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Development of Cloud Based Light Intensity Monitoring System Using Raspberry Pi

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Abstract— **Accurate and quantifiable measurement of light is essential in creating desired outcomes in practical day to day applications as well as unique applications such as Traffic lighting system, Poultry Industry, Gardening, Museum lighting system, at emergency exits etc. Hence, Light measurement and analysis is an important step in ensuring efficiency and safety.**

Many of the industries are burdened with limited number of resources and real shortage of experts on their fields; real time remote monitoring presents an effective solution that minimizes their efforts and expenditures to achieve the desired results within time. This paper introduces real time remote Light intensity monitoring system using Raspberry Pi which enables the user to track the lighting system remotely. Raspberry pi is a low cost ARM powered Linux based computer which acts as a server, and it communicates with clients with LAN or external Wi-Fi module. The key feature of this system is light intensity being monitored instantaneously and data stored in the database for future use, and shown in the form of dynamic charts to the user according to the user requirement in a terminal device like Tablet or Smart Phone or any internet enabled device. This empowers experts to make right decisions at right time to get desired results.

Keywords—Light Intensity; Remote Monitoring; Raspberry Pi; WebServer; Wi-Fi; Dynamic Charts

I. INTRODUCTION

There are many applications for Light Meters such as measuring and maintaining adequate light levels in schools, hospitals, production areas, laboratories, passageways and more. Adequate light levels in the work place ensure a healthier and safer environment for people. Some of important locations and light intensity is shown in TABLE I. [1]

TABLE I . OPTIMUM AVERAGE LIGHT INTENSITY AT VARIOUS LOCATIONS

Location	Illuminance (Lux)
Warehouses, Homes, Theaters, Archives	150
Library(Reading Area)	200
Classroom	300
Laboratory	500
General office work	500

Consider following applications as an example

A. Traffic Lighting System

To ensure safety on the road, traffic lights need to be clearly visible for road users. The light intensity has to be sufficient under every (weather) condition, which set in legal standards. Over the course of time, the luminous intensity of traffic lights slowly decreases. Possible reasons are pollution of lenses or reflectors, aging of the light source or individual LED failure. Remote monitoring enables the road authority to carry out timely services, in such a way that traffic lights keep satisfying the statutory rules for optimal traffic safety.

B. Poultry Industry

Light Intensity is an important management factor in poultry industry to obtain optimal production. The intensity depends upon the age and type of housing being used, and type of chicken, be it broiler, breeder or layer. With blackout housing both male and female can be exposed to 3.5 fc from day one to day six and then placed on 1 fc to 19 or 20 weeks. After 19 - 20 weeks the broiler breeders can be exposed to about 3.0 to 5.0 fc during the entire production period. Layers should be exposed to about .5 to 1.5 fc (One foot-candle = 10.76 lux) for better production [4-6].

C. Plants Growth

Deficient light intensities tend to reduce plant growth, development and yield. This is because low amount of solar energy restricts the rate of photosynthesis. Below a minimum intensity, the plant falls below the compensation point. Compensation point is the metabolic point at which the rates of photosynthesis and respiration are equal so that leaves do not gain or lose dry matter. Photosynthesis significantly slows down or ceases while respiration continues. Likewise, excessive light intensity should be avoided.

D. Museum Lighting System

Light intensity is a primary consideration in museums to protect historic artifacts from damage. 5 to 10 foot-candles (approx. 50 to 100 lux) is currently considered to be the maximum allowable light level for very sensitive materials, such as prints, drawings, watercolors, dyed fabrics, manuscripts, and botanical specimens. Up to 15 footcandles

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(approx. 150 lux) is thought to be appropriate for oil paintings, most photographs, ivory, wood and lacquer objects. Metal, stone, glass, ceramic, and enamel objects are generally thought to be unaffected by strong light [7-11].

It is not possible to rely upon eyesight to give accurate information about light intensity because eyes adapt to changing light conditions too efficiently. Chapter 2 describes Hardware Development details i.e. Raspberry pi, Analog to Digital converter and Light Dependent Resister, chapter 3 deals with Software Development i.e. Web server, Database and Data visualization, chapter 4 Design and Development i.e. Block Diagram, Experimental setup, chapter 5 is Evaluation and chapter 6 is Conclusions.

