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Characterization of the lighting system of hospital rooms

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***Abstract* – Artificial lighting in the hospital areas is equally essential for medical staff, patients, and their visitors. Adequate lighting can have beneficial effects on human health by contributing to the patient's recovery process and also increasing the performance and efficiency of medical staff. In contrast, inappropriate lighting generates harmful effects on health and well-being. Thus, parameters such as luminous intensity, luminance, luminous flux, and illuminance provide information regarding the lighting system. Therefore, determining these parameters is a key factor in establishing and determining possible negative effects as a result of prolonged exposure to artificial light.**

In this context, a systematic study was carried out to determine the correlated color temperature, light intensity and UV index of artificial light from three hospital areas, including waiting areas, patient ward rooms, intensive care units, and operating rooms, and to evaluate the quality of the lighting system.

I. INTRODUCTION

Light is essential for human health and well-being because it enables vision and daily activities. Over time, artificial lighting has evolved, marking major changes in the source of illumination. This progression spans from the utilization of candlelight to incandescent light and, most recently, to the use of LEDs [1]. Today in the modern world, artificial light is near-ubiquitous, being used in the medical field for sterilization of medical equipment, phototherapy, endoscopy and laparoscopy, in phototherapy, ambient lighting, and many other fields.

Numerous studies highlight the significant role of light in human psychological and physiological health, having both harmful effects on vision (contrast perception, myopia, dry eye syndrome, macular degeneration, glaucoma) and non-vision (depression, anxiety, gastrointestinal and cardiovascular diseases, breast cancer) but also, beneficial effects in decreasing depression, reducing fatigue, increasing alertness and regulating circadian rhythms [2]. These effects are generated by different radiometric and photometric parameters.

Comparing natural outdoor light with artificial light, significant differences regarding radiometric and photometric information, including the dimmer, spectral distribution, and illuminance and luminance levels, can be observed [3]. Despite the progress made in recent years, it has been found that no lighting technology has been able to reproduce all the characteristics of natural light to date. For example, indoor lighting has illuminance values of less than 1000 lux [4], while the sunlight can reach values up to 100000 lux [5].

In hospitals, both patients and medical staff are exposed to artificial light for a long time. Light intensity is essential to ensure adequate visibility and reduce the risk of medical errors, but insufficient or excessive lighting can cause visual discomfort and eye fatigue [6]. Correlated color temperature (CCT) directly impacts alertness and psychological comfort. The study conducted by Cajochen et al.[7] shows that cool light (5000–6500 K), rich in blue components, increases alertness and cognitive performance, being suitable for active medical spaces, such as operating rooms or treatment rooms. On the other hand, Knez and Kers [8] show that warm light (2700–3500 K) is perceived as more relaxing and contributes to a state of emotional comfort, thus being suitable for wards and rest areas. The information is also supported by applied studies in human-centered lighting, conducted by the Lighting Research Center [9]. Regarding UV radiation, it must be kept at safe levels, as prolonged exposure can damage the skin and eyes. Although UV-C technology is effectively used for disinfection, it is strictly applied in the absence of people, according to the safety protocols recommended by the WHO [10]. Adapting these characteristics to each area of the hospital significantly contributes to patient safety, effective recovery, and the performance of medical staff.

Therefore, it is important to determine the correlated color temperature (CCT), variation in light intensity, and UV index through standard metrics and to evaluate the possible effects according to the characteristics of the light.

In this context, a systematic study was carried out to determine the correlated color temperature, light intensity, and UV index of artificial light from three hospital areas. The main focus was on operating rooms, intensive Care units, and patient ward rooms.

II. MATERIALS AND METHODS

The development of the final device involves a hardware part (the integration of the sensors and other components) and a software part (the application development).

