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Contents

Predicting the classification of high vowel sound by using artificial neural network: a study in forensic linguistics

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A B S T R A C T

One of the tasks in forensic linguistics, especially forensic phonetics, is evaluating the speech sounds in the recordings. The speech evaluation aims at identifying and verifying speakers to predict if the sound were spoken by the suspect or not. The common problem in the task is determining which acoustic features of the speech sounds are reliable for the speaker identification and verification. The purpose of this research is studying formant frequencies to predict high vowel sounds /I/, and /u/ by using artificial neural network (ANN). Using three various normalization methods (i.e., softmax, z-score and sigmoid), we utilized multilayer perceptron on backpropagation ANN with the architectural models of 4-5-2, 4-10-2 and 4-20-2. The results show that the z-score normalization method provides higher accuracy than the other two in all formations and the 4-10-2 formation has shown the highest accuracy (92.26%).

Keywords: Artificial neural network Forensic linguistics Formant frequency Normalization method Vowel sound

1. INTRODUCTION

Forensic linguistics is a scientific study of language applied in legal discourse. The results of forensic linguistic studies can be utilized to provide linguistic evidence that can be used as evidence in court or as an additional source of information for criminal investigations. One of the tasks in forensic linguistics, especially forensic phonetics or forensic speech science, is evaluating the speech sounds in the recordings as legal evidence [1]–[3]. In forensic phonetics, there is the application of phonetic knowledge for legal purposes, especially for the identification or verification of speakers involved in crimes or legal cases. It involves the collection and analysis of sound data, including voice recordings, analysis of sound waves, spectrograms, and phonetic parameters such as intonation, pitch, and tempo. It also requires speech analysis techniques for acoustic modeling and spekares' sound profiling.

The speech evaluation in forensic phonetics aims at identifying and verifying speakers to predict if the sounds in the legal evidence were spoken by the suspect or not. The common problem in the task is determining which acoustic features of the speech sounds are reliable for the speaker identification and verification [4], [5]. Natural variations in pronunciation can affect the acoustic features of a speaker's voice, thereby making identification and verification difficult. In addition, the type of sound, both vowel and consonant, can affect the resulting acoustic features. So, it is important to combine acoustic analysis with linguistic analysis and other forensic contexts to ensure the reliability of identification or verification results.

The purpose of this research is studying formant frequencies as the acoustic features in classifying high vowel sounds /i/ and /u/ by using artificial neural network (ANN). Each vowel sound has different acoustic characteristics, so they can be distinguished from one another. However, vowel classification requires complex pattern recognition and machine learning to ensure the accuracy and precision of the classification results. By using formant frequencies as the acoustic characteristics, a classification

results. By using formant frequencies as the acoustic characteristics, a classification system can be created to identify and differentiate vowel sounds. Formant frequency refers to as the acoustic resonance of the human vocal tract which is the spectral peak of the spectrum [6], [7]. For an example, the formant frequency of vowel sound /i/ is the concentration of acoustic energy around a certain frequency in its speech sound waves as shown in Figure 1. It has several formants, each at a different frequency and each formant corresponds to a resonance in the vocal tract [6], [8]–[10].

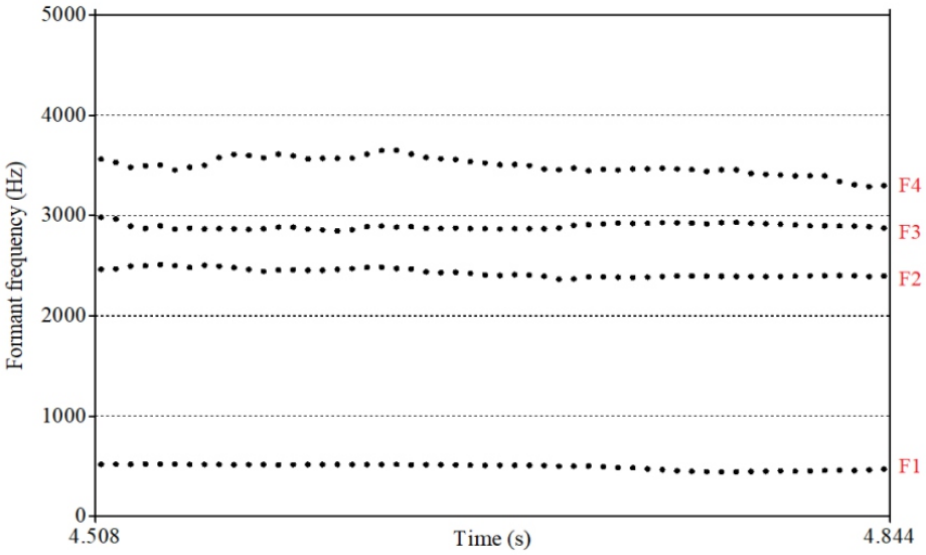

Figure 1. F1-F4 of the vowel sound /i/ (male speaker 12)

We use ANN to predict the classification of high vowel sounds /i/ and /u/. ANN is one method that can be used to predict the class of a data. One of the advantages of ANN is its ability to adapt and be able to learn from the input data so that it can map the relationship between input and output [11], [12]. In addition, ANN is able to predict the output based on the previously trained inputs. ANN has many network structures, including multilayer perceptron [13]–[15]. In this research, we utilized multilayer perceptron on backpropagation ANN with various normalization methods [16]–[19]. We analyzed the data classification using softmax [20]–[22], z-score [23]–[25] and sigmoid [26]–[28] as the normalization methods to obtain optimal classification results in predicting vowel sounds. The prediction is conducted with the formant frequencies F1, F2, F3 and F4 as the input data and the high vowel sounds /i/ and /u/ as the output data as shown in Figure 2.

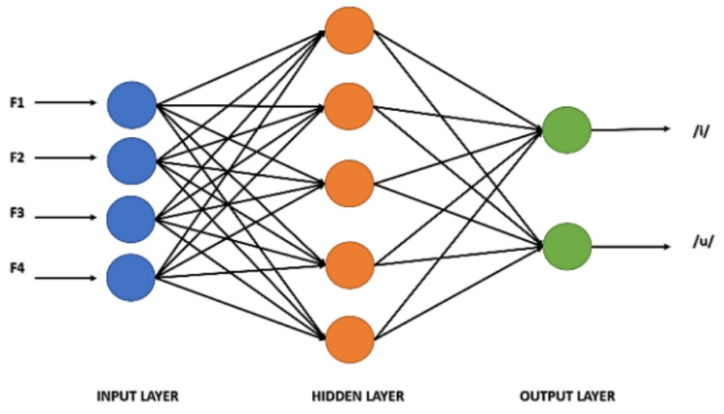

Figure 2. Multilayer perceptron ANN structure (4-5-2)

The normalization method in ANN can simplify the network optimization process and maximize the possibility of obtaining good results. Normalization can help avoid overfitting the ANN model. Overfitting occurs when the model is too complex and too specific for the training data, resulting in decreased model performance when tested on data that has never been seen before. Normalization can help reduce overfitting by normalizing input and output values, resulting in a more generalized, more generalized model. In addition, normalization can help avoid the problem of gradients that exceed the limit, either vanishing gradients or exploding gradients. Gradient exceeding the limit can cause problems in model training and cause slower convergence or even stop the training process. By using normalization, input and output values are converted into a normal distribution so that it is more stable and controllable, so that gradient problems can be avoided. Then, normalization can speed up the ANN model training process because it helps normalize input and output values. This makes it possible to use a higher learning rate, so that the training process can be carried out more quickly. And also, normalization can improve the accuracy of ANN models by reducing errors generated by abnormal input and output values. With normalization, input and output values will be converted into a normal distribution that is more controllable, so that the ANN model will be more accurate in predicting the desired output value.

In the research, we utilize only three normalization methods. One of the methods is sigmoid normalization method which converts the input value into a range between 0 and 1 with a sigmoid function. Another method is softmax which converts the value into a range between 0 and 1 using the sigmoid function with utilizing the mean and standard deviation. The last is z-score method which uses the average and standard deviation to normalize each input. In this method, each input is reduced with the mean value and its result is divided by the standard deviation value. The formulas of sigmoid, softmax and z-score are presented in (1), (2), and (3) respectively, where s is the input value, s' is the normalized input value, μ is the mean value and σis the standard deviation value [11].

$$s' = \frac{1}{1+e^{-s}} \tag{1}$$

$$s' = \frac{1}{1+e^{-\left(\frac{s-\mu}{\sigma}\right)}} \tag{2}$$

$$s' = \frac{s-\mu}{\sigma} \tag{3}$$

2. METHOD

We used a dataset of vowel sounds recorded at the Center for Studies in Linguistics, Universitas Bandar Lampung. The dataset contains the formant frequencies F1, F2, F3 and F4 for the high vowel sounds/i/ and /u/. The number of data is 120,685 with F1 – F4 distribution of the vowel sounds for male speakers (N=46) and female speakers (N=44) shown in Table 1. Data preprocessing is done by normalizing the data into 0 and 1 using softmax, z-score and sigmoid.

Table 1. F1-F4 og high vowels /i/ and /u/ in the dataset

	Male Speakers (N: 46)				Female Speakers (N: 44)			
	F1 (Hz)	F2 (Hz)	F3 (Hz)	F4 (Hz)	F1 (Hz)	F2 (Hz)	F3 (Hz)	F4 (Hz)
/i/								
Min	264	1884	2693	3243	252	1854	2899	4220
Max	482	2452	3019	4174	787	2670	3182	4695
SD	63	172	192	206	94	183	210	232
/u/								
Min	335	719	2290	3182	240	641	2196	3496
Max	585	1368	3142	4023	601	1232	3215	4511
SD	65	180	196	202	63	124	182	244

The concept of the backpropagation algorithm is to adjust the network weight by propagation of the error from output to input. During training, the network minimizes errors by estimating weights and stops at minimum squared error (MSE) 0.05 or a maximum iteration of 1,000 epochs. The activation function is used with a learning rate of 0.01. The minimization procedure was carried out with gradient descent backpropagation with adaptive gain and sigmoid activation function. The ANN architecture is one input layer, one hidden layer, and one output layer. In the input layer, the neuron is the formant frequency of vowel sound with four variables, namely F1, F2, F3 and F4. In the output layer, there are two neurons, namely the results of classifying the high vowel sounds /i/ and /u/. For the hidden layer, there are 5, 10 and 20 neurons for the architectural models of 4-5-2, 4-10-2 and 4-20-2 respectively. The stages of the research are shown in Figure 3.

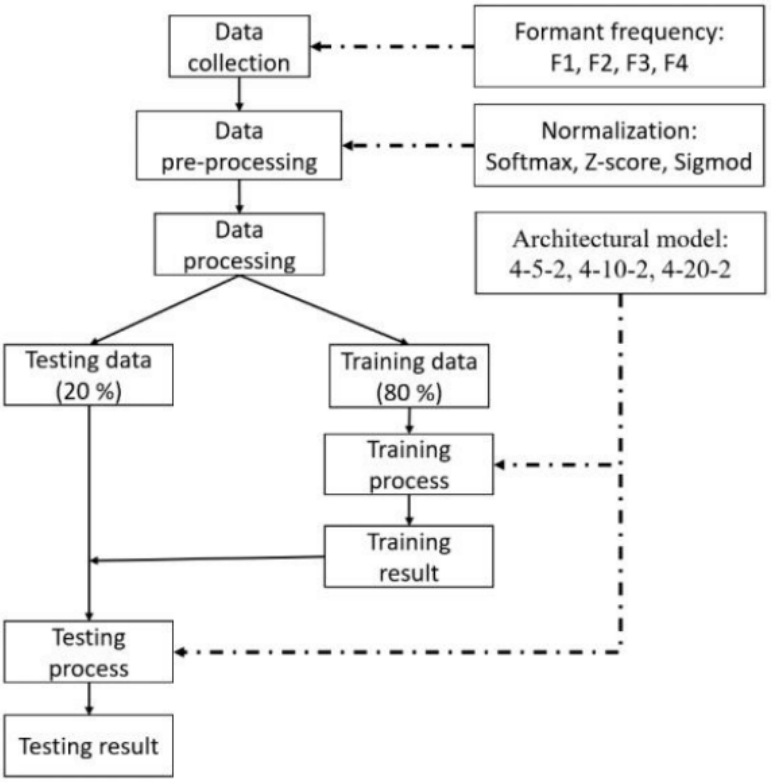

Figure 3. Research stages

3. RESULTS AND DISCUSSION

This experiment was carried out in two processes, namely the training process and the testing process.Derived from 120,685 data records, the training process uses 80% of the data, by randomizing

the data from male and female voice. While the remaining 20% is for the testing process. In each variation of the experiment, one hundred repetitions were carried out. Each repetition in the training process is given an initial random weight value and the number of iterations is obtained to achieve convergence. The experiment stops at the minimum squared error (MSE) 0.05 or at the maximum iteration 1,000 epochs and is assumed to have reached convergence and produces a weight that will be used for testing. Each training weight that has converged is used for testing. The classification data from the testing results are compared with the actual classification data so that the amount of data that is predicted to be correct and those that are predicted to be incorrect is obtained. The evaluation of the experiment was carried out by taking the average epoch and accuracy of one hundred tests. The test results in this study can be seen in Table 2 for the accuracy level in each formation and normalization method and Figure 4 for each linear epoch distribution.

