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Data-centric Smart Street Light Monitoring and Visualization Platform for Campus Management

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Abstract

Smart lighting systems have become increasingly popular in several public sectors because of trends toward urbanization and intelligent technologies. In this study, we designed and implemented a web application platform to explore and monitor data acquired from lighting devices at Thammasat University (Rangsit Campus, Thailand). The platform provides a convenient interface for administrative and operative staff to monitor, control, and collect data from sensors installed on campus in real time for creating geographically specific big data. Platform development focuses on both back- and front-end applications to allow a seamless process for recording and displaying data from interconnected devices. Responsible persons can interact with devices and acquire data effortlessly, minimizing workforce and human error. The collected data were analyzed using an exploratory data analysis process. Missing data behavior caused by system outages was also investigated.

Index Terms: Big Data Platform, Exploratory Data Analysis, Internet of Things (IoT), Light, Smart City

I. INTRODUCTION

Currently, there is a growing trend of people relocating to densely populated areas worldwide. By 2050, more than 60% of the population is anticipated to relocate to these areas [1]. Smart city concepts have emerged as solutions to promote quality of life in all aspects and to develop the socio-economy. Sensors and other interconnected devices, the so-called Internet of things (IoT), are essential in creating a conceptual environment [2,3]. According to Giffinger *et al*. [4], a smart environment, mobility, people, living, economy, and governance are six aspects of a smart city. In this study, a smart environment was considered. The smart street lighting system was implemented in a geographically specific location. We studied previous smart street lighting projects in various global locations. For example, the Amsterdam smart city (ASC) implemented smart street lights that can be adjusted using the ambient environment, which considers parameters related to weather and pedestrians. Optimizing energy usage and reducing the carbon footprint are the main goals [5]. Barcelona's smart street lighting system uses light-emitting diode (LED) devices to save energy and reduce costs [6]. Moreover, improvements in the quality of life, reduced crime rates, and enhanced public safety are potential advantages of efficient smart street lighting systems [7].

In our intelligent conceptual system for street lighting, the ability to manage and visualize data is critical for ensuring

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success. The establishment of the system requires the maintenance and monitoring of devices installed and controlled within the area. For example, the Barcelona project implemented an application programming interface (API), which enables communication between external platforms, such as a traffic data platform, and the proposed system to allow prompt data transfers [8]. Additionally, other environmental or meteorological data can be acquired using sensors to gain knowledge about a city and create intelligent systems [9]. A similar smart street lighting system located geographically near Thailand was also used in Singapore. The Land Transport Authority of Singapore installed and managed the LED street lighting devices. The project optimized energy consumption and maintenance [20]. They introduced a remote-control and monitoring system (RCMS) that depends on weather-related parameters [21].

Strong public and private sector collaborations are required to build sustainable smart cities [10]. Accordingly, we implemented a smart street lighting and environmental system as part of our smart city project at Thammasat University, Rangsit Campus in Thailand. The campus is situated in Pathum Thani, in Bangkok metropolitan region, as shown in Fig. 1. On the campus, 167 smart lights were installed. The pole-to-pole separation of the smart lighting devices was set to 20 m to comply with the Thailand's standard regulations and security requirements regarding street lighting. Smart streetlight devices can adjust the dimming LED up to a power consumption of 120 W. Efficient dimming can be achieved to compensate for natural illumination levels in the evening, night, and early morning. Our on-campus system assists vehicles and pedestrians. Reliable management and maintenance are necessary for proper functionality. Therefore, we developed a platform for administrators to monitor and control these devices. Each device's recorded data can be visualized and stored in a suitable database for analysis, introducing a data-centric scheme under the umbrella of a smart city. Exploratory data analysis was implemented to provide a deeper understanding of the data characteristics. These include correlation and regression analysis, and the study of problematic issues caused by missing values in a dataset. In the future, reasonable data analysis techniques can be used to obtain practically valuable conclusions using inferences from the data.

In summary, the proposed system improves data collection and monitoring. Further implementation can be facilitated more accurately using visualization and exploratory data analysis. For example, an automated light-adjusting system can optimize the illuminance and energy consumption in an area. This system and the intelligent campus concept advance the sustainable development of Thammasat University by driving toward optimal campus management solutions.

Fig. 1. Satellite map of Thammasat University, Rangsit Campus, Thailand; latitude/longitude location: 14°04'27"N 100°36'08"E. (Image from: Google Map)

II. INFRASTRUCTURE AND SYSTEM REQUIREMENTS

Smart street lighting and an environmental station consisting of sensors for measuring temperature (°C), relative humidity (%), wind velocity (m/s), wind direction (azimuth degrees), illuminance (lx), rain level (arbitrary), ultra violet A (W/m^2), ultra violet B (W/m^2), and air pressure (Pa) (MinebeaMitsumi, Inc., Japan) were installed at Thammasat University's Rangsit Campus in Thailand. A total of 167 dimmable LED lighting devices, each equipped with localized illuminance sensors and communication nodes, were installed on the campus area and connected to an external control system using three gateways. Six control zones were defined along the main road at the university to facilitate the management and control of these devices.