A. System description - Hardware

The hardware part integrates an analog UV light sensor GUVA-S12SD, two RGB color sensors TCS34725, and one luminosity sensor TSL2561. Two TCS34725 sensors are placed at a 90° angle to each other. One of the sensors is oriented vertically to capture light from the ceiling, and the other is oriented laterally to capture light from the walls, thus ensuring complete coverage of the measurement field and obtaining accurate data on the color of the light from different angles. To perform 360° scan measurements automatically, the sensor platform is rotated by a stepper motor GM12-15BYC ratio 1:30, controlled by a motor drive module EasyDriver A3967. Using an HC-06 Bluetooth module and Arduino module, the entire system can be controlled remotely using a smartphone application specially designed for performing measurements, saving, and sharing the obtained data. The aim is to develop a portable system with low energy consumption that allows easy control, including remotely, to ensure the safety of operators in high-risk areas, such as radiology rooms, isolators, and other similar environments.

B. System description - Software

The part of the system responsible for data acquisition runs a custom code developed in Arduino IDE, which integrates all the hardware components, while the part responsible for setting parameters, receiving in real-time data, saving and sharing them also runs a custom code developed in MIT App Inventor. The mobile application has implemented sections that allow setting the scan rotation values (in degrees), setting the values for the delay between steps (in seconds), and entering the name of the location where the measurement was performed. The control button section contains: a BT-C button - to connect the application to the device, a BT-D button - to disconnect the application from the device, a START button - to start the scan after the scan values have been entered, a STOP button - to stop the scan instantly, a RESET button - to bring the device to the initial position 0, a SAVE button - to initiate saving documents to a .csv file, and a SHARE button - to be able to share the file via methods such as email, message, cloud, etc. The application also contains a status bar where notifications are displayed, such as connection status, measurement stages, data retrieval, data saving, data export, etc.

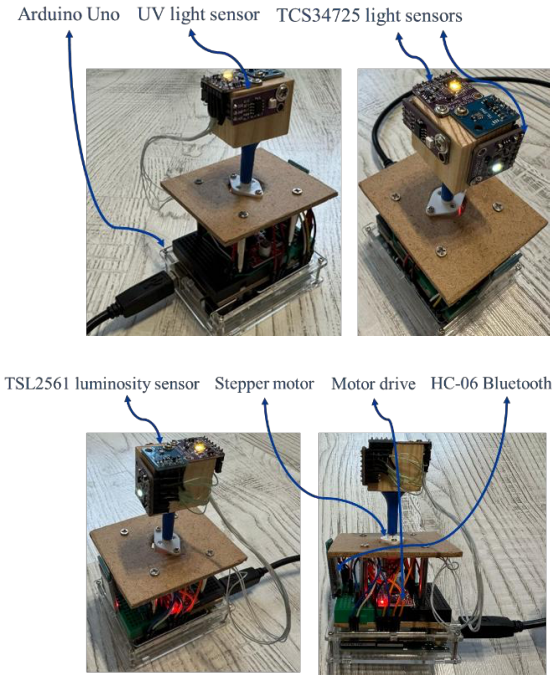

Fig. 1. The hardware components of the portable device.

C. Methods

The experimental measurements were carried out as a 360° scan of the space, with a one-second delay between steps. The device was set up at a distance of one meter from the light sources. It was done three measurements for each area, and one measurement takes around ten minutes.

III. RESULTS AND DISCUSSIONS

According to the European standard EN 12464-1:2021, the recommended illuminance levels vary significantly depending on the hospital area. For patient wards, the standard suggests an average illuminance between 100 and 300 lux, depending on the specific tasks performed and the space layout. Intensive care units typically require around 300 lux for general lighting to ensure adequate visibility for patient monitoring and staff activity. In contrast, operating theatres demand substantially higher lighting levels, with general lighting recommended at a minimum of 1,000 lux, and surgical field lighting often exceeding 10,000 lux. Regarding the correlated color temperature (CCT), lower values—typically in the range of 3,000 to 4,000 K—are preferred in patient recovery areas to support visual comfort and circadian alignment. In operating rooms, however, higher CCT values, often between 4,500 and 5,000 K, are used to improve visual acuity and accurate color rendering, which are critical during surgical procedures.

