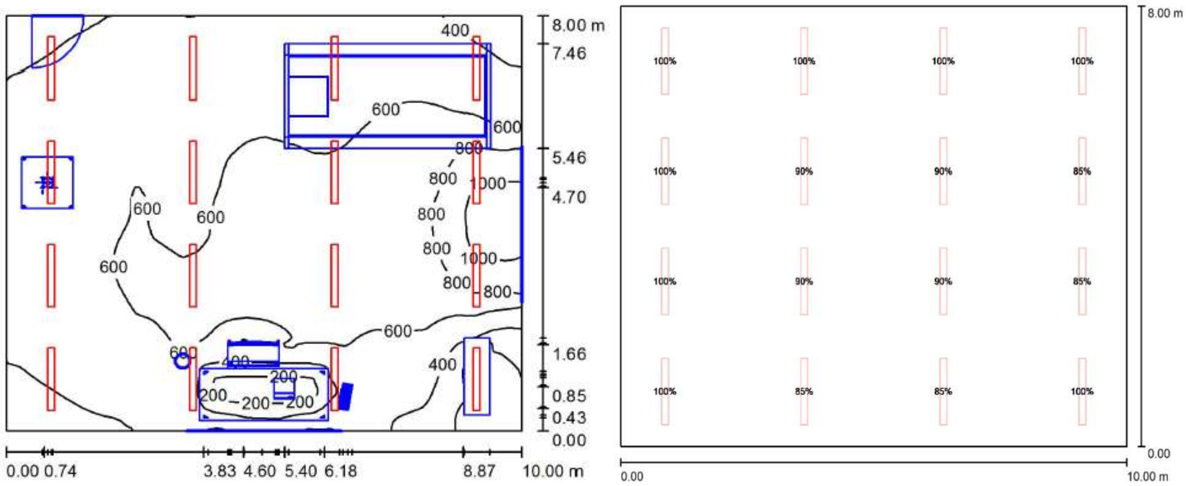


Figure- 7.9: Lighting Distribution of the Room with Objects Having Light Scene with Control Group at 12 PM

Table -7.10: Lighting Distribution of the Room with Objects Having Light Scene with Control Group at 12 PM

Surface	**Reflectance (Percentage) (% ρ)**	**Reflectance (Percentage) (% ρ)**	**Average Illumination (E_{avg})**	**Minimum Illumination ($E_{\min}$)**	**Maximum Illumination (E_{max})**	**Overall Uniformity (U_o)**
Work-Plane	Ceiling-80/ Walls-50/ Floor-20	Ceiling-80/ Walls-50/ Floor-20	549	73	1071	0.133

- **Luminaire Parts List**

  Specific connected load is described as:
- Lighting Power Density (LPD) = 14.80 W/m²
- Normalized power density (NPD) = 2.70 W/m²/100 lx (Ground area: 80.00 m²)

Table --7.11: Photometric Design Parameters According to Reflectance Values

Surface	Average illuminances [lx] direct	indirect	total	Reflection factor [%]	Average luminance [cd/m²]
Workplane	441	108	549	/	/
Floor	333	97	429	20	27
Ceiling	0.00	127	127	80	32
Wall 1	133	103	236	50	38
Wall 2	169	116	285	50	45
Wall 3	175	117	292	50	46
Wall 4	203	108	310	50	49

Photometric parameters according to reflectance values shown in above **Table-7.10** and different light scenes with control group shown in above **Table-7.11**

- **Room with Objects Having light Scene with Control Group at 1 PM**

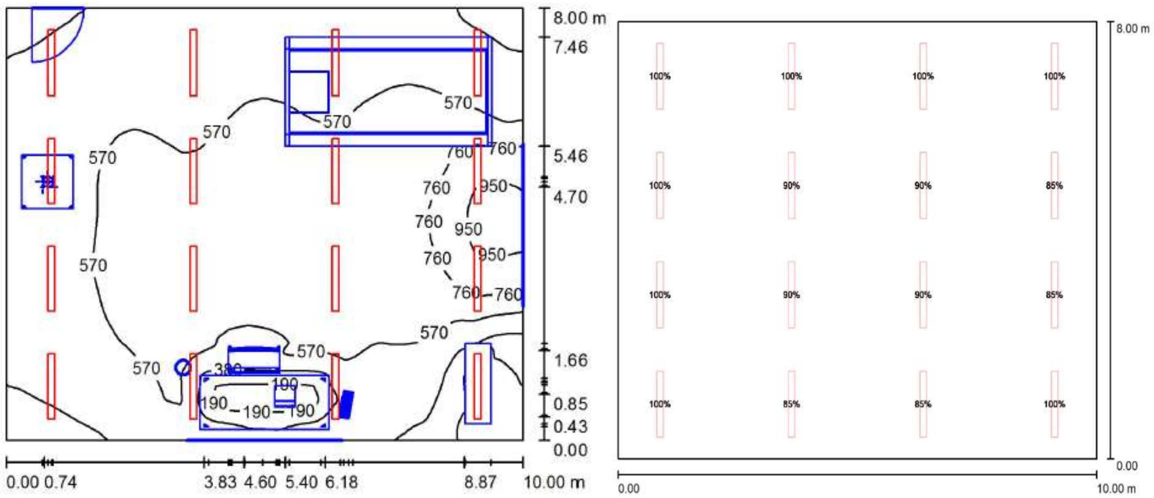


Figure-7.10: Lighting Distribution of the Room with Objects Having Light Scene with Control Group at 1 PM

Table-7.12: Work Plane Details

Surface	Reflectance (Percentage) (% ρ)	Average Illumination (E_{avg})	Minimum Illumination ($E_{\min}$)	Maximum Illumination (E_{max})	Overall Uniformity (U_o)
Work-Plane	Ceiling-80/ Walls-50/ Floor-20	538	69	1007	0.128

Specific connected load:
a)Lighting Power Density (LPD) = 14.80 W/m²
b)Normalized power density (NPD) = 2.75 W/m²/100 lx (Ground area: 80.00 m²)

Photometric result:

Table -7.13: Photometric Design Parameters According to Reflectance Values

Surface	Average illuminances [lx] direct	indirect	total	Reflection factor [%]	Average luminance [cd/m²]
Workplane	432	106	538	/	/
Floor	326	95	421	20	27
Ceiling	0.00	126	126	80	32
Wall 1	132	101	234	50	37
Wall 2	168	114	282	50	45
Wall 3	173	115	288	50	46
Wall 4	201	106	307	50	49

Photometric parameters according to reflectance values shown in above **Table-7.12** and different light scenes with control group shown in above **Table-7.13**

- **Room with objects having light scene with control group at 2 PM**

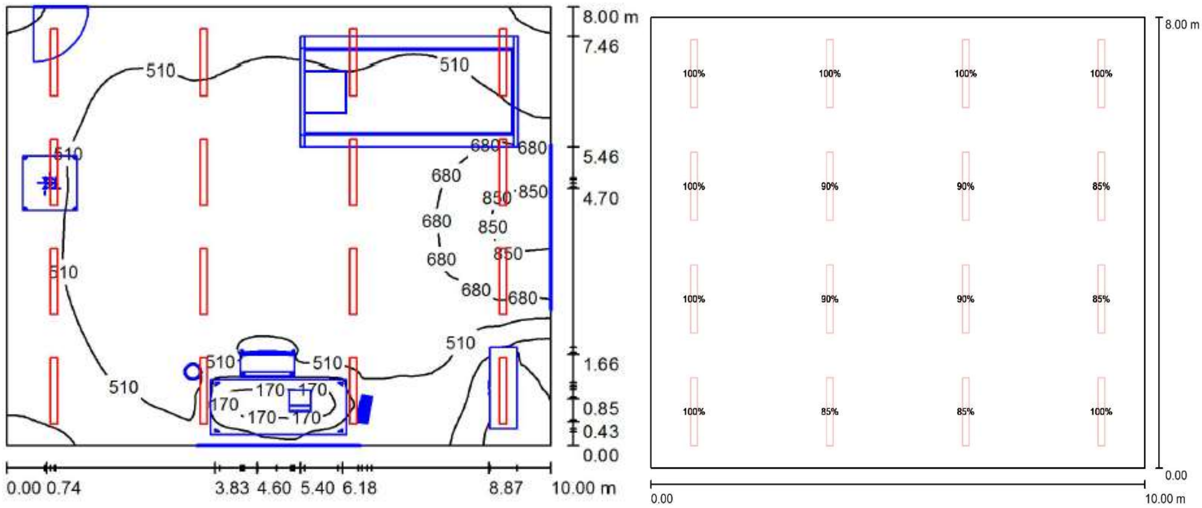


Figure-7.11: Lighting Distribution of the Room with Objects Having Light Scene with Control Group at 2 PM

Table-7.14: Work Plane Details

Surface	Reflectance (Percentage) (% ρ)	Average Illumination (E_{avg})	Minimum Illumination ($E_{\min}$)	Maximum Illumination (E_{max})	Overall Uniformity (U_o)
Work-Plane	Ceiling-80/ Walls-50/ Floor-20	521	61	896	0.118

- **Luminaire Parts List:**

Specific connected load is described as:
a) Lighting Power Density (LPD) = 14.80 W/m²
b) Normalized power density (NPD) = 2.84 W/m²/100 lx (Ground area: 80.00 m²)

Table -7.15: Lighting Distribution of the Room with Objects Having Light Scene with Control Group at 2 PM

Surface	Average illuminances [lx] direct	indirect	total	Reflection factor [%]	Average luminance [cd/m²]
Workplane	416	104	521	/	/
Floor	314	93	407	20	26
Ceiling	0.00	123	123	80	31
Wall 1	131	99	230	50	37
Wall 2	167	110	277	50	44
Wall 3	169	112	281	50	45
Wall 4	197	105	302	50	48

Photometric parameters according to reflectance values shown in above **Table-7.14** and different light scenes with control group shown in above **Table-7.15**

- **Room with Objects Having Light Scene with Control Group at 3 PM**

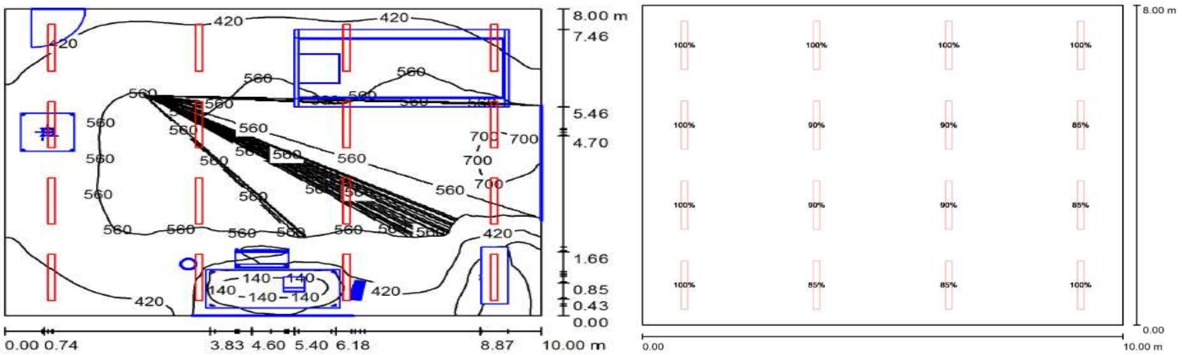


Figure-7.12 : Lighting Distribution of the Room with Objects Having Light Scene with Control group at 3 PM

Table-7.16: Work Plane Details

Surface	**Reflectance (Percentage) (% ρ)**	**Average Illumination (E_{avg})**	**Minimum Illumination ($E_{\min}$)**	**Maximum Illumination (E_{max})**	**Overall Uniformity (U_o)**
Work-Plane	Ceiling-80/ Walls-50/ Floor-20	496	52	748	0.105

- **Luminaire Parts List**

Specific connected load is described as:
a)Lighting Power Density (LPD) = 14.80 W/m²
b)Normalized power density (NPD) = 2.98 W/m²/100 lx (Ground area: 80.00 m²)

Table -7.17: Lighting Distribution of the Room with Objects Having Light Scene with Control Group at 3 PM

Surface	Average illuminances [lx] direct	indirect	total	Reflection factor [%]	Average luminance [cd/m²]
Workplane	395	101	496	/	/
Floor	297	89	387	20	25
Ceiling	0.00	118	118	80	30
Wall 1	130	95	224	50	36
Wall 2	165	106	271	50	43
Wall 3	163	109	272	50	43
Wall 4	192	102	294	50	47

Photometric parameters according to reflectance values shown in above **Table-7.16** and different light scenes with control group shown in above **Table-7.17**

- **Room with objects having light scene with control group at 4 PM**

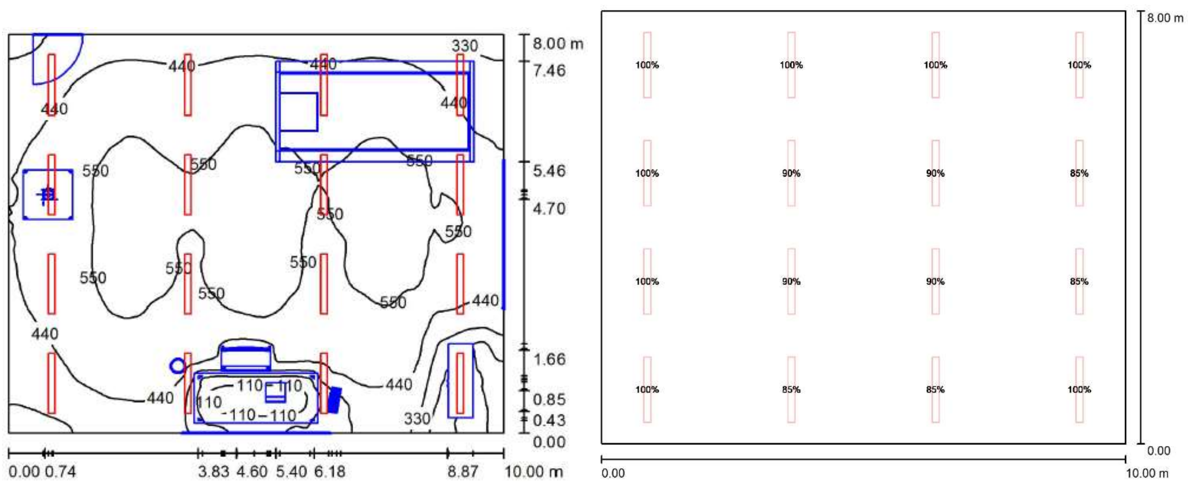


Figure- 7.13: Lighting Distribution of the Room with Objects Having Light Scene with Control Group at 4 PM

Table-7.18: Work Plane Details

Surface	**Reflectance (Percentage) (% ρ)**	**Average Illumination (E_{avg})**	**Minimum Illumination ($E_{\min}$)**	**Maximum Illumination (E_{max})**	**Overall Uniformity (U_o)**
Work-Plane	Ceiling-80/ Walls-50/ Floor-20	467	38	583	0.082

- **Luminaire Parts List**

  Specific connected load is described as:

  a)Lighting Power Density (LPD) = 14.80 W/m²

  b)Normalized power density (NPD) = 3.17 W/m²/100 lx (Ground area: 80.00 m²)

Table 7.19: Lighting Distribution of the Room with Objects Having Light Scene with Control Group at 4 PM