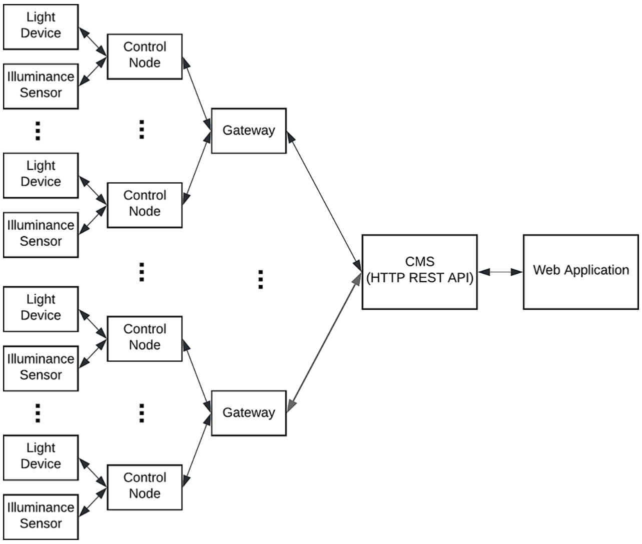


Fig. 2. Service disruption time measurement.

In the proposed system, dimmable smart lights are integrated with an external management platform, CMS Neptune - SC-v6.0.3 (Paradox Engineering, Switzerland), operated by the lighting product manufacturer. The representational state transfer (REST) was used to call the API on the hypertext transfer protocol (HTTP). The connection between the devices and the CMS API is shown in Fig. 2. The system's backend sends HTTP requests and receives responses using the REST API provided by the CMS. Additionally, it should be able to collect and visualize data and monitor the device status. The front end of the system is compatible with various operating systems because of its web application design. This promotes accessibility and uberization, as shown in Fig. 2.

III. BACK-END SYSTEM DEVELOPMENT

The back-end system development is fully explained in our previous conference paper titled "Smart Street Light Monitoring and Visualization Platform for Campus Management" [22], which was presented at the 17th International Joint Symposium on Artificial Intelligence and Natural Language Processing (iSAI-NLP) in Chiang Mai, Thailand. This study proposes an additional maintenance and logging system as follows: The backend system process is shown in Fig. 3.

A. Maintenance and Logging System

Owing to the current infrastructure on campus, electrical power failure may occasionally occur unpredictably. This causes risks of data loss in our database because communication must be performed between interconnected devices using gateways. Therefore, the back-end system can be improved by integrating the device disconnection detection API, where one or more devices are disconnected from the electrical grid, and responsible persons are acknowledged via notifications displayed on the user interface for maintenance. The detection system sends an HTTP request to the CMS API to listen for device disconnection events at a 10 min interval and records those events in the database. The ability to monitor and receive notification when devices fail to communicate with the network is important for maintaining a smart lighting system and enhancing the reliability of the data stored in the database. The detection system process is shown in Fig. 4.

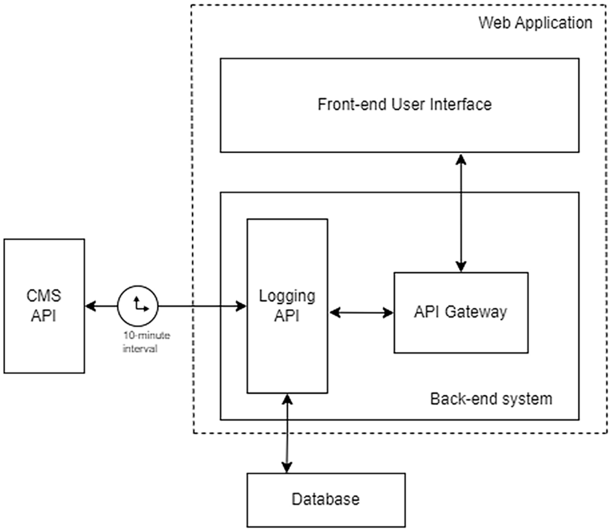


Fig. 4. The maintenance system process. The logging API will send an HTTP request to the CMS API on a 10 min interval basis. An HTTP response is sent back, containing the disconnection event if any. Later, those events are recorded in the database.

IV. FRONT-END USER APPLICATION DEVELOPMENT

A web application was designed to enhance the accessibility of cellular communication in the HTTP protocol using user experience [14-15]. The bootstrap CSS library was used to allow a responsive web design so that a full view could be shown on various screen sizes [16].