Table 2. The results of epoch average and accuracy

Formation	Normalization	Epoch	Accuracy
4-5-2	Softmax	84	86.45%
	Z-score	198	91.14%
	Sigmoid	406	89.48%
4-10-2	Softmax	196	83.24%
	Z-score	307	92.26%
	Sigmoid	643	85.81%
4-20-2	Softmax	179	88.51%
	Z-score	484	91.87%
	Sigmoid	672	89.73%

For the comparison of the average epochs of various normalization methods shown in Table 2, it can be seen that, in all formations, softmax has the lowest average epoch, i.e., 84 epochs in 4-5-2 formation, 196 epochs in 4-10-2 formation, and 179 epochs in 4-20-2 formation. That means the softmax method has the shortest time to achieve convergence. While the comparison of the average accuracy, z-score has the highest accuracy in all formations, i.e., 91.14% in 4-5-2 formation, 92.26% in 4-10-2 formation, and 91.87% in 4-20-2 formation. Based on the test results seen in Table 2, it can be considered the z-score normalization method is the best method in normalizing the input data of formant frequencies F1-F4 to predict the high vowles sounds /i/ and /u/. And it can also be considered that the 4-10-2 formation is the best architectural model used in this research.

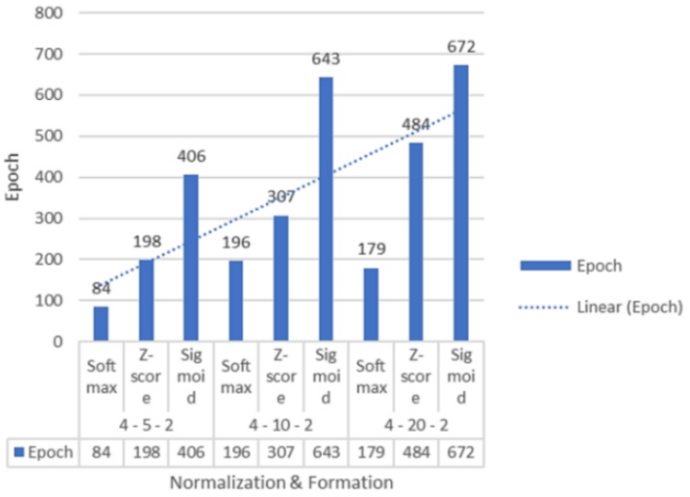

Figure 4. Linear epoch distribution

4. CONCLUSION

In predicting the classification of high vowel sounds /i/ and /u/ by using the four input variables of formant frequencies F1-F4 in this study, the results showed that the prediction can obtain an accuracy of 92.26% by using the backpropagation artificial neural network. We utilized the normalization methods of softmax, z-score and sigmoid and the architectural models of 4-5-2, 4-10-2 and 4-20-2. The highest level of accuracy can be obtained with the architectural model of 4-10-2 and the normalization method of z-score. It is also concluded from the research that the softmax normalization method has the shortest time to achieve convergence although it did not achieve the best accuracy comparing with the z-score and sigmoid normalization methods. For further research, normalization methods and other architectural models can be used to compare with the results obtained in this study. In addition, it can be done with different input variables or different classifications of vowel sounds. It is hoped that this will be a contribution in forensic linguistics, especially forensic phonetics in identifying or verifying sound data as legal evidence.

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Internet of things in public healthcare organizations: the mediating role of attitude

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A B S T R A C T

Internet of things (IoT) is a promising technology to face the challenges of COVID19 and enhance the capacities of public hospitals. However, few of the literature examined the behavioural intention (BI) of patients to use the IoT wearable health device (IoTWHD). This paper aims to examine the factor that affect the BI toward using the IoTWHD. The study proposes that variables of Technology acceptance model (TAM3) along with unified theory of acceptance and use of technology (UTAUT) can explain the BI. The population is the patients of public hospitals. Convivence sampling was deployed to collect the data using a questionnaire. 161 respondents participated in this study. The finding of Smart Partial Least Square showed that subjective norms (SN) affected the perceived usefulness (PU). Perceived enjoyment (PE) affected the perceived ease of use (PEOU). Further, PU, PEOU and perceived security (PS) affected the BI to use IoTWHD. Attitude mediated the effect of PU and PEOU on BI. More positive word of mouth are needed to enhance the perception of patients about BI to use IoTWHD in public health organizations.

Keywords: Internet of things Internet of things wearable health device Technology acceptance model Unified theory of acceptance and use of technology

1. INTRODUCTION

The COVID-19 outbreak has not only destabilized businesses and economies but also public health organizations [1]. Hospitals and healthcare facilities around the world are struggling to cope with the increasing number of COVID-19 patients who require hospitalization and care to recover. Even with the emergence of new COVID-19 variants such as Delta and Omicron, public hospitals, particularly in developing countries, continue to face challenges in managing patient capacities [2]. To combat this, the use of technology is crucial. One promising technology that has been utilized in medical care is the internet of things (IoT) [3].

IoT, a groundbreaking innovation, enables machines to communicate with each other without any human interaction or intervention, using sensors to share user data with other devices [4]. Its applications have permeated all aspects of life, including business, health, and education. Over the past decade, the number of IoT-enabled devices has seen a massive surge and continues to trend upward. Experts predict that by 2025, there will be over 74 billion IoT devices in existence, with an average of nine devices per person on the planet [5]. The utilization of IoT technology presents a solution to the capacity challenges faced by public hospitals. Wearable healthcare devices powered by IoT can monitor patients' statuses and transmit real-time information to hospital doctors. This application is particularly beneficial for patients with chronic diseases who require frequent medical check-ups. By using IoT-enabled wearable devices, such as watches or smartphones, patients can receive life-saving medical attention while minimizing overcrowding in public hospitals [6].

Although the usage of internet of things wearable health device (IoTWHD) is crucial, particularly

during the time of COVID19 and its new generation, it is still limited and in the early stages of development [7]. Current literature mainly focuses on developed countries that have the required infrastructure and technical expertise to use this technology [8]–[10]. Furthermore, the literature primarily addresses the technical aspects of using IoTWHD, such as connectivity, sensors, networking, and programming. The acceptance and individual usage of this technology are still under investigation [11]–[13].

Previous research suggests that studies on the individual usage and acceptance of IoT technology are predominantly technical in nature and the behavioral aspect has not received sufficient attention [14]–[17].

Furthermore, scholars argue that the mechanism through which IoT can affect individual and social acceptance is not yet fully understood [18]. The user experience of IoT is still emerging, and further research is necessary to explore the factors that can encourage users to adopt IoT [19], [20].

The adoption of new technology is a complex process, and several behavioral theories have been developed to explain it. One of the widely used models is the technology acceptance model (TAM), which was first proposed by [21]. TAM suggests that the use of new technology is influenced by two key factors: perceived usefulness (PU) and perceived ease of use (PEOU). Attitude (ATT) acts as a mediating variable that affects the behavioral intention (BI), which in turn influences use behavior (UB). To build on this model, Venkatesh and Davis [22] developed TAM2, which emphasizes the fit between the individual's work and the technology's usage. The latest development of TAM is TAM3, which includes additional variables such as anxiety and adjustment [23]. In the context of COVID-19, anxiety is an important factor that can affect the adoption of new technology. However, the original TAM and its extensions have been criticized for neglecting security and privacy factors [24], which are crucial for using any technology, including the IoT [24]–[26].

The adoption of IoT and IoTWHD in particular has been scarcely studied in developing countries, including Iraq [27]. Due to the limited use of technology in Iraq and the ongoing efforts of the government to improve infrastructure, facilitating conditions are crucial for the sustained usage of IoTWHD. This study seeks to investigate the factors that influence the adoption of IoTWHD among patients in Iraq who require regular medical treatment and visits to hospitals. The subsequent section will provide a review of the relevant literature, followed by a description of the methodology, findings, discussion, and conclusion.

2. LITERATURE REVIEW

The subsequent section explores the available literature related to IoT in Iraq. It introduces the theoretical framework which include the TAM3 and the UTAUT. These theoretical frameworks support the creation of the conceptual framework in this manuscript. In addition, the section also disucsses the development of the hypotheses of this study.

2.1. IoT in Iraq

Technology adoption in general in Iraq is limited and this could be due to long period of instability and the trust in the technology. IoT is being used by a limited number of users. The technology is provided by telecommunication companies for the purpose of commercial use. In Iraq and everywhere, technology has assisted the policy makers in tracking the infected with COVID19 and isolating them and their surrounding by using the QR scan [28]. Existing studies in the country noted the lack of using IoT among people in Iraq and the lack of studies that can explain the behavior of users toward this technology [7]. For this reason, this study examines the issue in the context of Iraq.

2.2. Theoretical framework

This study deploys TAM3 which indicate that the usage of technology is affected by the work context, anxiety, and the adjustment which have impact on the PU and PEOU [23]. Computer or technology anxiety as well as enjoyment are critical in determining the PEOU while the subjective norms and relevance of the technology can determine the PU. Both PU and PEOU proposed by original TAM to affect the ATT which also proposed to affect the BI. TAM was criticized for lack of using technological factors. To account for criticism, security of the IoTWHD is considered as an important variable in this study. Moreover, the UTAUT, developed by [29], highlights the significance of facilitating conditions (FC) in the context of Iraq.

2.3. Conceptual framework and hypotheses development

The proposed framework considers the role of perceived security (PS) as an important factor affecting BI. PS is considered as an essential factor in the adoption of IoT as it affects users' trust and confidence in the technology. The study also hypothesizes that subjective norms (SN) will positively influence PU since users are more likely to adopt IoTWHD if they perceive it as beneficial and socially acceptable. Additionally, the proposed framework posits that TA and PE will affect PEOU. Users with high levels of technology anxiety are expected to perceive IoTWHD as difficult to use, while users with high levels of perceived enjoyment are more likely to perceive it as easy to use. Finally, FC is expected to positively influence BI as it represents the external factors that may facilitate or inhibit the adoption of IoTWHD. Overall, the proposed framework provides a comprehensive and theoretically grounded approach to understanding the determinants of IoTWHD adoption in the context of Iraq. Figure 1 shows the proposed conceptual framework of this study.

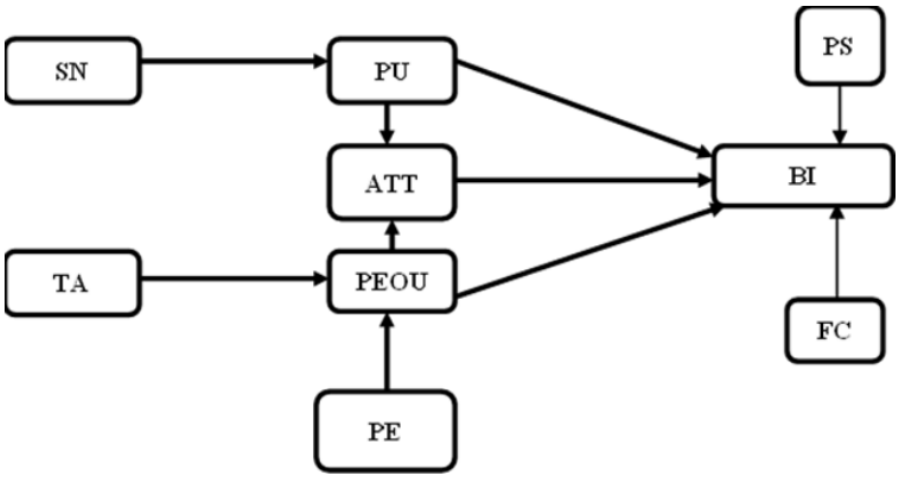

Figure 1. Proposed framework

2.3.1. SN and PU

According to [30], SN refers to the perception of significant others that influences individuals' decision-making. The Theory of Planned Behaviour (TPB) and Unified Theory of Acceptance and Use of Technology (UTAUT) have both suggested that SN is a crucial variable that can affect BI [29], [30]. Specifically, TAM3 proposes a direct relationship between SN and PU [23]. Previous studies have also investigated the association between SN and PU and found a positive correlation [31]–[33]. Based on these findings, it is suggested that:

H1: SN has a positive impact on PU.

2.3.2. TA and PEOU

The TAM3 model proposes that technology anxiety (TA) can impact the PEOU of a technology. Users who lack knowledge or experience with a technology tend to feel anxious about using it [34]. The effect of TA on PEOU is mixed in prior research. For example, one study [35] found that TA did not significantly affect PEOU, while others [36], [37] identified it as a critical determinant of PEOU. In the context of Iraq, where technology adoption is still limited, it is hypothesized that technology anxiety will have a significant impact on PEOU. Therefore, the following hypothesis is proposed:

H2: TA has a significant impact on PEOU.

2.3.3. PE and PEOU

Perceived enjoyment (PE) is a variable that determines the PEOU according to TAM3. Despite being less frequently studied, this variable is especially relevant in the context of COVID-19. Users who are interested in technology and eager to learn about IoT tend to enjoy using the technology [38], [39]. Previous studies have shown that PE has a significant impact on PEOU [38], [39]. Thus, this study proposes the following hypothesis:

H3: PE affects the PEOU.

2.3.4. PU and BI

The perception of an individual regarding the potential benefits of using a technology is referred to as PU [40]. PU is a critical factor in the technology acceptance model (TAM) and is linked to BI. Previous studies have found a positive correlation between PU and the usage of IoT, indicating that users tend to adopt IoT when they perceive it as beneficial [16], [41], [42]. Therefore, this study proposes that the BI of individuals towards using IoTWHD will be positively influenced by their PU.H4: PU affects positively BI to use IoTWHD.