Surface	Average illuminances [lx] direct	indirect	total	Reflection factor [%]	Average luminance [cd/m²]
Workplane	370	97	467	/	/
Floor	278	86	364	20	23
Ceiling	0.00	113	113	80	29
Wall 1	127	90	218	50	35
Wall 2	160	100	260	50	41
Wall 3	156	105	260	50	41
Wall 4	187	98	285	50	45

Photometric parameters according to reflectance values shown in above **Table-7.18** and different light scenes with control group shown in above **Table-7.19**

- **Room with objects having light scene with control group at 5 PM**

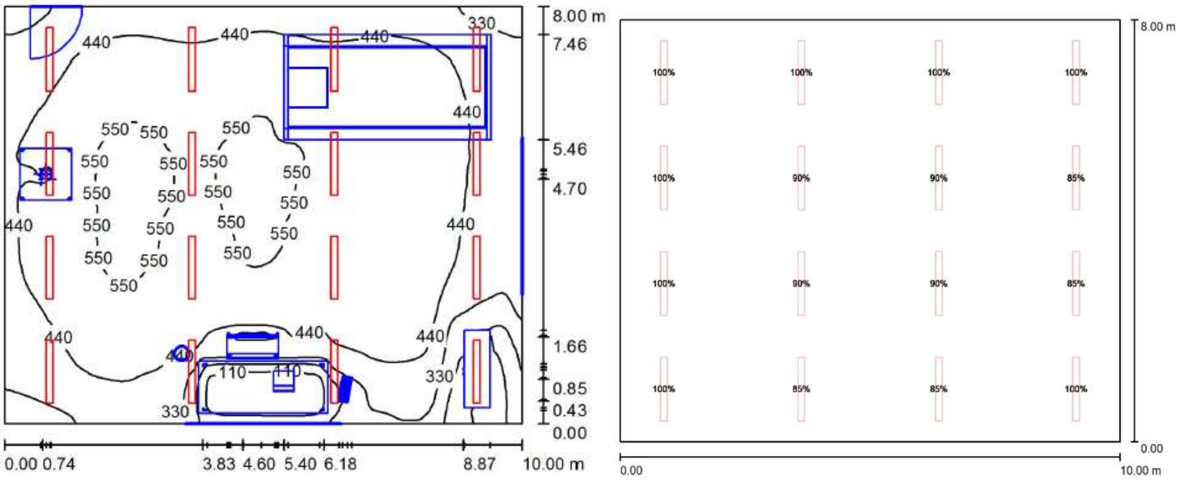


Figure- 7.14: Lighting Distribution of the Room with Objects Having Light Scene with Control Group at 5 PM

Table-7.20: Work Plane Details

Surface	Reflectance (Percentage) (% ρ)	Average Illumination (E_{avg})	Minimum Illumination (E_{min})	Maximum Illumination (E_{max})	Overall Uniformity (U_o)
Work-Plane	Ceiling-80/ Walls-50/ Floor-20	445	30	574	0.066

- **Luminaire Parts List:**

Specific connected load is described as follows.
a)Lighting Power Density (LPD) = 14.80 W/m²
b)Normalized power density (NPD) = 3.32 W/m²/100 lx (Ground area: 80.00 m²)

Table - 7.21: Lighting Distribution of the Room with Objects Having Light Scene with Control Group at 5 PM

Surface	Average illuminances [lx] direct	indirect	total	Reflection factor [%]	Average luminance [cd/m²]
Workplane	351	94	445	/	/
Floor	264	83	346	20	22
Ceiling	0.00	109	109	80	28
Wall 1	125	87	212	50	34
Wall 2	159	94	253	50	40
Wall 3	150	101	251	50	40
Wall 4	183	96	279	50	44

Photometric parameters according to reflectance values shown in above **Table-7.20** and different light scenes with control group shown in above **Table-7.21**

Daylight Parameters

Location: Calcutta, Longitude: 88.40°, Latitude: 22.50°, North deviation: -90.0°

Table-7.22: Luminaire Classification According to CIE: 88

Sl. No.	Pieces	Designation (Correction Factor)	Φ(Luminaire) (lm)	Φ (Lamps) (lm)	P (Watts)
1	12	ECLIPSE LIGHTING 511-LED60-(2)EBU-WHT 49"L. X 11"W. X 4"H. LED FIXTURE PRISMATIC LENS	6296	6296	70.5

Table-7.23: Luminaire Types

Sl. No	Control group (Luminaire)	Dimming values (Total) (%)
1	Control group_LED_CORNER (ECLIPSE LIGHTING 511-LED60-(2)EBU-WHT 49"L. X 11"W. X 4"H. LED FIXTURE PRISMATIC LENS)	100
2	Control group_led_Middle (ECLIPSE LIGHTING 511-LED60-(2)EBU-WHT 49"L. X 11"W. X 4"H. LED FIXTURE PRISMATIC LENS)	90
3	Control group_led_window (ECLIPSE LIGHTING 511-LED60-(2)EBU-WHT 49"L. X 11"W. X 4"H. LED FIXTURE PRISMATIC LENS)	80

- **Luminaire Parts List**

  Specific connected load is described as:

  a)Lighting Power Density (LPD) = 14.80 W/m²

  b)Normalized power density (NPD) = 2.33 W/m²/100 lx (Ground area: 80.00 m²)

Table-7.24: Luminaire Types

Sl. No.	Pieces	Designation (Correction Factor)	Φ(Luminaire) (lm)	Φ (Lamps) (lm)	P (Watts)
1	12	ECLIPSE LIGHTING 511-LED60-(2)EBU-WHT 49"L. X 11"W. X 4"H. LED FIXTURE PRISMATIC LENS (1.000)	6296	6296	70.5
Total			75547	75547	846.5

Date: 13.01.2018, Time: 10:00:00 (+5 hours difference to GMT)
Reference sky type: Overcast Sky

Height of Room: 3.500 m, Mounting Height: 3.500 m, Light Loss Factor: 0.80

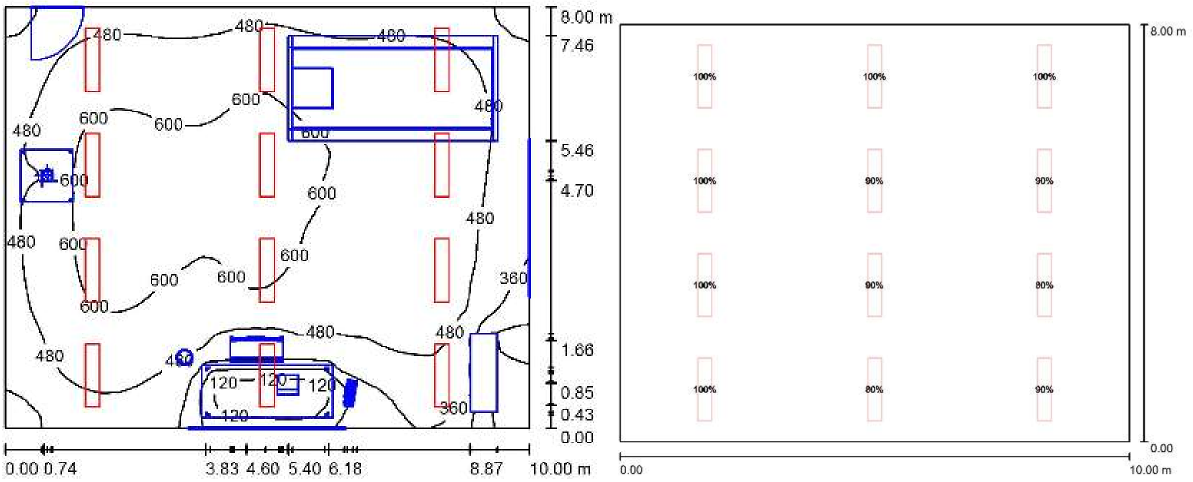


Figure- 7.15: Lighting Distribution of the Room with Objects Having Light Scene with Control Group at 10 AM

Table-7.25: Work Plane Details

Surface	Reflectance (Percentage) (% ρ)	Average Illumination (E_{avg})	Minimum Illumination ($E_{\min}$)	Maximum Illumination (E_{max})	Overall Uniformity (U_o)
Work plane	Ceiling-80/ Walls-50/ Floor-20	499	51	644	0.102

- **Luminaire Parts List**
  Specific connected load is loaded as follows:
  a)Lighting Power Density (LPD) = 10.58 W/m²
  b)Normalized power density (NPD) = 2.12 W/m²/100 lx (Ground area: 80.00 m²)

Table -7.26: Lighting Distribution of the Room with Objects Having Light Scene with Control Group at 10 AM

Surface	Average illuminances [lx] direct	indirect	total	Reflection factor [%]	Average luminance [cd/m²]
Workplane	341	158	499	/	/
Floor	254	131	385	20	25
Ceiling	78	135	214	80	54
Wall 1	150	125	275	50	44
Wall 2	195	129	324	50	52
Wall 3	180	146	327	50	52
Wall 4	237	139	375	50	60

Photometric parameters according to reflectance values shown in above **Table-7.25** and different light scenes with control group shown in above **Table-7.26**

Date: 13.01.2018, Time: 11:00:00 (+5 hours difference to GMT)
Reference sky type: Overcast Sky

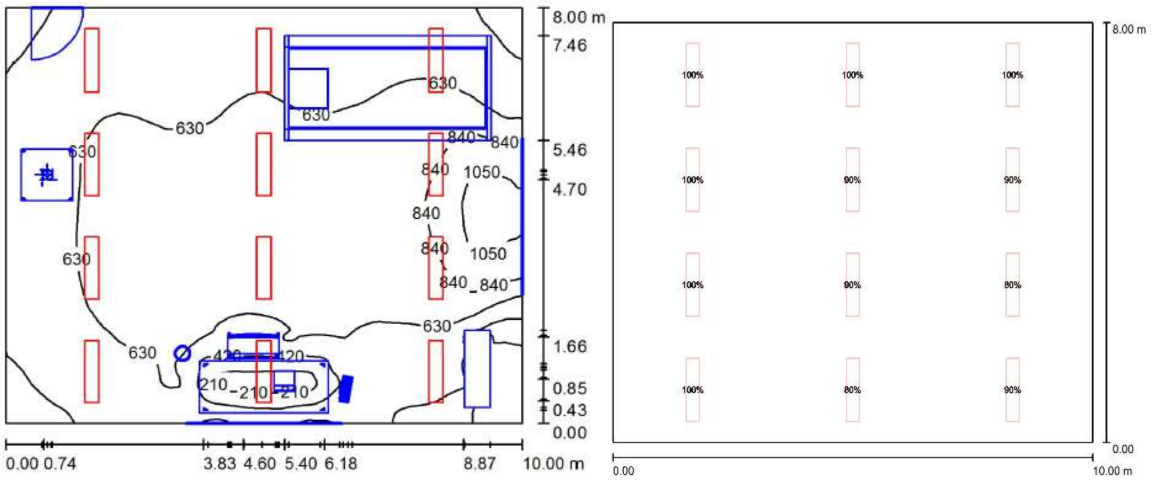


Figure-7.16: Lighting Distribution of the Room with Objects Having Light Scene with Control Group at 11 AM

Table -7.27: Work Plane Details

Surface	**Reflectance (Percentage) (% ρ)**	**Average Illumination (E_{avg})**	**Minimum Illumination ($E_{\min}$)**	**Maximum Illumination (E_{max})**	**Overall Uniformity (U_o)**
Work plane	Ceiling-80/ Walls-50/ Floor-20	603	104	1152	0.172

Luminaire Parts List

Specific connected load is described as:
a)Lighting Power Density (LPD) = 10.58 W/m²
b) Normalized power density (NPD) = 1.75 W/m²/100 lx (Ground area: 80.00 m²)

Table -7.28: Lighting Distribution of the Room with Objects Having Light Scene with Control Group at 4 PM

Surface	Average illuminances [lx] direct	indirect	total	Reflection factor [%]	Average luminance [cd/m²]
Workplane	433	170	603	/	/
Floor	324	145	469	20	30
Ceiling	76	153	230	80	58
Wall 1	160	140	300	50	48
Wall 2	203	150	353	50	56
Wall 3	207	161	369	50	59
Wall 4	258	150	408	50	65

Photometric parameters according to reflectance values shown in above **Table-7.27** and different light scenes with control group shown in above **Table-7.28**

Date: 13.01.2018, Time: 12:00:00 (+5 hours difference to GMT)
Reference sky type: Overcast Sky

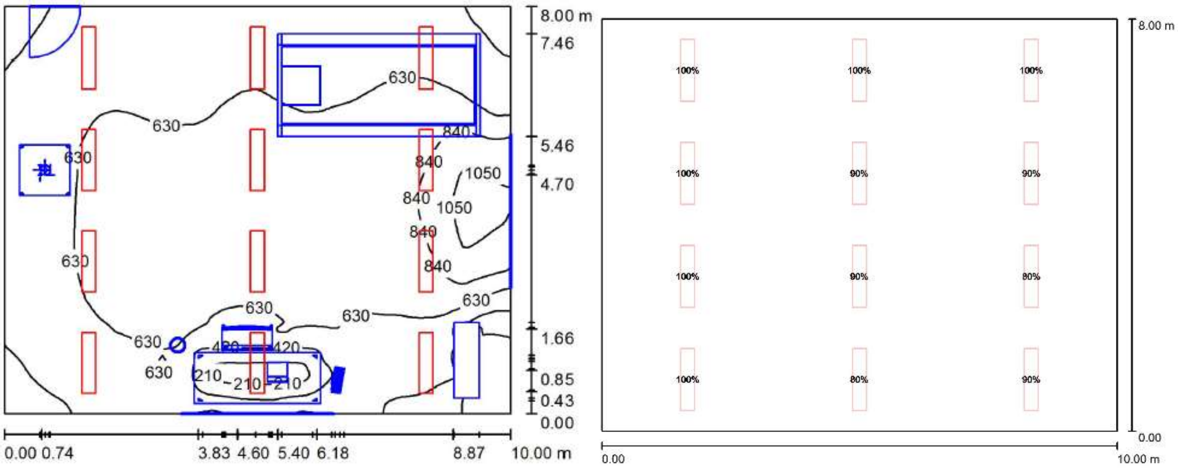


Figure- 7.17: Lighting Distribution of the Room with Objects having Light Scene with Control Group at 12 PM

Table -7.29: Work Plane Details

Surface	Reflectance (Percentage)	Average Illumination	Minimum Illumination	Maximum Illumination	Overall Uniformity
Work plane	Ceiling-80/ Walls-50/ Floor-20	601	103	1139	0.171

- **Luminaire Parts List**
  Specific connected load is described as:
  a)Lighting Power Density (LPD) = 10.58 W/m²
  b)Normalized power density (NPD) = 1.76 W/m²/100 lx (Ground area: 80.00 m²)

Table -7.30: Lighting Distribution of the Room with Objects Having Light Scene with Control Group at 12 PM

Surface	Average illuminances [lx] direct	indirect	total	Reflection factor [%]	Average luminance [cd/m²]
Workplane	431	170	601	/	/
Floor	323	145	468	20	30
Ceiling	76	153	229	80	58
Wall 1	160	139	300	50	48
Wall 2	203	150	352	50	56
Wall 3	207	161	368	50	59
Wall 4	258	150	408	50	65

Photometric parameters according to reflectance values shown in above **Table-7.29** and different light scenes with control group shown in above **Table-7.30**

Date: 13.01.2018, Time:13:00:00 (+5 hours difference to GMT)
Reference sky type: Overcast Sky

