BILINGUAL PUBLISHING CO.
Pioneer of Global Academics Since 1984

Journal of Electronic & Information Systems
https://ojs.bilpublishing.com/index.php/jeis

ARTICLE

Deploying a Deep Learning-based Application for an Efficient Thermal Energy Storage Air-Conditioning (TES-AC) System: Design Guidelines

Mirza Rayana Sanzana[1*] Mostafa Osama Mostafa Abdulrazic[2] Jing Ying Wong[1] Chun-Chieh Yip[3]

1. Department of Civil Engineering, Faculty of Science and Engineering, University of Nottingham Malaysia, Semenyih, Selangor, 43500, Malaysia
2. School of Computer Science, Faculty of Science and Engineering, University of Nottingham Malaysia, Semenyih, Selangor, 43500, Malaysia
3. Department of Civil Engineering, University Tunky Abdul Rahman, Bandar Sungai Long, Cheras, Kajang, Selangor, 43000, Malaysia

ARTICLE INFO

Article history
Received: 29 October 2021
Revised: 24 November 2022
Accepted: 13 December 2022
Published Online: 28 December 2022

Keywords:
Advanced application
Deep learning
Thermal-energy-storage
Air-Conditioner
Facility management and maintenance
Analysis
Design guidelines

ABSTRACT

Facility management and maintenance of the Thermal-Energy-Storage Air-Conditioning (TES-AC) system is a tedious task at a large scale mainly due to the charging load that can increase energy consumption if needed to be charged at peak hours. Besides, maintenance of TES-AC at a large scale gets complex as it contains many sensor data. By utilizing deep learning techniques on the sensor data, charging load prediction can be made possible, so facility managers can prepare in advance. However, a deep learning-based application will be unusable if it is not deployed in a user-friendly manner where facility managers can benefit from this application. Hence, this research focuses on gathering design guidelines for a deep learning-based application and further validates the design considerations with a developed application for efficient human-computer interaction through qualitative analysis. The approach taken to gather design guidelines demonstrated a positive correlation between expert-suggested features and the user-friendly aspect of the application as 67.08% of participants found the features suggested by experts to be most satisfactory. Furthermore, it evaluates user satisfaction with the advanced developed application for TES-AC according to the gathered design guidelines.

*Corresponding Author:
Mirza Rayana Sanzana,
Department of Civil Engineering, Faculty of Science and Engineering, University of Nottingham Malaysia, Semenyih, Selangor, 43500, Malaysia;
Email: sanzanarayana@gmail.com

DOI: https://doi.org/10.30564/jeis.v4i2.5211

1. Introduction

Global warming has become evident with rising temperatures, heat waves, and hurricanes being felt across the world more [1]. Mainly in tropical or subtropical areas, air-conditioning is considered a basic aspect of a building for warm weather conditions. Other than harmful Greenhouse Gas (GHG) emissions, buildings account for around one-fifth of global energy consumption due to the inefficiency of air-conditioning (AC) [2,3]. Some major corporations are shifting their focus to a more sustainable form of ac such as thermal storage air conditioning (TES-AC) systems instead of conventional AC units. By using TES-AC, the power consumption of a commercial building along with interrelated costs has been drastically reduced [4]. In a tropical country like Malaysia, Air Conditioners (ACs) have the most energy consumption in commercial buildings, and 68.5% savings can be achieved per year by using TES-AC [4]. A TES-AC simply works by transferring the charging time from on-peak to off-peak hours and storing the thermal energy to cool buildings for the next day thereby decreasing management costs as well as GHG emissions [5]. There are two types of chiller: air-cooled chiller and water-cooled chiller, and a Thermal-Energy-Storage (TES) water-cooled chiller is known to be more energy efficient [6]. Yet the companies are hesitant to incorporate TES-AC in commercial buildings as they are concerned about maintenance issues related to tanks not having an optimal volume of water to cool the building during working hours.

