IoT Applications towards the Implementation of Dynamic Artificial Lighting in the Workplace

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Received: 11 January 2023; Revised: 08 February 2023; Accepted: 13 February 2023; Published: 10 March 2023

Abstract: Dynamic lighting requires a support system to set and control lighting according to the design. With advances in lighting technology and the internet, lighting settings do not need to be done manually. This article will discuss the Internet of Things (IoT) based applications, namely Blynk and WiZ. In the installation process, Blynk effectively connects the lamps used for research with the WiZ application. The WiZ application is needed to arrange the illuminance level, correlated color temperature (CCT), and the lights' placement for creating dynamic lighting. This advantage makes Blynk and WiZ potentially effective for everyday use, including in the workplace. However, there are limitations to both applications that must be considered and anticipated to maximize their utilization.

Keywords: Blynk application, dynamic lighting, WiZ application

I. Background

Natural lighting, physiologically, is an effective stimulus to the human visual and circadian system (Boyce et al., 2003). However, most workers spend their working hours indoors. With office hours usually from 8 am – 4 pm, the workplace may have limited access to daylight because of limited space or functional requirements from work itself. Thus, the lighting source is dependent on artificial lighting. Artificial lighting can be an appropriate and effective method to create ambient lighting that is arranged to follow the sunlight cycle (known as circadian adaptive lighting) and meet the human biological needs cycle (known as bio-adaptive lighting) (amBX, 2017).

This adaptive lighting can increase the workers' productivity and performance and reduce workplace accidents and health complaints (Burnett, 2012). Artificial lighting that simulates dawn lighting has been considered to improve well-being, subjective mood, and cognitive performance, compared to dim or blue monochromatic lighting with minimum impact on the circadian phase (Gabel et al., 2013). The rapidly changing hue and chroma seem to create a live atmosphere to activate humans. Alternatively, the opposite atmosphere can be relaxing for relaxation (Li et al., 2019).

Lighting that changes dynamically can increase well-being rather than monotone lighting (Kronqvist, 2012). The workers under dynamic lighting feel more satisfied than static lighting (De Kort & Smolders, 2010). Following the circadian cycle, the changes from cool white to warm white all day have been proven to increase work performance and protect eyesight (Gomes & Preto, 2015). Dynamic lighting positively affects work stress related to psychophysiology (Canazei et al., 2014). The positive effect of dynamic lighting can appear long-term in an environment with minimal or even without natural lighting or one with varied illumination levels or correlated color temperature (CCT) contribution (De Kort & Smolders, 2010).

The application of dynamic lighting that is changeable in CCT and illuminance level to adjust for the activity requirements (amBX, 2017) may need a support system to set and control lighting according to the purpose. The lighting settings can create different levels of dynamic lighting (Jensen et al., 2016) by using Potentio (Bangsawan, 2013) or using automatic regulators (Engwall et al., 2015; Lu et al., 2019). However, with the development of technology, lighting control can be supported by the Internet of Things (IoT) for switching on/off (Patel & Salazar, 2016) and providing adaptive lighting (Ramasamy & Kadry, 2021). This article discusses the application of Blynk and WiZ apps as IoT-based, their potency for dynamization, and consideration for future implementation in the workplace.

II. Literature Review

IoT is an infrastructure network with an internet medium that connects intelligent equipment and integrates physical and virtual worlds by exchanging information and communication (Patel & Salazar, 2016). IoT works on connected devices with wireless communication (Wilianto, 2018). In a smart building, IoT enables the user to control intelligent lighting and remotely monitor the designed condition (Patel & Salazar, 2016; Ramasamy & Kadry, 2021). IoT can be applied to create a personal experience (Salazar & Silvestre, 2017) by communicating intelligent equipment and human as the user (Ramasamy & Kadry, 2021). Previous research

ISSN No. 231-2705 | DOI: 10.51244/IJRSI | Volume X Issue II February 2023

used IoT-based lighting controllers such as Luminair 3 application to set CCT and Red Green Blue (RGB) lighting (D. H. Kim, 2018; D. H. Kim & Mansfield, 2021), lighting controller manufactured by L company (S. Y. Kim & Kim, 2007), MudGet (Y. H. Kim et al., 2017), and the Mobile App UI (Y. S. Kim et al., 2016).

Included as IoT, the Blynk used in this research is a platform that allows users to control and access electronic devices remotely (Syaifuddin et al., 2018) using iOS and Android applications. Blynk can be a direct, remote, and even automatic lighting control (Pasau et al., 2019) and switch (Mazalan, 2019). This application is widely used because it is easy to access and utilize (Harir et al., 2019). When connected to Wi-Fi, Blynk can connect various devices for monitoring and controlling a maximum of 8 pieces (Durani et al., 2018) for multiple building functions. Research stated that switching the lighting on/off with the Blynk app will be appropriately functioned with a maximum distance range from 25 m (Herlina et al., 2022) to 35 m of distance (Artiyasa et al., 2021). The Blynk response was considered as fast that some delay from 0.5 – 1 s (Artiyasa et al., 2021) that might occur depending on the internet connection stability (Herlina et al., 2022).