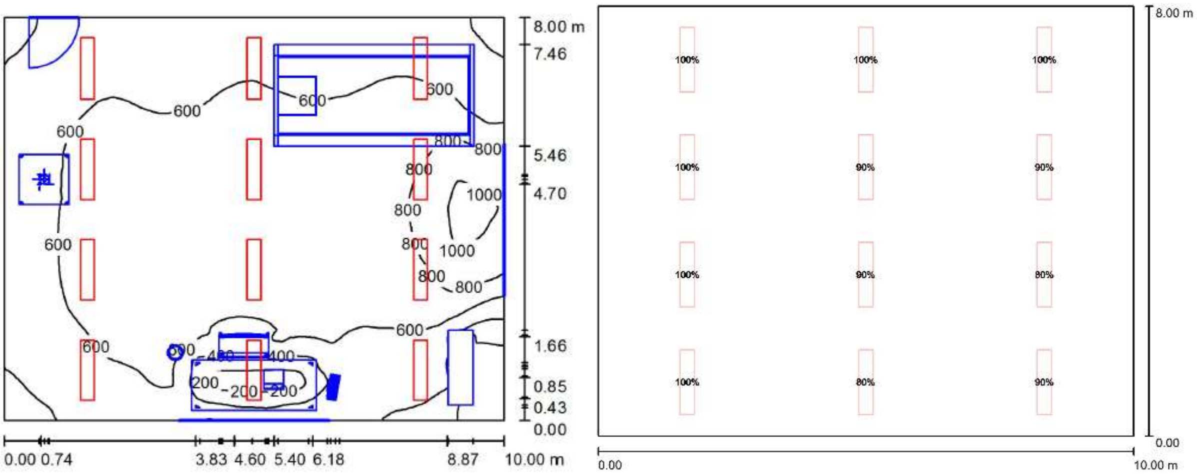


Figure-7.18: Lighting Distribution of the Room with Objects Having Light Scene with Control Group at 1 PM

Table-7.31: Work Plane Details

Surface	Reflectance (Percentage) (% ρ)	Average Illumination (E_{avg})	Minimum Illumination ($E_{\min}$)	Maximum Illumination (E_{max})	Overall Uniformity (U_o)
Work plane	Ceiling-80/ Walls-50/ Floor-20	591	96	1075	0.163

- **Luminaire Parts List**

  Specific connected load is described as:
  a)Lighting Power Density (LPD) = 10.58 W/m²
  b)Normalized power density (NPD) = 1.79 W/m²/100 lx (Ground area: 80.00 m²)

Table -7.32: Lighting Distribution of the Room with Objects Having Light Scene with Control Group at 1 PM

Surface	Average illuminances [lx] direct	indirect	total	Reflection factor [%]	Average luminance [cd/m²]
Workplane	422	169	591	/	/
Floor	316	143	459	20	29
Ceiling	77	151	227	80	58
Wall 1	160	138	297	50	47
Wall 2	202	148	350	50	56
Wall 3	204	159	364	50	58
Wall 4	255	149	404	50	64

Photometric parameters according to reflectance values shown in above **Table-7.31** and different light scenes with control group shown in above **Table-7.32**

Date: 13.01.2018, Time: 14:00:00 (+5 hours difference to GMT)
Reference sky type: Overcast Sky

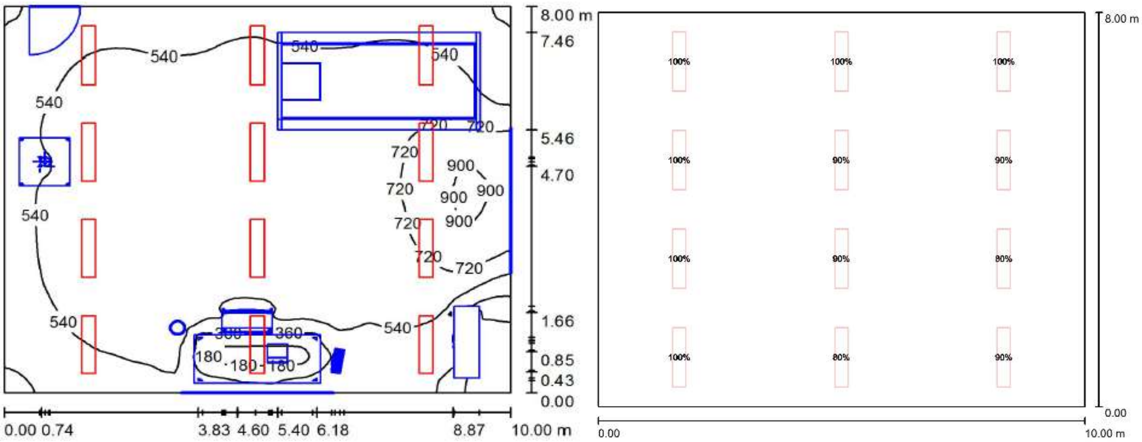


Figure-7.19: Light scene having control group at 2 pm placing 11 W LED fixture

Table-7.33: Work Plane Details

Surface	Reflectance (Percentage) (% ρ)	Average Illumination (E_{avg})	Minimum Illumination ($E_{\min}$)	Maximum Illumination (E_{max})	Overall Uniformity (U_o)
Work plane	Ceiling-80/ Walls-50/ Floor-20	573	91	965	0.158

Luminaire Parts List:

Specific connected load:
Lighting Power Density (LPD) = 10.58 W/m²
Normalized power density (NPD) = 1.85 W/m²/100 lx (Ground area: 80.00 m²)

Photometric result:
Table -7.34: Lighting Distribution of the Room with Objects Having Light Scene with Control Group at 2 PM

Surface	Average illuminances [lx] direct	indirect	total	Reflection factor [%]	Average luminance [cd/m²]
Workplane	406	167	573	/	/
Floor	304	141	445	20	28
Ceiling	77	148	225	80	57
Wall 1	157	135	292	50	46
Wall 2	201	144	345	50	55
Wall 3	200	157	356	50	57
Wall 4	252	147	399	50	63

Photometric parameters according to reflectance values shown in above **Table-7.33** and different light scenes with control group shown in above **Table-7.34**

Date: 13.01.2018, Time: 15:00:00 (+5 hours difference to GMT)
Reference sky type: Overcast Sky

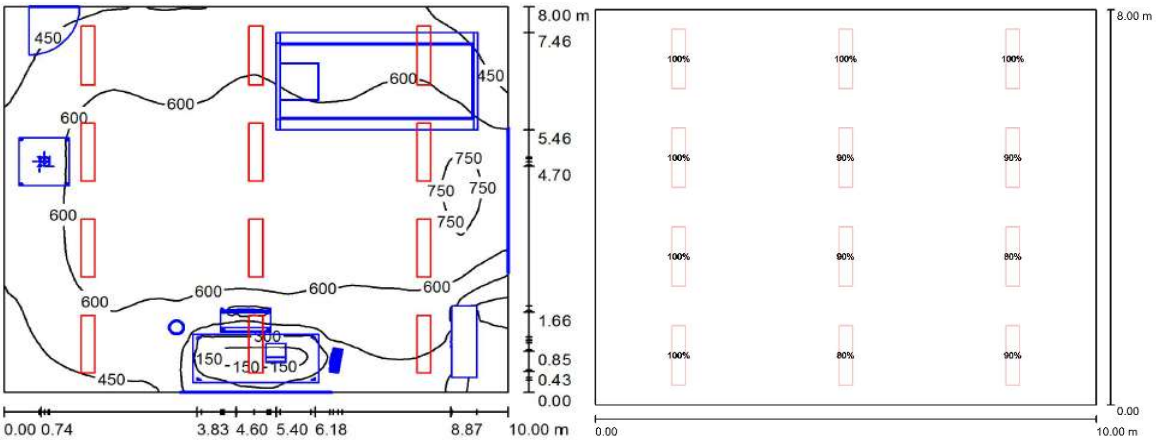


Figure-7.20: Light scene having control group at 3 pm placing 11 W LED fixture

Table-7.35: Work Plane Details

Surface	Reflectance (Percentage) (% ρ)	Average Illumination (E_{avg})	Minimum Illumination $(E_{\min})$	Maximum Illumination (E_{max})	Overall Uniformity (U_o)
Work Plane	Ceiling-80/ Walls-50/ Floor-20	549	77	815	0.140

Luminaire Parts List:

Specific connected load:
Lighting Power Density (LPD) = 10.58 W/m²
Normalized power density (NPD) = 1.93 W/m²/100 lx (Ground area: 80.00 m²)

Photometric result:

Table -7.36: Lighting Distribution of the Room with Objects Having Light Scene with Control Group at 3 PM

Surface	Average illuminances [lx] direct	indirect	total	Reflection factor [%]	Average luminance [cd/m²]
Workplane	385	164	549	/	/
Floor	287	138	425	20	27
Ceiling	77	145	222	80	56
Wall 1	155	131	286	50	46
Wall 2	200	139	339	50	54
Wall 3	194	154	347	50	55
Wall 4	247	144	391	50	62

Photometric parameters according to reflectance values shown in above **Table-7.35** and different light scenes with control group shown in above **Table-7.36**

Date: 13.01.2018, Time: 16:00:00 (+5 hours difference to GMT)
Reference sky type: Overcast Sky

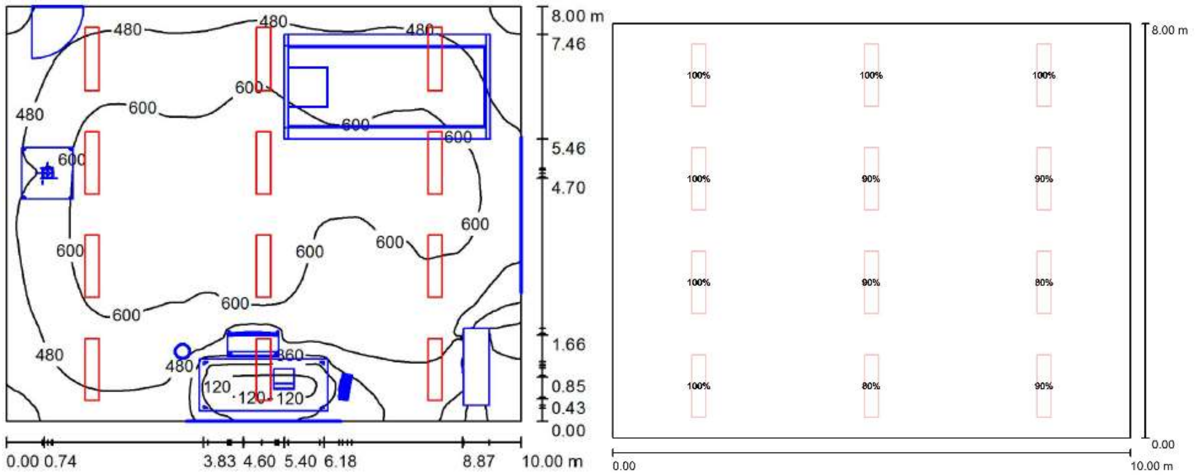


Figure-7.21: Light scene having control group at 4 pm placing 11 W LED fixture

Height of Room: 3.500 m, Mounting Height: 3.500 m, light loss factor: 0.80

Table-7.37: Work Plane Details

Surface	Reflectance (Percentage) (% ρ)	Average Illumination (E_{avg})	Minimum Illumination ($E_{\min}$)	Maximum Illumination (E_{max})	Overall Uniformity (U_o)
Work plane	Ceiling-80/ Walls-50/ Floor-20	521	64	654	0.123

Luminaire Parts List:

Specific connected load:
Lighting Power Density (LPD) = 10.58 W/m²
Normalized power density (NPD) = 2.03 W/m²/100 lx (Ground area: 80.00 m²)
Photometric result:
Table -7.38: Lighting Distribution of the Room with Objects Having Light Scene with Control Group at 4 PM

Surface	Average illuminances [lx] direct	indirect	total	Reflection factor [%]	Average luminance [cd/m²]
Workplane	360	161	521	/	/
Floor	268	135	403	20	26
Ceiling	77	140	218	80	55
Wall 1	152	128	280	50	45
Wall 2	198	133	331	50	53
Wall 3	186	151	337	50	54
Wall 4	241	141	382	50	61

Photometric parameters according to reflectance values shown in above **Table-7.37** and different light scenes with control group shown in above **Table-7.38**

Date: 13.01.2018, Time: 17:00:00 (+5 hours difference to GMT)
Reference sky type: Overcast Sky

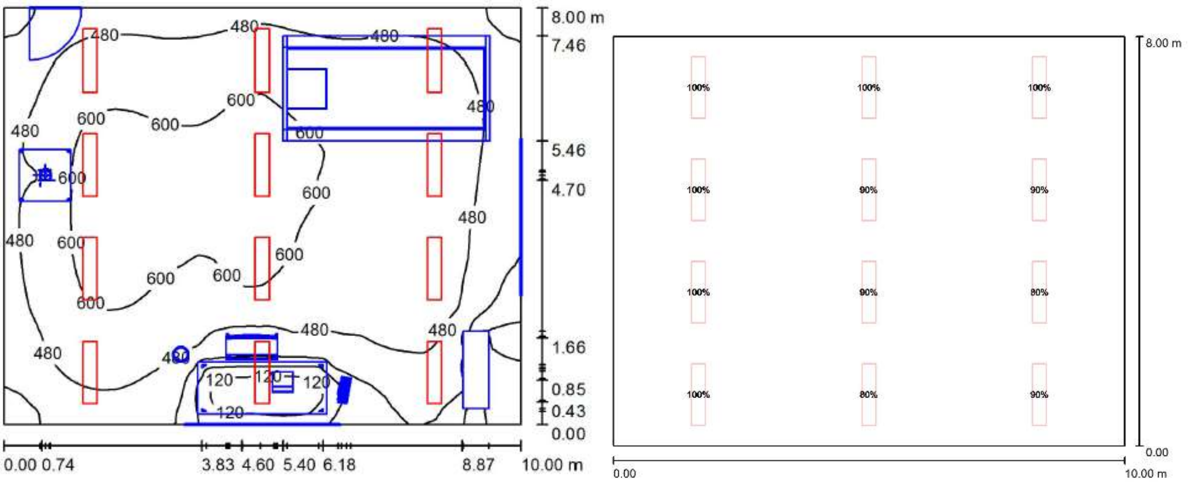


Figure-7.22: Light scene having control group at 5 pm placing 11 W LED fixture

Table-7.39: Work Plane Details

Surface	Reflectance (Percentage) (% ρ)	Average Illumination (E_{avg})	Minimum Illumination ($E_{\min}$)	Maximum Illumination (E_{max})	Overall Uniformity (U_o)
Work-Plane	Ceiling-80/ Walls-50/ Floor-20	499	51	644	0.102

Luminaire Parts List:

Specific connected load:
Lighting Power Density (LPD) = 10.58 W/m²
Normalized power density (NPD) = 2.12 W/m²/100 lx (Ground area: 80.00 m²)

Photometric result:
Table -7.40: Lighting Distribution of the Room with Objects Having Light Scene with Control Group at 5 PM

Surface	Average illuminances [lx] direct	indirect	total	Reflection factor [%]	Average luminance [cd/m²]
Workplane	341	158	499	/	/
Floor	254	131	385	20	25
Ceiling	78	136	214	80	54
Wall 1	150	125	275	50	44
Wall 2	195	129	324	50	52
Wall 3	180	146	327	50	52
Wall 4	237	139	376	50	60

Photometric parameters according to reflectance values shown in above **Table-7.39** and different light scenes with control group shown in above **Table-7.40**

7.8 Result analysis after Image processing for the same room

In daylight hours, daylight is entering through the window while fluorescent lamps are glowing with no dimming condition. It is assuming no dirt accumulation on the lamps' surfaces.**Table-7.5.1** shows already the daylight variation when fluorescent lamps are installed in the room. It is clear from the simulated result shown **Figure- 7.6.1** that the average illuminance during 10 am to 5 pm approximately 500 lx that was achieved on day 13-01-2018 near Kolkata location, Longitude: 88.40°, Latitude: 22.50°, North deviation: -90.0°. Now the challenge is to achieve the same value of lux level by image processing capturing the wireless image by the proposed system. In **Figure-7.23**, the leftmost image is true color or RGB image. Taking captured image from the destination folder of the personal computer, it was converted to grayscale image and after that, the histogram analysis was done. In this initial attempt, it was only realised that if the illumination level varies then similarly the pixel intensity of each different value between 0 to 255 (as for 8 bit) will also vary.

