PHOTOMETRIC PROTOTYPE FOR MEASURING LIGHT EMISSION AND INTENSITY OF AFL USING LINE RUNWAY LIGHT ROBOT

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ABSTRACT

Airport lighting systems are crucial for flight safety, especially during nighttime or adverse weather conditions. The development of a photometric measurement tool employs the miniEVB as the microcontroller, the BH1750 sensor to measure light intensity, and a photodiode to detect light emission. The JDY-40 module connects the robot to an Android application, while the ESP8266 transmits data to a web server. The system is supported by stable power supply from the XL6009 module. Testing through the Node-RED platform, connected with an MQTT broker, demonstrates the tool's accuracy in measuring the intensity and distribution of light in accordance with safety standards.

Keywords: *Photometric, BH1750, Photodiode, Light Intensity, Node-RED..*

1. INTRODUCTION

The Airfield Lighting System is a crucial element in ensuring operational flight safety, especially during adverse weather conditions or at night. A critical component of this system is the runway edge lights, which provide visual guidance to pilots as aircraft approach the runway for landing or takeoff. The quality of the illumination produced by these lights must meet international standards to ensure adequate visibility for pilots under all conditions. However, a major challenge in maintaining this system is ensuring that the lights remain in optimal condition, both in terms of light intensity and beam direction (Standards et al., 2004).

In practice, the maintenance of runway edge lights is currently limited to replacing non-functional or burnt-out lights. Meanwhile, performance degradation due to changes in light intensity or beam direction often goes undetected until it affects flight safety. This gap creates potential risks that could be avoided with a tool capable of routinely inspecting and ensuring the quality of illumination provided by the runway edge lights.

To address this issue, this research aims to develop a photometric prototype that accurately measures the light intensity and beam angle of runway edge lights. The prototype utilizes the BH1750 sensor, known for its high sensitivity to light, to measure intensity, while a photodiode sensor detects the light beam angle. The data generated by these sensors is processed and transmitted using the ESP8266 module, enabling real-time data transmission to a server.

Additionally, the photometric tool is designed to be mounted on a robot that can be controlled via an Android application using the JDY-40 module. The use of the robot provides greater flexibility in measurement, as it can be positioned at various distances from the light to obtain more comprehensive data. The Android application also facilitates operator control of the robot’s movement and real-time monitoring of measurement results.

The tool is tested to ensure accuracy in measuring light intensity and beam angle of the runway edge lights. The results of these tests are expected to provide a clearer picture of the condition of the lights, including any degradation in quality over time. With more accurate data, maintenance actions can be carried out more effectively and promptly, thus enhancing flight safety.

Overall, this research not only contributes to the development of airfield lighting system monitoring technology but also offers practical solutions for improved maintenance. The tool is expected to assist airport authorities in ensuring that each runway edge light remains in optimal condition, in accordance with established flight safety standards. Further research could focus on refining the tool by adding additional features to enhance its performance and expanding its measurement capabilities.

2. METHODS

Research Design

The research and development method is used to produce a prototype that can accurately measure the light emission and intensity of AFL. This process involves several stages, including problem identification, planning and design, as well as data analysis and conclusion. Each stage is designed to ensure that the developed prototype is effective and reliable in measuring both light intensity and light distribution of AFL on the runway. Below is the design plan for the tool using a block diagram:

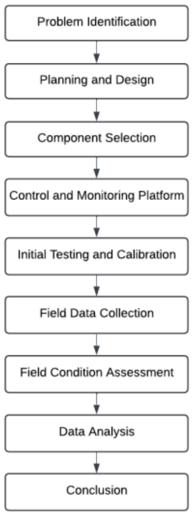

Figure 1. Research Design

Tool Design

In this tool's design, the miniEVB serves as the core microcontroller, orchestrating the operation and data management for the AFL lighting system. The system measures the AFL light's intensity and beam spread using a photodiode and a BH1750 sensor. Data collected from these sensors is transmitted via the ESP8266 module to a web server, enabling real-time monitoring by technicians. Concurrently, the JDY-40 wireless module facilitates control through an Android application, allowing for remote operation and live data viewing. Power is supplied by a 12V source regulated by a 3S Battery Management System (BMS) that manages six 18650 batteries, with the XL6009 module stepping down the voltage to 5VDC to power the servo motors. This comprehensive setup ensures precise, continuous measurement of the AFL lights, seamless real-time monitoring through the web, and efficient remote control via the Android app, thereby enhancing both operational efficiency and safety.