A water-cooled chiller has a lot of sensor data which is crucial for Facility Management and Maintenance (FMM) of the TES-AC system. FMM of a building is under the supervision of facility managers, and with the use of digital technologies, Industry 4.0 focuses on efficient building facility handling [7,8]. By applying deep learning techniques, such sensor data can be utilized for an efficient FMM as deep learning is essentially a subset of Machine Learning of Artificial Intelligence and is capable of identifying complex patterns in big data i.e., a large dataset with deep layers [9,10]. Adopting eco-friendly solutions like TES-AC with a proper maintenance system is important now more than ever to contribute positively to the environment. With deep learning, a smart predictive system to calculate the water volume needed to charge the tanks is possible for optimal water volume prediction for the next day's use considering the external factor of weather temperature [11,12]. Although deep learning has a significant role to play in benefiting facility managers mainly in predictive maintenance, the applications of deep learning can be explored further [13]. Predictive Maintenance is when facility managers use computational intelligence to predict a failure, downtime, or maintenance requirements before a failure happens or maintenance is required to lessen downtime and improve building efficiency. According to the study conducted by Sanzana et al. [14], Multilayer Perceptron, besides being one of the most common deep learning techniques has demonstrated satisfactory prediction for cooler conditions compared to other common Machine Learning algorithms. Thus, Multilayer Perceptron was preferred for applying deep learning techniques to the TES system to assist facility managers in managing the TES system and is intended to be deployed on the application developed in this study. However, such an advanced system based on deep learning such as Multilayer Perceptron, and Long-Short-Term-Memory, will not be useful to the facility managers if it is not deployed in a proper way for them to utilize it.

Hence, this paper researches the appropriate user-friendly design guidelines for a deep learning-based TES-AC application for efficient human-computer interaction through survey questionnaires for qualitative content analysis. Initially, experts were asked about their preferred features of an advanced FMM application for a water-cooled TES-AC system, and the application was developed accordingly. After that, engineering students were asked about their feedback on the Graphical User Interface (GUI) of the application. The paper aims to find the appropriate design guidelines for an advanced deep learning-based TES-AC application and then to analyze the user-satisfaction in consideration of the suggested guidelines.

2. Literature Review

Human-computer interaction is defined as a way a human interacts with a computer and is a crucial part of designing the GUI of applications. For human-computer interaction research, proper user engagement is a desirable effect and O'Brien et al. [15] suggest focusing on disengagement as a necessary human-computer interaction design. There are many challenges in designing graphical user interfaces due to the lack of availability of guidance and targeted experience [16]. Various graphical objects, such as cursors, and rendered objects are analyzed in user interaction [17]. In advanced applications where there is complex computational intelligence deployed, it becomes even more of a necessity to gather design guidelines so non-experts can benefit from it. Chaudhari et al. [18] focus on finding key characteristics of advanced applications for design considerations guidance.

However, in many cases, applications are developed without consulting the target audience which makes the

application cumbersome and not targeted towards the actual needs but solely based on the developer's intuition. Stephanidis [19] thoroughly discusses the appropriate methods to undergo for developing a computational environment that caters to the preferences, usability, and skills of non-experts as well so an advanced application can be used by the widest user base. Before an advanced application is developed for a specific use, experts can share valuable information such as pointing out which features they would want. This allows for sound development including the necessary features. When there is big sensor data involved, and when deep learning requires high Graphical Processing Units (GPUs), the application needs to be well-planned and useful for the target audience [9]. Martin-Rodilla et al. [20] mentioned how suitable interaction techniques are required to understand large data-dependent systems and discuss the challenges faced between human-computer interaction and data analysis applications. Using deep learning techniques, this study suggests improving the usability of the graphical user interface as compared to the manual process of fruit and vegetable identification with Internet-of-Things (IoT) [21].

Before an application is deployed, it is better to test the user-friendly aspect of the application. It is important to note the way the target audience manages to interact with the application's GUI. A way to test the necessary features is through a survey-based approach as it allows the consumers to outline the desired features through this and this is the reason this research adopted a survey-based approach [22]. The GUI involves how the application looks, and whether the features in the application manage to execute its actual purpose. It is required to have a methodology that will not let the users be overwhelmed when they are interacting with the GUI and the methodologist can implement new computational methods which will be already integrated into the GUI for ease of use [23]. It is also important to note if the ambiance, background, fonts, and navigation are not causing any visual disturbance to the users. A dark interface for an application is preferred as it causes less strain on the eyes mainly when it is used for a long. Recently, there has been an increase in the dark user interface trend to reduce ocular diseases of people in continuous use of digital devices [24]. Yang et al. [25] suggest a natural user interface to lessen the cognitive load. This study mentions the importance of having a user-friendly environment to run deep learning models [26]. Underlying human factors are reviewed by Leung et al. [27] to understand how targeted users may interact with the research area of highlighting techniques. The way users perceive an application is an important evaluation before an application is deployed.