Figure-7.23: Histogram Analysis during Day Time

7.8.1 Image Acquisition for Case Study 1

In the above result **Figure-7.23**, it was found after analysing the histogram of greyscale image that the pixel concentration below 150 is much higher. So, it might be clear that the illuminance level at workplane is not sufficient in **Figure-7.23**.But the processing is done on the whole image.Apprently, the rightmost pixel concentration value graph shown in **Figure-7.23** provides low level illumination information but it should be kept in mind that whole image was considered in spite of region of interest for particular work plane. So, according to pixel frequency the program was set to increase the light level switching the artificial light. The LED lamps are proposed to replace the conventional system as it is easily controllable and digitally addressable. Detecting that the illuminance is below the minimum threshold value, LED is dimmed or increased brightness condition. On the other hand, occupant detection is done by face recognition algorithm. As occupant is detected light is on. If no occupant is detected by the camera, LED becomes off to save the electrical energy consumption. In the following **Figure-7.23** some inaccurate result of face recognition (initial attempt) for occupant detection for energy saving. If the occupants or human are far away from camera then it is difficult to recognise face or if the person standing or sitting in workspace facing backside to camera then it is difficult to recognise. So another attempt or methodology is adopted to detect object with or without lighting condition.

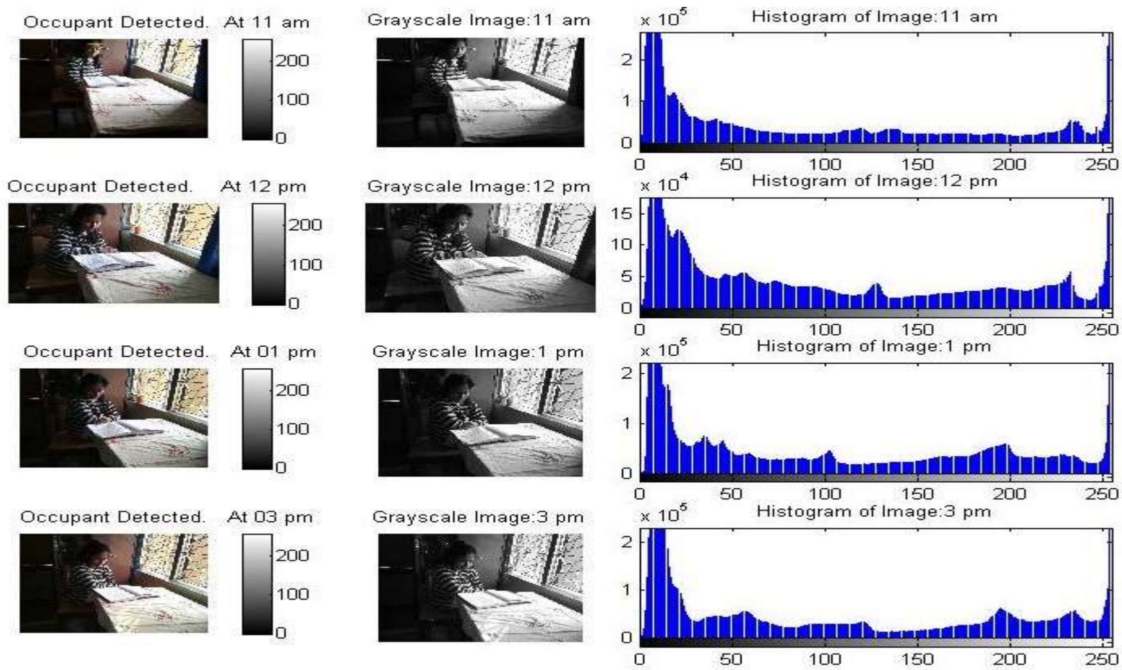


Figure- 7.24: Histogram of Captured Image at Different Time and Occupant Detection for Energy Saving

In comparison with proposed model DIALux simulation is done to evaluate the accuracy with respect to the recommended or desired value for certain interior space.Here in this household area the day light variation is captured throughout the day. In **Figure-7.24** daylight variation is notified notifying histogram. After that artificial light designed with LED panel is integrated having certain control group to achieve the recommended level.

7.9 Case Study 2:

While daylight entering through window and LED lamps are glowing with no dimming and no occupant was there in the captured image.

7.9.1 Image acquisition of Case Study 2:

Figure-7.25: Original Image

Figure-7.26: Image with ROI

Figure-7.27: ROI with co-odinate under LED Lamp

Figure- 7.28:The image with region of interest with co-ordinates taken.

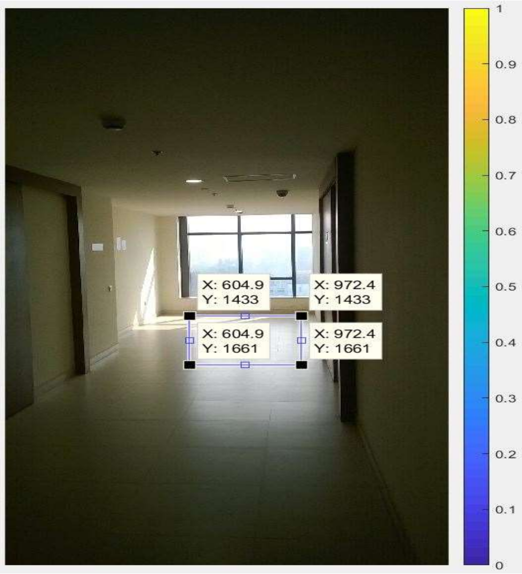


Figure- 7.29: Whole corner co-ordinates

Figure- 7.30: R-G-B of ROI of captured image

Figure- 7.31:Gray scale image

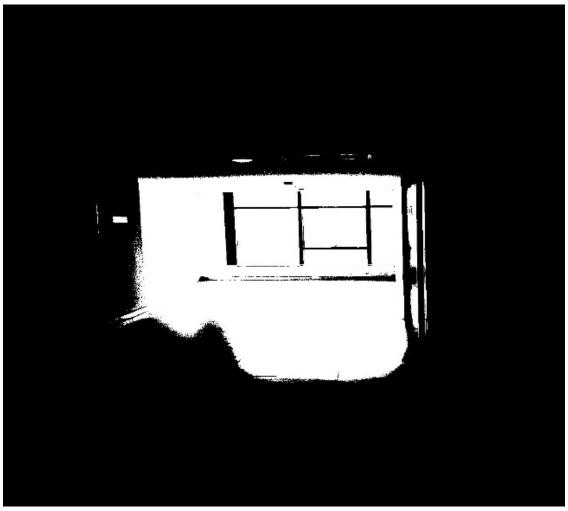


Figure- 7.32: Black & White image with threshold=0.5

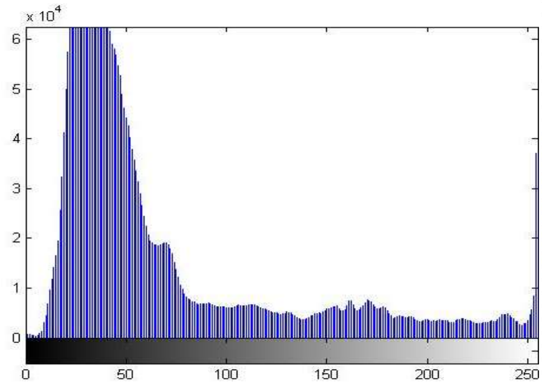


Figure- 7.32: Histogram of the gray scale image of the original image

	A	B	C
1	164	151	135
2	183	168	145
3	254	240	214
4	255	251	228
5	255	246	225
6	255	242	219
7	255	245	220
8	255	251	223
9	245	229	203
10	188	177	157
11	195	186	169
12	203	196	178
13	203	196	178
14	201	192	177
15	198	188	176
16	220	208	196
17	253	244	229
18	255	255	236
19	255	250	228
20	254	249	227
21	255	251	229
22	255	252	230
23	255	249	230
24	255	255	233
25	255	252	230
26	255	250	228
27	255	252	230
28	255	253	231

Figure- 7.33: Dataset of particular ROI (R- G-B)

7.9.2Result analysis of Case Study 2

Here, in the above, from **Figure-7.25**: to **Figure- 7.32**, observed intensities vary as to the background. A single block of grey will appear darker if placed on a white background than if it were placed on a black background. That is, we don't perceive grey scales, but rather as they differ from their surroundings. In the figure above grey is shown on two different backgrounds. This image varies continuously with daylight intensities (daylight distribution) from light to dark as we travel from left to right. However, it is impossible for our eyes not to see a few horizontal edges in this image. Like our visual system, machine tends to undershoot or overshoot around the boundary of regions of different intensities.

On the other hand, histogram equalisation process is considered. This approach is taken by using histogram equalisation on the captured image, which is an entirely automatic procedure. As the captured images have different grey levels, by using the above method total number of pixels in the images are counted, and according to the threshold value, artificial lighting loads are controlled. To transform the grey levels to obtain a better-contrasted image, I can change the grey level.

Spatial filtering may be considered as an extension of this, where we apply a function to a neighbourhood of each pixel. The idea is to move a mask like a rectangle in the form of a matrix (usually with sides of odd length) or another shape over the given image. As we do this, we create a new image whose pixels have grey values calculated from the grey values under the mask.

Table-7.40: Descriptive Table of Frequency of pixel value.

Descriptive statistics for the intervals (162.8826):				
Lower bound	Upper bound	Frequency	Relative frequency	Density
0	25	10	0.000	0.000
25	50	0	0.000	0.000
50	75	0	0.000	0.000
75	100	0	0.000	0.000
100	125	24	0.000	0.000
125	150	2777	0.022	0.001
150	175	8475	0.068	0.003
175	200	21464	0.172	0.007
200	225	50789	0.407	0.016
225	250	41181	0.330	0.013

Luminance is a measure for the amount of light emitted from a surface (in a particular direction). The measure of luminance is most appropriate for flat diffuse surfaces that emit light evenly over the entire surface, such as a (computer) display. Luminance is a derived measure, expressed in Candela per square metre (cd/m^2.).

During experimentation, Raspberry Pi with picamera arrangement was used to estimate luminance value. Absolute luminance measurement for particular region of interest of captured image was calculated. The CIE RGB colour space is one of many RGB colour spaces, distinguished by a particular set of monochromatic (single-wavelength) primary colors.The spectral response of the pi camera chip as well as linear mapping to the standard CIE-XYZ colour space have been measured, calculated and presented.

The equation shows the luminance value [30, 31, 32, 33] from RGB values is

Luminance=$(0.2126 * R + 0.7152 * G + 0.0722B)$ ………………………..(1)

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
162.8826	124720	0	124720	9.603	246.192	211.364	23.706

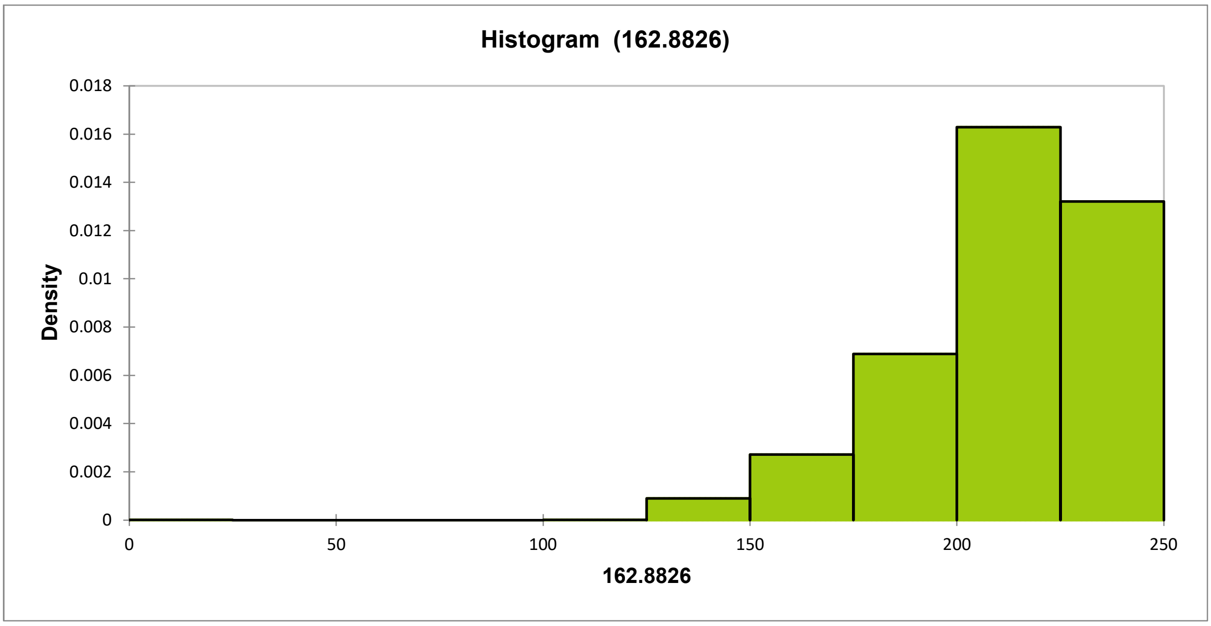
By using equation (1) the Average luminance=211.3803 cd/ m^2

Separating R-channel-channel-channel data, mean value of the individual channel data are calculated. After that, average luminance value is calculated by putting mean value of each channel from the large dataset that was created from ROI of the image.