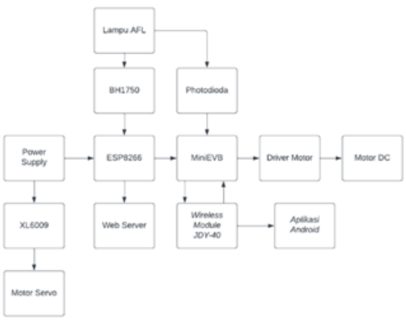

Figure 2. Block diagram of tool design

Testing Technique

To evaluate whether the designed tool functions correctly, it is necessary to conduct specific tests. The testing method used in this research is direct testing to examine particular functions of the tool

Light Intensity Sensor Testing: This test aims to ensure that the BH1750 module provides accurate data compared to a Lux Meter. Testing Procedure:

1. Prepare the required tools and materials
2. Turn on the Light Sensor and Lux Meter.
3. Expose both to the light source..
4. Record the results comparing the Lux Meter with the BH1750.
5. If there is a significant difference, recalibrate the BH1750 sensor
6. Once the readings from the BH1750 approach or match those of the Lux Meter, compare the results with the data displayed on the web server.

Light Emission Module Testing: This test evaluates the photodiode's ability to detect light emission and identify any errors or deviations in the light beam of the AFL lamp. Testing Procedure:

1. Prepare the necessary tools and materials.
2. Turn on the AFL lamp to be tested..
3. Position the sensor at various distances from the lamp, e.g., 100 cm, 50 cm.
4. Check if the sensor can still detect light at distances greater than 100 cm if needed.
5. Rotate the AFL lamp horizontally to ensure the sensor can detect light not directly in the center.
6. The third test, cover the LED light with plastic or paper to reduce the intensity of the Light.
7. Record the deviation results, such as if the lamp is tilted to the right by 3°.

Robot Testing: This test ensures that the robot operates correctly when commanded by the Android application to move forward. Testing Procedure:.

1. Prepare the required tools and materials.
2. Connect the robot to the Android application.
3. Test the controller to verify if the robot moves according to the provided commands.

Data Analysis Technique

From the previously described problems, a data analysis technique will be made to analyze whether or not the performance is good, then data analysis can be carried out according to the system through performance & data issued by the factory. The data analysis activities used are as follows:

1. Ensure that the components being applied are functioning properly and operating normally.
2. Compare the readings from the sensors with those from other measurement devices, such as lux meters.

3. Analyze the data collected from the web server and the Android application to verify that real-time monitoring and control are accurately reflecting the system’s performance and providing actionable insights.

This approach ensures a comprehensive evaluation of both hardware functionality and data accuracy, leading to a better understanding of the system's effectiveness and reliability.

3. RESULTS AND DISCUSSION

Light Intensity Testing Data

Here is a table showing the results of the Light Intensity Testing on 4 Runway Edge Lights**:**

Table 1. Light Intensity Measurement for Runway Edge Light 1

Distance from Light	Lux Meter	Robot
30 cm	1722 lx	1806 lx
50 cm	1441 lx	1514 lx
70 cm	1057 lx	1109 lx
100 cm	459 lx	481,4 lx
150 cm	276 lx	289,1 lx
200 cm	214 lx	212,5 lx
250 cm	111,4 lx	114,53 lx

Table 2. Light Intensity Measurement for Runway Edge Light 2

Distance from Light	Lux Meter	Robot
30 cm	1848 lx	1942 lx
50 cm	1528 lx	1678 lx
70 cm	1157 lx	1224 lx
100 cm	552 lx	587 lx
150 cm	351 lx	376 lx
200 cm	265 lx	301 lx
250 cm	131 lx	135 lx

Table 3. Light Intensity Measurement for Runway Edge Light 3

Distance from Light	Lux Meter	Robot
30 cm	1710 lx	1734 lx
50 cm	1430 lx	9.929 lx
70 cm	1047 lx	4.405 lx
100 cm	451 lx	2.623 lx
150 cm	271 lx	1.883 lx
200 cm	210 lx	1.261 lx
250 cm	109,7 lx	112,71 lx

Table 4. Light Intensity Measurement for Runway Edge Light 4

Distance from Light	Lux Meter	Robot
30 cm	1735 lx	1779 lx
50 cm	1450 lx	1514 lx
70 cm	1063 lx	1076 lx
100 cm	466 lx	471,7 lx
150 cm	280 lx	293,4 lx
200 cm	219 lx	221,9 lx
250 cm	112,9 lx	110,41 lx

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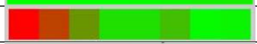
In this study, the evaluation of four Runway Edge Lights demonstrated that the developed prototype achieves a high level of accuracy in measuring light intensity. The results of the comparison between the BH1750 sensor readings on the robot and those from a lux meter showed a minimal difference of only 1-2 percent. This close agreement indicates that the prototype is highly reliable and capable of providing light intensity measurements that are consistent with those obtained from standard measurement tools.

The slight discrepancy between the BH1750 sensor and the lux meter underscores the effectiveness of the prototype in delivering accurate and dependable data. This precision is crucial for monitoring the performance of runway edge lights, as it ensures that any deviations from the expected light intensity can be detected and addressed promptly. By providing accurate measurements, the prototype plays a vital role in maintaining optimal lighting conditions, thereby contributing to enhanced safety for flight operations.