II. HARDWARE DEVELOPMENT

A. *Hardware Architecture*

The hardware architecture as shown in Fig.1 has following components Development Board, Analog to Digital converter, Light Dependent Resister, Signal conditioning circuit and Wi-Fi dongle with Raspberry Pi.

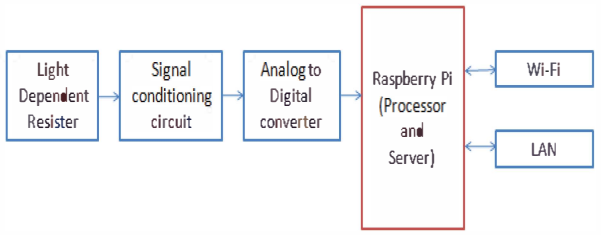


Fig. 1. Hardware Architecture

B. *Development Board*

Raspberry Pi (shown in Fig 2) is a credit-card-sized ARM powered Linux computer developed in the UK by Raspberry Pi foundation with the intention of stimulating the teaching of basic computer science in schools. It has five models; Model A has 256Mb RAM, one USB port and no network connection. Model B has 512Mb RAM, 2 USB ports and an Ethernet port [11].Model A+ has specifications very similar to Model A, but replaces the 26-pin GPIO connector, by a 40-pin connector, a micro SD slot takes the place of a full-sized SD slot, and power management has been improved so that it's more efficient, and can support "power hungry" USB devices.[2] Model B+ has specifications very similar to Model B, but replaces the 26-pin GPIO connector, by a 40-pin connector, a micro SD slot takes the place of a full-sized SD slot,replaces the 2 USB ports, by 4 USB ports and power management has been improved so that it's more efficient. [8-9] It has a Broadcom BCM2835 system on a chip which includes an ARM1176JZF-S 700 MHz processor, Video Core IV GPU, and an micro SD card. The GPU is capable of Blu-ray quality playback, using H.264 at 40MBits/s. It has a fast 3D core accessed using the supplied OpenGL ES2.0 and OpenVG libraries. The chip specifically provides micro HDMI and 3.5mm AV jack. Recently launched Raspberry pi2 has identical board Layout and footprint as the Model B+ but It has Quad processor runs at 900MHz and RAM of 1GB. The foundation provides following operating systems RASPBIAN, PIDORA, OPENELEC, RASPBMC, RISC OS and also Python as the main programming language, with the support for BBC BASIC, C and Perl

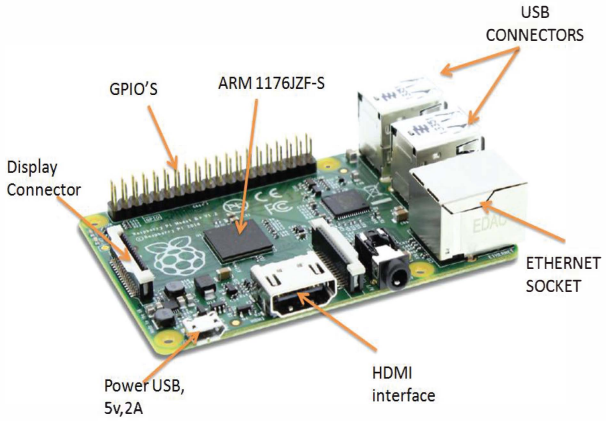


Fig. 2.Raspberry Pi Model B+ Board [2]

C. *Light Dependent Resistor And Analog to Digital Converter*

A LDR (Light Dependent Resistor) is variable resistor, the resistance of the LDR is inversely proportional to the light intensity, it exhibits maximum resistance in the absence of light and minimum resistance in the presence of light.