7.9.3 Summary Statistics of luminance of ROI

Summary statistics:

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
162.8826	124720	0	124720	9.603	246.192	211.364	23.706



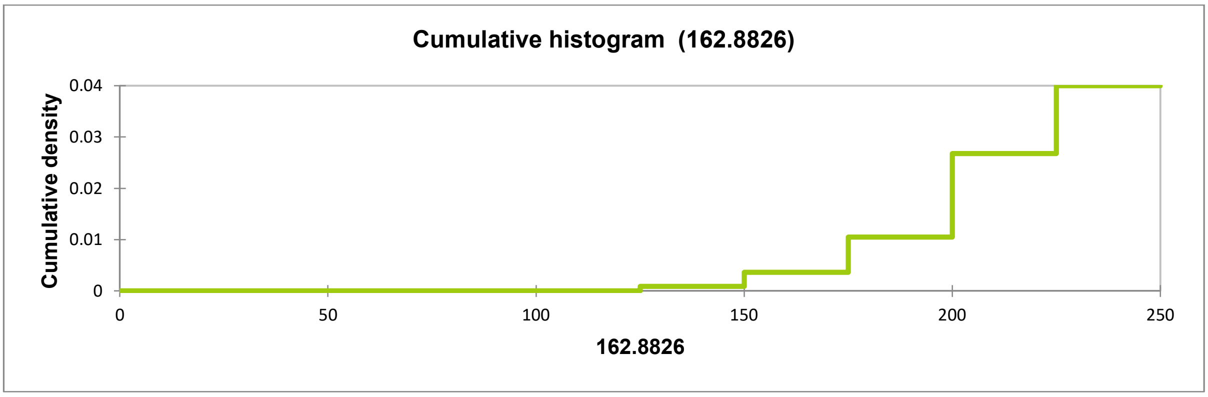


Figure- 7.34:Barchart of cumulative histogram of region of interest of the image

Luminance (standard for certain colour spaces) and illuminance from R-G-B

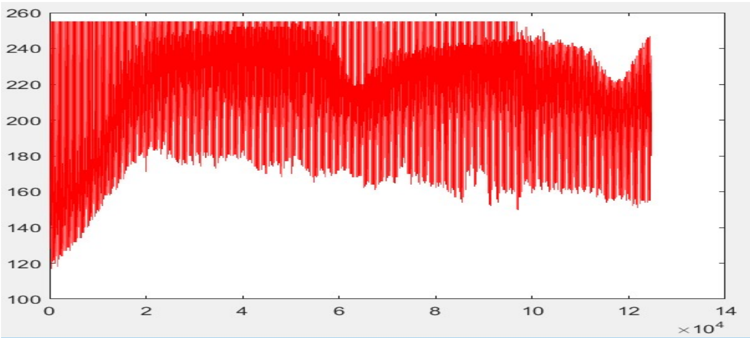


Figure 7.3.4.a: R-channel data plot

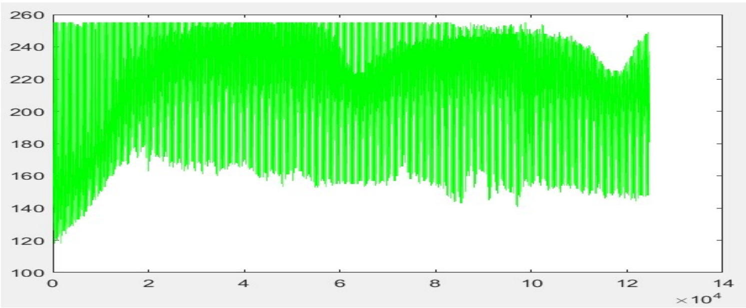


Figure 7.3.4.b: G-channel data plot

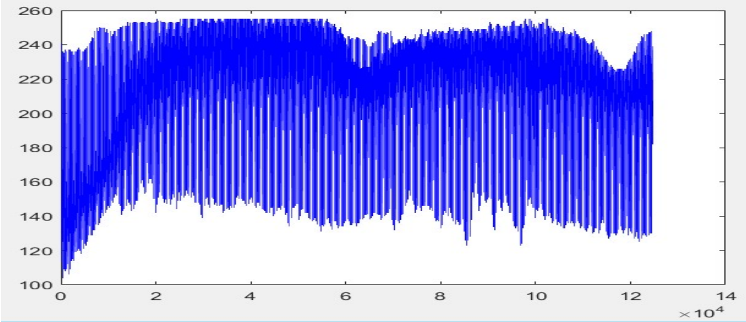


Figure7.3.4.c: B-channel data plot

Figure- 7.35: R-G-B channel data

Confidence interval (%): 95
Tolerance: 0.0001

Luminance and illumination are related, in the sense that luminance is typically used for light-emitting surfaces and illumination for surfaces that are being lit. Assuming a perfect diffuse reflecting surface,

$$E_v = L_v * \pi$$

Is-3646 part 1and 2, For perfect diffused surface,

E_v= (3.14*211.3803) lux = 663.7341 lux

Is-3646 part I and II ,the reflecting factor for floor for corridor space=10 (minimum)

For imperfect diffused surface,

E_v=663.734/10=66.3734 lux

So, to achieve 100 lux integration of artificial light is required.So spatial filter and better camera resolution is required to get improve result.

7.9.4 Database assosiation with cloud platform

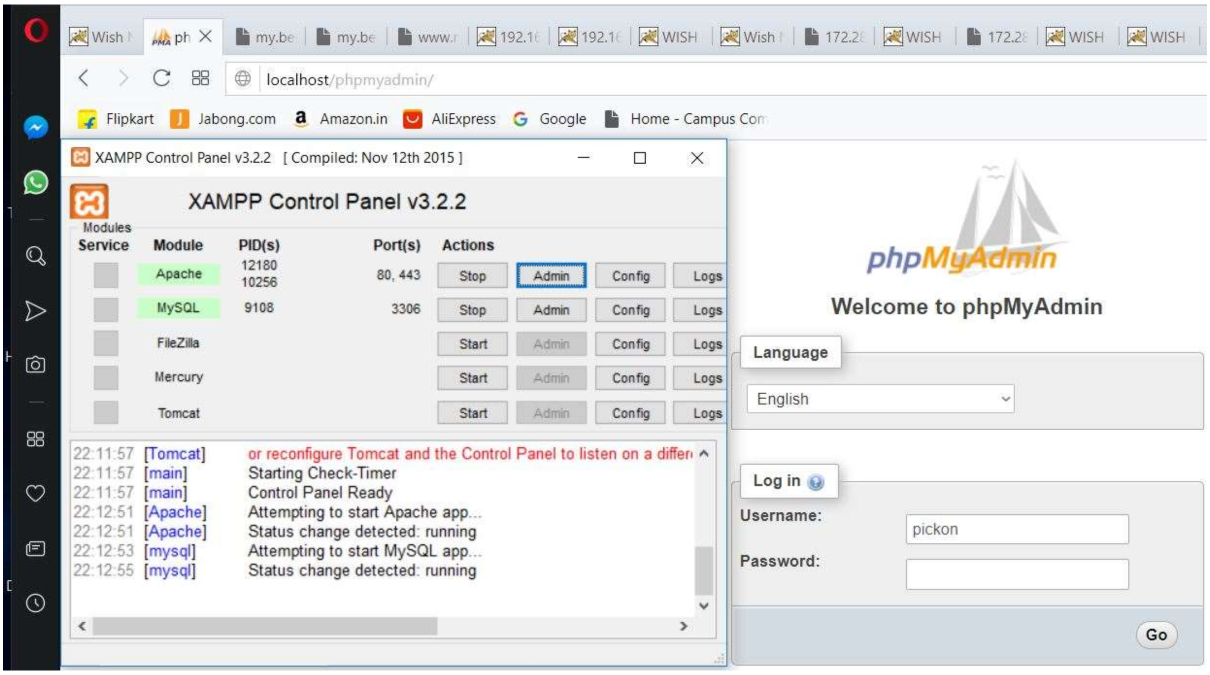


Figure- 7.36: phpMyAdmin tool for managing databases.

Figure- 7.37: phpMyAdmin user account

When the phpMyAdmin home page is opened, clicking the **Databases** tab and then selecting a database to manage by clicking its name.**phpMyAdmin** is a free and open source administration tool for MySQL and MariaDB. As a portable web application written primarily in PHP, it has become one of the most popular MySQL administration tools, especially for web hosting services.

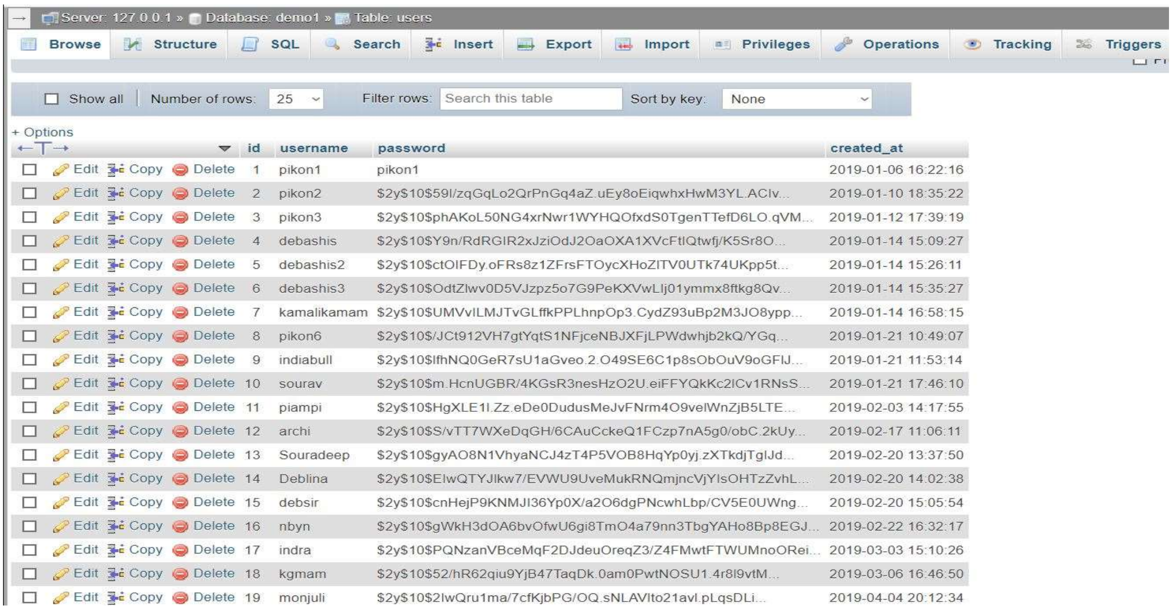


Figure- 7.38: phpMyAdmin user entry or list of users in local computer

The phpMyAdmin program is handy for performing maintenance operations on tables, backing up information, and editing things directly. Although many of the same tasks can be performed on the MySQL command line, doing so is not an option for many people.

To visualise data or to publish and subscribe to own custom data channel and logging all sent messages over that channel on the console,PubNub installed and instantiated.