Another IoT application used in this research was the WiZ application. The WiZ that Signify (*Signify Acquires WiZ Connected to Further Expand Its Leadership in Connected Lighting*, 2019) acquired must be connected to a 2.4 GHz Wi-Fi network with a strong signal to set the designed lighting. The lamps and the control device must also be in the same Wi-Fi network range (*Wiz App Setup Instructions*, n.d.). This setting can support human-centric lighting (*LED Strip Wireless*, n.d.) by enabling the dynamization of the lighting.

III. Material and Methods

This article observed the IoT application used to set the artificial lighting for dynamization possibility and the result of the setting. The research was conducted in an artificial workspace measuring 7.2 x 7.2 m2 with a height of 3.5 m with monochromatic colors. The white color was applied to the ceiling and wall, which are the acoustic panels and curtains. The lighting system initially contained in the room was in the form of three group lighting settings with lamp housings (1) pointing downwards (lights illuminate the work area), (2) directed to the side (lights illuminate the walls), and (3) directed upwards (lights shining on the ceiling). The three groupings were initially controlled with Potentio to change the illuminance level. The existing room uses TL fluorescent white daylight lamps, and although the current lighting system was dimmable, the lights in the room were not tunable, so the CCT cannot be changed. This weakness required that the lighting be adjusted for the research design to be carried out.

Figure 1. The condition of the test cell with the initial lighting controller

The dynamization lighting observation required lamps whereby the illuminance level and CCT can be changed. It was needed so there is no need to change other lighting systems or move to different rooms when switching from one to another setting. The research changed the existing lighting and implemented a Smart Wi-Fi LED strip from Philips that was tunable and dimmable. The lamp specification was a luminance of 1600 lm for the starter kit and 880 lm for the extension, with a CCT range of 2700 K (warm white) to 6500 K (cool white).

ISSN No. 231-2705 | DOI: 10.51244/IJRSI | Volume X Issue II February 2023

Figure 2. The condition of the test cell with the IoT application

The observed lighting settings were:

1. Overhead lighting in cool white CCT (OH Cool)
2. Overhead lighting in warm white CCT (OH Warm)
3. Cool white indirect lighting reflected by the wall (Wall cool)
4. Warm with indirect lighting reflected by the wall (Wall warm)
5. Cool white indirect lighting reflected by the ceiling (Ceiling cool)
6. Warm white indirect lighting reflected by the ceiling (Warm cool)

The illuminance level, CCT, and luminance resulting from the lighting setting were measured on the work plane, ceiling, and wall at the height of 0.75 m as the workplace height was 1,2 m as the sitting height, and 2 m as the standing visual height with 1,2 m distance between the measurement points.