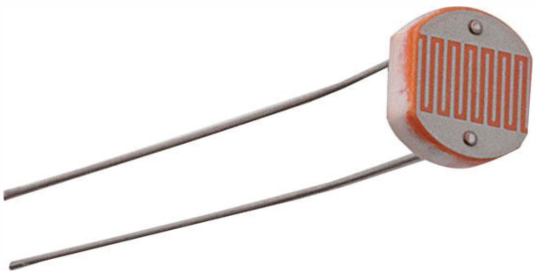


Fig. 3. Light Dependent Resistor [1]

LDR produces analog output voltage with respect to incident light, The Raspberry Pi computer does not have a way to read analog inputs. It is a digital-only computer. Compared to the Arduino, AVR or PIC microcontrollers that often have 6 or more analog inputs. Analog inputs are handy because many sensors are analog outputs, so we need a way to make the Pi analog-friendly.we can do that by wiring up an external ADC (Analog to Digital Converter) MCP 3208.

The MCP 3208 acts as a bridge between digital and analog.It is a 12 bit 8 channel Analog to Digital converter.It uses the SPI bus protocol which is supported by the pi's GPIO header.

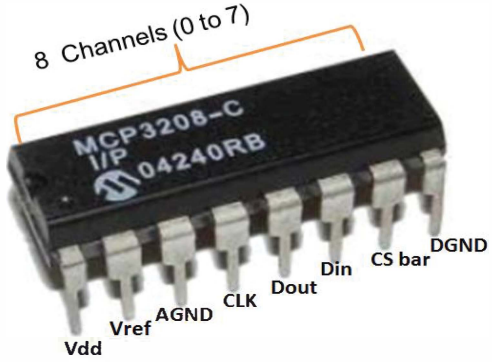


Fig. 4.MCP 3208 Analog to Digital Converter [3]

We need to enable the SPI interface on the raspberry pi by modifying the configuration file i.e., raspi-blacklist.conf the following command is used to open the configuration file *sudo nano /etc/modeprobe.d/raspi-blacklist.conf*. Add a '#' character in front of the line spi-bcm2708. Use CTRL-X, then Y, then Return to save the file and exit. Reboot using following command *sudo reboot*. In order to read data from the SPI bus in Python we can install a library called 'py-spidev'. Know ready to use SPI protocol in raspberry pi. Configure the ADC input registers to select particular channel in the ADC and use bitwise operators to get desired output from the output registers.

D. Signal Conditioning circuit

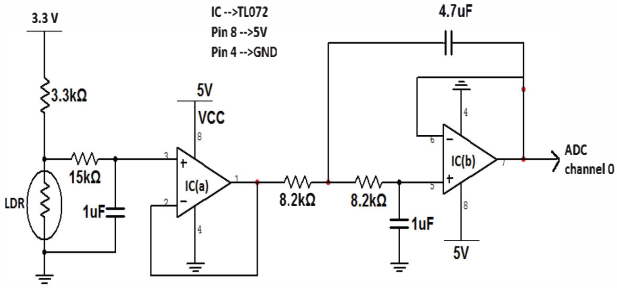


Fig. 5.Signal Conditioning circuit [1]

The signal conditioning circuit is as shown in Fig.5.The output of the potential divider circuit given to a 3rd order analog low pass filter (LPF). The filter is designed with dual op-Amp TL072 from Texas Instruments (TI) and which allows frequencies lower than 100Hz to pass and stops anything above this value. The LPF is here needed to reduce noise and unwanted high frequency transitions due to sudden flickering lights, glare, pulsating light sources and so on [1]. Next the output from the LPF is fed to the first analog input channel of the ADC MCP 3208.

E. Calibration of Light Dependent Resister

The relationship between the resistance R_L and light intensity Lux for a typical LDR is [1]

$$R_L = \frac{500}{Lux} \text{ Kohm} \quad (1)$$

With the LDR connected to 3.3V through a 3.3K resistor, the output voltage of the LDR is

$$V_0 = \frac{3.3 * R_L}{(R_L + 3.3)} \quad (2)$$

From equation (1) and (2)

We obtain Light intensity $$Lux = \frac{(\frac{1650}{V_0} - 500)}{3.3} \quad (3)$$

F. Wi-Fi dongle with Raspberry Pi

Wi-Fi is a popular wireless networking technology that uses radio waves to provide wireless high-speed Internet and network connections. The Wi-Fi Alliance, the organization that owns the Wi-Fi registered trademark term specifically defines Wi-Fi as any "wireless local area network (WLAN) products that are based on the Institute of Electrical and Electronics Engineers' (IEEE) 802.11 standards [14].