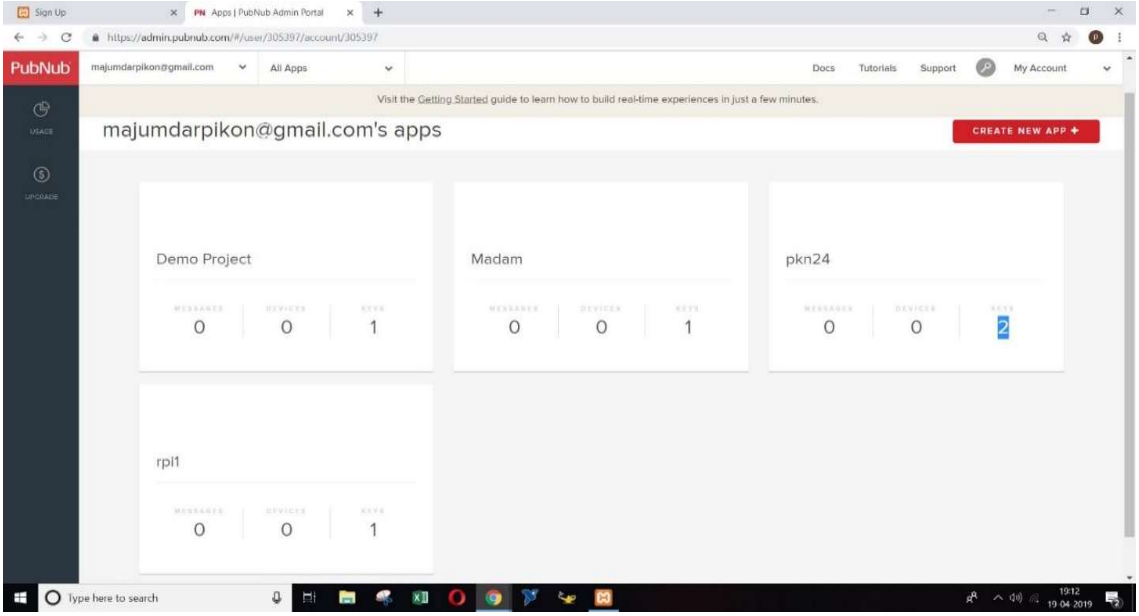


Figure- 7.39: Creting new app in PubNub cloud

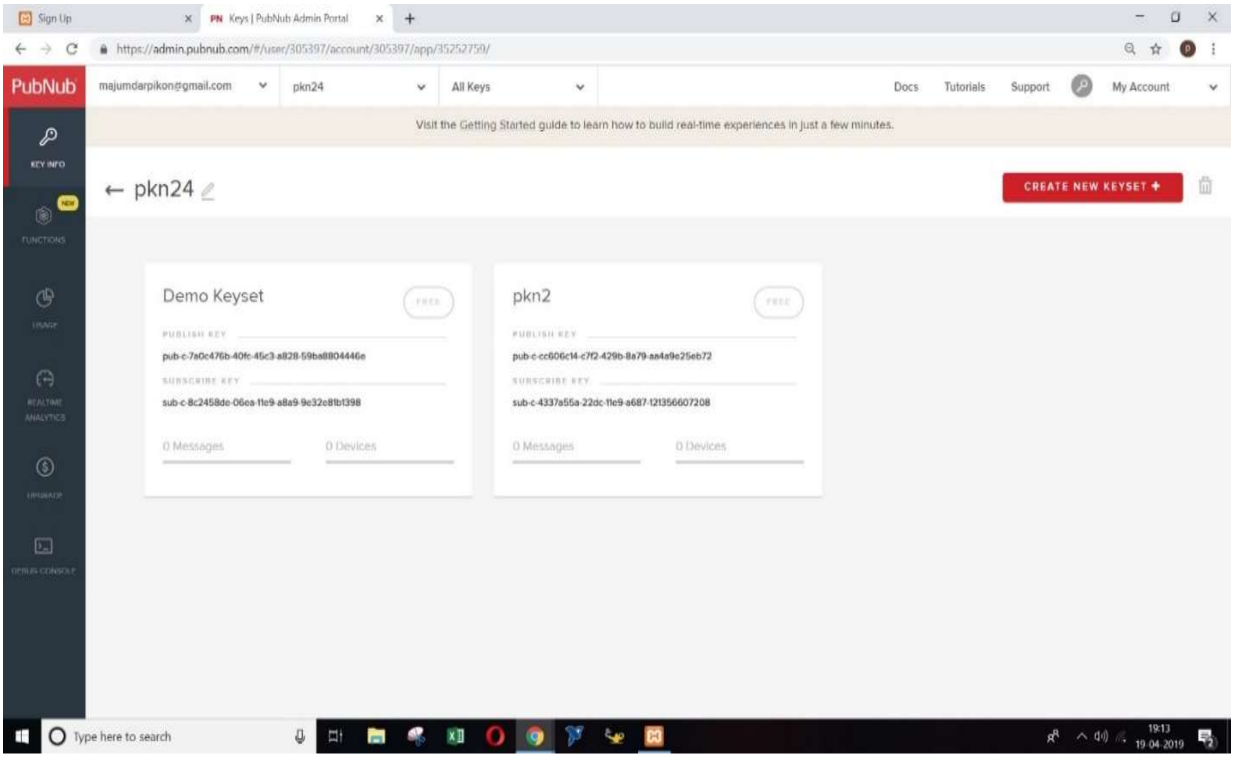


Figure- 7.40:: Creating new keyset at the created channel in PubNub cloud

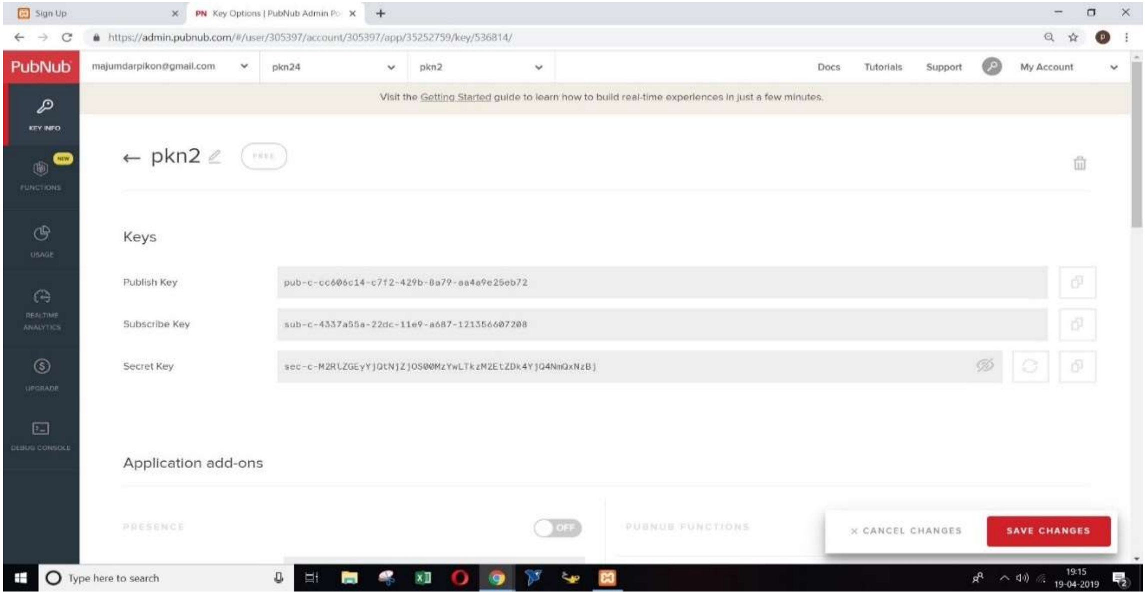


Figure- 7.41: Generated keys i.e. Publickey, Subscribe key & Secret key having some random values for publish or subscribe information through PubNub cloud platform

To make the channel private, the PubNub Access Manager is used for security purpose.

After I have subscribed to my own channel, I can then publish your own messages to it.

To send it to another device, pressing "Send" to see my message in the console. "Stream" will automatically send greetings to my channel every second.

PubNub operates on a publish/subscribe (pub/sub) paradigm, which consists of a few components:

- Publisher
- Subscriber
- Message
- Channel
- Channel group

As soon as data is uploaded (published), PubNub will immediately push out that data to anyone (or thing/device) that was interested in it (subscribers). Subscribers will continue to receive these data streams in real-time as more data is published.

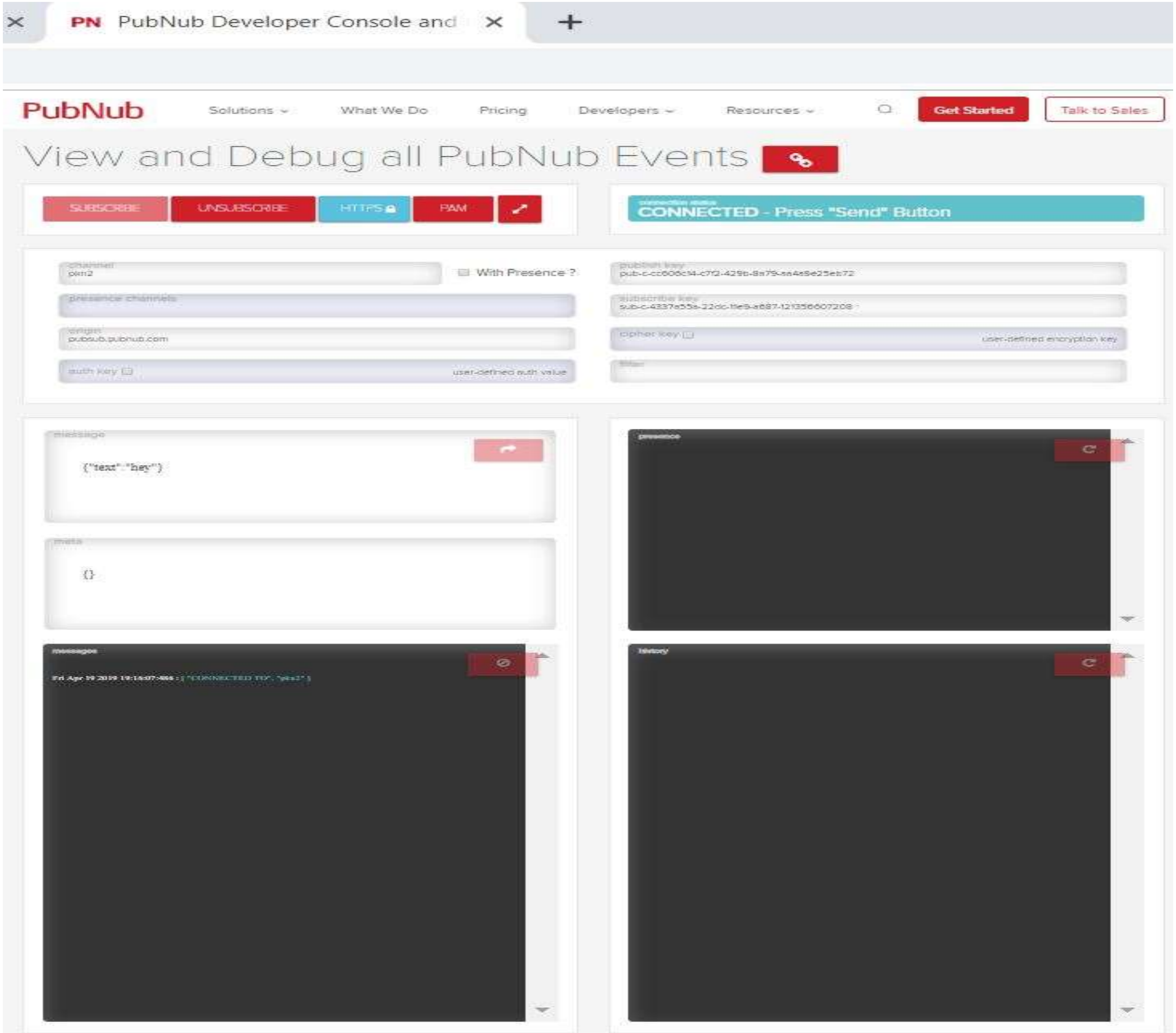
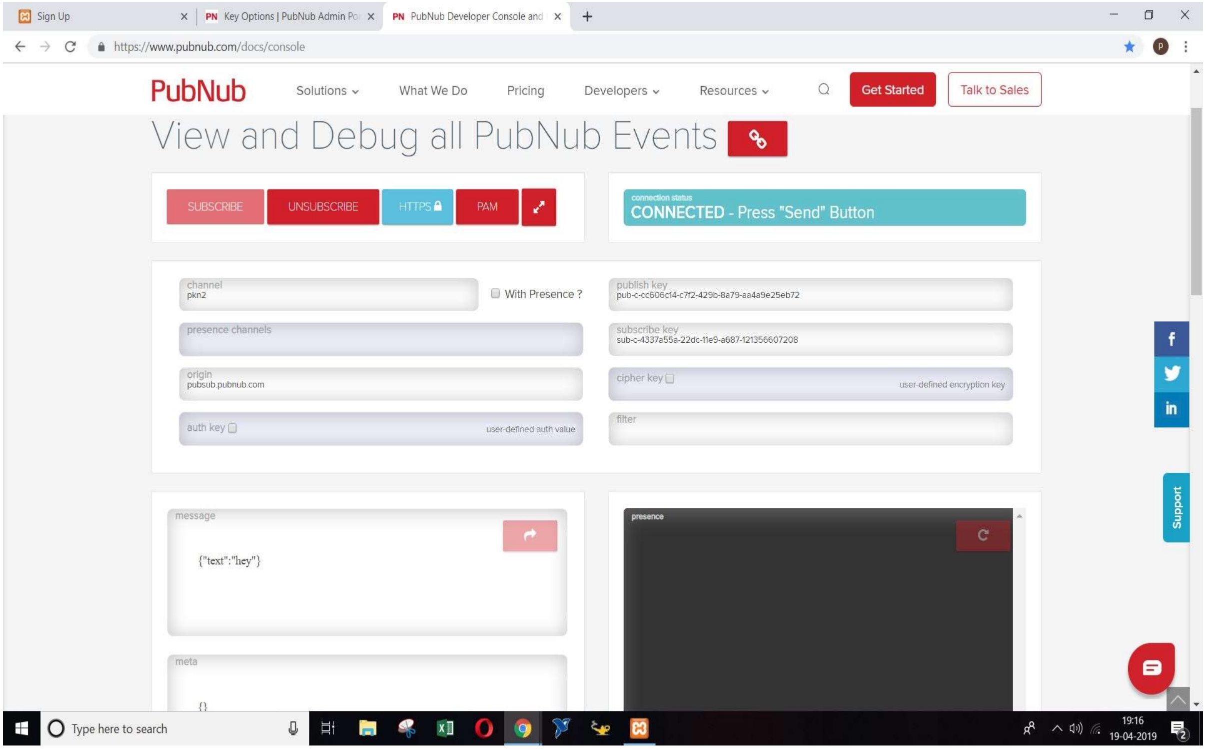


Figure- 7.42: PubNub Developer console is connected to the webpage by recognising public & subscribe key



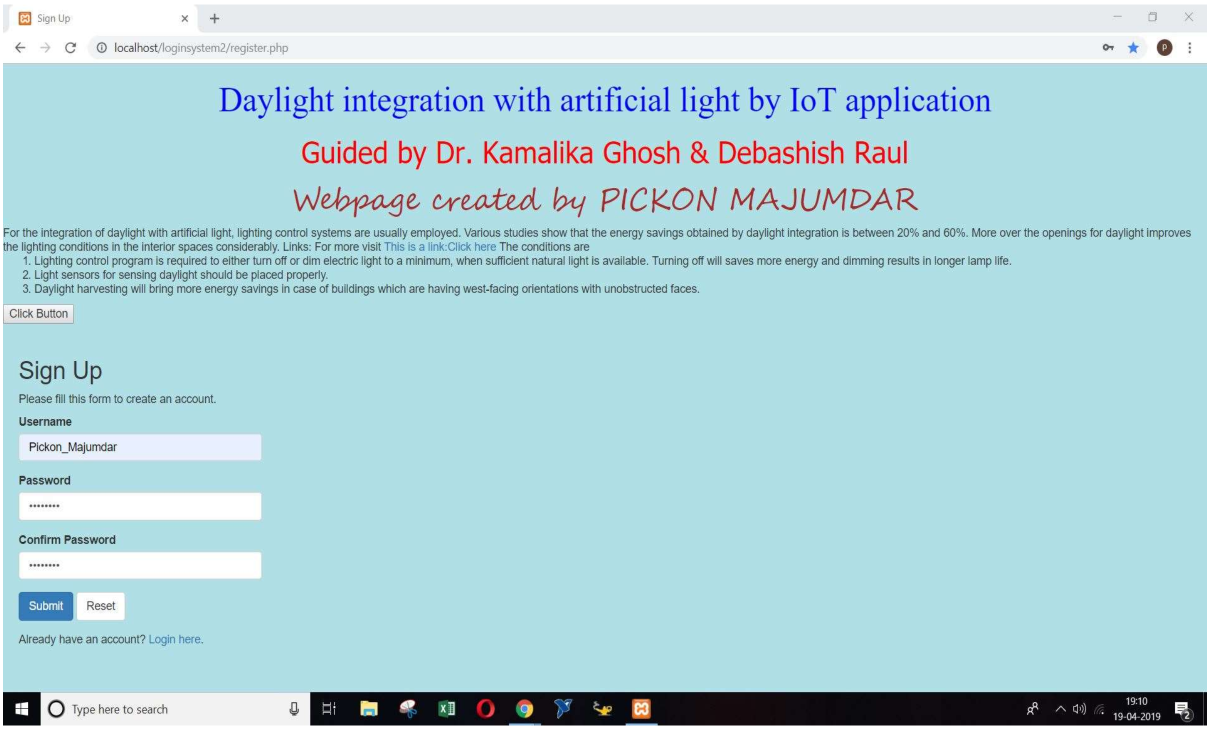


Figure- 7.43: Webpage created for IoT application controlling lighting loads from remote location via cloud platform where registration for initial users or particular users.