The data visualization dashboard was written in JavaScript using the Chart.js library [17]. The values were obtained from each sensor every 10 min. The measurements include temperature (°C), relative humidity (%), wind velocity (m/s), wind direction (azimuth degrees), illuminance (lx), rain level

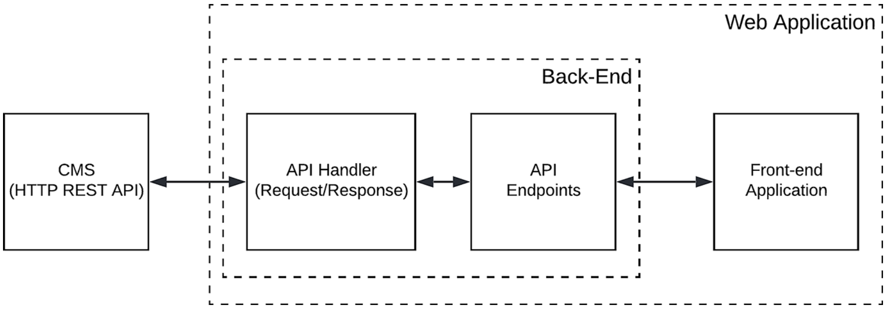
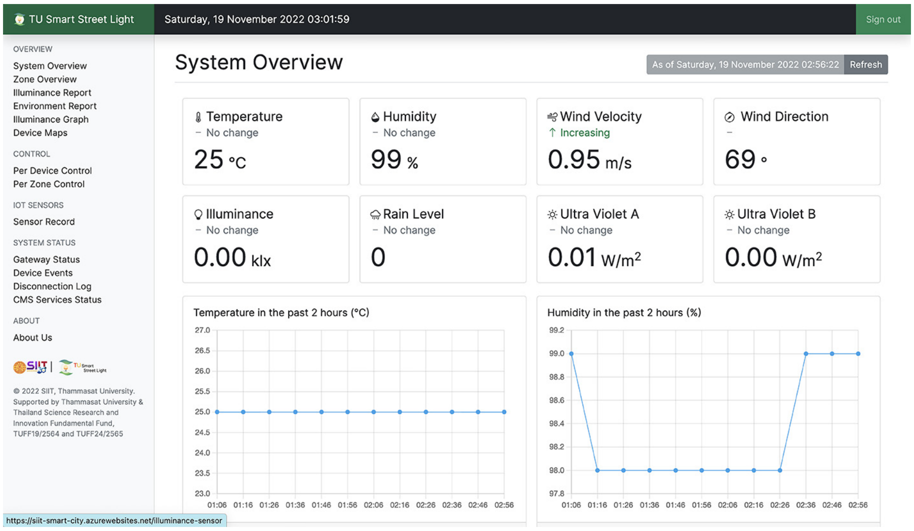


Fig. 3. An illustration of the connection of the CMS API, back-end part, and front-end part of the web application.



Saturday, 19 November 2022 03:01:59

System Overview

As of Saturday, 19 November 2022 02:56:22

Temperature – No change 25 °C

Humidity – No change 99 %

Wind Velocity ↑ Increasing 0.95 m/s

Wind Direction – 69 °

Illuminance – No change 0.00 klx

Rain Level – No change 0

Ultra Violet A – No change 0.01 W/m²

Ultra Violet B – No change 0.00 W/m²

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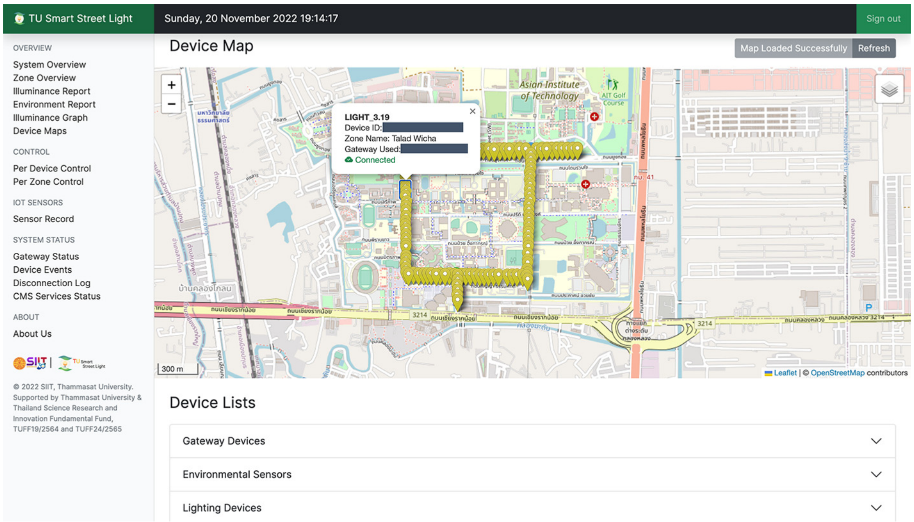
Fig. 5. The web application user interface, which shows the environmental values measured at the installed station.



Sunday, 20 November 2022 19:14:17

Device Map

LIGHT_3.19
Device ID: [redacted]
Zone Name: Talad Wicha
Gateway Used: [redacted]
Connected

Device Lists

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Fig. 6. Map showing the locations of 167 LED smart lighting devices.

