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IJRC

EDITORIAL NOTE

The launch of the first issue of the International Journal of Research in Computing (IJRC) marks a significant milestone in the Faculty of Computing, General Sir John Kotelawala Defence University. The overarching objectives of initiating this journal were to facilitate national and international researchers to publish their research in the field of Computing and to enhance the research strength of the Faculty of Computing, KDU, while giving the opportunity for local and international researchers to disseminate their scholarly work.

The editorial team of the IJRC expects that it would serve as a forum for the dissemination of high-quality research in a vast array of research areas in computing such as Artificial Intelligence, Machine Learning, Robotics and Automation, Image Processing and Computer Vision, Human Computer Interaction, Multi-Agent Systems, Big Data Analytics, Bioinformatics, Software Engineering, Communication Networks, Cyber Security, Internet of Things, Cloud Computing, e-Learning, Information Systems and Emerging Areas of Computing.

Each article in this volume is written as the outcome of high-quality research and this will contribute to the expansion of the literature in the field of computing for the benefit of future research. Furthermore, each article is blind-reviewed through three (3) expert reviewers in the respective research area and the best quality papers have been selected based on the recommendation of the eminent members of the editorial board.

Editorial team specially thank the Vice-Chancellor, current and former Deans of the Faculty of Computing for their encouragement and guidance to make this journal success .Furthermore, the editorial team wishes to express sincere appreciation to the chief advisor, editorial board, panel of reviewers, steering committee, editorial assistants, staff of the Faculty of Computing and academic staff of the Department of Languages and all the parties who actively contributed to the development of the web site, proof reading, graphic designing and publishing, for their contribution and authors of the articles.

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Sher-Locked: A Hybrid Deep Learning Model Based Mobile Platform for Social Media Fact-Checking

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ABSTRACT In the present context, false news can be easily constructed and circulated through various social media platforms. As a result, people on those platforms have difficulty in distinguishing between correct and incorrect information. Therefore, a firm desire appears to develop a fact-checking platform to address this issue. From this research study, the authors present 'Sher-Locked' which is a hybrid deep learning model based mobile platform to fact-check information on social media. The process of checking and verifying information is referred to as fact-checking. A hybrid deep learning model which is mainly focused on CNN and RNN-LSTM networks integrated with the mobile application to check and verify information on social media. The high-level characteristics and interdependencies among the input text capture from the hybrid model. The mobile application consists of several features such as fact-checking, daily news updates, news reporting, social media trends and daily COVID-19 reports. Flutter chose as the mobile application development framework along with Firebase as the backend development framework with REST APIs to develop the entire system. When checking and verifying the information mitigating on social media, the hybrid model achieved a 92% accuracy by surpassing most of the traditional models today with 91% score rates for Precision, Recall and F1-Score. After delivering the mobile app as a complete system to various users for testing, the authors discovered that the user satisfaction and usability rates are high when compared to other related software.

KEYWORDS: Deep Learning, Fact-Checking, Fake News Detection, Hybrid Approach

I INTRODUCTION

Nowadays, social media is used by almost half of the population worldwide. As a result, people are shifting away from conventional news media and moving towards new social media platforms. Furthermore, by surfing through social media news feeds people can get to know about what is going on around the globe. Because of the openness and clarity afforded by such social media platforms, at any moment anybody can assert anything that results in the development and dissemination of misleading information via social media platforms. As a result, people on those platforms have a challenging time distinguishing between correct and incorrect information.

Most Sri Lankans are unable to recognize misleading content in their social media posts because of the limited number of verified accounts to check the content. As a result, most of them share the posts and articles except confirming them and this points to propagating false information via social media platforms. As an example, During the 2019 Easter Sunday attacks in Sri Lanka, the authorit-

ies chose to restrict the social media access because of misinformation and hoax propagating rapidly on social media that drives misunderstandings between people and religions [2]. Not only that, but before the 2019 Sri Lankan presidential election, a lot of misleading information was generated and distributed via social media platforms to influence people's perceptions and attitudes [3]. Following figure 1 represents the social media ban related news headline in Sri Lanka in 2019.