2.3.5. PEOU and BI

PEOU is a key construct of TAM, and it is proposed to have an impact on BI. Previous studies have explored the relationship between PEOU and BI in various contexts. For example, a study by [43] investigated the relationship between PEOU and BI in healthcare devices and found a positive association. Likewise, the study by [44] revealed a positive correlation between PEOU and BI in the use of IoT. In the context of IoTWHD, Mital et al. [16] demonstrated that PEOU has a positive impact on BI, and Karahoca et al. [41] arrived at a similar result in Turkey. However, some studies have reported no significant link between the two variables [45]. Therefore, the hypothesis is formulated as follows:

H5: PEOU affects BI to use IoTWHD.

2.3.6. Perceived security and BI

Perceived security (PS) refers to users' perception of IoT as being safe, secure, and trustworthy [46]. Many studies have emphasized the significance of PS in the usage of IoT. For example, Pinochet et al. [47] highlighted the importance of PS in IoT adoption and repurchase intention. Similarly, Chouk and Mani [48] found a positive association between perceived enjoyment and smart services. In this study, it is hypothesized that higher levels of PS will lead to increased adoption of IoTWHD by users.

H6: PS affects significant BI to use IoTWHD.

2.3.7. FC and BI

Favorable FC can increase an individual's intention to use IoT devices [49]. For instance, if a person has reliable and fast internet connectivity, access to devices that are compatible with IoT technology, and the requisite skills to use and integrate these devices into their daily lives, they are more likely to intend to use IoT technology [50]. Conversely, if an individual lacks access to necessary resources like compatible devices or reliable internet connectivity, their intention to use IoT technology may decrease. Furthermore, if an individual perceives the use of IoT technology as complicated or difficult, this can also negatively affect their intention to use it [43].

H7: FC affects the BI to use IoTWHD.

2.3.8. ATT as a mediator

TAM proposes ATT as a mediating variable, which has been studied in the context of IoT in a few instances. For instance, previous research by Choi and Kim [44] examined the impact of ATT on BI to use IoT, and found a positive correlation between the two variables. Additionally, Hsu and Lin [20] investigated the mediating role of ATT and discovered a partial mediation. Furthermore, Wang et al. [51] found that ATT mediated the impact of PU on BI to use IoT. Based on these findings, the following hypothesis is proposed:

H8: ATT mediates the effect of PU on BI.
H9: ATT mediates the effect of PEOU on BI.

3. RESEARCH METHODOLOGY

The present research is grounded on a positivist philosophy, utilizing a deductive approach. The research methodology adopts a survey strategy, and the data is collected through a cross-sectional time horizon. The study population is comprised of patients who seek medical attention at hospitals in Iraq. Convenience sampling was employed as there is no existing database of individuals with chronic illnesses in Iraq. A questionnaire serves as the primary research instrument, which was adapted from several previous studies. PU (4 items), ATT (4 items), and PEOU (3 items) were adopted from [41], PS (3 items) from [52], and FC (5 items) and BI (5 items) from [53]. SN (4 items), TA (4 items), and PE (4 items) were adopted from [23]. Experts fluent in both Arabic and English languages translated and validated the questionnaire. Prior to the data collection, a pilot study was conducted to assess the reliability of the measurements using Cronbach's Alpha (CA), and it was determined that all the measurements were reliable with CA greater than 0.70, as recommended by [54]. The management of five public hospitals was contacted to assist in distributing the questionnaire. In total, 391 questionnaires were distributed with reminders sent to collect additional responses, resulting in a total of 179 collected questionnaires. According to [55], responses between 100-150 are deemed sufficient for using smart partial least square (Smart PLS). The collected data were analyzed for missing values, outliers, normality, and multicollinearity. Seven responses had more than 15% missing responses and were subsequently deleted, while 11 responses were identified as outliers. This led to 161 complete responses. Normality and multicollinearity were also checked and found to be satisfactory. These analyses were conducted following the recommendations of [56], with the results presented in Table 1.

Table 1. Data screening (N=161)

Variable	Normality		Multicollinearity	
	Skewness	Kurtosis	Tolerance	VIF
ATT	-.39	-.37	.49	1.31
TA	-.32	-.41	.48	1.22
FC	-.43	-.49	.59	1.19
PEOU	-.79	-.49	.69	1.49
PS	-.49	-.59	.68	1.19
PE	-.78	-.49	.49	1.29
SN	-.69	-.39	.48	1.39
BI	-.59	-.38	-	-

4. FINDINGS

Descriptive information of respondents as well as the analysis of smart partial least square are discussed in this section. The section disucsses the profile of the respondents. In addition, the measurement model and the structural model are discussed in this section. The hypotheses testing of this study are examined in the following sub-sections.

4.1. Profile of respondents

The total of 161 respondents participated in this study. The respondents are majority males (73%) and 27% are females. The age group of the respondents is between 50-60 years (71%) and between 60 and above 21% while those less than 50 years are 8%. The education of the respondents are bachelor's degree 44%, high school 31% and less than high school is 25%. Majority of the respondents are self-employed 52%, 29% are working in public sector and 19% working for private sector.

4.2. Measurement model

To assess the measurement model (MM), the factor loading (FL), CA, composite reliability (CR), convergent validity using average variance extracted (AVE), and discriminant validity were assessed. FL for all items is larger than 0.70 except for SN2, PE1, and PS2. The CA and CR for all the variables is greater than 0.70 as shown in Table 2. In addition, the convergent validity is good since the AVE of the variables are greater than 0.50. For the discriminant validity, the root square of AVE is greater than the cross loading. This is acceptable based on [56].

Table 2. Outcome of assessing the reliabilities and validities

Variable	CA	CR	AVE	ATT	BI	FC	PEOU	PS	PU	PE	SN	TA
ATT	0.89	0.84	0.79	**0.91**								
BI	0.89	0.87	0.82	0.41	**0.90**							
FC	0.93	0.88	0.77	0.31	0.17	**0.88**						
PEOU	0.89	0.90	0.83	0.42	0.31	0.20	**0.92**					
PS	0.79	0.89	0.72	0.33	0.29	0.21	0.31	**0.84**				
PU	0.86	0.87	0.79	0.49	0.39	0.33	0.43	0.29	**0.90**			
PE	0.88	0.89	0.81	0.30	0.39	0.21	0.23	0.20	0.18	**0.89**		
SN	0.79	0.81	0.73	0.39	0.29	0.31	0.43	0.13	0.17	0.14	**0.87**	
TA	0.82	0.83	0.61	0.21	0.23	0.32	0.13	0.19	0.16	0.12	0.19	**0.72**

4.3. Structural model

The structural model in this study is evaluated against multiple criteria outlined in [56]. Analysis of the R-square revealed that 47.5% of BI could be explained by the variables. A Q-square greater than zero

was observed, indicating that the independent variable has the ability to predict the dependent variable. With regards to the f-square, all paths except for FC→BI and TA→PEOU have values greater than 0.02. The structural model is presented in Figure 2.

Table 3 displays the path coefficient and the outcomes of the hypotheses testing for both direct and mediating effects. The outcomes of the hypotheses testing are presented in Table 3. The results indicate that H1 is supported, as SN has a positive effect on PU at B=0.58 and P<0.001. However, H2 is rejected since TA did not affect PEOU (P>0.05). H3 is supported, as the impact of PE on PEOU is significant at B=0.21 and P<0.001.

H4 is also supported, as the effect of PU on BI is significant. Similarly, H5 is supported as the impact of PEOU on BI is positive and significant. The effect of PS on BI is positive, hence H6 is supported. However, H7 is rejected as the effect of FC on BI is not significant. H8 is supported, as ATT mediates the effect of PU on BI through the indirect effect (PU→ATT→BI). The mediation is partial since both the direct and the indirect effects are significant. Finally, H9 is supported as ATT partially mediates the effect of PEOU on BI through both the indirect and direct effects being significant.

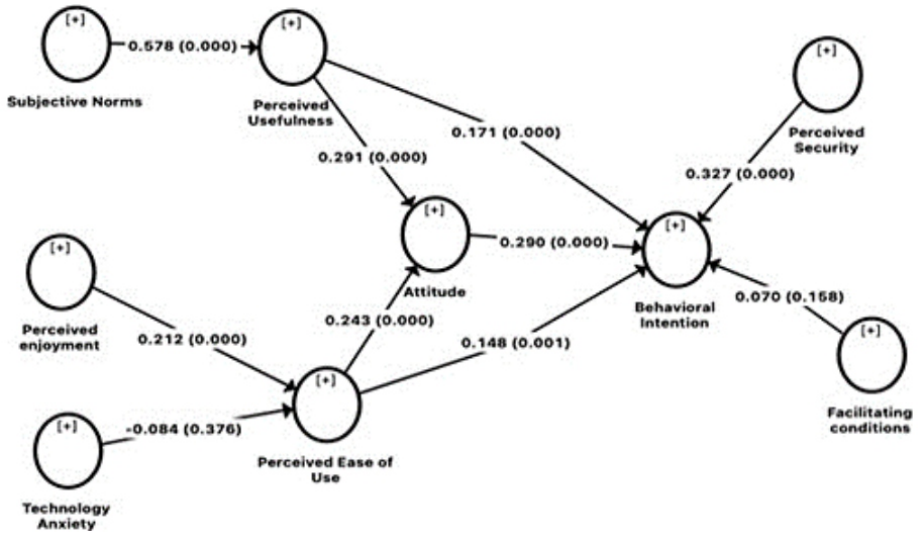

Figure 2. Structural model

Table 3. Result of hypotheses

H	Path	B	STD	T	P	Label
H1	SN -> PU	0.58	0.03	18.12	0.00	Supported
H2	TA -> PEOU	-0.08	0.10	0.89	0.38	Rejected
H3	PE -> PEOU	0.21	0.05	4.15	0.00	Supported
H4	PU -> BI	0.17	0.05	3.49	0.00	Supported
H5	PEOU -> BI	0.15	0.04	3.37	0.00	Supported
H6	PS -> BI	0.33	0.04	8.72	0.00	Supported
H7	FC -> BI	0.07	0.05	1.41	0.16	Rejected
H8	PU -> ATT -> BI	0.08	0.02	3.88	0.00	Supported
H9	PEOU -> ATT -> BI	0.07	0.02	3.48	0.00	Supported

5. DISCUSSION AND IMPLICATIONS

This study investigated the potential of IoTWHD in Iraq and its impact on patients in public hospitals. The study aimed to determine the effect of SN on PU and found a positive relationship between the two variables. This implies that if positive word-of-mouth about IoTWHD spreads among users through SN,

their perception of PU will increase. Meanwhile, the study hypothesized that TA would negatively affect PEOU but found no evidence of this relationship. These findings are consistent with previous research that found a positive effect of SN on PU [31]-[33], as well as with research that investigated the impact of TA [35] and perceived enjoyment (PE) [38], [39] on PEOU.

The positive relationship between PE and PEOU indicates that incorporating fun and enjoyment in the use of IoTWHD can enhance the ease-of-use perception. Additionally, the study found that PU and PEOU are positively associated with BI, which suggests that the usefulness and ease of use of the technology are important for patients and can increase their willingness to use it. These findings are consistent with previous research [16], [41], [42]. Furthermore, the study found that PS has a positive impact on BI, indicating that patients are more likely to adopt IoTWHD when they perceive the technology as secure. Conversely, FC did not have a significant effect on BI, possibly because IoTWHD are similar to watches and do not require significant infrastructure beyond fast internet. These findings align with those of [47] for PS and [49] for FC. The study also confirmed the mediating role of ATT between PU, PEOU, and BI, indicating that ATT partially explains the effect of PU and PEOU on BI. This finding is consistent with the research conducted by Hsu and Lin [20].

This paper has made a significant contribution to the literature on the usage of IoT technology in public health organizations in developing countries. Unlike previous studies that primarily focused on the technical aspects of IoT, this study examined the behavioral approach and identified the factors that influence patients to use IoTWHD. By using a combination of TAM3 and UTAUT frameworks, the study was able to explain nearly half of the variation in BI, which is a significant achievement. In addition, the study also deployed mediating variables such as ATT to further explain the BI. This approach helped to provide a more comprehensive understanding of the relationships between the various constructs in the model and how they influence patients' intention to use IoTWHD. The findings of the study highlight the importance of considering not only the technical aspects of IoT but also the behavioral factors that affect patients' adoption and usage of this technology.

This study is particularly significant for public health organizations in developing countries that face resource constraints and high pressure on their healthcare systems. By identifying the factors that influence patients to use IoTWHD, healthcare providers can devise strategies to enhance the adoption and usage of this technology, leading to improved health outcomes for patients. The study's findings provide valuable insights into the usage of IoT in public health organizations and open up opportunities for further research in this area. These findings are particularly relevant for decision-makers in public healthcare organizations in Iraq and other countries with similar characteristics.

The study highlights the importance of SN, which needs to be improved to enhance the BI toward the usage of IoTWHD. Spreading positive word-of-mouth through TV series, social media advertisements, and educational institutions will encourage people to use IoTWHD and understand its benefits. Moreover, PE is another critical factor that should not be overlooked. Adding gamification elements to IoTWHD applications can make the experience more enjoyable for patients, especially during the COVID-19 pandemic. The study also emphasizes the importance of PU and PEOU, as they have been found to be critical for BI. Therefore, IoTWHD applications should be easy and straightforward to use, and their usage should be beneficial for patients. Ensuring the security of these applications is also important. By highlighting the benefits of using IoTWHD and spreading positive word-of-mouth, healthcare providers can help patients develop a positive attitude toward this technology.