3. Materials and Methods

This section will describe the research design adopted for this study in brief and will discuss how the study was conducted. The participants of the study including the questionnaire will be also discussed along with a summarized overview of the application.

3.1 Research Design and Methods

The methodology taken by this research can be viewed in the research framework in Figure 1. There were two different groups of participants, where the initial group consisted of experts in the construction industry, and the latter group involved University students who are pursuing Engineering degrees. Qualitative content analysis is carried out initially by 15 experts to understand the features that will be useful regarding the deep learning-based TES-AC application. After the application is structured based on the suggested features according to the analysis, further analysis is carried out to evaluate the user satisfaction, usability, and interactivity of the application by 35 participants. The participants got a demonstration of the application, and all information they received was in the English Language. No personal information was collected from the participants, and they all were informed about the reasons for the study being conducted before they took part in it. The study had minimal risk and all the participants were adults i.e., 18 years and older. The study was verified to be conducted by the institutional ethics committee.

The following questions were asked in the survey questionnaire for the experts as shown in Table 1. The questions were in Multiple-Choice-Question (MCQ) format in Google Forms for their availability. The MCQ format was chosen so the experts can point out what they prefer within options instead of completely giving them a blank canvas. These questions helped to understand the desirable features and outlook of the application such as whether they want a horizontal or vertical navigation bar. There were also questions to understand whether the experts will find it useful if deep learning is deployed in the predictive maintenance of FMM. Then they were also asked how they would like to view predictions for charging load, statistics related to efficiency, and whether they wanted a "Tips" tab. The experts were also asked regarding the Import feature to upload the sensor data related to TES-AC for charging load prediction and the Export feature to retrieve all the information from the application in a PDF file to view the information.

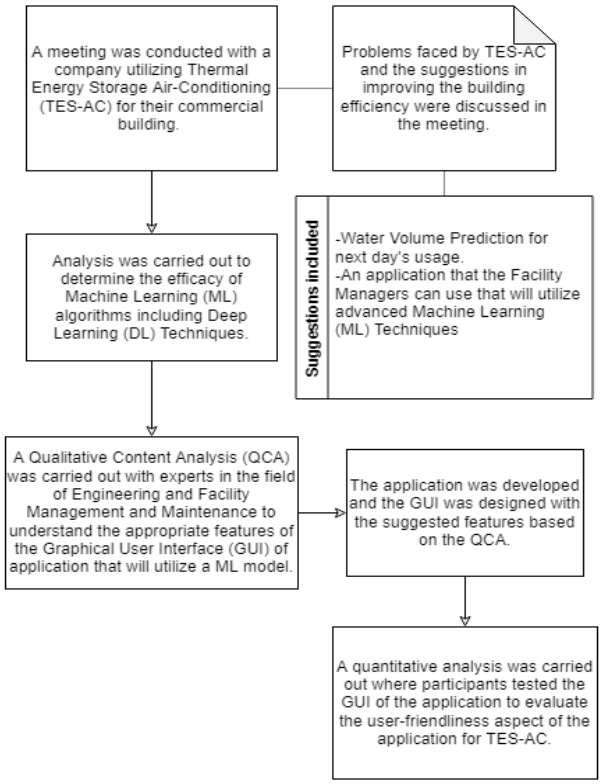

Figure 1. Research Methodology Framework

The following questions as shown in Table 2 were asked to measure the user-interaction aspect of the application to the participants who were pursuing engineering since they might choose to become facility managers. The questions were on a linear scale where 1 denoted least satisfaction and 5 denoted most satisfaction and were available on Google Forms. The questions were designed to understand how they like the overall look of the application, and whether they find a feature easy to use.