There have been numerous scenarios recorded from various countries that related to the propagation of misinformation. During the 2016 US presidential election, "Pizzagate" false news was rapidly propagated on Twitter, resulting in over one million tweets [4], and for insulting a Quran statement during the 2016 Jakarta gubernatorial campaign, governor Ahok was convicted to two years in jail [5]. Following figure 2 represents the above incident.

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[1] This paper is an extended version of the paper "SherLock: A CNN, RNN-LSTM based Mobile Platform for Fact-Checking on Social Media" [1] presented at the 13th International Research Conference of General Sir John Kotelawala Defence University.

Figure 1 : Social media ban in Sri Lanka in 2019
Source: https://images.app.goo.gl/ydmFT2pdZLrxghgm8

Figure 2 : Gubernatorial campaign in Jakarta in 2016
Source :
https://images.app.goo.gl/H3wG2iEg8YmurCB37

As per the above, these incidents have evidently demonstrated that a firm desire appears to develop a fact-checking platform to address these issues. Following figure 3 represents the problem statement related to a false message received via WhatsApp.

From this research study, the authors present 'SherLocked' which is a hybrid deep learning model based mobile platform to fact-check information on social media including other functionalities such as fact-checking, social media news trends, news reporting, daily news updates and daily COVID-19 reports etc. This is the final version of the mobile application called 'SherLock' [6] developed by the authors.

The primary goal of this research work is to reduce the effort and time to verify the legitimacy and trustworthiness of social media posts utilizing contemporary technology primarily for social media users and traditional media consumers.
The remainder of the paper is formed in this way. Section II depicts the related works and tools with a comprehensive review and Section III enhances the design and implement-

Figure 3 : False message received via WhatsApp

ation of the system. After that, Section IV demonstrates the technologies that are adopted to develop the system. Furthermore, Section V describes how the mobile app works and Section VI comprises of evaluation and testing of the system. Finally, Section VII represents the conclusion and future work of the research study.

II LITERATURE REVIEW

A substantial number of researchers have investigated this area and developed some tools to overcome this problem. Hoaxy [7] is a website that collects and tracks misinformation. The misinformation that is captured from Hoaxy can be visualized using technologies such as web scraping, Twitter API, web syndication and RSS parser. By the use of deep learning methods such as LSTM and autoencoder FakeNewsTracker [8] gathers and visualizes false news on social media.

A tool called 'dEFEND' has been developed using the Hoaxy API to form a news dissemination network that includes the latest popular news and top assertions. That tool can provide further explanation for Twitter user remarks as well. News Verify [9] was created to identify the trustworthiness of news by utilizing techniques such as sentiment analysis, feature extraction and web crawling etc.

The authors of [10] created a 'B.S. Detector' plugin for both Mozilla and Chrome browsers that checks untrustworthy sources against a personally curated list of domains. A deep learning network that consists of several methods such as word2vec, CNN, feature extraction and word embeddings is applied in Fake News pattern Detector [11] to identify patterns in false news. An LSTM-RNN model is used in TRACEMINER [12] to afford good accuracy.

Software	Filter Fake News Articles	Send Alerts about Fake News and Breaking News	Check credibility and validity of social media posts	Add a crowdsource fact-checker	Leverage app usage statistics for users
Oigetit	✓	✗	✗	✗	✗
WatchDog	✗	✓	✗	✗	✗
Fact-Bounty	✗	✗	✗	✓	✓
Listle	✗	✓	✗	✗	✗
SherLock	✓	✓	✓	✓	✓

Figure 4 : Comparison of features in related software

Following are some of the existing research works that are carried out in this false news detection area.