6. CONCLUSION

The main objective of this study was to investigate the factors that could lead to an enhancement in the BI toward IoTWHD. The research data were obtained from patients who received treatment in public

hospitals in Iraq. The study found that SN had an impact on PU, while PE affected PEOU. The study also revealed that PU, PEOU, and PS had a positive influence on BI toward IoTWHD, while FC did not. Moreover, ATT played a mediating role in the relationship between PU/PEOU and BI. The present findings are limited to the participants who took part in this study in Iraqi public hospitals and the usage of IoTWHD. To expand upon the results of this study, future research could be conducted using a random sampling technique. The findings could also be extended by examining patients in private hospitals, which may have better or worse equipment compared to public hospitals. Furthermore, future research should incorporate other variables such as the reliability of IoTWHD and the availability of these applications. The study's conclusions could be valuable for decision-makers in public health organizations looking to enhance the usage of IoTWHD.

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A study on the impact of artificial intelligence on talent sourcing

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ABSTRACT

Talent sourcing is one of the most effective mechanisms to engage with the talent pool and convert a candidate into an applicant. Today, machine learning has emerged as a trend to assist employers in addressing recruitment challenges with the help of tools such as neuro-linguistic programming (NLP) and automated assessments. 80% of the executives strongly believe deep learning makes candidate screening highly efficient. Including current start-ups globally, only 15% use artificial intelligence (AI) and are expected to increase by 31%. The study focused on the impact of AI in recruitment process. There are a few metrics, such as application completion rate, number of candidates per filled position, cost per hire, and so on. Here we would like to analyze the impact of using AI in various phases of hiring in the organization.

Keywords: Artificial intelligence Candidate evaluation Machine learning Neuro-linguistic programming Predictive analytics Screening

1. INTRODUCTION

Artificial intelligence (AI) showcased its potential by silver lining its influence in making smart decisions and automating the redundant tasks to ease the struggle of job applicants in this technology-based ecosystem [1]. In addition to this, by considering the advantages of AI from the perspective of technology, the government also plays a vital role in implementing a road map for AI [2]. AI complements human capital management by digitizing the recruitment process and enriching how employees work [3], [4]. Nearly 30% of companies are changing their technology reasonably, and almost 90% are trying to prepare the workforce for the future [5].

Global leaders mine professional social sites and academic information from various sources andpinpoint the required talent pool for the desired position. Using multiple job posting channels and employeereferrals are the key things used to source the candidate [6]–[8]. This study depicts how AI created a propellingimpact in the hiring process and created a competitive advantage in the market, which helps create a tangiblepositive impact [9], [10]. The paper's purpose portrays how AI leveraged the selection process and paved theway to engage with the applicants in new ways.

AI paves a channel to engage the top talent and add value to the business. To manage the

employment practices effectively, Bain and company opine that the hiccups lie in tapping the digital trend. Across nations,most employees believe that their performance can be very well optimized by digital technologies and bridge talent acquisition gaps [11], [12]. The adoption helps us assess workforce planning and formulate a wellstructured procedure to identify the metrics to ensure better performance and increase hiring accuracy.Recruiters are seeking talented individuals that can handle problems even in stressful situations. They mustalso be capable of making better decisions in a systematic way [13].

AI helps to cope with disruption and streamline the talent lifecycle in the age where the recruiter'sability is crucial in making better decisions to create business value [14], [15]. The capabilities of AI help inaccurate assessments and facilitate better prioritization for job acquisitions. One of the most differentiatedapplications of AI in recruitment is sound compensation planning, where it optimizes the pay decisions andelevates transparency in the actual decision of managers.

AI builds momentum in hiring smarter candidates and focuses primarily on strategic planning [16],[17]. This AI application helps save time when the talent sourcing professionals can design key performanceindicators to meet the business objectives and establish a core competence at the organizational level. Apartfrom all these features, it also gives us a new dimension to reducing employee attrition and helps formulate astrategy to address the pitfalls of high priority [18]. The main research objectives are i) to figure out the majorapplications of AI in talent acquisition, ii) to evaluate the core barriers to adopting AI in recruitment, andiii) to study the potential drawbacks associated with implementing AI in hiring. The study focused on how AIcan be used in talent sourcing.

2. RESEARCH METHODOLOGY

As part of our research study, we conducted both primary and secondary research to analyze the impact of AI on hiring candidates. Accordingly, various newspapers, company blogs, official sites, and articlesby leading consulting firms have been considered to draw these conclusions. Primary research was carried out to find out the potential of AI from screening to onboarding in talent acquisition and how it enhances the employer's brand. It was done by surveying through an online questionnaire.

To achieve the mentioned objective, we had the following research design. The sample size includes 1,000 respondents, including undergraduates/Postgraduates, working professionals, and homemakers, ranging from 20 to 60. We chose age and gender as our segmentation variables in terms of segmentation. Moreover, we used various tools such as bar graphs, pie charts, and line charts to pursue a detailed analysis of the obtained responses. The research methodology is purely based on the facts and insights that we collected through secondary research and the responses we received through the questionnaire as part of primary research. The dependent variables are professional skills and academic qualifications, while the independent variables are age and gender.

Profile of the target sample, we included males and females of an age group ranging from 20 to 60, where the sample size comprises students, working professionals, and homemakers.Source of the data, primary research: Sample size of 1,000. Secondary research: newspapers, official sites, blogs, and articles published by consultingfirms. Period of the study, this study was conducted for a month (On March 2022).

2.1. Secondary research

AI stands as a bedrock in establishing ethical human resource systems to ensure the bias factor is addressed and helps implement efficient performance measures to fine tune the accuracy of the hiring process [19]–[21]. In addition to this, AI provides accurate predictions and helps recruitment heads and hiring professionals to identify the potential candidates. AI mines candidates' facial expressions and body language to get good insights that help match people as per the requirement [22], [23]. AI-based

systems are used for evaluating the applicant's resume. It will identify the keywords present in the applicant's resume which the recruiters are looking for. AI-enabled systems are unbiased in shortlisting the right applicants. It can also detect fraudulent applications [24], [25].

AI drives the hiring activity with the advent of technology and rived job opportunities, facilitating the acute challenge of employment shortage globally [26], [27]. Data-driven businesses evolved, and employee retention became a great challenge to resolve [28]–[30]. Implementing AI in the organization enables talent acquisition leaders to fuel the hiring process by automating specific repetitive jobs. The candidate's facialexpressions can be used for assessing the honest answers using an AI-enabled system. So, this online interview creates convenience for both applicants and the interviewer's end [31], [32].

AI helps to trigger the individual's intellect and creates a compelling impact on attracting talent pool,development, and employee retention [33], [34]. It completely reshaped the traditional outlook and achieved good diversity among the employees. The beneficence of AI in the human resource function lies in crippling the typical barriers like reliability and bias and deriving very productive conclusions [35], [36]. The perceptions of workforce development can be phenomenally transformed with the use of AI in organizations.

2.2. Primary research: Primary data was collected with a sample size of 1,000

2.2.1. The age groups

Figure 1 shows people from different age groups who have participated in this survey. Age groups ranging from 20-30 scaled up by 65.74%, followed by 31-40 who's percentage of participation is 28.8%. It is good to see that even age groups beyond 40 have expressed their opinion. According to the data, most respondents are male with 71%, followed by females with 29%, which is shown in Figure 2.

2.2.2. Gender

According to the data, most respondents are male with 71%, followed by females with 29%. In other words, out of 1000 participants, 710 were male and 290 were female. The same is shown in Figure 2.

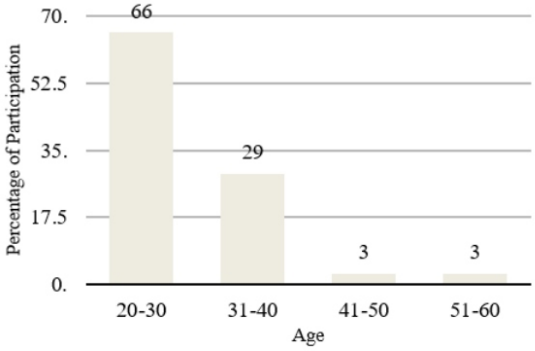


Figure 1. Age group

Figure 2. Gender

2.2.3. Academic qualification/profession

Figure 3 shows the academic qualification/profession of the responders who has participated in this survey. As per the responses, postgraduates are more with 41%, followed by working professionals with 39%. It is also noticed that around 16% are graduates and remaining 4% are home makers.

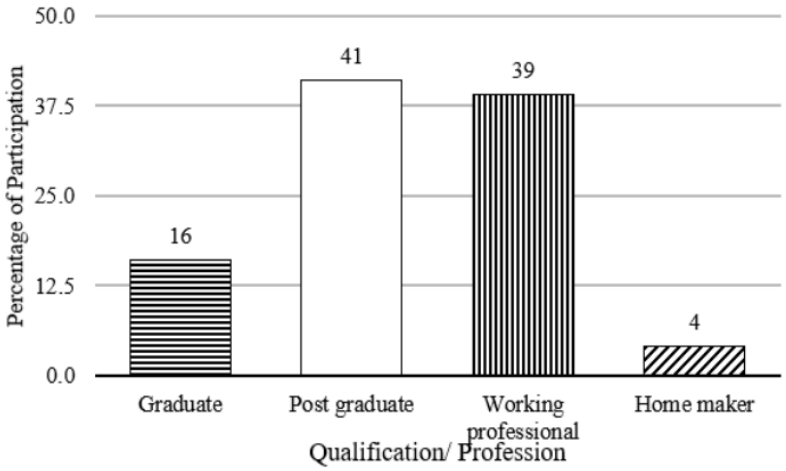


Figure 3. Academic qualification/profession

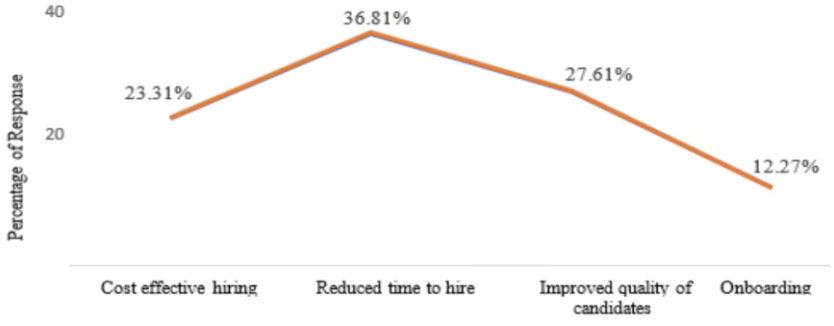
2.2.4. Benefits of implementing AI in talent acquisition

Most of the respondents opined that implementing AI will reduce the man-hours in hiring, where the time can be utilized on associated tasks of high priority [37], [38]. In addition to that, respondents opine that the quality of candidates can be significantly improved, and recruitment can be done by optimizing the costs. Figure 4 shows the benefits of implementing AI in talent acquisition. Around 36% opined that implementing AI will be benefited in reducing the time to hire, while 27% opted that it will improve the quality of idates. 23% opined that the implementation of AI helps in reducing the cost of hiring, while rest of 12% opined onboarding.

2.2.5. The major applications of AI in recruitment

Figure 5 shows the major applications of AI. The majority of the respondents opine that imparting AI to talent sourcing functions, social candidate discovery, and job market forecasting, followed by a screening of the candidates, can be done effectively. The mechanism to find talented candidates from an existing database is known as candidate discovery, which helps to reduce the cost and time of hiring for the organization [39].

Job market forecasting predicts future employment trends. The profession and its required skills along with the vacancy numbers are predicted [40], [41]. The skills required for the target position will be analysed from the resume. If matched, such resumes will be shortlisted [24], [42]. Around 25% responders mentioned that AI application is ingot market forecasting, while 24% mentioned each for social candidate discovery and resume filtering. It is also seen that 17% mentioned application in screening/assessments, while remaining 10% mentioned for reduced advertisement spend on recruitment.