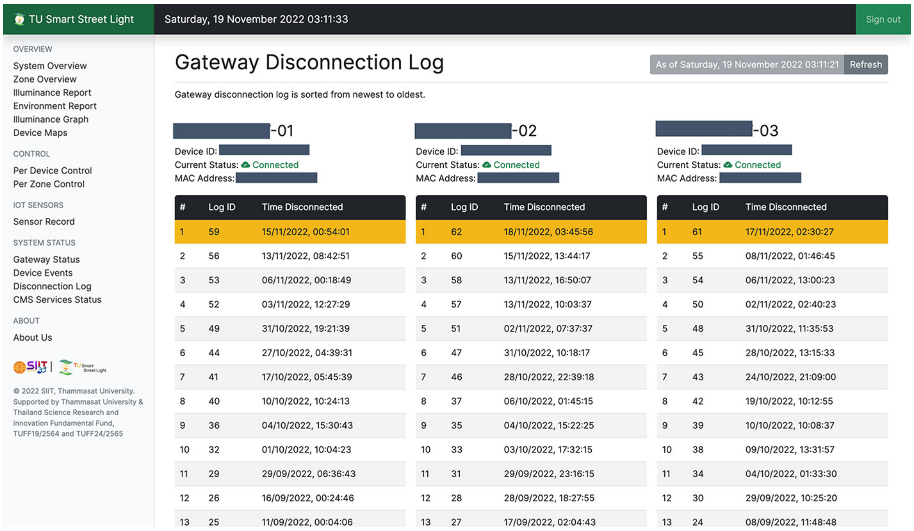
(arbitrary), ultraviolet A (W/m^2), and ultraviolet B (W/m^2). Fig. 5 shows a dashboard that displays the numerical values from the latest readings.

The line graphs show the past two-hour entries. As mentioned in Section III, the API endpoint was used to acquire all sensor values. The data were stored in the database, and monthly reports for all environmental sensors were produced in a comma-separated value (csv) format. Monthly datasets are available for download at https://siit-smart-city.azurewebsites.net/csv-download and are updated every 10 min. This provides time-series data for analyzing environmental data on campus.

The Leaflet.js JavaScript library was used to display an interactive map of 167 lighting devices and three gateways [18], enabling access to the precise locations and status information of each device (Fig. 6). Finally, the platform, which is a merger of Sections III and IV, was installed on the Microsoft Azure App Service, where Node.js applications are well supported [19]. A public URL was generated that allows the user to access and monitor smart streetlights and environmental sensors. The data can be stored for reference and used for further analysis.

A. User Interface for the Maintenance System

A detection system was implemented to handle device disconnection events. The user interface was made available to the maintenance staff to notify them of a system disconnec-



Saturday, 19 November 2022 03:11:33

Gateway Disconnection Log

As of Saturday, 19 November 2022 03:11:21

Gateway disconnection log is sorted from newest to oldest.

[redacted]-01

Device ID: [redacted]
Current Status: Connected
MAC Address: [redacted]

#	Log ID	Time Disconnected
1	59	15/11/2022, 00:54:01
2	56	13/11/2022, 08:42:51
3	53	06/11/2022, 00:18:49
4	52	03/11/2022, 12:27:29
5	49	31/10/2022, 19:21:39
6	44	27/10/2022, 04:39:31
7	41	17/10/2022, 05:45:39
8	40	10/10/2022, 10:24:13
9	36	04/10/2022, 15:30:43
10	32	01/10/2022, 10:04:23
11	29	29/09/2022, 06:36:43
12	26	16/09/2022, 00:24:46
13	25	11/09/2022, 00:04:06

[redacted]-02

Device ID: [redacted]
Current Status: Connected
MAC Address: [redacted]

#	Log ID	Time Disconnected
1	62	18/11/2022, 03:45:56
2	60	15/11/2022, 13:44:17
3	58	13/11/2022, 16:50:07
4	57	13/11/2022, 10:03:37
5	51	02/11/2022, 07:37:37
6	47	31/10/2022, 10:18:17
7	46	28/10/2022, 22:39:18
8	37	06/10/2022, 01:45:15
9	35	04/10/2022, 15:22:25
10	33	03/10/2022, 17:32:15
11	31	29/09/2022, 23:16:15
12	28	28/09/2022, 18:27:55
13	27	17/09/2022, 02:04:43

[redacted]-03

Device ID: [redacted]
Current Status: Connected
MAC Address: [redacted]

#	Log ID	Time Disconnected
1	61	17/11/2022, 02:30:27
2	55	08/11/2022, 01:46:45
3	54	06/11/2022, 13:00:23
4	50	02/11/2022, 02:40:23
5	48	31/10/2022, 11:35:53
6	45	28/10/2022, 13:15:33
7	43	24/10/2022, 21:09:00
8	42	19/10/2022, 10:12:55
9	39	10/10/2022, 10:08:37
10	38	09/10/2022, 13:31:57
11	34	04/10/2022, 01:33:30
12	30	29/09/2022, 10:25:20
13	24	08/09/2022, 11:48:48

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Fig. 7. User interface of historical gateway connection devices. The table shows the disconnection log for each gateway device along with other useful information such as device name and current connection status. The yellow highlighted rows show the most recent disconnection event.

tion event. The data shown on this interface were obtained from a database by logging into the API. In the case of the most critical devices, such as gateway devices, the historical disconnection log was also shown in a tabular form to inform the maintenance staff about previous events and perform their duties accordingly. Figure 7 shows the system's user interface.