Based on machine learning methods and n-gram analysis in [13] authors presented a false news detection algorithm. Six alternative machine learning algorithms were explored and compared by the authors, namely, Linear Support Vector Machines (LSTM), Stochastic Gradient Descent (SGD), Support Vector Machines (SVM), Decision Trees (DT), K-Nearest Neighbour (KNN) and two various feature extraction methods, namely, Term Frequency-Inverted Document Frequency (TF-IDF) and Term Frequency (TF). To describe the context of the document and create characteristics to categorize it, a word-based n-gram is utilized. In the data pre-processing steps authors performed some modifications such as tokenization, stop-word removal, punctuation removal, sentence segmentation and a lower casing to minimize the size of real data and eliminate the useless information. The authors looked for the false news dataset on Kaggle.com [14] and for real news items, real news sources as Reuters.com [15] explored. Furthermore, using the dataset Horne and Adali [16] the authors evaluated their model. The authors also examined the dataset known as the LIAR dataset [17]. Authors [18] conducted a review on media-rich false news identification and claimed that the majority of false news identification techniques are formed on feature extraction methods.

In [19], [20], [21], [22], [23] and [24] authors presented techniques which are formed on feature extraction methods. Linguistic features-based techniques, such as punctuation, n-grams, readability, psycho-linguistic aspects and syntax utilized to extract significant linguistic aspects from false news. Authors employed n-grams such as bigrams and unigrams to extract information from a group of words in a tale, and punctuation aids in distinguishing between genuine and false texts. LIWC lexicon approach

was utilized to choose optimal proportions. Furthermore, readability measures such as Flesch Reading Ease, Gunning Fog, Flesch-Kincaid and the Automatic Readability Index (ARI) were utilized to extract the content elements such as word count, complicated words and word kinds [25].

The syntax approach extracts Context-Free Grammar (CFG) based characteristics. Vector Space Modelling (VSM) and Rhetorical Structure Theory (RST) are utilized to model deceptions. RST is utilized to identify the logic of a tale in terms of functional matchings [26] and VSM is utilized to find rhetorical structure matchings of a text [27], [28]. RST-VSM approach outperformed similarity cluster analysis significantly. A vast amount of data was compared using Clustering-based approaches. Authors created GCLUTO (Graphical Clustering Toolkit) to distinguish news items based on their comparison using the Euclidean distances values and K-Nearest Neighbour approach. Predictive modelling-based strategies employed logistic regression model whereras content cues-based methods analyzed syntactic and pragmatic levels of analysis and lexical and semantic levels of analysis. Authors presented non-context-based approaches for manipulating emotions and understanding user behavior on social media, such as picture analysis and user-behavior analysis. Based on the study, authors presented various prominent datasets that utilize for false news identification such as [29], [30] and CREDBANK [31] etc. In their survey, the authors recommended various open research issues such as multi-model verification approach, multi-model dataset, author trustworthiness check and source verification. Authors [32] utilized linguistic analysis on tweets to generate a bag of words for pattern identification before applying K-Nearest Neighbour algorithms to assess reputable news sources.

The authors of the paper [33] outlined various approaches for combating false news. Recursive Trust Labelling (RTL) is a flexible learning algorithm that utilizes linguistic characteristics as well as a graph-based classifier with recursive labelling techniques. The authors achieved a high accuracy by employing Hidden Markov Models (HMMs) and characteristics such as n-grams and body text lexical measurements. The authors extracted statistics from Twitter's historical API and utilized Rumour Gauge to forecast the authenticity of rumours on Twitter.

The authors of the study [34] explored several deep learning mechanisms to identify false news. Authors investigated deep learning mechanisms such as Very Deep Convolutional Neural Network (VDCNN), Shallow Convolutional Neural Networks (CNN), Gated Recurrent Unit Network (GRU), Long Short-Term Memory Network (LSTM), Convolutional Neural Network with Gated Recurrent Unit (CNN-GRU) and Combination of Convo-

lutional Neural Network with Long Short-Term Memory (CNN-LSTM). When the authors utilized Convolutional Neural Networks (CNN) they achieved better accuracy. In addition, the authors investigated the efficacy of word2vec and word embeddings functions in Deep Neural Networks. Following are some of the available strategies for dealing with false news the majority of the time.