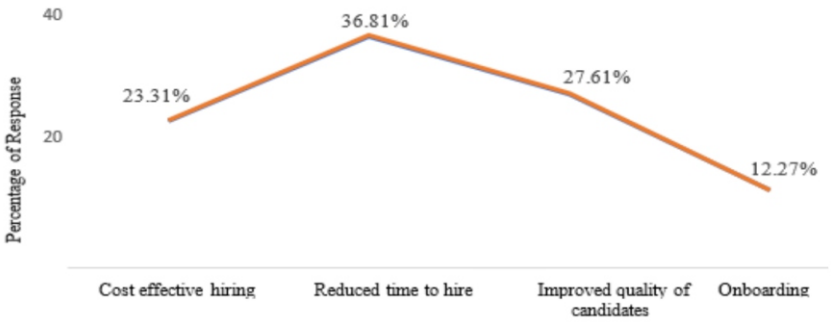


Figure 4. Benefits of implementing AI

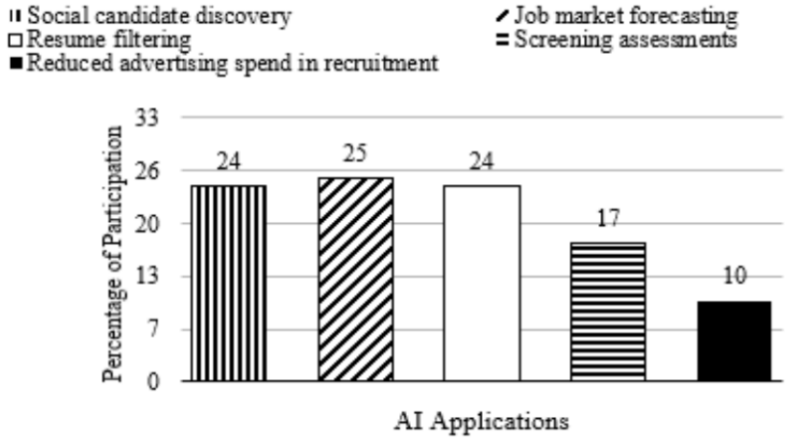


Figure 5. Major applications of AI

2.2.6. The core barriers to adopting AI in talent sourcing

Based on the data, people opine that lack of relevant skills to understand the pattern and flow of AI is the primary concern, followed by the inadequate budget are the core barriers to adopting AI [43]. Because if and only if the data set is trained with quality inputs, we can expect our desired output to be of high quality. Figure 6 shows the barriers to adopting AI in talent sourcing. Around 40% opined about the lack of skilled HR professionals, while 23% opined about the lack of budget. 21% opined about the challenges in feeding quality data, while lack of accurate evaluation and high risk have 11% and 5% chances.

2.2.7. The possible drawbacks associated with implementing AI in talent acquisition

According to the data, people opine reliability is the area that needs to be addressed before implementing AI. Because by implementing AI, there is a chance of reliability (only identifies certain patterns and can't accept beyond if there is a deviation) getting hampered because AI identifies only specific patterns and cannot go beyond the instructions programmed. Figure 7 shows the possible drawbacks of AI.

Figure 6. Core barriers to adopting AI

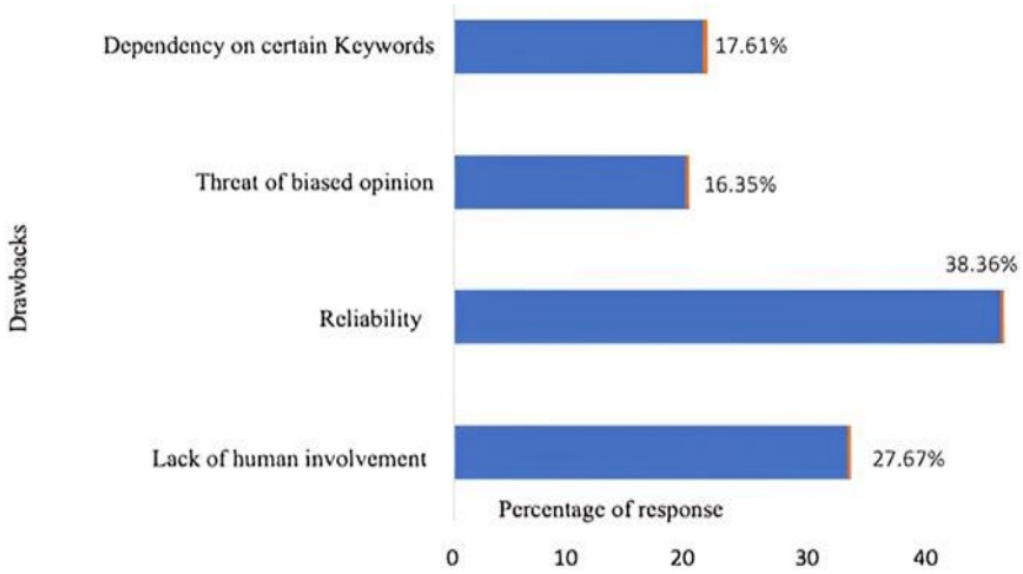


Figure 7. Possible drawbacks of implementing AI

2.2.8. The effectiveness of AI applications in screening/candidate evaluation

The majority (33%) opine that evaluating through chatbots is very effective, followed by evaluating personality traits and automated assessments. The evaluation of chatbots achieved good significance because, despite any deviation from the expected output, human intervention is coupled and ensures customer service excellence. Around 29% opined that combination of personality trait, chatbots and automated assessments will be very effective in evaluation/screening process of the candidates. Figure 8 shows its summary.

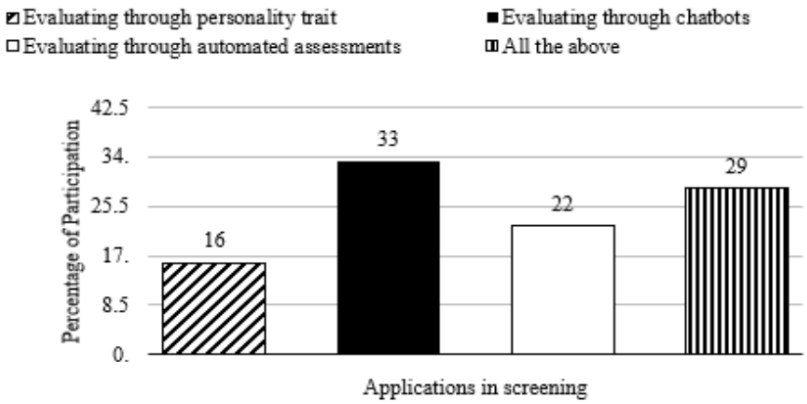


Figure 8. Effective applications of AI in screening

2.2.9. Imparting AI in training employees

Based on the data as shown in Figure 9, most people opine that imparting training through AI dramatically benefits the organization because automated assessments are very effective in scrutinizing the workforce. People centric evaluations may sometimes lead to biased assessment. Around 92% agreed that AI based training will be benefited, while 8% people disagreed with the questioner.

2.2.10. Satisfaction of AI in the hiring process

Scheduling a hiring process with AI satisfies your requirements in selecting the right candidate and reduces recruitment costs. Most respondents opine that implementing AI in the hiring process reduces recruitment costs and adds exceptional value to selecting the right candidate. Around 79% opined about their satisfaction in implementing AI in hiring process, while remaining 21% is not satisfied. Figure 10 shows its summary.

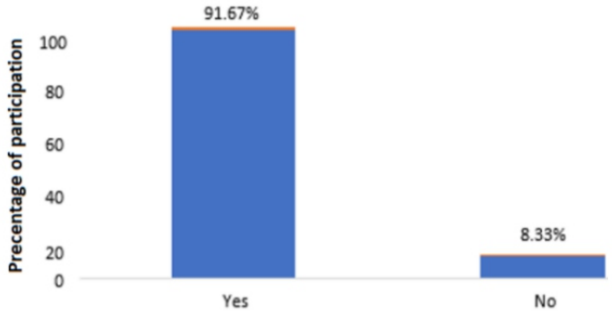


Figure 9. Opinion on implementing AI

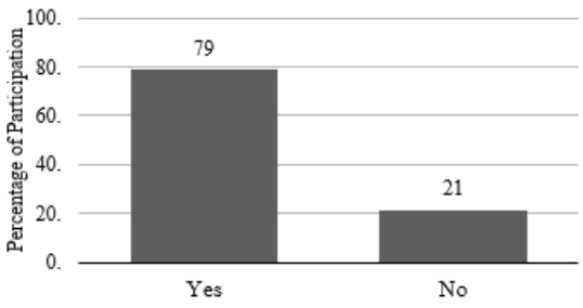


Figure 10. Benefits of implementing AI

3. CONCLUSION

Based on the opinions of the respondents, a few insights can be depicted, such as the primary application of AI in hiring function lies in social candidate discovery (It is a tool where it screens the digital behavior of the job applicant and decides whether the application is selected/rejected as per the requirement), job market forecasting and filtering the resumes with the help of tools powered by AI. Respondents also stated that the potential drawback of AI lies in lack of reliability as it can only identify a few trained patterns but cannot exceed beyond the instructions coded. In addition to this, the potential barrier to adopting AI is a lack of relevant skills in understanding the usage and format to resolve various complex issues. In other words, for some organizations, it is even more critical to feed quality data consistently. It is highly recommended to use AI in talent sourcing. It will reduce the cost of hiring process, recruitment

will be unbiased and the skilled persons can be found out in a fraction of seconds based on the job descriptions.

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Jellyfish search algorithm for economic load dispatch under the considerations of prohibited operation zones, load demand variations, and renewable energy sources

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ABSTRACT

This paper suggests a modified version of the former economic load dispatch (MELD) problem with the integration of wind power plant (WPP) and solar power plants (SPP) into thermal units (Tus). The target of the whole study is to cut the total producing electricity cost (TPEC) as much as possible. Three meta-heuristic algorithms, including particle swarm optimization (PSO), jellyfish search (JS) and salp swarm algorithm (SSA), are applied to solve the MELD. The real performance of these optimization tools is tested on the first system with six thermal units considering prohibited zones, and the second system with the combination of the first system and one solar, and two WPPs. In addition, the variation of load demand in 24 hours per day is also taken into account in the second system. JS is proved to be the most effective method for dealing with MELD. Furthermore, JS can also reach lower or the same TPEC as other previous algorithms. Hence, JS is a recommended to be a strong computing method for dealing with the MELD problem.

Keywords: Jellyfish search Load variation Modified economic load dispatch Solar power plant Thermal unit Wind power plant

1. INTRODUCTION

The economic load dispatch (ELD) problem is one of the most considered problems in power system operation. The determination of the optimal solution to ELD not only reduces the total producing electricity cost but also mitigates the environmental damage [1]. Most of the early studies only focused on solving ELD with fixed load demand. In addition, the thermal power plant is the only generating source. Recently, the former ELD problem has been modified to different versions under the name of the modified economic load dispatch problem (MELD), where renewable energy sources and load demand variation are evaluated [2]. Cutting the total producing electricity cost (TPEC) of thermal power plants is mostly considered while solving ELD problems. Besides, wind and solar energies have contributions to significant reduction of TPEC. These sources can partly support thermal sources to serve load demand at peak times [3], [4]. While environmental problems are on high alert, the use of renewable energy sources (RES) is attracted more attentions than ever. By fully aware of the current trend, this study presents a solution of using RES by solving MELD considering the presence of both wind and solar energies.

Currently, meta-heuristic algorithms are acknowledged to be the most effective computing methods to cope with a wide range of optimization problems. ELD and MELD are not exception because they are both classified the optimization problems. There were a lot of researches solving ELD by applying meta-heuristic methods such as hybrid grey wolf optimizer (HGWO) [5], distributed roust optimization

(DRO) [6], particle swarm optimization and its improved versions [7]–[9], evolutionary algorithm (EA) [10], tunicate swarm optimizer (TSO) [11], marine predator optimization algorithm (MPOA) [12], k-mean cluster and elbow technique (KMC-ET) [13], a selection of Hyper-heuristic [14], equilibrium optimizer algorithm (EOA) [15], modified social spider optimization (MSSO) [16], ameliorated dragonfly algorithm (ADA) [17], improved jaya algorithm [18], marine predator algorithm [19], modified equilibrium algorithms (MEA) [20], coyote optimization algorithm (COA) [21], harmonic search algorithm (HSA) [22], hybrid swarm intelligence-based HSA (HIS-HAS) [23], squirrel search optimizer (SSO) [24], and improved firefly algorithm (IFA) [25]. The studies have applied different algorithms, such as original and improved versions of metaheuristic algorithms. However, some of these studies have irnorged the comparisons between improved and original versions. Other studies have not coped with the shortcoming, but they have neglected the fair comparison criteria such as settings of iterations and population. On the other hand, almost all previous studies only focused on thermal power plants rather than the integration of renewable energies to ther conventional power source.

In this study, we implement particle swarm optimization (PSO) [26], jellyfish search algorithm (JS) [27], and salp swarm optimization (SSA) [28] to search the optimal solutions of ELD and MELD problems. In ELD problem, the constraint about prohibited operation zone (POZ) of thermal power plants is taken into account to investigate the outstanding performance of applied methods. In MELD problem, two wind and one solar power plants are integrated with the first power system. Alongside with that, the variation of load demand over 24 hours is also taken into account. Finally, the study focuses on reaching the smallest values of TPEC as the main objective function. The main contributions of the entire study can be summarized,

− Apply successfully a novel meta-heuristic algorithm, named jellyfish search algorithm (JS) to determine the optimal solutions for both original and modified version of ELD problem.

− Prove the effectiveness of JS over two remaining methods, including PSO and SSA and other methods from previous studies.

− The variation of load demand within a day and the presence of both solar and wind power are successfully implemented.

In addition to the introduction, other sections of the study are organized: Section 2 describes the main objective function and all involved constraints. Section 3 introduces the applied method. Section 4 presents the results and discussion obtained by the applied methods in different case studies. Finally, the conclusions are revealed in section 5.

2. METHOD

2.1. Objective function

The study considers the generation cost from thermal power plants due to the high fuel cost from the plants, especially for hours with high generation, while generation from renewable energies power plants is the base supply. The fuel cost for each Megawatt (MW) is different for different power generation values.

