Abstract

The rising demand for improving the quality of life requires for increase in system complexity. Nowadays, the physical objects are connected to a network which can be wired or wireless in nature and can be accessed through the internet and is known as 'Internet of Things'. The objects contain embedded technology by which it can interact with the external environment. The sensor values obtained from the connected objects can be displayed, recorded for future use and may be transmitted to a remote location for similar applications or for any other purpose. A concept named Internet of Human Centric Lighting has been conceived theoretically in this study by which the installed lighting systems can be monitored and administered by smart internet enabled gadgets for stimulating our work efficiency and relaxation at night to reinforce the natural circadian rhythm for a better living environment.

Illuminance and Correlated Colour Temperature (CCT) measurement are salient features to evaluate the quality of lighting in an indoor space. This is required in situations where the daylight is not sufficient enough and compensatory lighting arrangement is to be installed as we spend most of our quality time in the indoors. The real-time acquired data or imported data from a dataset is trained using regression methods to formulate the sensor model. Then, it needs to be validated using the testing dataset to find out the efficacy of those techniques relying on their generalization capability. Regression analysis is done for prediction of sensor values and qualitative as well as quantitative performance evaluation of them is performed with respect to a standard reference meter. A lux sensor was intended to be calibrated using machine learning based regression techniques for estimation of illuminance data in terms of a pre-calibrated lux meter. For acquisition of sensor data, a lux sensor was interfaced with a wireless microcontroller that served as the client unit. At the same elevation, just beside to the sensing platform, a standard lux meter was placed and data from the reference lux meter were also noted. The client unit transmitted the lux information to a server computer in presence of a wireless router. Now, using the captured lux data from both the sensor and from the reference lux meter, machine learning based regression techniques were applied to develop the sensor model and predict the actual lux value. After successful execution of this experiment, the same technique was applied for estimation of both illuminance and CCT values from RGB sensor data with reference to a standard chroma meter. For capturing of data, RGB sensor and wifi enabled microcontroller together functions as the client platform

in an indoor wireless network. A calibrated chroma meter was utilized to sense the illuminance and CCT values for each RGB reading. The client unit transmitted the RGB values to a computer system, which served as server unit under the influence of a wireless router. The captured data have been used to train and validate the system using various types of regression techniques. Conversion of RGB values into lux and CCT data or periodic calibration were not required at the client terminal. Only, the sensed values were transmitted in a wireless network to server computer for conversion into illuminance and CCT values using the formulated regression model. Finally, from the estimated sensor values, corrective measures and preventive actions can be designed such that the parameters never fall below a certain threshold limit. Moreover, the maintenance personnel may become alert about the situation as and when it arrives.

In this research work, we also propose to develop an IoT based illuminance monitoring system which may enable the users to measure lux values at multi-positional indoor space using mobile sensors and store them in a cloud server wireless network. The sensing unit was designed by the integration of a lux sensor for capturing the illuminance values and IR transceiver was used for position detection. The sensors were interfaced with embedded microcontroller having on-chip wifi device and the designed system was placed over a RF controlled car. The car when moved through a selected indoor space, gathered positional lux information at certain time interval and store them on a cloud server using wireless mobile sensor network. These values were used to generate a lux map that was compared with the benchmark data and the result of comparison was considered to be an intelligent information for modification of any faulty illumination system. A similar type of system was also developed by the interfacing of RGB sensor with IR transceiver and this unit was mounted above a RF operated remote car to capture positional RGB data at certain duration. Now, using the formulated model obtained during machine learning based sensor calibration, the RGB information was converted into lux as well as CCT values and the positional lux and CCT data were saved in a cloud server using similar wireless mobile sensor network, as before. These values can further be utilized for development of an intelligent sensor data monitoring platform similar to the previous case-study.

During conduction of our earlier experiments in the selected indoor space, it was observed that the illuminance values declined suddenly and it was presumed to be a concern with the installed lighting system. After inspection by the maintenance section and detailed analysis of the issue, it was detected that the shadow of an object was the reason behind it. Various methods were studied and finally some edge detection techniques were utilized to find a

solution to the persisting problem. A comparative performance analysis has been conducted in this real-time experimental platform to find out the most preferred solution. A lux-map was initially developed along X-Y coordinate locations for the entire selected space from acquired real-time positional lux data. Then, they were converted into images and Canny, Prewitt, Sobel, and LOG type computer vision techniques were applied to detect the possible position and shape of the object at the indoor space.

Furthermore, another study was conducted to classify the illuminance images after acquisition from a lux sensor that was interfaced with wifi-enabled microcontroller. The experimentation set-up was placed over the roof of a remote operated car in a client-server wireless mobile sensor network configuration. The illuminance data thus gathered were converted into images that were analysed using PCA-eigenface technique, histogram based intersection method, and histogram based euclidean distance technique for evaluation of its illuminance class in comparison with the standard lux images. The feature value was detected for both training and testing image to find out the proximity of neighbouring pixels between training and testing images in PCA-eigenface technique. Similarly, histograms are represented as frequency dispersal of pixel intensity values. While the training stage was conducted, image histograms were formed and stored in the database. During the testing stage, histogram of a test image was matched with each training stage histogram either by means of histogram similarity analysis technique that computed their overlapping region or by the help of Euclidean distance between them.

Finally, the social, economic, and environmental aspects of the conducted research work have been described and the study concludes with identification of its future perspectives.