Fig. 6. Wi-Fi dongle

We are using Wi-Fi dongle is shown in Fig.6 for Wi-Fi communication between Raspberry Pi and clients.The first task is to burn the Rasbian OS into the raspberry pi and we can configure the device with following command *sudo nano /etc/wpa_supplicant/wpa_supplicant.conf* then we can see a window as shown in Fig.7.we need to swap "YOUR_SSID" and "YOUR_PASSWORD" and give name and password of our Wi-Fi network. Then reboot the raspberry pi using following command *sudo reboot.* Now we are ready to use Wi-Fi communication.

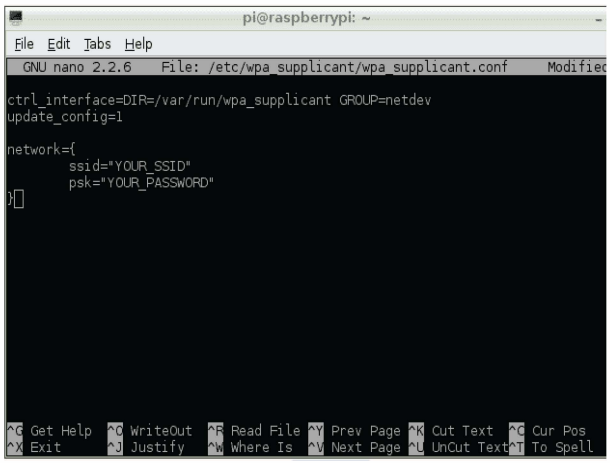


Fig. 7.Wi-Fi Configuration Settings [2]

III. SOFTWARE DEVELOPMENT

Software is the brain of this system, we can develop software using HTML (HypertText Markup Language) which is Skelton of the webpage, JavaScript for client side programming, PHP for server side programming and Dynamic charts API (Application Program Interface) for Data Visualization.

A. Raspberry Pi as a Webserver

The Raspberry Pi is a good choice for a web server that will not receive too much traffic, such as a testing server, or small intranet, as it doesn't have overheating problem. Apache is a web server application that we can install in the raspberry pi which allows to serve web pages. Use the following command to install Apache2, *sudo apt-get install apche2 –y*. Apache can serve HTML files over HTTP, and additional modules can serve dynamic web pages using scripting languages such as PHP.

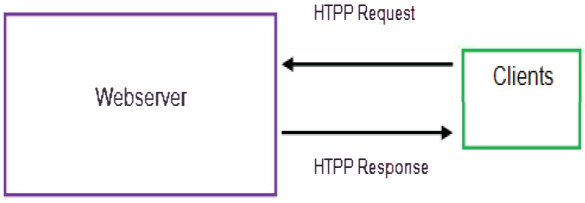


Fig. 8.Server and Client Communication

B. Data Base

We have to gather and track information from the data acquisition unit for the analysis. we can do so by installing MySQL database server in raspberry pi using following command sudo apt-get install mysql-server. Then the following operations can be done sequentially to store the data.

- Create a Database
- Create a table
- Load data into the table from data acquisition unit

C. Interactive Data Visualization

Data visualization is the presentation of data in a pictorial or graphical format. For centuries, people have depended on visual representations such as charts and maps to understand information more easily and quickly.Interactive data visualization goes a step further moving beyond the display of static graphics, interactive data visualization deals with dynamic graphs and charts. As more and more data is collected and analyzed, decision makers can take decisions quickly.

IV. DESIGN AND DEVELOPMENT

A. Block Diagram

Complete block diagram is as shown in Fig.9.signal from LDR is given to the signal conditioning circuit which is responsible to eliminate the noise, output of signal conditioning circuit given to the one of the analog channel of ADC which converts signal into digital signal, then the signal given to the GPIO (General Purpose input/output) of the Raspberry Pi.