Normally, each MW of high-power generation cost more fuel than that of low power generation. However, it is very difficult to determine the most suitable power generation for the lowest cost of one MW. So, the use ofmetaheuristic algorithms for finding the generation is key task of the study, and the duty of the applied metaheuristic algorithms is to reach the following objective function,

$$Cutting\ TPEC = \sum_{n=1}^{N_T} \delta_n + \gamma_n TG_n + \beta_n TG_n^2 \quad (1)$$

where N_T is the number of thermal power plants; δ_n, γ_n, and β_n are coefficient of thermal power plant; and TG_n is the power output produced by the nth thermal power plant.

2.2. Constraints

Power balance constraint: Total generation by thermal, wind and solar power plants is supplied to demand of load over operation time. On the other hand, a small part of the transmission power through transmission lines with resistance and reactance is lossed. These power plants must compensate the loss so that load demand is fully supplied. Hence, the total generation (generation from wind, solar and thermal power plants), the loss on transmission lines and the load demand must exactly like the (2),

$$\sum_{n=1}^{N_T} TG_n + PW + PSr - (PRD + PL) = 0 \quad (2)$$

where *PW* and *Psr* are the power outputs of wind and solar power plants; *PRD* and *PL* are demand and loss.

Generation and prohibited operation zone limits: Power output of each thermal power plant must satisfy the constraints,

$$TG_{n,min} \leq TG_n \leq TG_{n,max} \quad (3)$$

$$TG_n \in \begin{cases} TG_{n,min} \leq TG_n \leq TG_{n1}^l \\ TG_{nk-1}^u \leq TG_n \leq TG_{nk}^l ; k = 2, \dots, z \\ TG_{nz}^u \leq TG_n \leq TG_{n,max} \end{cases} \quad (4)$$

In (3) and (4), $TG_{n,min}$ and $TG_{n,max}$ are the lower and upper limits of thermal power plant n. z is the number of prohibited operation zones belonging to the thermal power plant i. The illustration of prohibited operation zones is given in Figure 1.

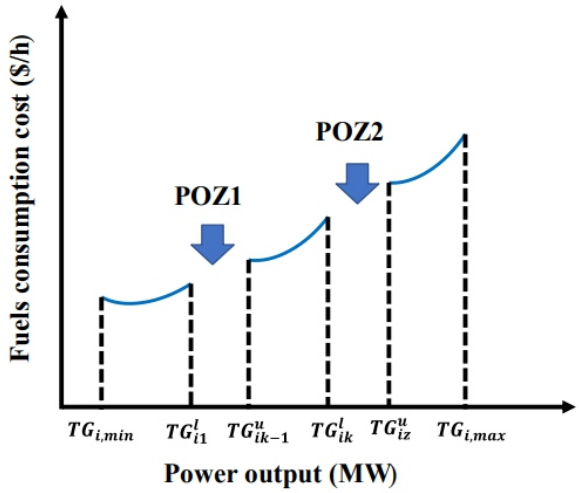

Figure 1. The illustration of prohibited zone operation (POZ)

Generation constraints of solar power plants (SPPs): All SPPs must satisfy the general and individual constraints [21],

$$\sum_{q}^{N_{SL}} PSr \leq 80\% \times PRD \quad (5)$$

$$PSr_q^{min} \leq \left|PSr_q\right| \leq PSr_q^{max} \quad (6)$$

where $\sum_{q}^{N_{SL}} PSr$ is the total power output generated by solar power plant; PSr_q is power produced by solar power plant q; PSr_q^{min} and PSr_q^{max} are the minimum and maximum power output supplied by solar power plant z.

3. THE COMPUTING METHOD

The jellyfish search algorithm (JS) is a meta-heuristic algorithm proposed in 2021 [27]. The algorithm has two methods to generate new solutions. The first method uses only one model, but the second method uses two models based on comparison conditions. These methods are expressed in (7) and (8),

$$X_k^{new} = X_k + 0.1 \times Rnd(UB_k - LB_k)\ with\ k = 1 \ldots N_{pop} \quad (7)$$

$$X_k^{new} = \begin{cases} X_k + Rnd \times DF\ , \text{if}\ Rand \leq (1 - SE) \\ LB_k + 0.1 \times Rnd \times (UB_k - LB_k), \text{otherwise} \end{cases} \quad (8)$$

where, X_k^{new} and X_k are the old and new solution k; Rnd is the random value in the interval of 0 and 1; UB_k and LB_k are the upper and lower boundaries of solution k; DF is a step size and determined by:

$$DF = \begin{cases} X_q - X_k\ if\ F_q - F_k \\ X_k - X_q\ if\ F_k - F_q \end{cases} \quad (9)$$

where Xq and Fq are a randomly chosen solution and its fitness function; and Fk is fitness function solution k.

Note that, the determination of which method will be applied is dependent on the select factor (SE). If the SE is equal or greater than 0.5, Method 1 will be selected, otherwise Method 2 will be executed. The factor SE is a function of randomization factor, maximum iteration and current iteration obtained by,

$$SE = 1 - \left(M \times \frac{1}{M^{Max}}\right) \times (2 \times rand - 1) \quad (10)$$

4. RESULTS AND DISCUSSIONS

In this section, we apply three meta-heuristic algorithms including particle swarm optimization (PSO) [26], jellyfish search algorithm (JS) [27] and salp swarm algorithm (SSA) [28] to determine the optimal results of for two systems. This work is conducted on a personal computer with a 2.2 GHz central processing unit alongside 8GB of random memory access. Coding and simulation are implemented using MATLAB software version R2018a.

4.1. The conventional ELD with fixed load demand

In this subsection, the power system, including six thermal power plants with prohibited operation zones, must fulfill a fixed load demand of 1263 MW. All data of thermal power plants and boundaries of prohibited operation zones are cited from [22]. Three applied meta-heuristic methods are applied to reach the minimum TPEC while satisfying the load demand and all related constraints of the conventional ELD problem. The initial parameters of these methods regarding population size, the maximum number of iterations, and the number of independent runs are 10, 50, and 100, respectively.

Figure 2 presents the detail and summary of 100 runs by implementing three applied algorithms. The curves in Figure 2(a) describes the results of PSO, while the blue and black ones illustrate the costs of

SSA and JS. PSO is the most unstable method, while JS proves itself to be the most reliable method among the three applied ones. Figure 2(b) shows four comaprison criteria, including the minimum cost (Min.cost), mean cost (Mean.cost), maximum cost (Max.cost), and standard of deviation (std). The summary of fifty costs indicates that JS has smaller minimum, mean and maximum costs, and more stability than PSO and SSA excluding the same minimum cost as SSA. As a result, JS is the highest performance method.

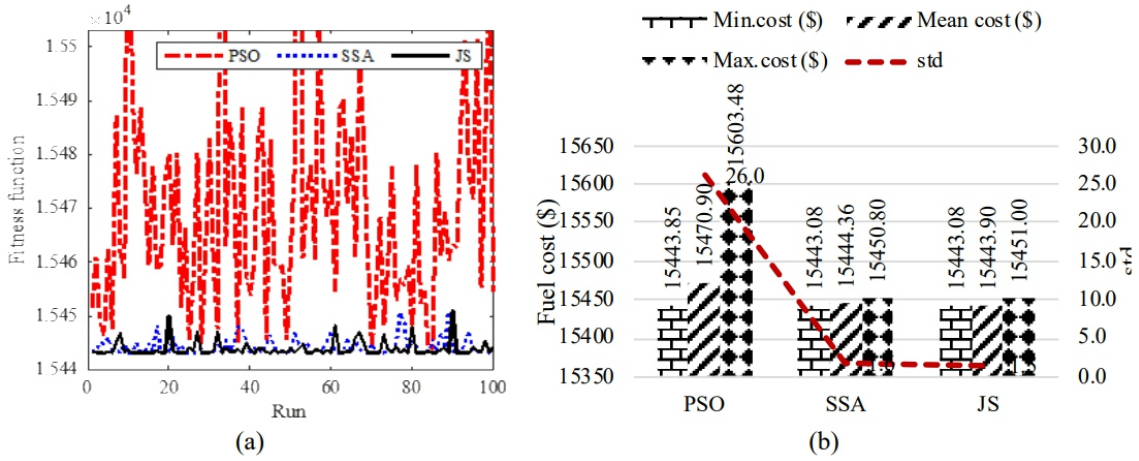

Figure 2. Results obtained by applied methods for 100 runs: (a) the fitness function of 100 implemented runs and (b) summary of minimum fuel, maximum fuel cost, mean fuel cost and standard deviation from 100 implemented runs

The search processes of three applied algorithms are summarized in Figure 3. Figures 3(a)-3©, respectively, show the best, mean and worst convergence processes of 100 tria runs. JS provides the fastest response capability in all comparisons. Specifically, this method only requires over 35 iterations to reach the optimal value for the best convergence. SSA needs approximately 40 iterations to reach the same solution as JS, while PSO cannot achieve the optimal result for the best run. In terms of the mean and the worst convergences, JS is still the fastest method while PSO is the lowest one.

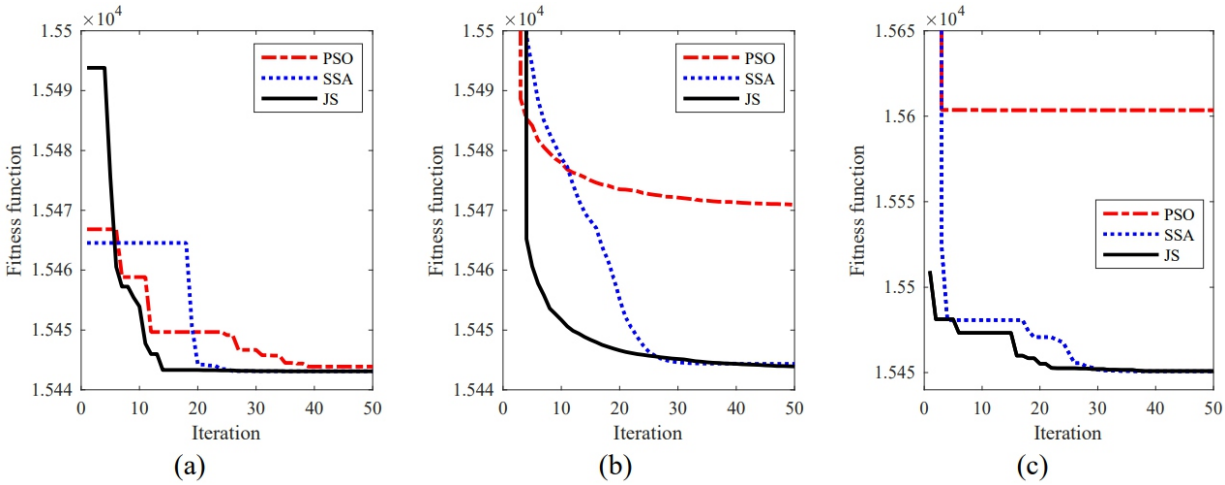

Figure 3. The convergences charactersitics: (a) the best run, (b) the mean run, and (c) the worst run

To see the effectiveness of JS, the results of JS are compared with other methods from previous studies as described in Table 1. The minimum cost comparison indicate that JS can reach the same cost as IFA

[25] and smaller cost than HSA [22]. HIS and SSO reported smaller cost than others; however, the methods have used slightly different loss coefficients as reported in the original method [22]. As using the same coefficients as [23], [24], JS can reach a little bit smaller than HSA and HIS as seeing the results with the * in the table. So, JS is really effective as compared to previous methods.

Table 1. The comparison of JS and other method

Method	Min.cost ($/h)	Mean.cost ($/h)	Max.cost ($/h)	std	N_{pop}	Iterations
HSA [22]	15449	15450	15453	-	-	-
HIS-HAS [23]	15442.8423	15446.7142	-	1.8275	30	200
SSO [24]	15442.4	15442.6	-	0.0352	20	100
IFA [25]	15443.075	15443.12	15443.52	-	55	30
JS	15443.075	15443.90	15451.00	1.5	10	50
JS	15442.378*	15442.705*	15444.505*	0.87	10	50

Note that * mean JS is run by using the same system data as [23], [24]

4.2. The MELD with load demand variation

In this section, JS is reapplied to determine the optimal results of the MELD problem. In the second system, six thermal units in System 1 are integrated to two wind power plants (WPP) and one solar power plant. The system is optimally scheduled over 24 hours with different load values. All data of wind and solar plants are taken from [29] and [30], respectively.

Figure 4 shows results obtained by the three applied algorithms for the system. Figure 4(a) presentes the results obtained by the three applied methods after 100 independent runs. Throughout 100 runs, JS can reach more optimal results than both SSA and PSO. In addition, Figure 4(b) indicates that JS is the most effective method while PSO is the worst one. The effectiveness of PSO, SSA and JS is clearly shown in Figure 4(b). In the figure, four comaprison criteria, including Min.cost, mean cost, Max.cost, and std are given. It is easy to acknowledge that, JS reaches much better results than two others. Specifically, the Min.cost and std values given by JS are 269814.1 ($) and 7.5, while those of SSA and PSO are ($269843.7 and 21.3) and ($269951 and 120.4). The comparisons reveal that JS has advantages over SSA and PSO in terms of strong search process and high stability. So, JS should be used for the MELD problem on behalf of PSO and SSA.

Figure 5 reports the generation of all thermal power plants and renewable energy plants in addition to hourly cost from six thermal units. The generation height of plants indicates that thermal units 1 and 6 are, respectively, the most effective and ineffective since unit 1 account for the highest generation but unit 6 just produce a small power. At hours with high load demand, cost is much higher than others, but the cost is much dependent on wind and solar power plants.