The experimental measurements were performed in three hospitals, including operating rooms, intensive care units, and patient ward rooms. Table 1 shows the main

characteristics of the rooms in which the determinations were performed.

Table 1. The general parameters of the hospital rooms.

Operating rooms (OR)				
Surface (m2)		Window	Type of light	Number of lighting
H1	56	3	LED	4
H2	60	4	LED	4
H3	59	3	LED	5
Intensive care units (ICU)				
Surface (m2)		Window	Type of light	Number of lighting
H1	20	2	LED Fluorescent	4
H2	25	2	LED Fluorescent	4
H3	22	2	LED Fluorescent	4
Patient ward rooms (PWR)				
Surface (m2)		Window	Type of light	Number of lighting
H1	10	4	Incandescent	2
H2	12	4	Incandescent	2
H3	12	4	Incandescent	2

A. Illuminance levels

According to international and national standards *[11]* the general lighting in operating rooms is necessary to be more than 1000 lx.

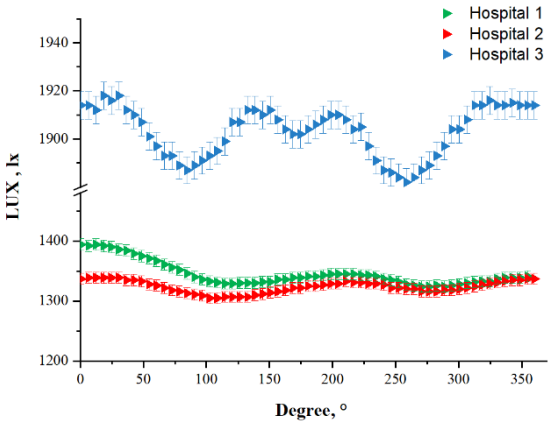

Fig. 2. The illuminance values for the operating rooms.

In the case of hospital 3, the illuminance values show the most significant oscillations, with the highest number of minima and maxima. These oscillations are not completely symmetrical, which may indicate significant variations in light sources.

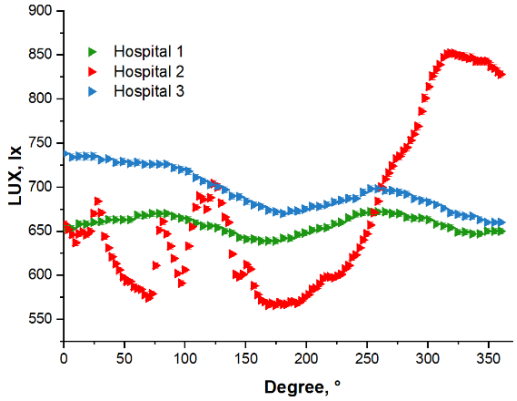

Fig. 3. The illuminance values for the intensive care units.

Fig. 3 presents the illuminance profiles from intensive care units in three hospitals. For hospital 1, the illuminance values show two clear cycles of light variation without abrupt fluctuations. The lighting exhibits a slightly oscillating behavior, which could affect the uniformity of light. The same behavior could also be identified in the case of hospital 3. In the case of hospital 2, the illuminance values show multiple peaks and sharp drops without a familiar periodic pattern. The lighting has a generally higher intensity but lacks consistency in terms of stability.

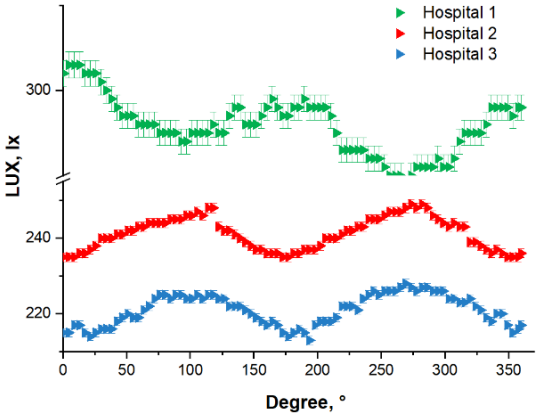

Fig. 4. The illuminance values for the patient ward rooms.