3.2 Application Overview

The application has been designed in an untraditional way to make it easier to use and to keep it more interesting. While most maintenance applications would have a very simple design that does not pay attention to details and just places controls and information in front of the user, this application design focused on making an impactful design. The user interface is very easy to use with buttons and text being very clear. The whole application is designed using a science fiction-like theme which makes it more appealing to younger audiences who are most likely to be using this application. It reflects a futuristic design to uplift the mood of the user and relies on visuals and graphics to keep it interesting to look at and boost creativity.

Table 1. Survey questionnaire to understand opinion of experts

No.	Question description
Q1	Do you suggest a Login feature for the application so not just anybody gets to view your information?
Q2	For the overall outlook of the application, which option do you suggest will help you to concentrate on your daily activities?
Q3	A navigation bar for the application will allow you to switch to different windows within the application. For the application, do you suggest a horizontal navigation bar or a vertical one?
Q4	This application will be based on a deep learning model for water prediction of Thermal Energy Storage Air-Conditioning (TES AC). Knowing the volume of water needed for the demand of the next day helps improve the building efficiency. Do you believe it will help the facility managers to know the water prediction for the tank?
Q5	Would you want to view the deep learning model-based water volume prediction in a graphical form or just a numerical value?
Q6	A tasking feature will allow you to add tasks and show the completed ones. For better management of TES-AC related tasks, would you suggest the application to have an in-built tasking feature?
Q7	The main reason of water volume prediction is to optimize the energy efficiency of the building. Besides the water volume prediction of the chiller plant, do you also want to view the energy efficiency of your building?
Q8	Do you think displaying the current weather temperature inside the application is useful?
Q9	A lack of interest in upgrading in utilizing deep learning methods are mainly related to many models requiring constant real-time input of sensor data that have specific requirements. Do you suggest that more enterprises will be interested to utilize such advanced deep learning methods if they do not require to change their equipment?
Q10	Would you suggest the application to have an import feature so the .csv dataset files can be used to predict the water volume?
Q11	Do you suggest letting the Facility Managers control the settings for the overall outlook of the application to have a customization aspect?
Q12	Do you think it will be useful to also have an export feature to export the charts and information to a .pdf file for viewing?
Q13	In this TES-AC application, do you think adding a “Tips” tab with helpful information regarding maintenance, or using the application or what certain values depict will make the app better?

Table 2. Survey questionnaire to evaluate the user-interaction of the application

No.	Question description
Q1	Do you like the ambience of the application?
Q2	Do you find the login feature to access the application to be complicated?
Q3	Do you find the overall controls of the application, such as navigating, easy-to-use?
Q4	Do you find the form of water volume prediction easy to understand by looking at the application's graphical output?
Q5	Do you find the efficiency graphical output to be useful?
Q6	Do you like the customization aspect of the application to control the general settings?
Q7	Do you find changing the control settings of the application easy-to-use?
Q8	Do you find the tasking feature easy-to-use?
Q9	Do you think the "Tips" tab is useful for the users?
Q10	Do you think displaying the current weather temperature is useful?
Q11	Do you think the "Import/Export" tab is a necessary feature for the application?

As seen in Figure 2 (top), the design of the application relies on a simple but informative interface. The user can easily access the most crucial information and it is easy to navigate the rest of the application. Proper graphics and visuals are used to convey the meaning of the information without the user having to look through manuals to understand what each component of the interface stands for. Figure 2 (bottom) shows how statistics are displayed in the application, using simple graphics that look better than traditional charts but also provide very rich information. A top navigation bar makes it easy to access the different main components of the application while the bottom bar displays information like the time, date, and weather information.