Light Beam Angle Testing Data

Table 5. Light Beam Spread Testing

Distance from Light	Horizontal Tilt Angle	Lux Meter	Robot	Beam Spread
100 cm	3°	314 lx	298,9 lx	
50 cm	3°	1023 lx	1054 lx	
30 cm	3°	1695 lx	1711 lx	
100 cm	5°	128 lx	109 lx	
50 cm	5°	709 lx	715 lx	
30 cm	5°	1375 lx	1411 lx	

Testing the Light Beam Angle using the photodiode sensor provided noteworthy insights into the performance of the Runway Edge Lights. When the light was tilted horizontally at a 3-degree angle, the sensor successfully detected the light beam up to a distance of 100 cm. This indicates that at a minor tilt, the light distribution remains adequately detectable. However, when the tilt angle was increased to 5 degrees, the sensor's detection range decreased significantly, with the beam only being detectable at a distance of 50 cm. This reduction highlights how the angle of tilt can dramatically impact the effective range of light detection.

These results underscore the importance of the tilt angle in the light distribution of Runway Edge Lights. A greater tilt can significantly reduce the distance over which the light is detectable, potentially affecting the visibility and safety of the runway lighting. The findings are supported by academic literature on light intensity and beam angle measurements, which validates that the photometric tool developed is not only effective but also provides precise and reliable measurements. This effectiveness in accurately measuring light intensity and beam spread reinforces the tool's value in assessing whether the runway lights comply with the required aviation safety standards.

4. CONCLUSION

From the whole research trial, it can be concluded as follows:

1. Measurement Accuracy: The photometric prototype developed for this research has shown exceptional accuracy in measuring the light intensity of Runway Edge Lights. The results indicate a high level of precision, with the BH1750 sensor's readings closely matching those from a standard lux meter, differing by only 1-2 percent. This minimal discrepancy underscores the reliability of the BH1750 sensor in delivering accurate light intensity measurements, confirming the prototype’s effectiveness in assessing lighting conditions.
2. Light Beam Angle Detection: The evaluation of light beam angles highlighted the significant impact of the tilt angle on the detection range of the photodiode sensor. It was observed that a greater tilt angle of the Runway Edge Light leads to a shorter detection distance. This finding emphasizes the importance of carefully considering the beam angle to maintain optimal light distribution and ensure aviation safety. Proper alignment and angle adjustments are crucial for compliance with safety standards.
3. Simple Interface: The design of the Android application and the web server interface, supported by Node-RED, was intentionally made simple and intuitive. The user interface is designed to be clear and accessible, facilitating ease of monitoring and controlling the system. This straightforward approach minimizes the learning curve for users, ensuring that they can efficiently interact with the system without unnecessary complexity. The simplicity of the interface enhances user experience and operational effectiveness.
4. **Easy Robot Control**: The prototype provides a seamless control experience for the robot through the Android application. The app’s interface is both intuitive and responsive, allowing users to manage the robot effortlessly. With straightforward control features and quick accessibility, users can operate the robot effectively without encountering operational difficulties. This ease of control contributes to a more efficient and user-friendly system
5. System Robustness and Future Improvements: The prototype has demonstrated robust performance in real-world conditions, validating its practical applicability. However, there are opportunities for further enhancements. Future improvements could include expanding the system's capabilities to accommodate more complex light measurement scenarios, integrating advanced features for automated calibration, and enhancing data analysis tools. These advancements would further solidify the prototype’s role in maintaining high safety standards for runway lighting systems and contribute to ongoing improvements in aviation safety technology.

5. SUGGESTION

To refine and enhance the functionality and performance of the tool, the following recommendations are proposed:

1. Integration of LoRa Module: Consider incorporating a LoRa (Long Range) module, such as the LoRa SX1278, to extend the range of data communication. LoRa technology provides long-range connectivity with low power consumption, making it ideal for transmitting data over greater distances. This integration would improve the system's ability to transmit data from remote or hard-to-reach locations, enhancing the overall effectiveness of the monitoring and control system.
2. Addition of Camera for Light Detection: Integrate a camera module, such as a Raspberry Pi camera or an Arduino-based camera, to enable the detection of lights in front of the tool. The inclusion of a camera would allow for the identification of light sources and provide a visual map of light distribution. This enhancement could improve the accuracy of light detection and provide valuable visual data to complement the sensor measurements.
3. Implementation of Polar/Isocandela Diagram: To gain a better understanding and visualize the results of light intensity measurements, incorporating polar or isocandela diagrams is recommended. These diagrams graphically represent light intensity distribution from the source, mapping how light spreads over different angles and distances. By visualizing the data in this manner, it becomes easier to analyze and interpret the distribution patterns of light, providing more comprehensive insights into the performance of the lighting system.

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