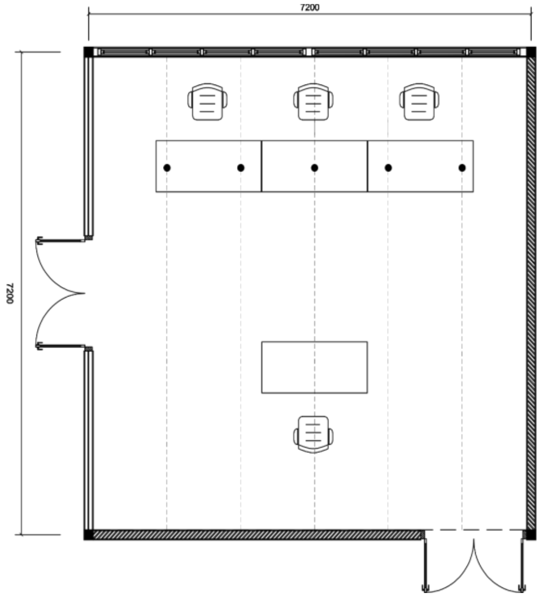

Figure 3. The measurement point on the work plane

ISSN No. 231-2705 | DOI: 10.51244/IJRSI | Volume X Issue II February 2023

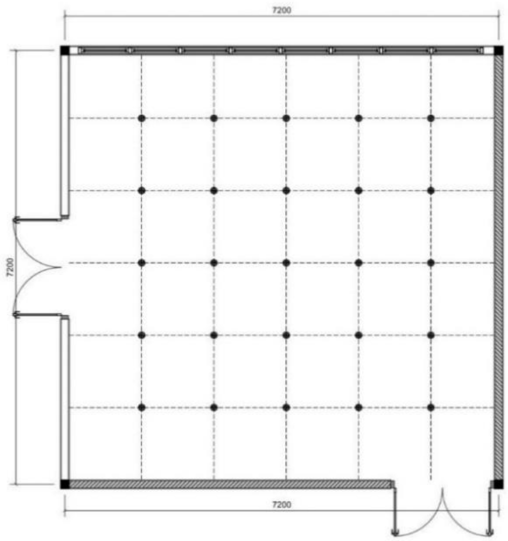

Figure 4. The measurement point on the ceiling

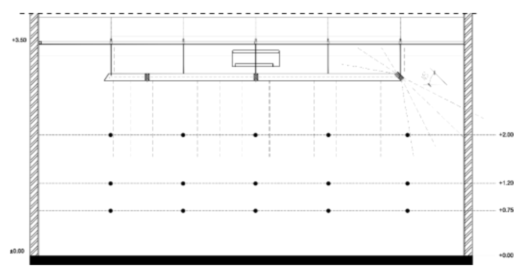

Figure 5. The measurement point on the north side wall

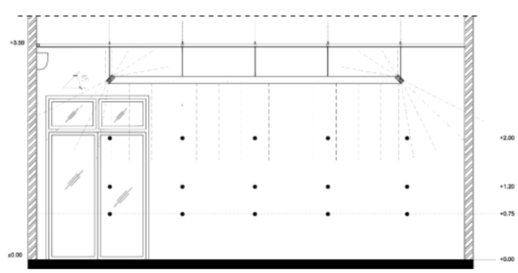

Figure 6. The measurement point on the west side wall

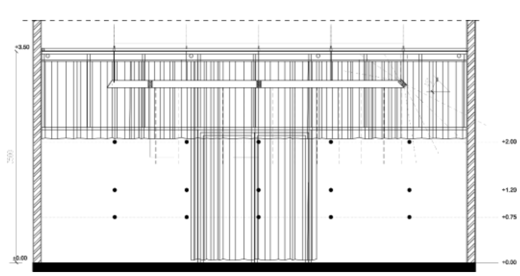

Figure 7. The measurement point on the south side wall

ISSN No. 231-2705 | DOI: 10.51244/IJRSI | Volume X Issue II February 2023

III. Result and Analysis

The research observed the different illuminance levels, CCT, and lamp placement. Therefore, the observation room requires a lighting system that can be changed (1) bright – dim the illuminance level, (2) cool – warm CCT, and (3) overhead – peripheral – ceiling lighting where the lights were placed. The implementation was supported with applications 1) Blynk to switch the lamp on/ off and 2) WiZ to set the illuminance level and CCT. The Blynk application is beneficial for installing the lighting grouping into the WiZ application, which, in the process, needs to switch on/off 3 to 5 times quickly.

Blynk App

The Blynk application acts as an interface for on/off light control to make it easier for users to turn it on and off remotely. An electrical panel is needed as a voltage source in the controller system, and an internet network is necessary to control everything remotely. The 12 Volt (V) adaptor changed the voltage from AC to DC from the electrical source. The step-down lowers the DC voltage from 12 V to 5 V; hence the voltage can be accepted by the Node Micro Controller Unit (MCU) as a microcontroller that only works at 5 Volt DC. This microcontroller was equipped with a Wi-Fi module to function as a remote controller. The relay DC 5 Volt became the electrical on/off switch; hence needs the microcontroller and 5 V DC voltage to be operated. The output from the relay is connected to lamps to be controlled easily and connected to the WiZ application.

Figure 8. Blynk controller

Figure 9. Blynk user interface

There are three lighting groupings in the new lighting system: (1) overhead, (2) peripheral walls, and (3) peripheral ceiling. The three groups consist of four ceiling lamp fixtures, three peripheral wall fixtures, and two overhead lighting fixtures. Blynk managed eight devices in this research, so the two overhead lighting fixtures are integrated into one grouping.

WiZ App Implementation

WiZ application can be used to change the illuminance level and CCT, which, like Blynk, must also be connected to Wi-Fi to operate. The application was set on the maximum left for warm white and maximum right for cool white when testing the effect of

ISSN No. 231-2705 | DOI: 10.51244/IJRSI | Volume X Issue II February 2023

different CCTs. WiZ app was turned on or off any group's lighting settings to test the effect of varying lighting placement and distribution. The changing from one set to another can be done at minimum 0.00 s time of fading (directly change) to 600 s. The lighting set can be done by a device that must be connected to the same Wi-Fi as the lamps to avoid some errors.