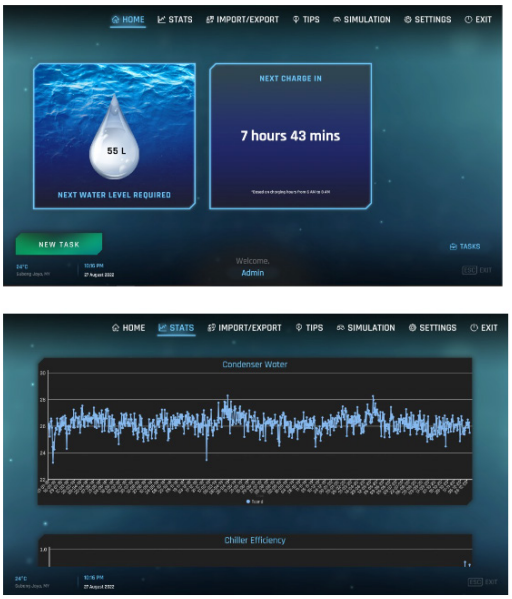

Figure 2. Application snippets

4. Results

According to the QCA, for a user-friendly GUI, the features to include based on experts in the field in the application are displayed in Figure 3. The experts were asked to fill up a survey to understand their desirable features in a deep learning-based facility management application. The participants for the application feature evaluation involved experts aged from 34-60 years (average age 51.8 years), and 14 were males and 1 female. Among 15 experts, 9 were facility managers, 5 were from Civil Engineering and 1 was from Architectural Engineering.

Out of the participants, 86.67% of participants suggested a login feature, 53.33% suggested a futuristic sci-fi background whereas 26.67% wanted a dark background. A total of 73.33% of expert participants wanted a horizontal navigation bar. However, all participants mentioned knowing the charging load required will be useful, and 66.67% wanted to view the information in a graphical form and suggested including a tasking feature. 86.67% of participants also mentioned that viewing energy efficiency statistics will be useful, and 60% of participants said that displaying weather data within the application will be beneficial. When asked if more enterprises will be interested in utilizing advanced technologies such as deep learning if they do not require changing or upgrading their equipment, no participants said no, and 86.67% said that more enterprises will be interested. All the participants wanted an import .csv file feature. 86.67% of participants mentioned that customization of the application would be interesting. Regarding exporting the information displayed

in the application in a pdf file, 86.67% of participants suggested it whereas 13.33% said maybe it will be useful. 80% of participants mentioned including a "Tips" tab as it will be useful for staff.

Among the participants who evaluated the developed application, they were mostly of Civil Engineering background i.e., 20 (68.57%), 5 participants were from Mechanical Engineering background, and 4 participants were from Electrical Engineering background. The age range of participants was between 19-32 years with an average age of 24.66 years. The participants were selected to be young individuals as they will be going for jobs and will handle the chores. Hence their feedback regarding the application interaction was important. As mentioned earlier, the survey was based on a linear scale of 1-5 where 5 exhibited the most satisfaction, and 1 exhibited the least satisfaction. The graphical form of the feedback is shown in Figure 3.

Out of the participants, 19 participants i.e., 54.29% showed the most satisfaction, i.e., scale 5 regarding the ambiance of the application, and 12 participants i.e., 34.29% chose scale 4. Regarding the login feature, no participants found it complicated and found the application controls easy to use. 33 participants i.e., 94.29% chose scale 5 as they found the water volume prediction easy to understand. A total of 29 participants i.e., 82.86% found the graphical efficiency output to be useful, and 30 participants (85.71%) liked the customization aspect of the application. Out of the 35 participants, 25 participants (71.42%) chose scale 5 for changing the controls of the application, and 27 participants (77.14%) found the tasking feature easy to use. Regarding the display of tips for facility management of TES-AC, 19 participants i.e., 54.29% chose a scale of 5. A total of 22 participants which is 62.86% found the displaying of current weather information within the application to be useful. However, 17 participants (48.57%) found the Import/Export feature to be a necessity for the application as they chose a scale of 5.

To find out if some of the questions' responses had a significant dependency on the responses of other questions the Chi-square method was used. Using SPSS, the questions that had more than one answer chosen were paired and tested for dependency with other questions. For instance, Q2 asking about the general design of the application retained the null hypothesis with all the other questions confirming that the answers were independent of each other, however, the asymptotic 2-sided p-value was 0.010 with Q9, indicating some sort of relationship between the responses of the two questions. Similarly, Q3 asking about the choice of the navigation bar and Q13 asking about whether to include a Tips section or not had an asymptotic 2-sided p-value of 0.039 indicating that the responses might share a relationship and are somehow interconnected. Moreover, Q5 asking about the choice of visualization for the deep learning model outcome had a significant relationship to Q12 asking about an export feature to export the charts as PDF files. The asymptotic 2-sided p-value here was 0.032. Finally, an asymptotic 2-sided p-value of 0.029 meant that Q11 regarding allowing facility managers to customize the application had a significant relationship with Q13 regarding adding a "tips" feature to the software. All the other question combinations had p-values over 0.05 and therefore retained the null hypothesis which means there are no significant relationships between those questions.