In the last examined area, hospital 1's illuminance values show a gradual decrease with slight fluctuations in the middle section. For hospital 2, the illuminance values indicate a double sinusoidal pattern, alternating exposure to a strong light source. The space has two intense light spots and transition zones between them, suggesting a directional lighting distribution. In the case of hospital 3, the illuminance values show a sinusoidal pattern, suggesting light coming from multiple directions, with

wide zones of consistent illumination.

B. Correlated color temperature

As can be seen from Fig. 5 a), the CCT values start high, followed by an abrupt drop, after which a stabilization appear, indicating a transition from cold to neutral light, while in the case of hospital 2 (Fig. 5 b)) the CCT values remain stable initially, followed by a sharp jump. The light presents a neutral color with a stable chromatic spectrum and intensity fluctuations. The CCT values of the operating room from hospital 3 (Fig. 5 c)) present a rapid drop at the beginning, followed by stabilization, indicating warmer lighting.

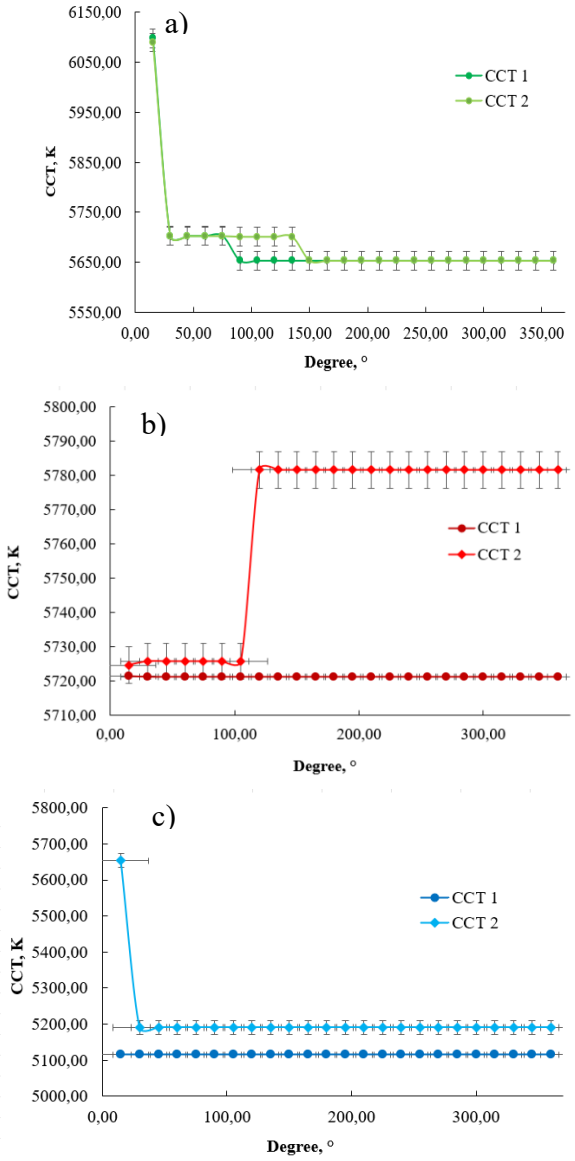

Fig. 5. The CCT values for operating rooms from a) hospital 1, b) hospital 2, and c) hospital 3.

Figure 6 presents the CCT values of the intensive care units determined in the second area. The CCT values for hospital 1 reflect a uniform lighting system, with small areas sensitive to color temperature. In the case of hospital 2, the CCT values reflect a very stable system with ideal behavior. In the last hospital (Fig. 6 c)) the CCT values suggest good and consistent color calibration of the lighting system.