V. DATA INFERENCE

The dataset was gathered from environmental sensors, and the values were stored in an external database, which can be called by an API. Environmental information ranged from February to November 2022. Artificial intelligence applications can be used to predict future environmental values. These datasets contain information on various environmental variables, including temperature, humidity, wind speed, and ultraviolet A and B indices. These variables can be used to build a predictive model that considers the relationships among environmental conditions. However, the illuminance value was the only parameter that we intended to analyze and pre-investigate. This dataset was preprocessed using Pandas, the most powerful Python package for data analysis, time-series analysis, and statistics. The main task of the exploratory data analysis process using the environmental database system is described in this section. In this section, we describe the data preparation, correlation assessment between parameters, exploratory data analysis of the dataset, and assessment of missing data.

A. Data Preparation

Raw illuminance value data were gathered as time-series data using date and time as indices. These raw indexes were acquired in the format of "yyyy-mm-dd hh:mm:ss", where the first set of data refers to the year, month, and day, and the latter set refers to the timestamp indexes of hour, minute, and second within the day. We collected responses from interconnected smart devices every 10 min. However, communication delays often occur while sending data. Therefore, the data were rounded to 10 min between adjacent records to correct them before performing further statistical analysis to make sense of the acquired dataset. There were six timestamps per hour, for a daily total of 144 timestamps.

B. Correlation Matrix

To explore the relationships among different environmental parameters collected from the sensors, we conducted a correlation matrix analysis. This analysis allowed us to determine the correlations between each pair of variables, their directions, and identify any significant relationships. Seven variables were studied: illuminance, temperature, wind velocity, air pressure, humidity, ultraviolet A index, and ultraviolet B index. The correlation coefficients ranged from −1 to 1. Correlation values close to 1 represent strong positive relationships, whereas those close to −1 represent strong negative relationships. A correlation close to zero denotes little or no correlation observed.

As shown in the correlation matrix in Fig. 8, our correla-

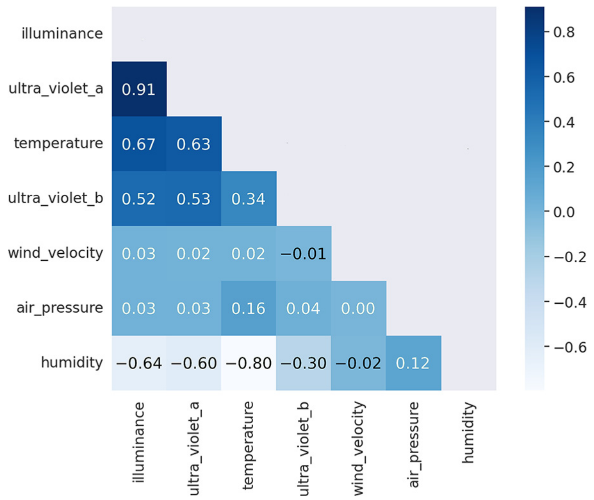

Fig. 8. Correlation matrix for assessing correlation between different parameters, i.e., illuminance, ultraviolet A, temperature, ultraviolet B, wind velocity, air pressure, and relative humidity, respectively.

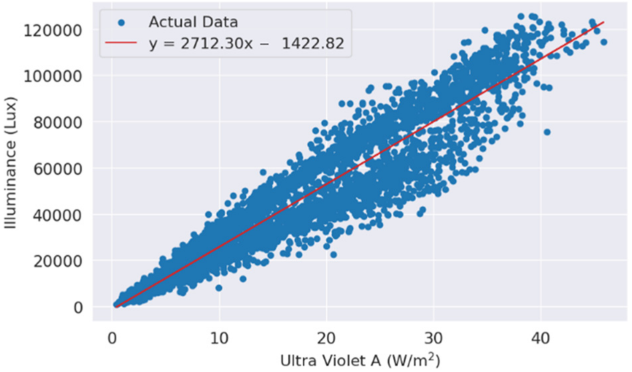

Fig. 9. Scatter plot of predicted against actual values, and a linear fitting illustrating the correlation between illuminance and Ultra Violet A.

tion analysis revealed several significant correlations between environmental variables. The strongest positive correlation was found between illuminance and the ultraviolet A index (r = 0.91), indicating that light information is strongly related. Additionally, we found a strong positive correlation between illuminance and temperature (r = 0.67), suggesting that higher illuminance levels are associated with higher temperature levels. Illuminance, ultraviolet A, and temperature are directly proportional. Relative humidity and temperature also have a high negative correlation (−0.80), indicating that they are inversely proportional. This is in agreement with the observation that the radiation components at midday consist of 95% ultraviolet A and 5% ultraviolet B [23]. We then consider the regression of ultraviolet A, as shown in Fig. 9.