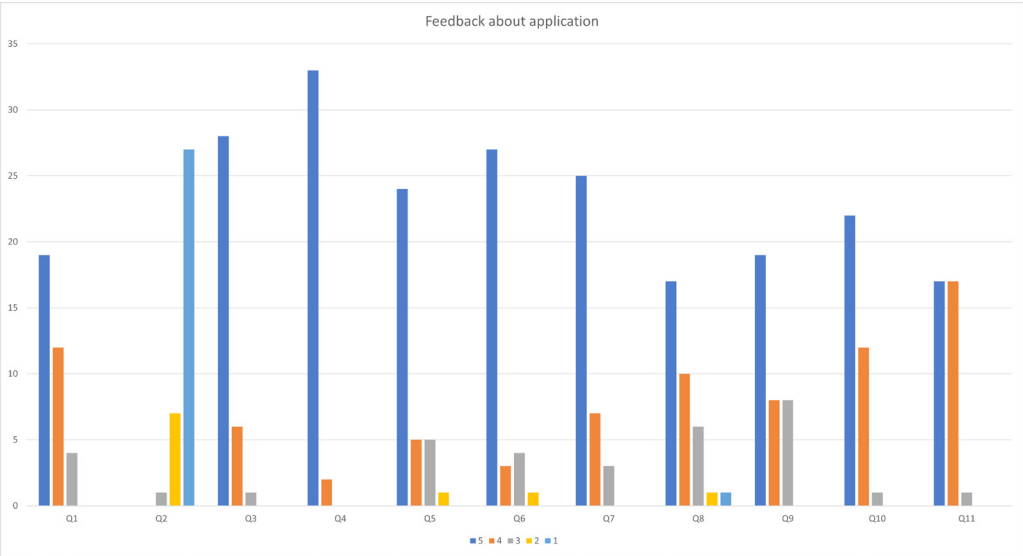

Figure 3. Feedback from the participants on the application

5. Discussion

The facility managers clearly factored in the need for a user-friendly application that can predict the charging load required for the next day's use for the commercial building. As charging load prediction will utilize deep learning, the application needs to be developed with the aspect of user-friendly human-computer interaction. The experts in the facility management field chose certain features to be included in the application. They pointed out that they want a dark futuristic interface for the application which may be because it causes less stress on the eyes. The login feature was suggested by 86.67% as it is an installed desktop application, and it may be useful in data protection. Since 53.33% of experts suggested a futuristic sci-fi background and 26.67% of experts wanted a dark background, the application was developed with a dark futuristic interface. 73.33% of participants wanted a horizontal navigation bar to access the tabs which can be because it is a desktop application, and it is easier to navigate with a horizontal bar. Most of the participants suggested demonstrating energy efficiency statistics and 60% of experts suggested displaying weather data within the application for accessibility reasons. A "Tips" tab was also included according to the suggestion.

When the application was tested for the human-computer interaction aspect by the participants, the overall feedback was positive. This shows initially gathering design guidelines for an advanced application from experts and then developing it is a good approach as it meets the necessary requirements. Among the participants, 88.57% were satisfied with the interface, and 85.71% liked the customization aspect. Also, most of the participants indicated high satisfaction with the user-friendly aspect of switching tabs, using the application, and viewing the predicted charging load and statistics. The participants also appreciated the tasking feature and the accessibility of getting to know the "Tips". Based on the analysis after the demonstration of the application developed, it had the necessary features for the GUI, and the analysis, these design guidelines demonstrated a satisfactory output. To test if the responses to any given question had any significant relationship with the responses to another question, a Chi-square test was applied to the results and while most of the questions retained the null hypothesis and had no significant relationships, four question fairs rejected the null hypothesis and demonstrated having a significant relationship.