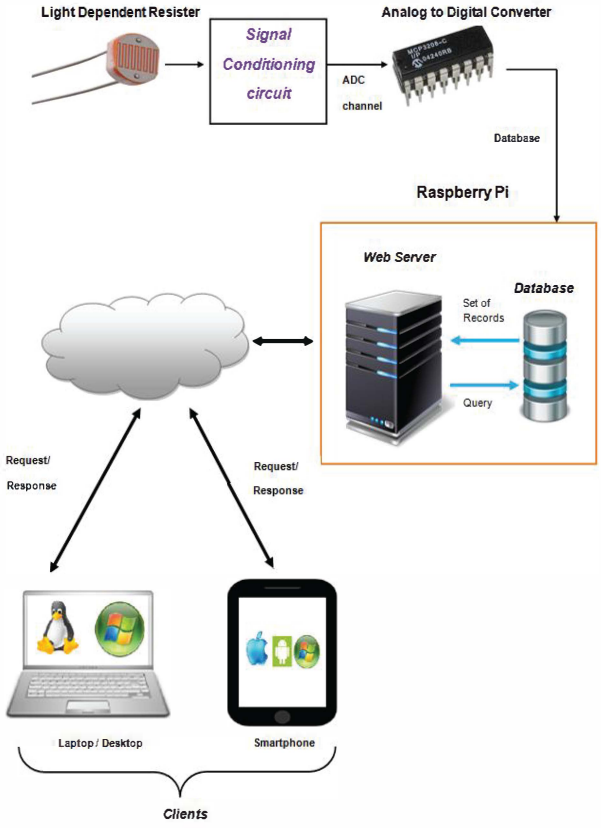


Fig. 9.Block Diagram of Proposed System

We can store Acquire in the database, developed web application stored in the server. Client can access the system with IP address (represented in Fig.10) through computer or Smartphone or Tablet or any other internet enabled device.

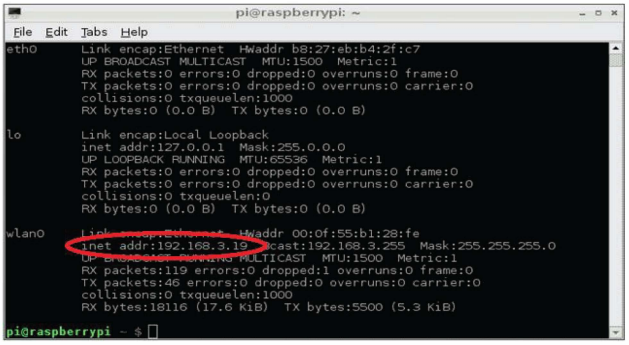


Fig. 10.System IP address [2]

B. *Experimental Setup*

Experimental setup is shown in Fig. 11.connected all components on the bread board.

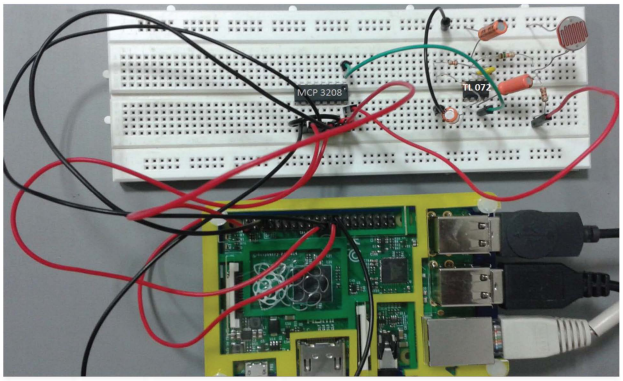


Fig. 11.Experimental Setup

V. EVALUATION

The purpose of evaluation is to evaluate the performance of proposed system.