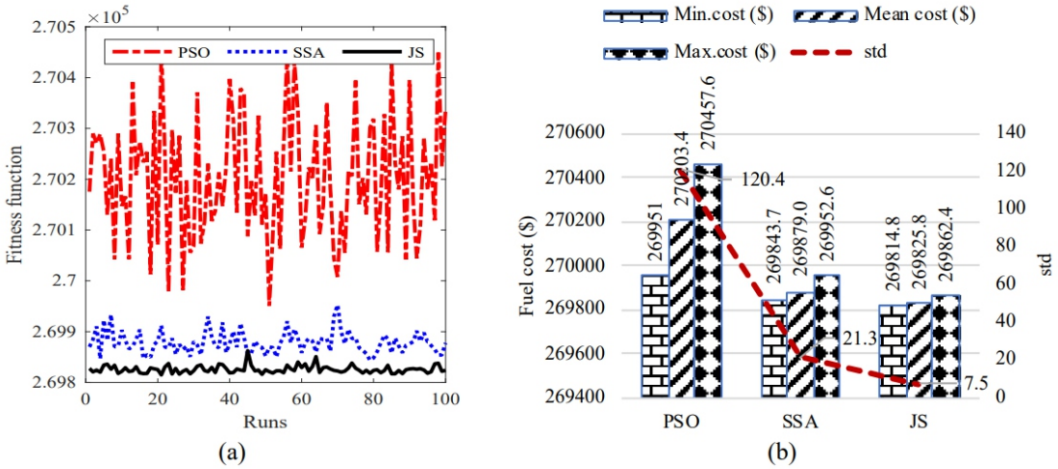

Figure 4. Results obtained by the three applied algorithms (a) the fitness function of 100 runs, and (b) the

fuel cost comparison summary from 100 trial runs

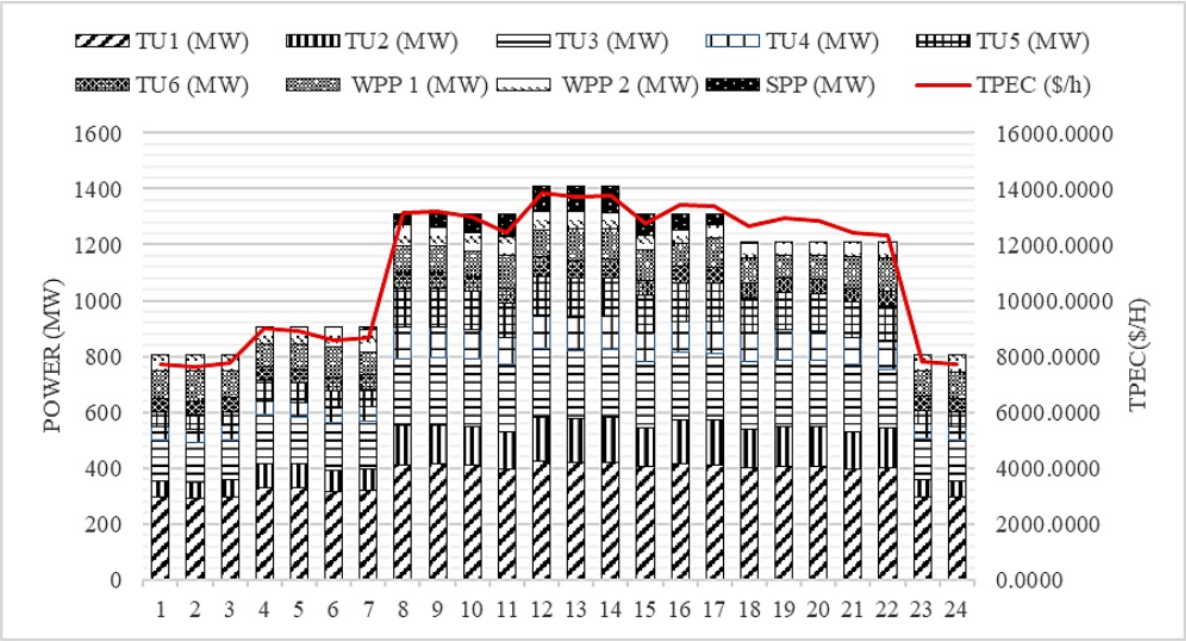

Figure 5. Optimal generation of power plants and hourly cost of all thermal power plants obtained by JS

5. CONCLUSIONS

In this study, three meta-heuristic algorithms, including PSO, SSA and JS, were successfully applied to solve both the original and modified version of the ELD problem with renewable energies and one working day. During the whole process of finding the optimal value of TPEC, different states of load demand are considered, including fixed and varied load demands. Besides, the prohibited operation zones and the presence of wind and solar power plants are also taken into account. JS proved it was the most effective method. Besides, while compared with other previous methods, JS also showed its high performance by reaching the same or better cost but using less population size and iterations. Therefore, JS is considered the most powerful search tool, and it is highly recommended for solving MELD problems. In future work, JS will be modified to improve their raw performance for dealing with higher-degree complex problems. In addition, the MELD problem should also be expanded by the consideration of large-scale power systems with various generating sources, more complicated constraints such as multiple fuels, ramp-rate and valve point effect constraints.

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Sentence embedding to improve rumour detection performance model

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ABSTRACT

Recently, most individuals have preferred accessing the most recent news via social media platforms like Twitter as their primary source of information. Moreover, Twitter enables users to post and distribute tweets quickly and unsupervised. As a result, Twitter has become a popular platform for disseminating false information, such as rumours. These rumours were then propagated as accurate and influenced public opinion and decision-making. The issue will arise when a decision or policy with substantial consequences is made based on rumours. To avoid the negative impacts of rumours, several researchers have attempted to detect them automatically as early as feasible. Previous studies employed supervised learning methods to identify Twitter rumours and relied on feature extraction algorithms to extract tweet content and context elements. However, manually extracting features is time consuming and labour-intensive. To encode each tweet's sentence as a vector based on its contextual meaning, we proposed utilising Bidirectional Encoder Representation of Transformer (BERT) as a sentence embedding. We then used these vectors to train some classifier models to detect rumours. Finally, we compared the performance of BERT-based models to feature engineering based models. We discovered that the suggested BERT-based model improved all parameters by around 10% compared to the feature engineeringbased classification model.

Keywords:Bidirectional encoder representation of transformer Feature extraction Rumour detection Sentence embedding Text classification

1. INTRODUCTION

Much false information spread worldwide swiftly due to the difficulty of proper control on social media platforms like Twitter. People often post and distribute breaking news without verifying its accuracy, leading to the widespread sharing of captivating but deceptive content. Consequently, such content may be shared thousands of times, despite containing misleading information. The most prevalent phrase for false information on the Internet is a rumour. A rumour appears to be a credible story, yet it is not easy to confirm. The rumours are of dubious veracity and provoke concern or skepticism among the audience [1], [2]. A characteristic of a rumour is difficult to confirm because it may be accurate, partially true, false, or unsubstantiated [3]. This study focuses on rumours transmitted through the Twitter network.

After reviewing the existing literature, we found that most methods for detecting rumours on Twitter employ supervised learning algorithms that rely on extracting features. They extracted features from both content and context of tweets [1]–[5]. The context-based feature components include information about tweets' surroundings, such as user and network information [2]–[7]. The content-based feature involves extracting features from the text of tweets, especially those related to language, like lexical, syntactic, and semantic features [6]–[9]. Unfortunately, manual feature extraction is ineffective and time-consuming. Moreover, Twitter does not always provide the supplementary data necessary for feature extraction beyond the tweet's text [10].

In recent years, transfer learning with pre-trained language models, such as Bidirectional Encoder Representation from Transformer (BERT), has become a powerful technique in natural language processing (NLP) [11], [12]. This method employs an encoder to encode a sentence into an embedding vector using an attention mechanism [13] to derive a numeric representation of a text that enables a computer to comprehend the context and meaning of the text [11]. This study aims to enhance the performance of classifier models in identifying rumours on Twitter by proposing a novel model that utilises BERT and neural networks as sentence embedding and classifiers in detecting rumours on Twitter and comparing the model's performance between feature engineering-based vectors and sentence embedding-based vectors to detect rumour on Twitter.

The structure of the study is: Section 2 investigates previous attempts at detecting rumour, and section 3 details our suggested approach for utilising BERT to identify misleading tweet information. Then, section 4 presents our experimental results and compares them to recent studies. Lastly, in section 5, the study concludes with a summary of our findings.

2. LITERATURE REVIEW

The majority of previous research on fake information detection employed supervised computer models to classify tweets as rumour or non-rumour based on extracted content and contextual features [6], [7], [10]–[12]. Context-based techniques extract features by considering information about tweets, such as user and network data. Table 1 illustrates the context-based elements derived from tweets and the studies that employed them. The content-based techniques extract features from tweets, particularly language characteristics such as lexical, syntactic, and semantic characteristics that indicate how words were employed in a tweet. For example, previous research suggested that terms of ambiguity, denial, conciseness, and brevity may disclose the legitimacy of a tweet [1]. Table 2 depicts the content-based features and their application in the research.

Table 1. Contextual characteristics retrieved from tweets

Contextual-based features	
1. Verified account or not [4], [5]	6. Having over 500 followers [14]
2. Has a description or not [5]	7. Post on a day or weekday [4], [5]
3. Has a URL or not [4], [6]	8. Number of tweets [4], [5], [9]
4. Followers [4], [6], [9], [14]	9. Is it retweeted or not [4]–[6]
5. Number of friends [4], [6], [9]	

Table 2. List of tweet features based on their content

Text content-based features	
1. Hashtags [4]–[6], [9]	16. The number of smile emote [5], [6]
2.Words length [5], [6], [9]	17. The number of frown emote [5], [6]
3.Characters length [5], [6]	18. Number of sentiment (+) words [5]
4. Contains 100 top domain [2]	19. number of sentiment (-) words [4], [5]
5. Is it contains URL [4], [6]	20. Sentiment score [4], [5]
6. The number of URLs [4]–[6]	21. The number of 1st pronouns [5], [15]
7. Mention news agency [14]	22. The number of 2nd pronouns [5], [15]
8. The number of mention users [5], [6]	23. The number of 3rd pronouns [5], [15]
9. Contains stock symbol [2]	24.The number of temporal reference [15]
10. Contains numbers [14]	25.The number of lexical density [15]
11. Contains selected users [2]	26. Slang Terminology [14]
12. Uppercase [2], [6]	27. The number of intensifiers [14]
13. Question mark [5], [6]	28. Contains repeated characters [14]
14. Exclamation mark [2], [3], [5], [6]	29. Contains all uppercase word [14]
15. Contains multi '?' or '!' [2], [3], [6]	30. Title capitalisation [14]

Content-based or context-based manual extraction tasks to classify rumour tweets take a lot of time and are hard to do. For this reason, recent studies have used neural networks (NN) techniques to sort tweets about rumours. In the finding false information context, recurrent neural network-based (RNN) frameworks are used a lot [10], [16], [17] and convolutional neural networks (CNN) [18], [19]. Alkhodair et al. reported the recent performance of the RNN model for rumour detection, which got 71.6% and 83.9% F1 scores for the rumour and non-rumour classes, respectively [17]. The most recent CNN model for classifying rumours, presented by Bharti and Jindal et al. did the best job and got a weighted average F1-score of 0.84. [19].

Other researchers, like Ajao et al. [20], employed a hybrid framework using a combination of CNN and long short-term memory (LSTM) to automatically extract features from a Twitter post without any prior knowledge of the subject area or topic of discussion to identify fake news on Twitter. Their model achieved an accuracy of 82.29% for all classes but only a precision score of 44.35%. Other researchers, Kotteti et al. sought to improve the performance of supervised learning models in detecting rumours by reducing the time required for detection. To achieve this, they proposed a strategy that analyses multiple time-series data to utilise temporal aspects of tweets instead of relying on the content, which requires feature selection and text mining [9]. They used the Gaussian Naive Bayes classifier to implement their proposed approach, which made computations easier and achieved a high precision score of 94%. However, their method only scored 35.6% for recall and 51.8% for F1-score.

Xu et al. proposed a new algorithm for detecting fake news on Twitter called the topic-driven novel detection (TDRD) algorithm [21]. They were inspired by a communication theory that suggests the topic of a post can indicate whether it is likely to be spread as a rumour. The TDRD algorithm classified tweet topics and incorporated them into a deep-learning framework for rumour detection. The authors employed the CNN model, which achieved an accuracy of 82.66%, the highest among their experimental results.

BERT is a unique language model created by Google AI that uses a deep bidirectional transformer to extract information from unlabeled text. It combines both left and right context representations of a token from all layers to capture relationships between words and create a vector representation for each word based on its relationship with other words in the phrase [11]. This allows BERT to infer the meaning of a word from its surrounding context. For example, the vector for the word "apple" in the sentences "I got a new apple tablet" and "I have a fresh apple" would differ. BERT comes in two versions: BERT-Base, which has twelve transformer blocks, and BERT-Large, which has twenty-four transformer blocks. This study used BERT-Base, resulting in 768 vector arrays for each sentence.

3. MATERIAL AND METHOD

The model proposed in this study involves several steps for detecting rumours using BERT. Firstly, BERT is used to generate sentence embeddings that represent each tweet as a vector based on its contextual meaning and linguistic patterns. Next, these vectors are utilised for training different classifier models for rumour detection. Finally, the results obtained from the proposed BERT-based method are compared with those obtained using traditional feature engineering techniques. Figure 1 illustrates the overall process of the proposed rumour classification model that uses BERT's sentence embeddings.