Table 1. Linear regression model of the three most correlated variables to illuminance

Variable	Correlation coefficient (r)	Linear fitting of illuminance vs. variable	Standard deviation
Ultra Violet A	0.91	$y = 2712.30x - 1422.82$	9,442.33
Temperature	0.67	$y = 4603.43x - 100236.55$	27,596.01
Ultra Violet B	0.52	$y = 88012.85x + 6691.25$	11,931.14

C. Exploratory Data Analysis

Table 1 shows the top three variables that correlate with illuminance: ultraviolet A, temperature, and ultraviolet B. All standard deviation values are high compared with the target variables. This was also observed in the analysis of the residuals between the actual and predicted illuminances using a time-series model [24]. Ultraviolet A, the most correlated parameter, had the highest correlation with the illuminance profile. In Fig. 9, the actual and predicted values are plotted and fitted to a line graph, further illuminating the relationship between these two parameters. Illuminance increases significantly when ultraviolet A increases, which is consistent with the physical properties of visible light and radiation [23]. Contrary to the correlation coefficient, the results in Table 1 also show the standard deviation, which considers the difference between the actual and predicted illuminance values. These statistical values allowed us to observe the characteristics of the errors distributed in the predicted values, which is useful for further analysis.

D. Missing Data

Missing values in the dataset could occur if there is an issue with the data collection tools or if a weather station goes offline, as shown in Fig. 10. Data gaps lead to errors in the forecast and a lack of confidence in model accuracy. Missing values can also affect prediction tasks by introducing bias into the forecast, which can occur when certain features of the data are more likely to be missing than others. Therefore, it is important to minimize the impact of missing values as much as possible. Figure 11 shows the entire illuminance dataset as time-series data, where the x- and y-axes represent the time of day and date, respectively. Missing values in the series dataset can be easily observed using this type of illustration. The specific time window of this illustration ranges from midnight on 2022-02-05 to midnight on 2022-11-01.

VI. DISCUSSION

This study develops a web application to address the need

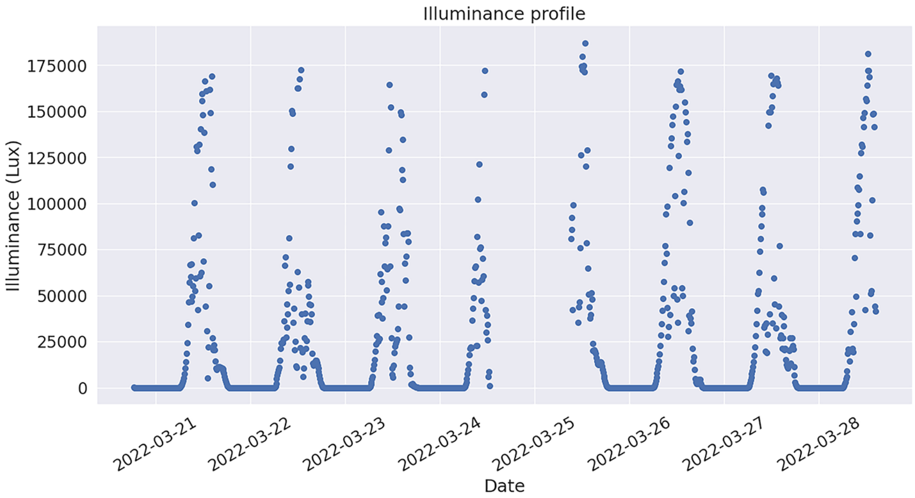

Fig. 10. Illuminance profile with some missing values introducing gaps in the time-series data.