- Verified News Sources:- One of the methods to distinguish between false and authentic news items is to use verified news sources. This strategy makes it simple to distinguish between false and legitimate news reports on social media networks. ([35], [36])

- Fact-Checking Websites:- Focusing on the most recent news worldwide these websites provide rapid updates on the situations that are occurring throughout the world. These websites assist in distinguishing between true and fraudulent news on social media networks. ([37], [38])

- User Profile Based Approaches:- User-based techniques refer to how social context aids in distinguishing between false and true news items. Explicit profile elements such as status count, verified user accounts and follower count aid in determining whether or not a user account is false. [39]

- Google Reverse Image Search:- This reverse image search is used to submit a picture and manually examine incidents linked to that image, which aids in distinguishing between false and real photographs on social media sites. [40]

As described in the literature review a large number of researchers presented numerous techniques to form the research study. However, following the existing mechanisms, techniques and related works a CNN, RNN-LSTM based hybrid model was selected as the method to develop the main feature which is the fact-checking feature of the proposed mobile app. Because, as evidenced by similar studies, integrating many Deep Neural Networks yielded some highly accurate findings.

From the third chapter of the paper, the authors demonstrate the design and implementation of the suggested mobile app. The design and implementation chapter elaborates the high-level software architecture of the suggested system, the software process model of the suggested system and the walkthrough of the interfaces of the suggested system.

III DESIGN AND IMPLEMENTATION

A The High-Level Architecture of the System

A. The High-Level Software Architecture of the System The suggested system comprises various components including MVVM architecture which highlights the mobile application development pattern which is the model-view-view-model pattern. The mobile app is built on consists of various functionalities such as fact-checking, social media news trends, news reporting, daily news updates and daily COVID-19 reports. After that, the cloud database is developed by including a few crud operations for all the functionalities of the mobile app. To create the hybrid deep learning model REST APIs and web scraping methods are utilized to gather facts from various news items. Following that, the hybrid deep learning model is also kept in the exact cloud database.

Figure 5 depicts the high-level software architecture of the suggested system. As for the suggested system's front end built a mobile app with the aforementioned functionalities. Furthermore, the suggested system's backend employed a cloud-hosted database to keep the hybrid deep learning model.

B Software Process Model of the System

Dividing requirements into modules and smaller systems is the Incremental software process model [41]. As a result, the suggested system used an Incremental software process model.

Figure 6 depicts the software process model of the system. The first subsystem collects information to develop the deep learning model, and the second subsystem uses the hybrid deep learning model to check social media postings. The last subsystem makes use of the mobile app to check the status of the postings.

C Walkthrough of the Mobile App interfaces

The suggested mobile app comprises many interfaces such as registration screen, onboarding screen, home screen, login screen and other function-specific screens. However, just the screens of the main functionalities are included here.