5.1 Limitation

The application takes a unique approach in how it was designed, which resulted in positive feedback, however, it might also result in negative feedback. While most people preferred this type of interface, some users might not be very satisfied with the futuristic design and might prefer a simpler black-and-white interface. This application design would not be very suitable if the users who will be using it prefer the old and traditional way of application designs. It requires the users to be more open to change and willing to adapt.

5.2 Future Direction

The application could be further enhanced by turning it into a website that could be accessed from anywhere so that there is no need to install the application every time on the computers. This allows for better productivity and allows the staff to use the application from home. Moreover, the application could be developed as a phone application which allows the users to have access to it anywhere and at any time. However, developing either of these would be time-consuming, or require professionals to develop it.

6. Conclusions

This research determines the appropriate features to be integrated with a user-friendly GUI for the application for facility management and maintenance of TES-AC that can be used by facility managers and deduces the validity of the human-computer interaction aspect of the application. Furthermore, this study contributes to being a possible approach for gathering design guidelines for an advanced application as the expert suggestions demonstrate satisfaction from the users when included in the application. Among the participants, 67.08% participants found the application developed from the design guidelines collected from the experts to be most satisfactory, which shows the positive correlation measure from expert feedback and user-friendly features. By using the deep learning-based application, facility managers will be able to prepare in advance regarding the charging load, handle the maintenance schedule, allocate tasks, and even prepare for maintenance with suggested tips increasing labor and building efficiency. Also, the design guidelines collected for the deep learning-based application for facility management and maintenance of TES-AC will be beneficial for future researchers and developers who wish to apply computational intelligence for assisting facility managers to make better management decisions through user-friendly softwarei.

Conflict of Interest

Authors declare they do not have any competing interest.

References

[1] Bryant, C., 2019. Air conditioning is the world's next big threat [Internet]. The Economic Times. [Accessed 2020 Jan]. Available from: https://economictimes.indiatimes.com/news/science/air-conditioning-is-the-worlds-next-big-threat/articleshow/69999842.cms.

[2] MacMillan, A., 2016. Global Warming 101. NRDC [Internet] [Accessed 2019 Oct]. Available from: https://www.nrdc.org/stories/global-warming-101#weather.

[3] Ashish, 2022. How Does an Air Conditioner (AC) Work? [Internet] [Accessed 2022 Aug 25]. Available from: https://www.scienceabc.com/innovation/air-conditioner-ac-work.html.

[4] Awang, N.A., Kamar, H.M., Kamsah, N., 2017. Energy saving potential of an air-conditioner-Ice thermal storage (AC-ITS) system. Journal of Advanced Research in Fluid Mechanics and Thermal Science. 31(1-10), 1-2.

[5] Tanks, D., 2015. How Thermal Energy Storage Works [Internet] [Accessed 2022 Aug 22]. Available from: https://www.dntanks.com/what-we-do/thermal-energy-storage/how-tes-works/.

[6] Araner. Difference Between Air Cooled and Water Cooled Chiller System. [Online]. Ahvailable from: https://www.araner.com/blog/difference-between-air-cooled-and-water-cooled-chiller. [Accessed 30 09 2022].

[7] Araszkiewicz, K., 2017. Digital technologies in Facility Management - the state of practice. Creative Construction Conference 2017, CCC 2017, Primosten, Croatia. Procedia Engineering. 196(2017), 1034-1042.

[8] Haines, B., 2016. The benefits of lifecycle BIM for facility management [Internet] [Accessed 2019 Nov]. Available from: https://fmsystems.com/blog/the-benefits-of-lifecycle-bim-for-facility-management/#:~:text=Business%20Information%20Modeling%20(BIM)%20has,transformed%20architecture%2C%20engineering%20and%20construction.&text=Facility%20managers%20are%20finding%20value,th.

[9] Education, I.C., 2020. Deep Learning. IBM [Internet][Accessed 2022 Sep 1]. Available from: https://www.ibm.com/cloud/learn/deep-learning#:~:text=Deep%20learning%20is%20a%20subset,from%20large%20amounts%20of%20data.

[10] Mathworks.2022. The mathworks: Deep learning toolbox [Internet] [Accessed 2022 Jan 29]. Available from: https://www.mathworks.com/products/deep-learning.html.