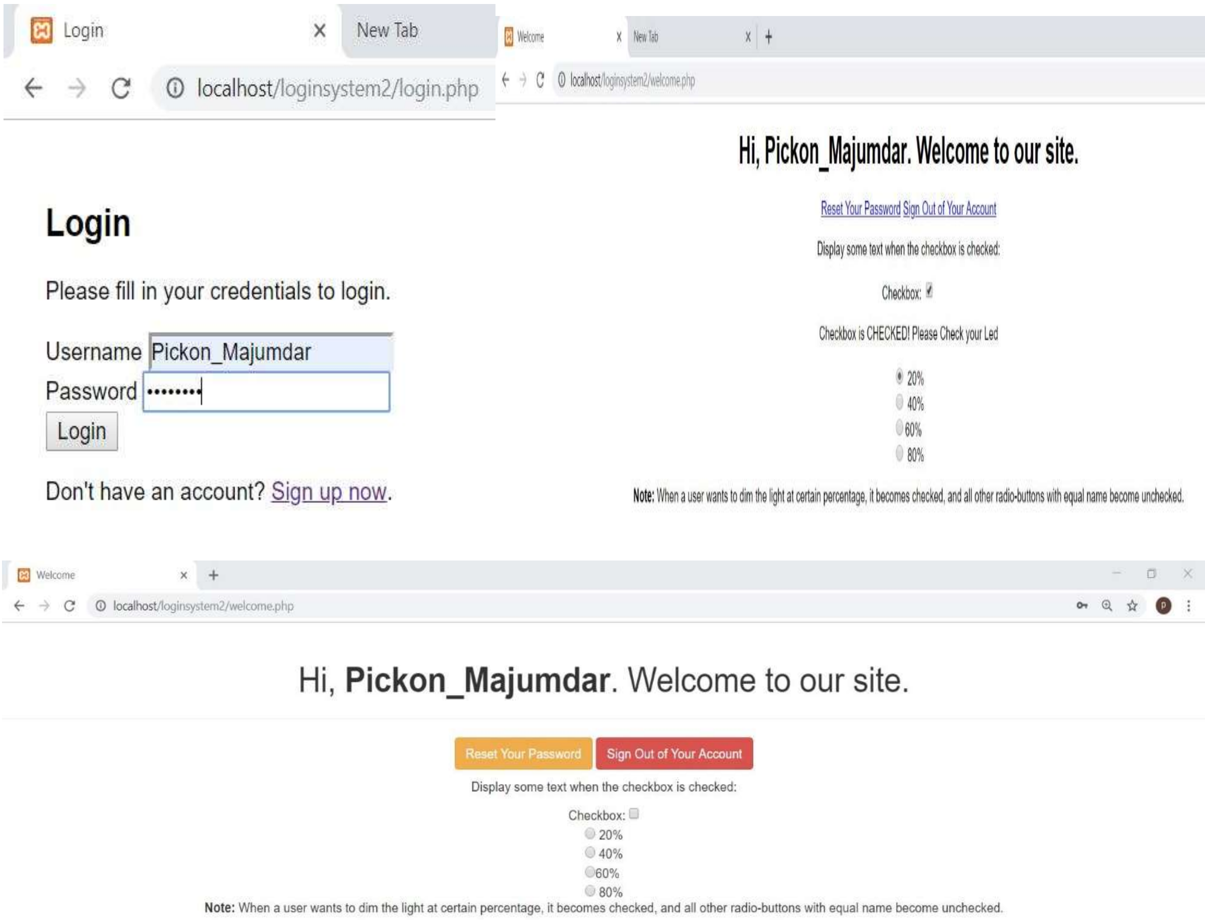


Figure- 7.44: Welcome page after login while checkbox off

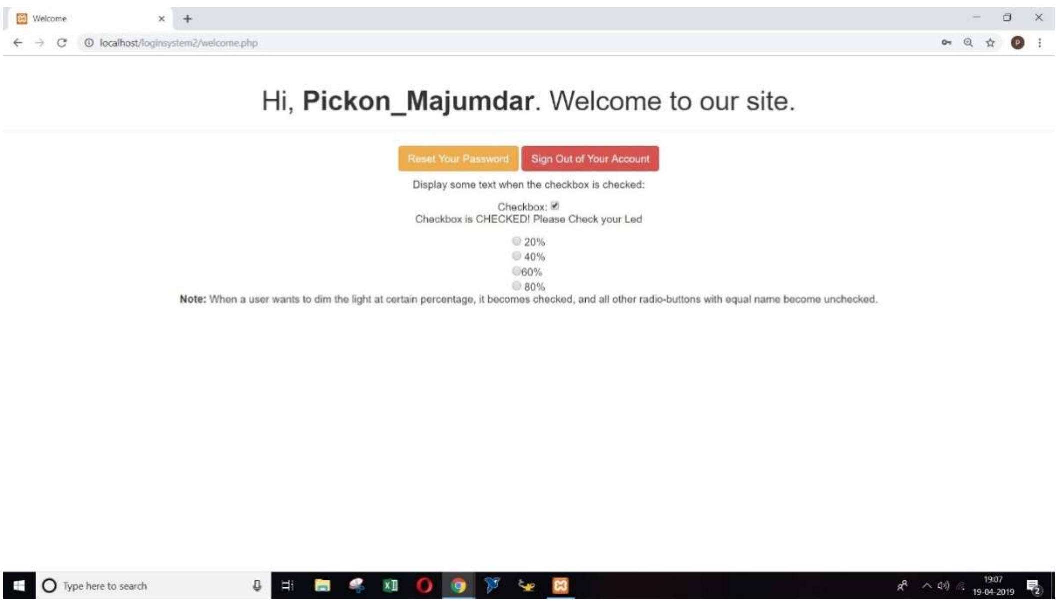


Figure- 7.45: Welcome page after login while checkbox on

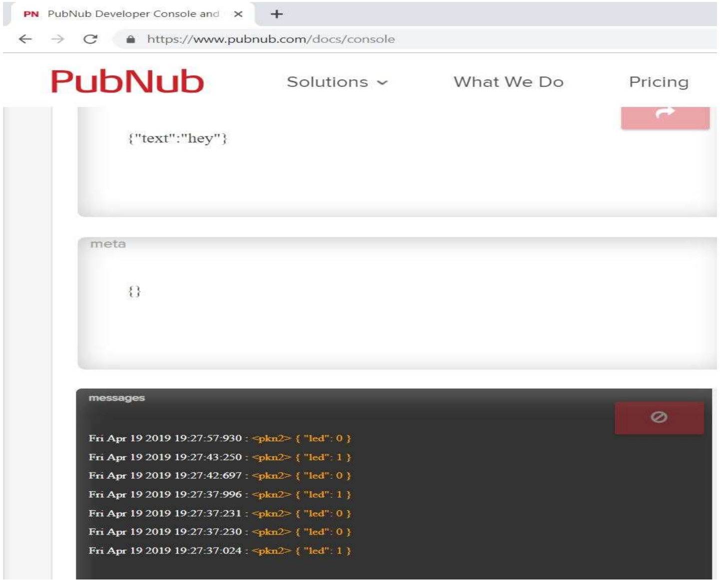


Figure- 7.46: Outcome of LED control at Cloud Platform

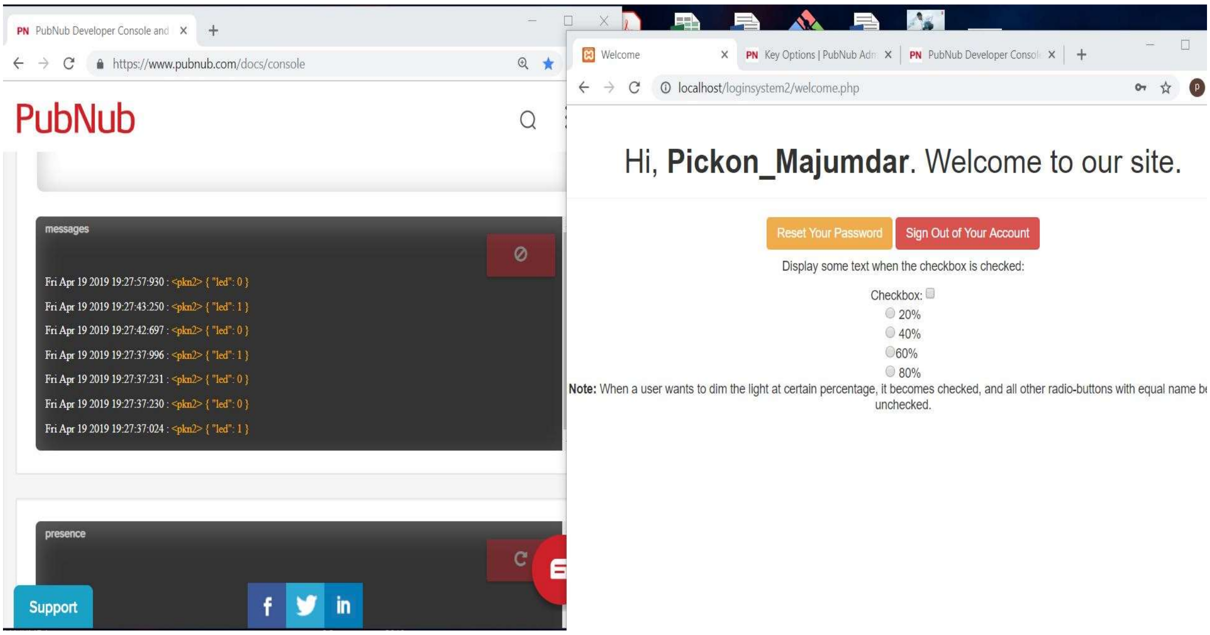


Figure- 7.47: Visualisation of LED control & RPi control at Cloud Platform for certain cases

7.10 Occupant detection for energy saving

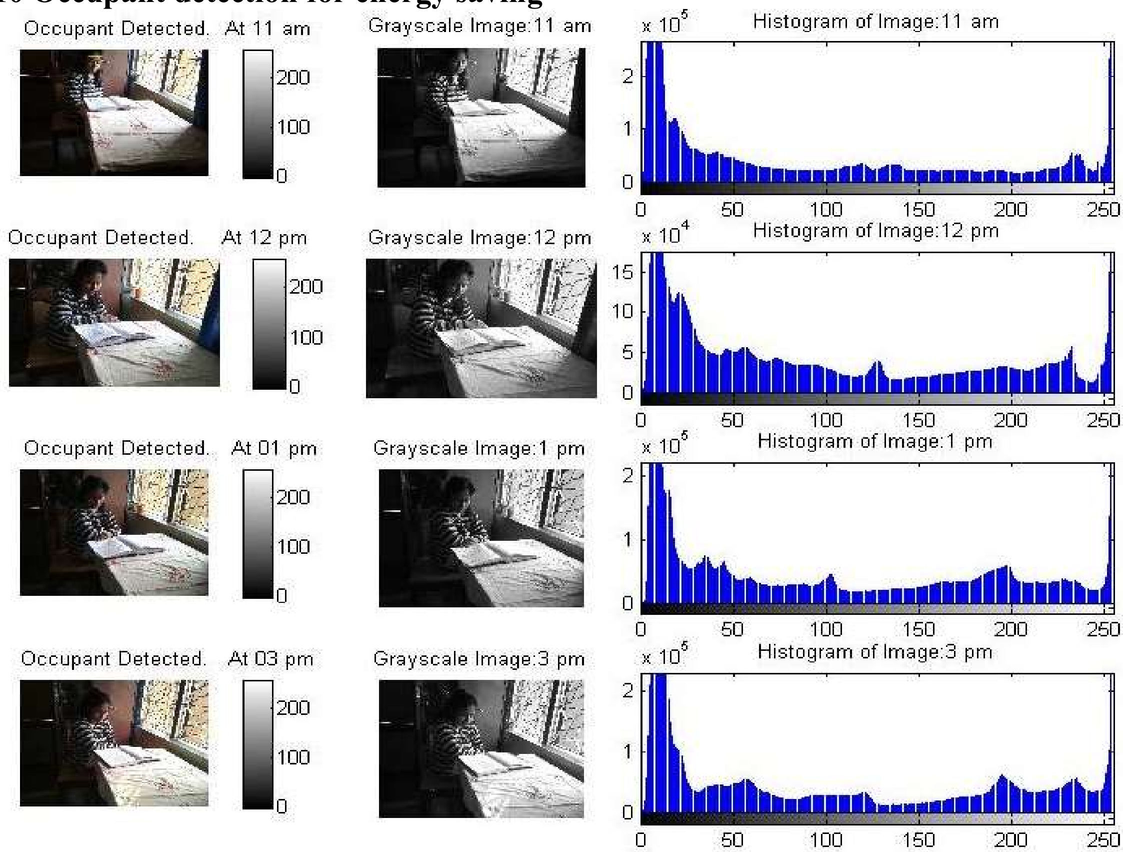


Figure- 7.48: Real Time Based Images Applying Face Detection Algorithm For Occupant Detection

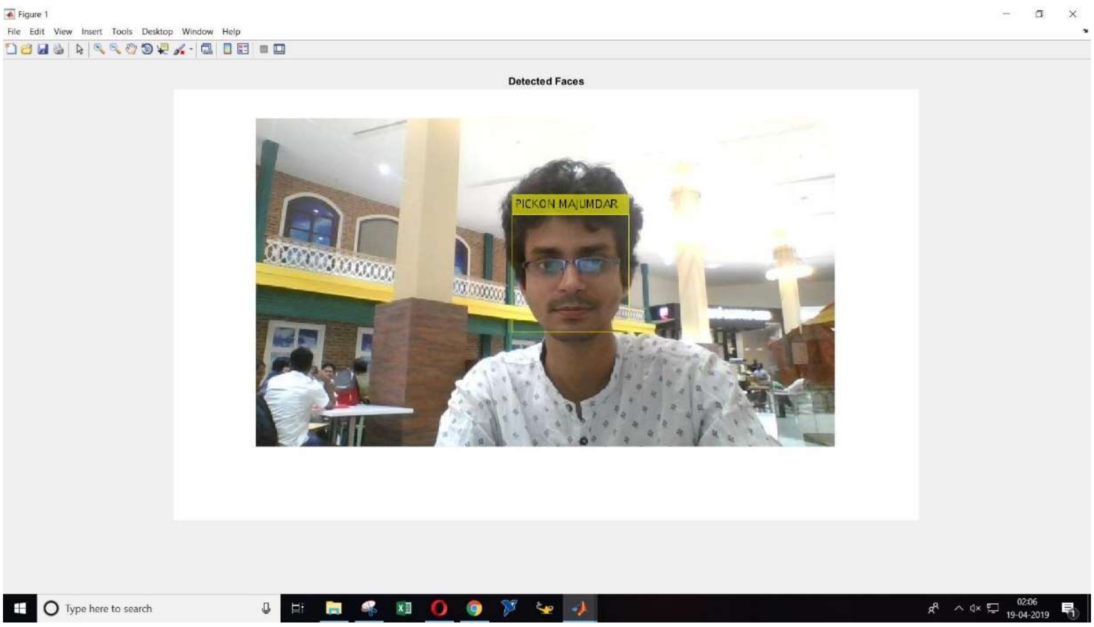


Figure- 7.49: Facial Recognition To Detect Occupant

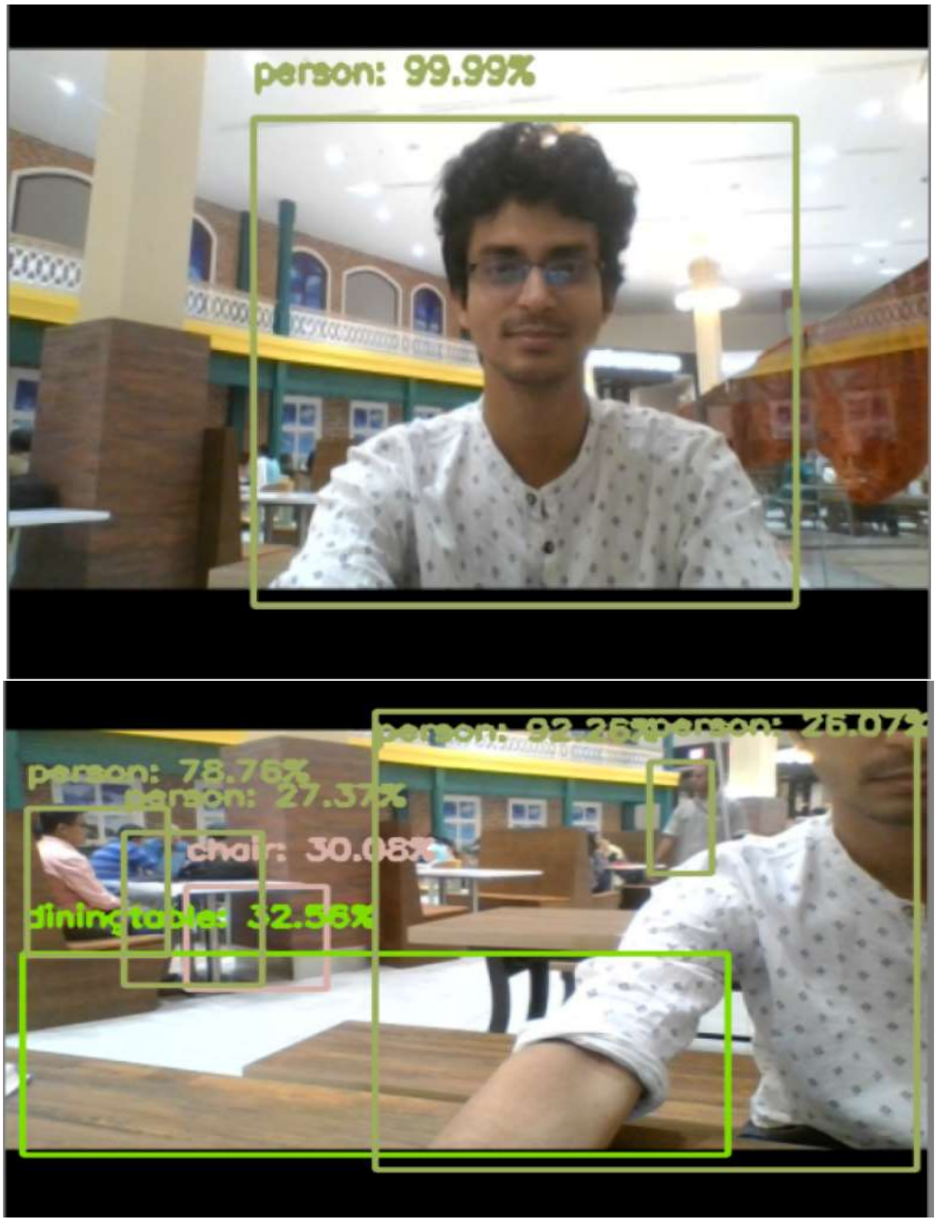


Figure- 7.50: Occupant& object detection using deep learning

As the face detection was not giving the accurate result here, object detection was done through deeep learning process.In this **Figure- 7.50**, the percentge of accurcy was done such as **32.58%** table detection,**78.76%** persons detection those who are far siiting.This method is comparitavely better.If the occupant will show his/her back side then it will not be possible to detect that occupant or if the occpant is far away from camera.By using MobileNet on the basis of Deep Learning it was possible to detect mobile occupant whereever his/her position with respect to the field of view of camera.This accuracy level can enhance the occupant detection as well as different object recognition.Eventually by adopting this process energy saving is done for this proposed artificial lighting control system.