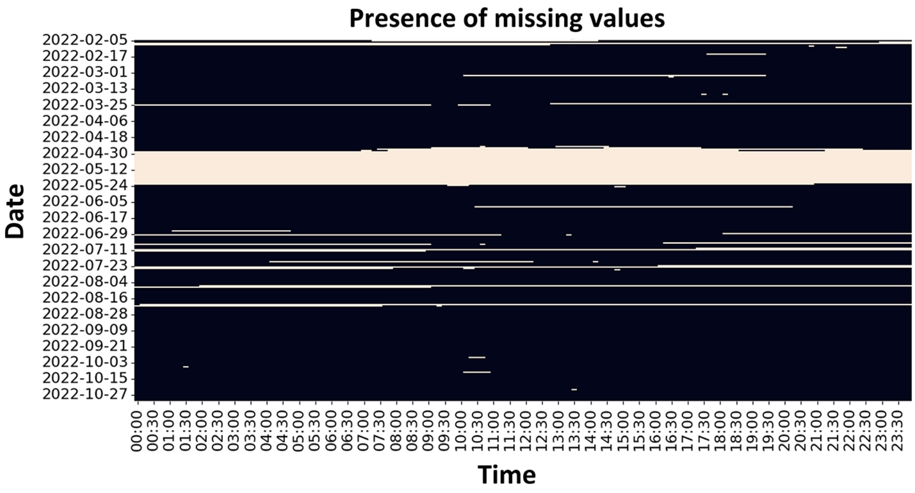

Fig. 11. Presence of missing values.

for data visualization and device monitoring at Thammasat University, Rangsit Campus, Thailand. The application offers a user-friendly interface that is easy to use for managing the system, enabling real-time data acquisition from environmental sensors and monitoring devices. The system measures light-related information, such as illuminance and ultraviolet A and B indices, and monitors other environmental parameters, including temperature and humidity. Our preliminary observations suggest that these environmental parameters correlate with lighting parameters, demonstrating the need for a system that facilitates further data analytics. To achieve this, we designed a system that minimizes the human effort required to collect these data and provides an easy-to-use interface for operational staff to manage streetlights. The proposed system also integrates a maintenance and logging system to monitor the disruptions caused by electrical blackouts and grid instability. However, data gaps remain a challenge and require proper statistical analysis, including missing data analysis and correlation assessment. These statistical processes help to identify and address inconsistencies in the data, allowing for more accurate predictions. Our research aims to investigate the potential of an intelligent platform for monitoring and visualizing smart street lighting devices in campus management. We found that illuminance, ultraviolet A, ultraviolet B, and temperature are directly proportional to solar radiation; hence, they were strongly correlated, as expected. Relative humidity and temperature also had a high negative correlation, suggesting that they are inversely proportional. This shows that once the temperature is high, the air is so dry that it can absorb more moisture before reaching saturation, causing low relative humidity. Conversely, when the temperature decreases, the relative humidity increases. These behaviors and the prediction of natural light levels can be observed, leading to the prediction of the necessary LED lighting levels at a particular timestamp, day, and season. Our primary objective was to reduce energy consumption and promote sustainability. To achieve this, we sought to develop a prediction model that facilitates the automatic adjustment of lighting systems on campus, providing a sophisticated solution for outdoor environments. The anticipated benefits of this endeavor are expected to be extended to both campus students and system administrators.

VII. CONCLUSION AND FUTURE WORK

This study developed a web application to monitor smart lighting devices at Thammasat University, Rangsit Campus, Thailand. The back-end of the application has a feature called the API endpoint, which can send data from an external platform to the front-end. The front-end application uses a responsive design with a bootstrap CSS framework. Additionally, the application provides a Leaflet.js map to display the device locations. It uses a Chart.js map to display the device locations, and a Chart.js to visualize the environmental sensor data. The web application is available on Microsoft Azure App Service and can be accessed through its public URL. The collected data were carefully analyzed using data inferences, particularly for missing data caused by system downtime. Future work could include data applications such as prediction models and further contribute to energy conservation and sustainability. Attempts to address the issue of missing or anomalous values, such as smoothing and statistical techniques may provide clues toward more precise predictions. Learning about current and future data is impossible without an efficient system for collecting, storing, and visualizing data, which together form a data-centric platform. To advance the infrastructure and ability for a more in-depth analysis, it is necessary to consider the interaction of the system with the camera and motion sensors, which provide other types of information related to the distributions of pedestrians and vehicles in ambient areas. This complex information will incur more costs on computational resources and robust algorithms to process but will allow more thorough insights with appropriate problem statements and subsequent data analysis to be determined.

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REFERENCES

[1] G. C. Delgado-Ramos, "Water and the political ecology of urban metabolism: the case of mexico city," *Journal of Political Ecology*, vol. 22, no. 1, pp. 98-114, Dec. 2015. DOI: 10.2458/v22i1.21080.

[2] T. M. Chen, "Smart grids, smart cities need better networks [editor's note]," *IEEE Network*, vol. 24, no. 2, pp. 2-3, Mar. 2010. DOI: 10.1109/MNET.2010.5430136.

[3] L. G. Cretu, "Smart cities Design using Event-driven Paradigm and Semantic Web," *Informatica Economica,* vol. 16, no. 4, pp. 57-67, 2012.

[4] R. Giffinger, C. Fertner, H. Kramar, and E. Meijers, "City-ranking of european medium-sized cities," *Centre Of Regional Science*, vol. 9, no.1, pp. 1-12 Jan. 2007.

[5] M. Somayya and R. Ramaswamy, "Amsterdam smart city (ASC): fishing village to sustainable city," in *WIT Transactions on Ecology and the Environment*, vol. 204, pp. 831-842, Jul. 2016. DOI: 10.2495/sc160681.