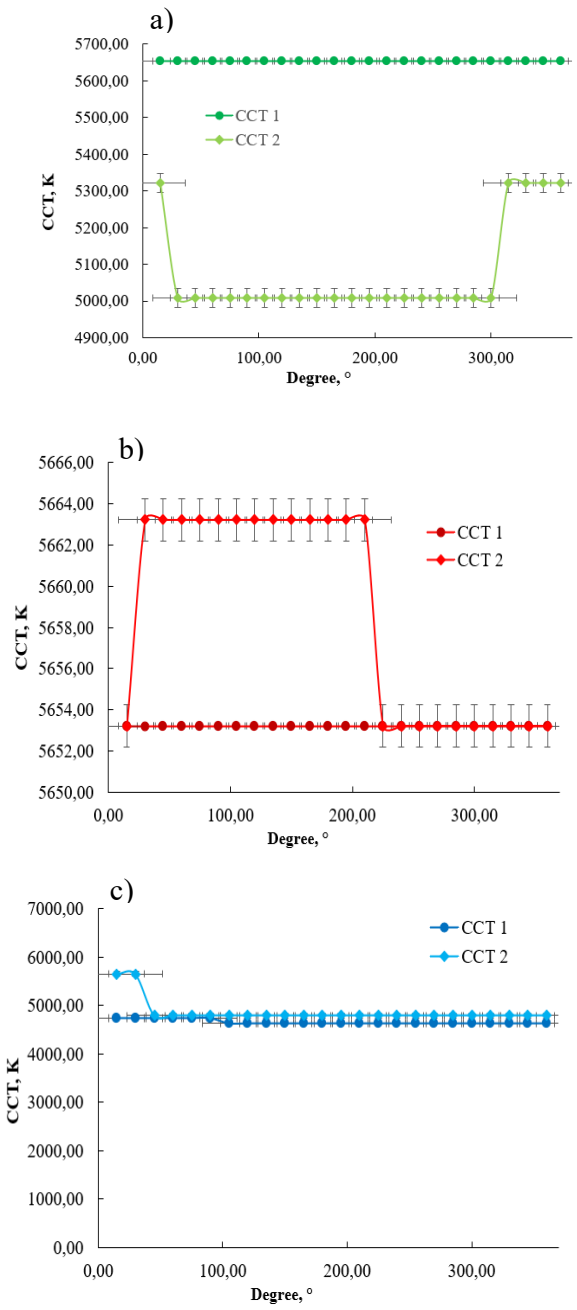

Fig. 6. The CCT values for intensive care units from a) hospital 1, b) hospital 2, and c) hospital 3.

In the patient ward room, for hospital 1, the CCT values initially show variation, followed by stabilization at constant levels, resulting in minimal changes. Fig.4 c) presents a high decrease followed by steady stabilization. This behaviour indicates a stable color system.