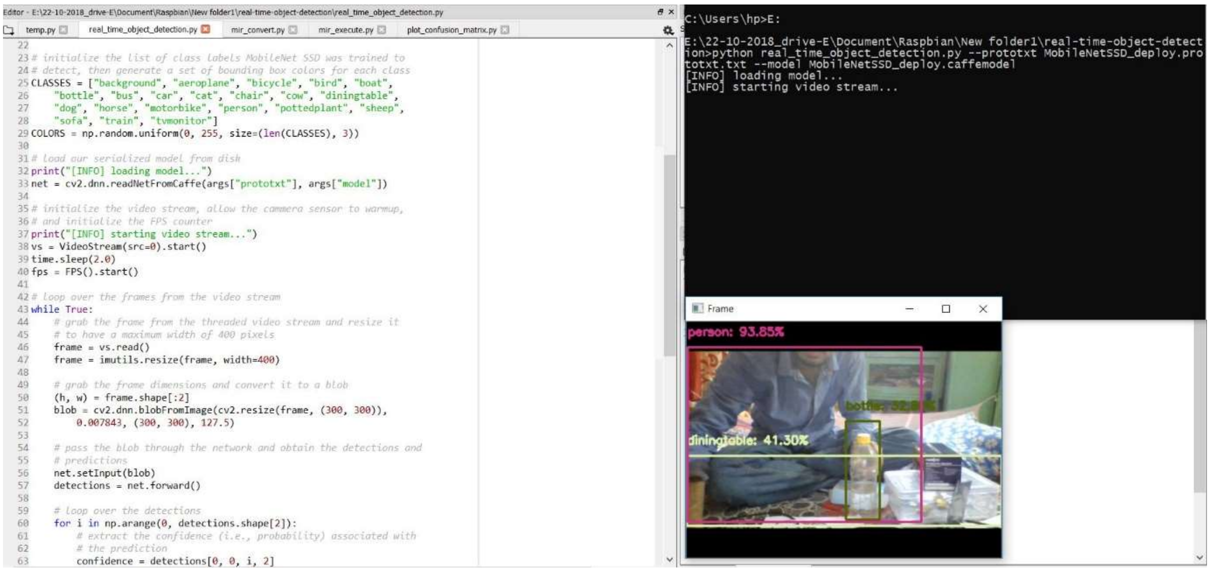


Figure- 7.51: Image analysis by Raspberry Pi

The Figure- 7.51 shows the python programming for object detection.

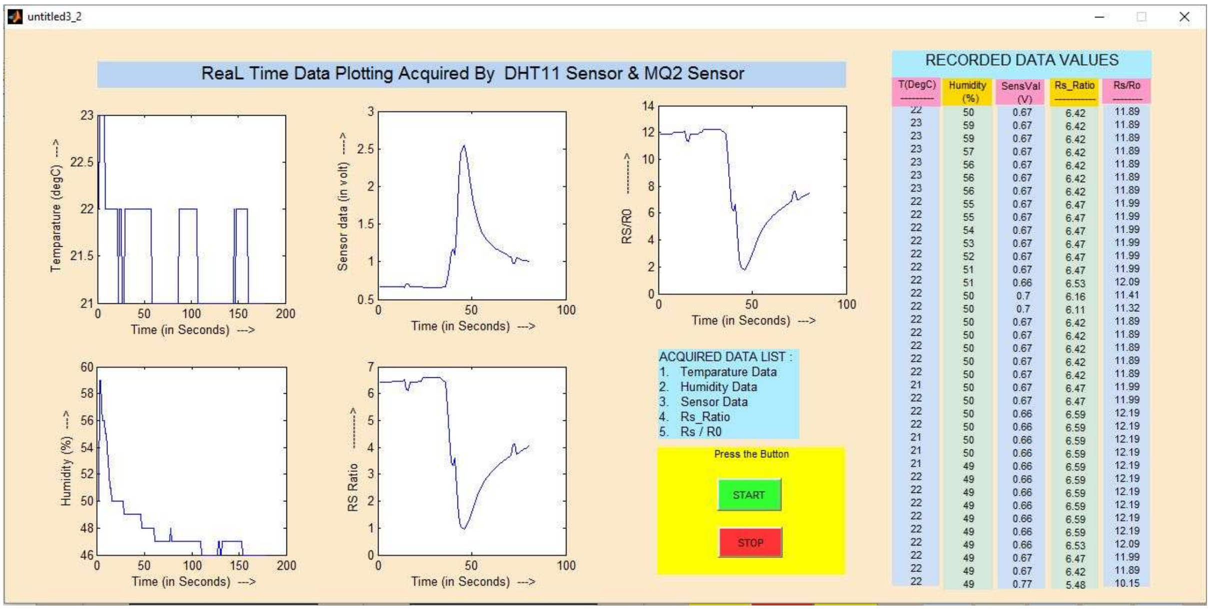


Figure- 7.52: Temperaturea and Humidity and Internal Air Condition Monitoring Result

The above **Figure- 7.52** temperature and humidity monitoring by DHT11 sensor and internal air condition monitoring result are shown by this GUI in MATLAB. The sensors were used here to observe the internal thermal and humidity data which is also useful to control both lighting and cooling loads according to set threshold value.

Chapter 8:
Conclusion and Future Scope

8.1 Conclusion:

In this Work by capturing real time images and by processing those and finding the Region of Interest, the Daylight Control is optimized with artificial light integration taken into account the variation of Daylight throughout the day. Earlier studies on Daylight integration helped the fact to develop the concept in adopting the methodology here within this thesis work that are mentioned in Chapter-3.In this Thesis Work, real time images are taken for several times, maintaining a proper interval on a specific time condition and their respective histogram and greyscale images are taken for the purpose of occupant detection. Beside this the same object model is created in the DIALux software, putting the same environmental parameters to get the lighting design parameters such as lux level, uniformity to compare these same with the region of interest of the images captured. This images is varied continuously with daylight intensities (daylight distribution) from light to dark as we travel from left to right of the figures. However, it is impossible for our eyes not to see a few horizontal edges in this image. Like our visual system, machine tends to undershoot or overshoot around the boundary of regions of different intensities. On the other hand, histogram equalisation process is considered. This approach is taken by using histogram equalisation on the captured image, which is an entirely automatic procedure. As the captured images have different grey levels, by using the above method total number of pixels in the images are counted, and according to the threshold value, artificial lighting loads are controlled. To transform the grey levels to obtain a better-contrasted image, the grey level can be changed. This may be considered s proposition of lighting control.

8.2 Future Scope

Spatial filtering may be considered as an extension of this, where we apply a function to a neighbourhood of each pixel. The idea is to move a mask like a rectangle in the form of a matrix (usually with sides of odd length) or another shape over the given image. As we do this, we create a new image whose pixels have grey values calculated from the grey values under the mask.

References

REFERENCES

[1] Paul J. Littlefair, Building Research Establishment Ltd, Garston, Watford WD2 7JR, UK "Predicting lighting energy use under daylight linked lighting controls," Building Research &Information,ISSN: 0961-3218.

[2] Fabio Sicurella, GianpieroEvola, Etienne Wurtz,"A statistical approach for the evaluation of thermal and visual comfort infree-running buildings"

[3] Luigi Martirano,University of Rome Sapienza, "A Smart Lighting Control to Save Energy", The 6th IEEE International Conference on Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications

[4] Luigi Martirano," A Smart Lighting Control to Save Energy", The 6th IEEE International Conference on Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications, 978-1-4577-1425-2/11/$26.00 ©2011 IEEE 132.

[5]https://www.sciencedirect.com

[6]Xun Xu n Department of Mechanical Engineering, University of Auckland,Auckland1142, NewZealand," From cloud computing to cloud manufacturing",ELSEVIER.

[7] N. Tianlong, "Application of Single Bus Sensor DHT11 in Temperature Humidity Measure and Control System [J]," Microcontrollers & Embedded Systems, vol. 6, p. 026, 2010.

[8] Daeman Joan, Rijmen Vincent, "The Design of Rijndael: AES - The Advanced Encryption Standard (Information Security and Cryptography)" ISBN-13: 978-3642076466, 1st ed. 2002

[9] C P Kurian, R S Aithal, “Robust control and optimization of energy consumption in artificial daylight integrated schemes”, Lighting Research & technology, Vol 40, pp 17-24, 2008.

[10] Sheryl G Colaco,“ Adaptive predictive lighting controllers for daylight artificial light integrated schemes” , Ph.D thesis, ManipalUniversity,India, 2011

[11]https://www.google.com/search?biw=1440&bih=789&tbm=isch&sa=1&ei=O5vvXI3LMIXjz7sP4u2VuAE&q=machine+learning+%26+deep+learning&oq=machine+&gs_l=img.1.0.35i39j0i67j0j0i67j0j0i67l3j0j0i67.5874.8453..10018...0.0..0.149.1105.1j8......0....1..gws-wiz-img.....0.txdfn0n8SkE#imgrc=lIwvW4Xf7vXR_M:

[12]
https://www.google.com/search?biw=1440&bih=789&tbm=isch&sa=1&ei=R5vvXP35BsrVz7sPtK208Ac&q=Deep+Learning+%28DL%29+with+Performance+Curve&oq=Deep+Learning+%28DL%29+with+Performance+Curve&gs_l=img.12...2261853.2377121..2377877...0.0..0.104.114.3j1......0....2j1..gws-wiz-img.....0.hxPIaWT1CCQ#imgrc=8aTniYMSKem91M:

[13]https://www.google.com/search?q=Machine+learning+(ML)+vs+Deep+learning+(DL)&source=lnms&tbm=isch&sa=X&ved=0ahUKEwiR44bt-sLiAhWBfCsKHfl3DN4Q_AUIDigB&biw=1440&bih=789#imgrc=4UJZTvHvwMWIJM:

[14]https://www.google.com/search?biw=1440&bih=789&tbm=isch&sa=1&ei=5aTvXNmxDsGzmgeNpLf4BQ&q=Convolution+Neural+Network+%28CNN%29&oq=Convolution+Neural+Network+%28CNN%29&gs_l=img.12..0i10i24.51026.51026..52069...0.0..0.109.109.0j1......0....2j1..gws-wiz-img.-1HjBytZTyo#imgrc=NF1b0qO0_JYxrM:

[15]
https://www.google.com/search?biw=1440&bih=789&tbm=isch&sa=1&ei=5aTvXNmxDsGzmgeNpLf4BQ&q=Convolution+Neural+Network+%28CNN%29&oq=Convolution+Neural+Network+%28CNN%29&gs_l=img.12..0i10i24.51026.51026..52069...0.0..0.109.109.0j1......0....2j1..gws-wiz-img.-1HjBytZTyo#imgrc=cOV3OmzftZrfmM:

[16]https://towardsdatascience.com/an-introduction-to-convolutional-neural-networks-eb0b60b58fd7

[17] https://www.quora.com/What-is-MobileNet

[18] https://arxiv.org/abs/1704.04861

[19] https://github.com/topics/mobilenet-ssd

[20] https://medium.com/@RaghavPrabhu/understanding-of-convolutional-neural-network-cnn-deep-learning-99760835f148

[21] https://en.wikipedia.org/wiki/Internet_of_things

[22] https://en.wikipedia.org/wiki/XAMPP

[23] https://www.guru99.com/what-is-dbms.html

[24] http://www.infosys.tuwien.ac.at/Staff/sd/papers/Buchbeitrag%20V.%20Emeakaroha.pdf

[25] C P Kurian, "Advanced Lighting simulation tools: An asset to assess energy saving potentials in lighting", Lighting India Magazine, pp 78-89, 2006.

[26] Li DHW, Tsang EKW, "An analysis of daylighting performance for office buildings in Hong Kong", Building and environment, Vol 43(9), pp1446-1458, 2008.

[27] REMOTE VIDEO MONITORING SYSTEM USING RASPBERRYPI 3 BASED ON GPRS MODULE AND PPP PROTOCOLS, N. Kale1, Prof. R. D. Patil2,ISSN (PRINT): 2393-8374, (ONLINE): 2394-0697, VOLUME-4, ISSUE-5, 2017ME Electronics Engineering, Associate Professor

[28] Christian Floerkemeier Marc Langheinrich,Elgar Fleisch Friedemann Mattern,Sanjay E. Sarma (Eds.),The Internet of Things,First International Conference, IOT 2008,Zurich, Switzerland, March 26-28, 2008

[29] EMBEDDED IMAGE CAPTURING SYSTEM USING RASPBERRY PI SYSTEM

G.Senthilkumar1, K.Gopalakrishnan2 , V. Sathish Kumar3,1Associate Professor & Head, Department of Electronics S.N.R Sons College, Coimbatore, India.,2Professor of Electronics, Bharath University, Chennai-73, India

[30] An Introduction to Digital Image Processing with Matlab,Notes for SCM2511 Image Processing 1,Alasdair McAndrew,School of Computer Science and Mathematics,Victoria University of Technology.

[31] Solomon C., Breckon T. Fundamentals of Digital Image Processing,"A Practical Approach with Examples in Matlab" (Wiley-Blackwell, 2011)(ISBN 9780470844724) (en) (355s)

[32] Digital image processing using matlab (Gonzalez)

[33] Shri Swagato Guin , Shri Partha Banerjee and Shri Pickon Majumdar, "Real Time Data Acquisition and Encrypted Data Transmission using Microcontroller" Advanced Research in Electrical and Electronic Engineering p-ISSN: 2349-5804; e-ISSN: 2349-5812 Volume 4, Issue 3 April-June, 2017, pp. 113-117

[34] Sudeshna Sarkar, "DEEP LEARNING" ,IIT Kharagpur.

[35] Deep Learning,Ian_Goodfellow,Yoshua Bengio,Aaron Courville

[36] Simon Haykin , "Neural Networks and Learning Machines" ,Third Edition
McMaster University Hamilton, Ontario, Canada