Figure 1 The steps of the proposed model for rumour detection using BERT

3.1. Dataset

Due to the complexities of data collection procedures, there are few publicly available datasets on rumour classification [1]. Therefore, to validate our models, we obtained datasets from the PHEME project [5], which is considered a benchmark and publicly accessible over the Internet. This dataset contains rumour-tagged (1,969 tweets) and non-rumour-tagged (3,822 tweets). We allocate 70% of each dataset class for training and 30% for testing.

3.2. Classifier model

We trained different supervised-classifier models and a simple neural network model (MLP) using BERT-embedded and feature-based vectors from tweet text and then compared their results. An MLP is made up of a layer for receiving signals, a layer for making predictions, and any number of hidden layers that work as the MLP's computing engine [22]. We used some supervised learning approaches that are widely known as eminent methods in text classification [23]. Those supervised models included support vector machines (SVM), logistic regression (LR), Naive Bayes classifier (NBC), AdaBoost, and k-nearest neighbors are some of the supervised classifier models (KNN).

3.3. Evaluation model

We evaluated our model using a confusion matrix and the following formulas to calculate its Accuracy, Precision, Recall, and F1 scores. The confusion matrix measures the performance of a model by comparing its predictions against the actual outcomes. The four key metrics derived from the confusion matrix are,

– True-positive (TP) : Tweets that are correctly predicted as non- rumour tweets.
– False-negative (FN) : Rumour tweets that are wrongly identified as non-rumour tweets.
– False-positive (FP) : Non-rumour tweets that are wrongly identified as rumour tweets.
– True-negative (TN) : Non-rumour tweets that are correctly predicted as non-rumour tweets.

$$\text{Accuracy (A)} = \frac{TP+TN}{TP+TN+FP+FN} \quad (1)$$

$$\text{Precision (P)} = \frac{TP}{TP+FP} \quad (2)$$

$$\text{Recall (R)} = \frac{TP}{TP+FN} \quad (3)$$

$$F1 = \frac{2 \text{ x (Precision x Recall)}}{\text{Precision+Recall}} \quad (4)$$

3.4. Experiment steps

By utilising SKlearn [24] and PyTorch [25], a well-known library for machine learning and deep learning tasks, we experimented with feature engineering-based techniques and sentence embedding using BERT to recognise a rumour tweet and compare these approaches' performance. Figure 2 shows our procedures in our experiment to discriminate between rumour and non-rumour tweets. First, we preprocessed and tokenised the tweets using BERT to provide the tokenised form of the tweets for the

proposed approach. The tokenised sentences were then transformed into vectors using BERT-base and Sentence Transformer. Finally, the vectors mentioned at the second step were employed for model training, which encompassed algorithms such as AdaBoost, k-nearest neighbors, support vector machines (SVM), logistic regression (LR), Naive Bayes classification (NBC), and a four layers perceptron (4L-MLP).

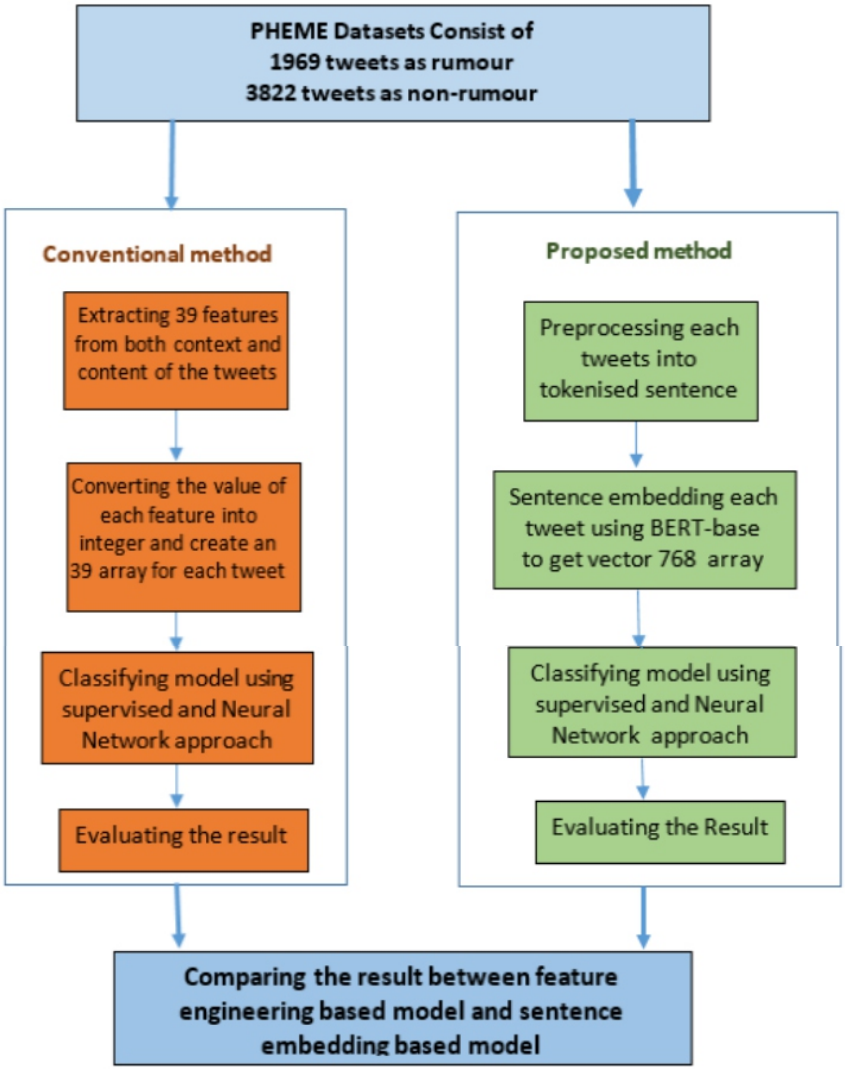

Figure 2. The experiment steps to detect rumour

In addition, we employ the feature engineering technique by extracting 39 characteristics from the context and content of tweets, as shown in Tables 1 and 2. Then, we transform the values of those features to integer data types and generate a 39-element array of features for each tweet. Finally, we used these vectors to train and compare all the similar models we trained with BERT-embedding vectors and evaluate the performance result using (1) to (4).

4. RESULT

We analysed and compared the performance of these classifier models by examining and comparing their confusion matrices. The confusion matrix for each model's prediction outcomes is depicted in Table 3. We evaluated the performance of each classifier model based on the predictions in Table 3. Table

4 compares the performance of classifier models based on BERT and classifier models based on feature engineering, revealing that BERT-based classifier models perform better than feature engineering-based classifier models for all parameters. Each model's accuracy and precision improved by approximately 10% on average by employing BERT vectors. In addition, a basic neural network utilising 4-MLP earned the best performance across all classes. These findings provide a positive outlook on the use of BERT sentence embedding as a viable approach for identifying rumour tweets, as it has shown the ability to minimise the effort needed for rumour detection by eliminating the need for text feature extraction. In simpler terms, the suggested technique has demonstrated its potential in streamlining the process of identifying rumours in tweets.

Table 3. Confusion matrix result for each classifier model

Classifier	Approach	Prediction	Non-Rumours	Rumours
Support Vector Machine	BERT	Non-Rumours	1000	155
		Rumours	160	422
	39 Features	Non-Rumours	1035	332
		Rumours	125	245
Logistic Regression	BERT	Non-Rumours	1020	154
		Rumours	140	423
	39 Features	Non-Rumours	1037	332
		Rumours	123	245
Naive Bayes	BERT	Non-Rumours	835	131
		Rumours	325	446
	39 Features	Non-Rumours	645	129
		Rumours	515	448
ADA Boost	BERT	Non-Rumours	983	198
		Rumours	177	379
	39 Features	Non-Rumours	1001	296
		Rumours	159	281
K-Nearest Neighbor	BERT	Non-Rumours	989	108
		Rumours	171	469
	39 Features	Non-Rumours	914	260
		Rumours	246	317
4- layers MLP	BERT	Non-Rumours	1016	125
		Rumours	144	452
	39 Features	Non-Rumours	972	237
		Rumours	188	340

Table 4. Comparison results in rumour detection using BERT and feature engineering

Model	Dataset	All Classes				Non-Rumours			Rumours		
		Acc	Prec	Rec	F1	Prec	Rec	F1	Prec	Rec	F1
Support Vector Machine	BERT	81.9%	79.50%	79.7%	79.6%	86.6%	86.2%	86.4%	72.5%	73.0%	72.8%
	39 Features	73.7%	71.00%	65.8%	68.3%	75.7%	89.2%	81.9%	66.2%	42.5%	51.7%
	Improved	8.2%	8.6%	13.8%	11.3%	10.9%	-3.0%	4.5%	6.3%	30.7%	21.1%
Logistic Regression	BERT	83.1%	81.0%	80.6%	80.8%	86.9%	87.9%	87.4%	75.1%	73.3%	74.2%
	39 Features	73.8%	71.2%	65.9%	68.4%	75.7%	89.4%	82.0%	66.6%	42.5%	51.9%
	Improved	9.3%	9.8%	14.7%	12.4%	11.1%	-1.5%	5.4%	8.6%	30.8%	22.4%
Naive Bayes	BERT	73.7%	72.1%	74.6%	73.4%	86.4%	72.0%	78.6%	57.8%	77.3%	66.2%
	39 Features	62.9%	64.9%	66.6%	65.8%	83.3%	55.6%	66.7%	46.5%	77.6%	58.2%
	Improved	10.8%	7.2%	8.0%	7.6%	3.1%	16.4%	11.9%	11.3%	-0.3%	8.0%
ADA Boost	BERT	78.4%	75.7%	75.2%	75.5%	83.2%	84.7%	84.0%	68.2%	65.7%	66.9%
	39 Features	73.8%	70.5%	67.5%	69.0%	77.2%	86.3%	81.5%	63.9%	48.7%	55.3%
	Improved	4.6%	5.2%	7.7%	6.5%	6.1%	-1.6%	2.5%	4.3%	17.0%	11.6%
K-Nearest Neighbor	BERT	83.9%	81.7%	83.3%	82.5%	90.2%	85.3%	87.6%	73.3%	81.3%	77.1%
	39 Features	70.9%	67.1%	66.9%	67.0%	77.9%	78.8%	78.3%	56.3%	54.9%	55.6%
	Improved	13.1%	14.6%	16.4%	15.5%	12.3%	6.5%	9.3%	17.0%	26.3%	21.5%
4-Layers oMLP	BERT	84.5%	82.4%	83.0%	82.7%	89.0%	87.6%	88.3%	75.8%	78.3%	77.1%
	39 Features	75.5%	72.4%	71.4%	71.9%	80.4%	83.8%	82.1%	64.4%	58.9%	61.5%
	Improved	9.0%	10.0%	11.6%	10.8%	8.6%	3.8%	6.2%	11.4%	19.4%	15.5%

4.1. Comparison models

Using the PHEME dataset, previous researchers have employed several techniques to identify rumours on Twitter. These earlier works served as benchmarks against which we compared the results of our experiment. Table 5 compares our best model to the models from previous studies using the PHEME dataset. It demonstrates that our presented model outperforms existing classifier models and surpasses the current state of the art in regard to performance parameters.

Table 5. Comparison of our model to earlier studies on the PHEME dataset

Previous works on PHEME dataset	Method	Best Result			
		Accuracy (%)	Precision (%)	Recall (%)	F1 (%)
Zubiaga *et al*. [4]	Conditional random field (CRF) based on content and social features	NA	66.7	55.6	60.7
Hassan *et al*. [5]	Various supervised learning algorithms	78.4	79.6	91.9	85.2
Ajao *et al*. [20]	Combining CNN and LSTM models	82.29	44.35	NA	NA
Kotteti et al. [9]	using time series data to reduce time and supervised learning algorithms	NA	94.9	35.6	51.8
Alkhodair *et al*. [17]	Using word embedding and CNN	NA	72.8-R, 83.3-NR	70.6-R, 84.7-NR	79.5-all class 71.6-R, 83.9-NR,
Bharti and Jindal [19]	CNN	NA	79-R 87-NR	76-R 89-NR	77-R 88-NR
Xu *et al*. [21]	Topic-driven rumour detection (TDRD), by combining topic model and CNN	82.66	81.33-R, 83.14-NR	63.55-R, 92.49-NR	71.20-R, 87.55-NR
Our model	By using BERT as a sentence embedding and 4-layers MLP as a classifier	84.5	82.4-all 75.8-R 89.0-NR	83.0– all 78.3– R 87.6- NR	82.7– all 77.1– R 88.3- NR

*all: all class, R: rumour, NR: non-rumour

5. CONCLUSION

According to the findings of our experiment, it was discovered that sentence embedding vector utilisation significantly enhances the performance of all classifier models by 10% compared to feature extraction vectors. Moreover, by employing BERT's embedding vectors and four layers of MLP, we achieve the most optimal model performance, surpassing baseline models with accuracy, precision, recall, and F1 scores of 84.5%, 82.4%, 83.0%, and 82.7%, respectively. Therefore, we confidently suggest that sentence embedding using BERT is a promising technique for identifying rumours, eliminating the need for traditional feature extraction steps.

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