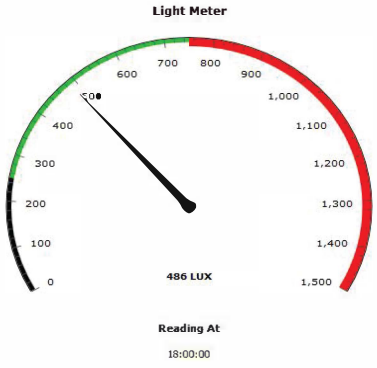


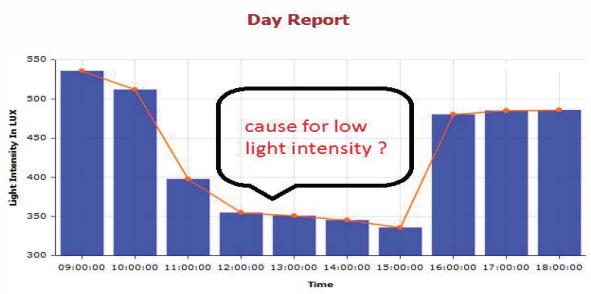
Fig. 12. Light Meter

We analyzed our laboratory lighting for a week from 15/12/2014 to 21/12/2014. Fig. 12 shows the light meter which shows instantaneous light intensity. Fig .13 represents how day data stored in the database. Pictorial representation of the data shown in Fig.14.

log_id	Date	Time	zone	Light_intensity
1	2014-12-15	09:00:00	LAB	536
2	2014-12-15	10:00:00	LAB	512
3	2014-12-15	11:00:00	LAB	398
4	2014-12-15	12:00:00	LAB	355
5	2014-12-15	13:00:00	LAB	351
6	2014-12-15	14:00:00	LAB	345
7	2014-12-15	15:00:00	LAB	336
8	2014-12-15	16:00:00	LAB	480
9	2014-12-15	17:00:00	LAB	485
10	2014-12-15	18:00:00	LAB	486

Fig. 13.Sample data for day (15/12/2014)

Fig.14 shows Day report of 15/12/2014,It give the experts to know the causes for the rise and fall in the light intensity with respect to time, once causes are found it is easy to solve the issues within less time. If we observe the Fig.15 in between 11 to 15 hours light intensity recorded less than the average light intensity (500 LUX).It is also showing maximum light intensity, minimum light intensity and average light intensity with date, time and location.



Maximum Light Intensity:

Date	Time	zone	Light Intensity(LUX)
2014-12-15	09:00:00	LAB	536

Minimum Light Intensity:

Date	Time	zone	Light Intensity(LUX)
2014-12-15	15:00:00	LAB	336

Average Light Intensity:

Light Intensity(LUX)
428.4

Fig. 14 . Day Report on 15/12/2014

Every day average light intensity stored in the database as shown in Fig .15. Pictorial representation of the data shown in Fig.16.

log_id	Date	zone	Light_intensity
1	2014-12-15	LAB	428.4
2	2014-12-16	LAB	435.5
3	2014-12-17	LAB	416.8
4	2014-12-18	LAB	524.4
5	2014-12-19	LAB	530.2
6	2014-12-20	LAB	524.6
7	2014-12-21	LAB	509.2

Fig. 15. Sample data for Week (15/12/2014 to 21/12/2014)

Fig.16 shows week report (15/12/2014 to 21/12/2014), it helps data analyst to understand average light intensity of each day. If we observe the Fig.16 in between 15/12/2014 to 17/12/2014 the light intensity recorded less than the average light intensity (500 LUX) and there is sudden change in light intensity on the day 18/12/2014 where it is recoded more than the average light intensity. It is also showing maximum light intensity, minimum light intensity and average light intensity with date and location

Maximum Light Intensity:

Date	zone	Light Intensity(LUX)
2014-12-19	LAB	530.2

Minimum Light Intensity:

Date	zone	Light Intensity(LUX)
2014-12-17	LAB	416.8

Average Light Intensity:

Light Intensity(LUX)
481.3000008719308

Fig. 16. Week Report from 15/12/2014 to 21/12/2014

Fig.17 shows performance of the system with (i.e. Week2) and without (i.e. Week1) controlling

Week1 Light Intensity in LUX (Monitoring)	Week2 Light Intensity in LUX (Monitoring and Controlling)
428.4	492.1
435.5	518.5
416.8	498.9
524.4	498.2
530.2	504.5
524.6	522.2
509.2	504.9

Fig. 17. Performance Comparison

VI. CONCLUSIONS

The Facility manger will have skill, training and experience but lagging with lack of information to take action immediately.In the paper, we have proposed and developed cloud based light intensity monitoring system. This helps to Facility manger to take necessary action at right time, with proper controlling with can achieve desired results. To evaluate the system, we have considered laboratory as an example but it can be used at various applications like traffic light monitoring, poultry lighting and museum lighting etc to avoid damages.

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