Figure 7 demonstrates the latest global news interface. Based on the interests users can shift between various news categories. This function displays the most recent worldwide news classifying it as health, sports, entertainment, science and business. The user can get to know further information about particular news by clicking on the news article.
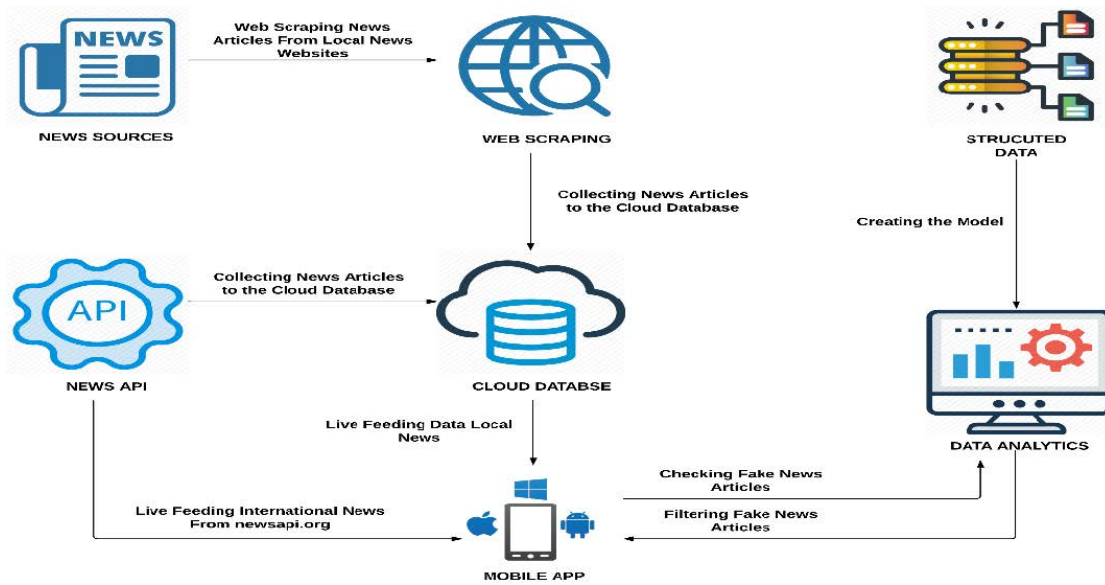
Figure 5 : The high-level architecture of the proposed system
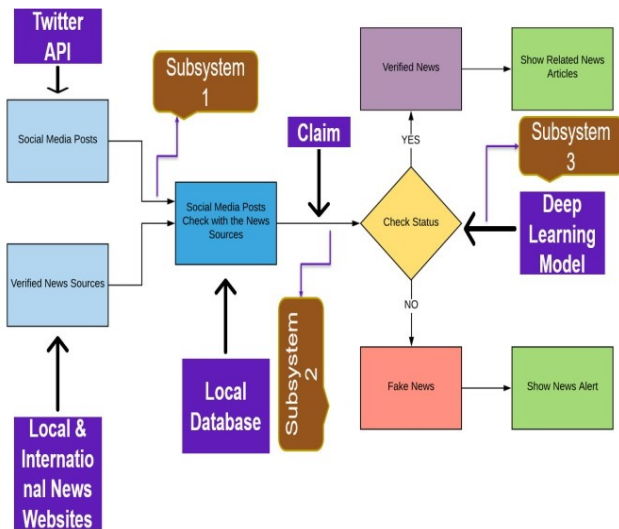
Figure 6 : The software process model of the proposed system

Figure 7 : The latest global news screen

Figure 8 depicts the newest fact-checking and Twitter trends. If the user wishes to learn further about certain news trends, they can follow the news story which takes them to a page with additional information about the trending news stories.

Figure 9 depicts the news reporting interface from which news reporters can submit news to the platform by giving accurate information such as the relevant photography of the news, the reporter's identity, the caption of the news and more details about the news.

Figure 10 demonstrates the latest COVID-19 updates in Sri Lanka and in Globe. Based on their preferred languages users can get to know more facts. The majority of the data consists of total fatalities, total local and global cases, total
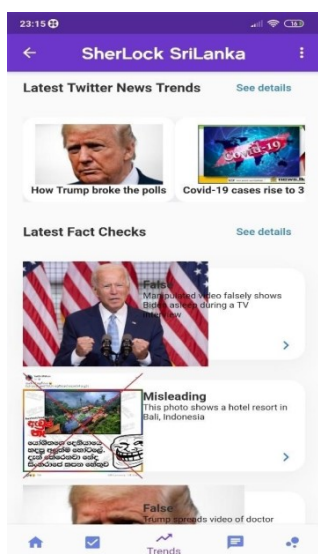
Figure 8 : Latest Twitter trending news screen

Figure 10 : COVID-19 updates using English language
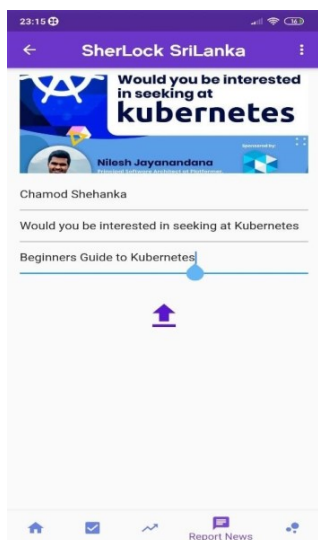
Figure 9: News reporting screen

Figure 11 : COVID-19 updates using Sinhala language

recovered and hospital statistics.