[11] Sanzana, M.R., Abdulrazic, M.O.M., Wong, J.Y., et al., 2022. Effects of external weather on the water consumption of thermal-energy-storage air-conditioning system. SSRN Electronic Journal. DOI:10.2139/ssrn.4232763.

[12] Nguyen, H., Makino, Y., Lim, Y., et al., 2017. Short-term prediction of energy consumption of air conditioners based on weather forecast. 2017 4th NAFOSTED Conference on Information and Computer Science; 2017 Nov 24-25; Hanoi, Vietnam. USA: IEEE. Available from: https://ieeexplore.ieee.org/document/8108063

[13] Sanzana, M.R., Maul, T., Wong, J.Y., et al., 2022. Application of deep learning in facility management and maintenance for heating, ventilation, and air conditioning. Automation in Construction. 141(9), 104445.

[14] Sanzana, M.R., Abdulrazic, M., Wong, J.Y., et al., 2022. Analysis of machine learning techniques for predictive maintenance in cooler condition. The International Symposium on Intelligent Signal Processing and Communication Systems (ISPACS); 2022 Nov 22-25; Penang, Malaysia.

[15] O'Brien, H.L., Roll, I., Kampen, A., et al., 2022. Rethinking (Dis)engagement in human-computer interaction. Computers in Human Behavior. 128(3), 107109.

[16] Lee, C., Kim, S., Han, D., et al., 2020. GUIComp: A GUI design assistant with real-time, multi-faceted feedback. CHI 20: Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems; 2020 Apr 23. p.1-13.

[17] Seinfeld, S., Feuchtner, T., Maselli, A., et al., 2021. User representations in human-computer interaction. Human-Computer Interaction. 36(5-6), 400-438.

[18] Chaudhari, B.S., Zennaro, M., Borkar, S., 2020. LPWAN technologies: Emerging application characteristics, requirements, and design considerations. Future Internet. 12(3), 46.

[19] Stephanidis, C., 2001. User interfaces for all: New perspectives into human-computer interaction. User Interfaces for All-Concepts, Methods, and Tools. Lawrence Erlbaum Associates:Hillsdale, NJ. pp. 3-17.

[20] Martín-Rodilla, P., Panach, J.I., Pastor, O., 2014. User interface design guidelines for rich applications in the context of cultural heritage data. 2014 IEEE Eighth International Conference on Research Challenges in Information Science (RCIS); 2014 May 28-30; Marrakech, Morocco. USA: IEEE.

[21] Femling, F., Olsson, A., Alonso-Fernandez, F., 2018. Fruit and vegetable identification using machine learning for retail appligtcations. 2018 14th International Conference on Signal-Image Technology & Internet-Based Systems (SITIS); 2018 Nov 26-29; Las Palmas de Gran Canaria, Spain. USA: IEEE.

[22] Park, C.S., Srinivasan, V., 1994. A survey-based method for measuring and understanding brand equity and its extendibility. Journal of Marketing Research. 31(2).

[23] Wallace, B.C., Dahabreh, I.J., Trikalinos, T.A., et al., 2012. Closing the gap between methodologists and end-users: R as a computational back-end. Journal of Statistical Software. 49(5).

[24] Eisfeld, H., Kristallovich, F., 2020. The Rise of Dark Mode: A qualitative study of an emerging user interface design trend [Internet] [Available from: 2020 Sep 23]. Available from: http://www.diva-portal.org/smash/record.jsf?pid=diva2%3A1464394&dswid=-2106.

[25] Yang, H., Li, J., Han, Y., et al., 2020. Research on the application of new generation of Human-computer interaction in education. 2020 International Conference on Information Science and Education (ICISE-IE); 2020 Dec 04-06; Sanya, China. USA: IEEE.

[26] Gómez-de-Mariscal, E., García-López-de-Haro, C., Ouyang, W., et al., 2021. DeepImageJ: A user-friendly environment to run deep learning models in ImageJ. Nature Methods. 18, 1192-1195.

[27] Leung, J., Cockburn, A., 2021. Design framework for interactive highlighting techniques. Foundations and Trends® in Human-Computer Interaction. 14(2-3), 96-271.