WiZ can control a maximum of 10 lightings adaptor in one room lighting arrangement. As this research used strip-type lamps, the lighting can create a maximum of 10 m length for each starter kit with adaptor lighting. It was made by connecting the 2 m main lighting to a maximum of 8 one-meter extension lights. Each connected strip of lighting can only be arranged in 1 grouping. Therefore, the arrangement was three for overhead grouping, three for indirect wall grouping, and four lighting indirect ceiling grouping.

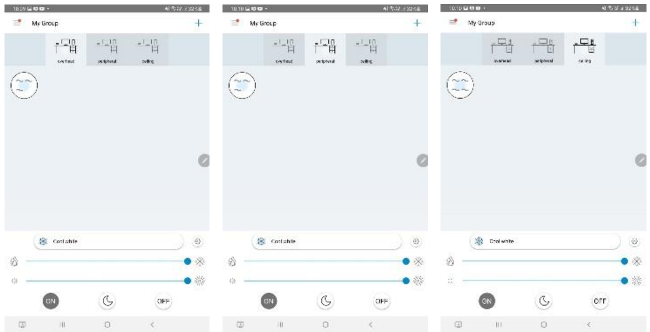

Figure 10. WiZ user interface

Measurement result

Below are the illuminance level, CCT, and luminance measured on the wall, ceiling, and work plane due to different light setting exposure.

Table 1. Measured result of illuminance level (lx)

No	Lighting Setting	Wall	Ceiling	Work plane
1.	OH Cool	17.27	8.95	143.34
2.	OH Warm	17.7	10.22	156.38
3.	Wall Cool	86.36	26.05	3.42
4.	Wall Warm	95.26	29.17	3.72
5.	Ceiling Cool	27.14	114.74	4.92
6.	Ceiling Warm	29.52	122.4	5.36

Table 2. CCT (K)

No	Lighting Setting	Wall	Ceiling	Work plane
1.	OH Cool	4289	3624	5202
2.	OH Warm	2451	N/A	2999
3.	Wall Cool	5149	4663	4795
4.	Wall Warm	2727	2591	2638
5.	Ceiling Cool	4677	5082	4811
6.	Ceiling Warm	2623	2711	2662

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Table 3. Measured result of luminance level (cd/m2)

No	Lighting Setting	Wall	Ceiling	Work plane
1.	OH Cool	4.65	2.73	8.68
2.	OH Warm	4.94	2.93	11.04
3.	Wall Cool	21.27	7.04	2.6
4.	Wall Warm	21.32	7.38	2.88
5.	Ceiling Cool	7.12	35.38	3.86
6.	Ceiling Warm	7.52	33.03	

When all lights are turned on with the maximum level of illuminance, and CCT settings are in the WiZ App, the measured brightness on the work plane is 249.3 lx 18.5 cd/m2 and 5093 K. If the CCT is minimal in the WiZ application, then in the field of work it will measure 267.8 lx 22.55 cd/m2 and 2677 K. This result may need to be considered in the implementation if it is planned to have a higher illuminance level and/or CCT.

The lighting placement that led to the distribution direction might affect the CCT measured on the work plane, wall, and ceiling. It is because the CCT was slightly different, although each set was within the same maximum range of CCT on the WiZ app.

Figure 11. The cool white setting appearance

Figure 12. The warm white setting appearance

The lighting intensity of every setting was also affected by the lighting placement and distribution. The highest illuminance level resulted in the work plane under direct overhead lighting. In contrast, the lowest one was also measured on the work plane exposed to indirect peripheral lighting.

Figure 13. The overhead lighting setting appearance

Figure 14. The peripheral wall lighting setting appearance

Figure 15. The peripheral ceiling lighting setting appearance

The effect of lighting placement and distribution direction was also found on the illuminance and luminance levels. The measurements on the work plane, wall, and ceiling show significant differences between every set. The highest illuminance level has resulted in the work plane that applied direct overhead lighting. The lowest one was also measured on the work plane exposed to indirect peripheral lighting. The highest luminance level was achieved on the ceiling when it was exposed to indirect lighting reflected onto the ceiling to the work plane. The lowest one resulted in the work plane that applied indirect lighting reflected onto the wall to the work plane.

IV. Conclusion

From the discussion above, it can be concluded that dynamic lighting is applicable with IoT's support in controlling and setting. However, several things should be considered, such as (1) the maximum limit of devices connected to WiZ and Blynk, (2) the maximum and minimum illuminance level and CCT that the lamps and WiZ app can create. This research only observed the illuminance level, CCT, and lamp placement supported by WiZ. Since WiZ and smart LED strips can be adjusted for many colors, further research can investigate their effect on mood.

Acknowledgements

The first author gratefully thanks the Universitas Sebelas Maret for the financial support for this research in the form of a doctoral scholarship. The researchers would also like to show their sincere gratitude to Bagas Dhannes Kesworo and Wahyu Widodo for their support in IoT setting.

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