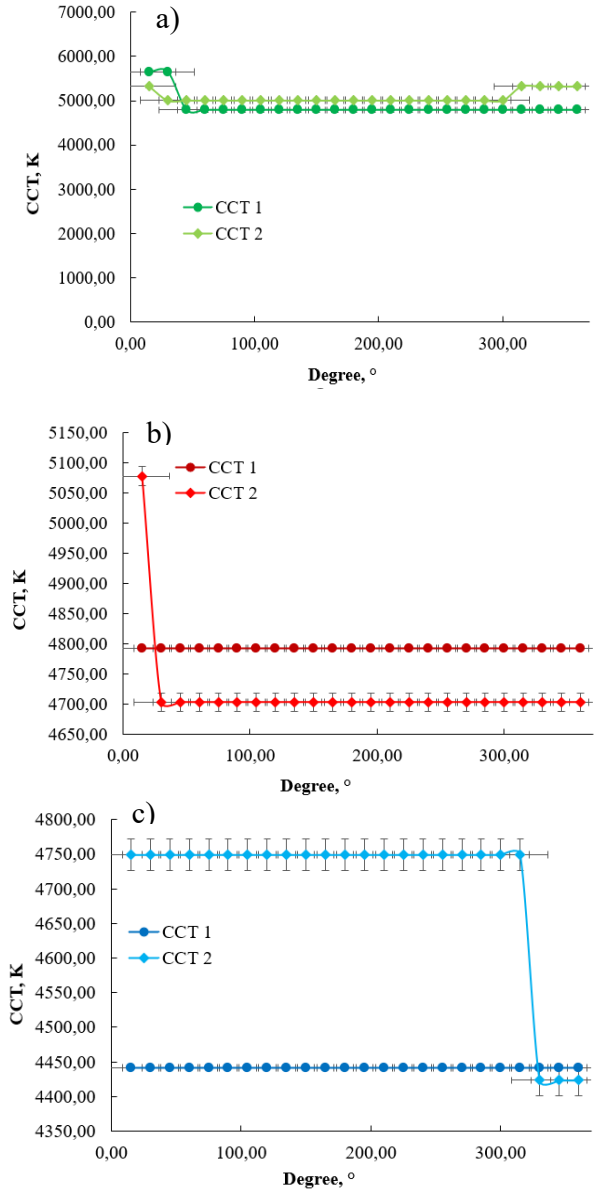

Fig. 7. The CCT values for the patient ward room from a) hospital 1, b) hospital 2, and c) hospital 3.

C. UV index

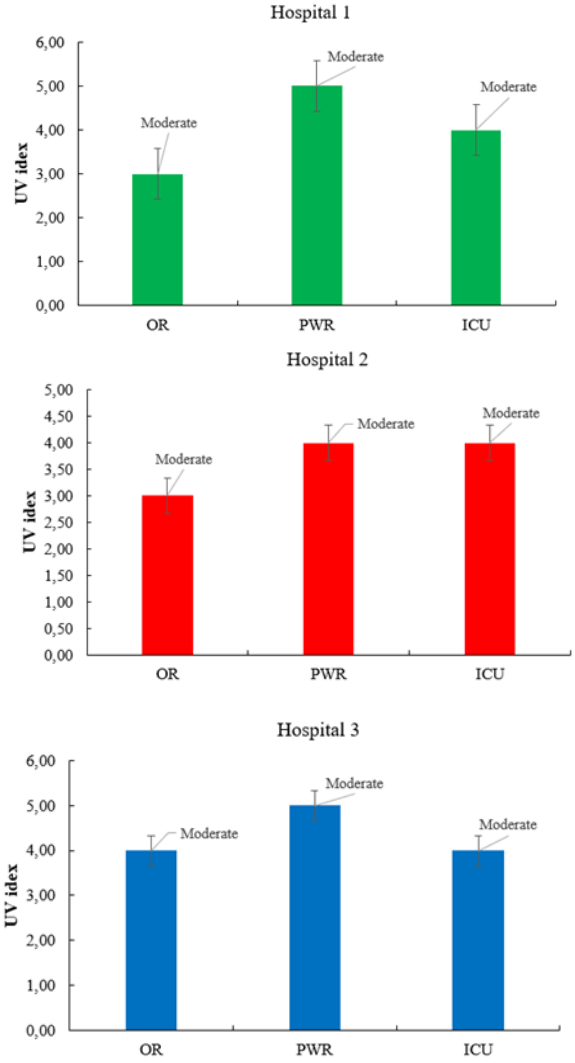

Fig. 8. The UV index in the examined areas.

As can be seen from the presented graphs, the UV index measured in each room from each hospital is in the moderate limits, according to the World Health Organization scale.

IV. CONCLUSIONS

A portable device was made using a microcontroller to be able to acquire data from the area of interest, using specific sensors added to the stepper motor. The acquired data is transmitted via Bluetooth in real time to the specially designed smartphone application. The application is responsible for setting the measurement parameters, receiving the data, saving them in the smartphone's internal memory, as well as sharing using applications as mail, cloud, message etc. The experimental

data show that Lighting levels, UV index, and Correlated color temperature are, with small variations, in accordance with International standards.

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