[6] Zigurat Global Institute of Technology, Barcelona smart city: Most remarkable example of implementation. Jul. 2021. [Online] Available: https://www.e-zigurat.com/blog/en/smart-city-barcelona-experience/.

[7] D. P. Farrington and B. C. Welsh, "Improved street light and crime prevention," *Justice Quarterly*, vol. 19, no. 2, pp. 313-342, Jun. 2002. DOI: 10.1080/07418820200095261.

[8] E. Pejstrup and J. Egenolf, "Integrated infrastructures factsheets," Nov. 2019. [Online] Available: https://grow-smarter.eu/fileadmin/editor-upload/Smart/Action_Area_2-compressed.pdf.

[9] M. L. George, "A concise review of fifteen intelligent street lighting systems which can pave the way for the emergence of smart cities in the Caribbean," *i-manager's Journal on Future Engineering and Technology*, vol. 15, no. 4, p. 28, Apr. 2020. DOI: 10.26634/jfet.15.4.17313.

[10] D. Das, "Smart city," *The Wiley Blackwell Encyclopedia of Urban and Regional Studies*, pp. 1-7, Apr. 2019. DOI: 10.1002/9781118568446.eurs0294.

[11] N. Chhetri, "A Comparative Analysis of Node.js (Server-Side JavaScript)," Master's thesis, St. Cloud State University, 2016.

[12] A. Mardan, "Using express.js to create node.js web apps," *Practical Node.js,* pp. 51-87, Nov. 2018. DOI: 10.1007/978-1-4842-3039-8_2.

[13] "Axios." 2022. [Online] Available: https://axios-http.com/.

[14] N. R. Dissanayake and K. A. Dias, "Web-based applications: Extending the general perspective of the service of web," in *10th International Research Conference of KDU (KDU-IRC 2017) on Changing Dynamics in the Global Environment: Challenges and Opportunities,* Rathmalana, Sri Lanka, 2017.

[15] F. Almeida and J. Monteiro, "The role of responsive design in web development," *Webology*, vol. 14, no. 2, pp. 48-65, Dec. 2017.

[16] "Get started with bootstrap." 2022. [Online] Available: https://getbootstrap.com/docs/5.2/getting-started/introduction/.

[17] H. Magnusson Millqvist and N. Bolin, "A comparison of performance and scalability of chart generation for Javascript data visualisation libraries: A comparative experiment in Chart.js, ApexCharts, Billboard,

and ToastUI," Bachelor's thesis, University of Skövde, 2022.
[18] V. Agafonkin, "Leaflet – an open-source Javascript library for interactive maps," 2022. [Online] Available: https://leafletjs.com/.
[19] V. P. Desai, K. S. Oza, P. P. Shinde, and P. G. Naik, "Microsoft azure: Cloud platform for application service deployment," *International Journal of Scientific Research in Multidisciplinary Studies*, vol. 7, no. 10, pp. 20-23, Oct. 2021.
[20] K. H. Bachanek, B. Tundys, T. Wiśniewski, E. Puzio, and A. Maroušková, "Intelligent street lighting in a smart city concepts — A direction to energy saving in cities: An overview and case study," *Energies*, vol. 14, no. 11, p. 3018, May 2021. DOI: 10.3390/en14113018.
[21] LEDinside. "Singapore aims to convert all roads to smart LED streetlighting systems by 2022." 2017. [Online] Available: https://www.ledinside.com/news/2017/1/singapore_aims_to_convert_all_roads_to_smart_led_streetlighting_systems_by_2022.
[22] S. Deepaisarn, P. Yiwsiw, C. Tantiwattanapaibul, S. Buaruk, and V. Sornlertlamvanich, "Smart street light monitoring and visualization platform for campus management," in *2022 17th International Joint Symposium on Artificial Intelligence and Natural Language Processing (iSAI-NLP)*, Chiang Mai, Thailand, pp. 1-5, 2022. DOI: 10.1109/iSAI-NLP56921.2022.9960257.
[23] S. Deepaisarn, P. Yiwsiw, S. Chaisawat, T. Lerttomolsakul, L. Cheewakriengkrai, C. Tantiwattanapaibul, S. Buaruk, and V. Sornlertlamvanich, "Automated street light adjustment system on campus with AI-assisted data analytics," *Sensors*, vol. 23, no. 4, p. 1853, Feb. 2023. DOI: 10.3390/s23041853.
[24] F. El Ghissassi, R. Baan, K. Straif, Y. Grosse, B. Secretan, V. Bouvard, L. Benbrahim-Tallaa, N. Guha, C. Freeman, L. Galichet, and V. Cogliano, "A review of human carcinogens—Part D: Radiation," *Lancet Oncol*, 2009, vol. 10, vo. 8, pp. 751-752, Aug. 2009. DOI: 10.1016/S1470-2045(09)70213-X.