Figure 11 demonstrates the daily COVID-19 updates interface in the Sinhala language.

Figure 12 depicts the mobile application's key capability, which is the fact-checking of social network posts. Based on the text input by the user, the hybrid model determines whether the social media postings are authentic or fraudulent.

For example, if the user enters the message as in figure 16 the hybrid model checks and displays a message as confirmed news by highlighting the content in green. If the user enters a text as in figure 18 then the hybrid model flags it as a forgery by displaying the text in red. The CNN, RNN-

LSTM-based hybrid model is utilized in this interface to fact-check social media postings.

IV   TECHNOLOGY ADOPTED

A   Flutter

The purpose for utilizing Flutter [42] as the suggested mobile application's front-end framework is to create attractive, natively build mobile applications using a single codebase for both Android and IOS versions. The nicest thing about Flutter is that it is accessible easily with native APIs. In contrast to the existing frameworks, Flutter offers a rapid development approach by providing some basic interfaces.

Figure 12 : Fact-checking screen

B Firebase

The proposed application deals with a wide range of unstructured data types. As a result, Firebase [43] is used as the suggested system's back-end framework. Login screen utilized to authenticate users from Firebase Authentication. And to collect news reports Firebase Database is utilized. Then Firebase Storage is utilized to store illustrations of the news reports. Finally, to keep the hybrid deep learning model Firebase Machine Learning is adopted.

C Scrapy

Using the web scraping approach data are gathered from several news items prior to developing the hybrid deep learning model. For that, Scrapy [44] which is a free web scraper and web crawler is used.

D TensorFlow

TensorFlow [45] is utilized to develop the hybrid deep learning model while Python is chosen as the programming language. As it offers significant help for both front-end and back-end frameworks and as well as a diverse and vast ecosystem.

E GitHub

GitHub [46] is utilized to manage the project repository for the suggested system. GitHub Actions [47] is utilized to construct the CI/CD (Continuous Integration/Continuous Delivery) pipeline and publish the mobile app.

F IntelliJ IDEA

IntelliJ IDEA [48] is chosen as the IDE for developing the mobile app as it offers significant help for both front-end and back-end frameworks and as well.

G PyCharm

PyCharm [49] is chosen as the IDE for developing the data gathering process. Furthermore, Natural Language Processing methods such as Tokenization, Preprocessing and Word Embeddings are included. After completing the above steps build the hybrid model.

H Kaggle Kernels/Google Colab

Because of the amount of the dataset and the model's complexity, the hybrid deep learning model required additional processing resources to run. Following that, to execute the model Kaggle kernels

V HOW MOBILE APP WORKS

The suggested mobile app developed including various main functionalities such as fact-checking, social media news trends, news reporting, daily news updates and daily COVID-19 reports.

To begin, the user must register with the system by giving accurate information. All the functionalities of the mobile app can be accessed by the admin user. Other users can only access defined functionalities. From the target stakeholders, the news agency can access all the functionalities of the mobile app and other users like social media users, daily newsreaders and daily news reporters can access specific defined functionalities only. For example, daily news reporters can access the news reporting functionality, but the other secondary users cannot access that functionality. Role-based authorization is utilized to control the access for different user roles.

From the following subtopics, we demonstrated how the main functionalities such as fact-checking, social media news trends, news reporting, daily news updates and daily COVID-19 reports of the suggested mobile app works.

A Latest Global News Feature

The user gets to the homepage after providing the right details. Based on their interests users can shift between various news categories. This function displays the most recent worldwide news classifying it as health, sports, entertainment, science and business. The user can get to know further information about particular news by clicking on the news article. This function is accessible to all users. News API [52] is utilized to retrieve the latest news items to the mobile app through an endpoint.
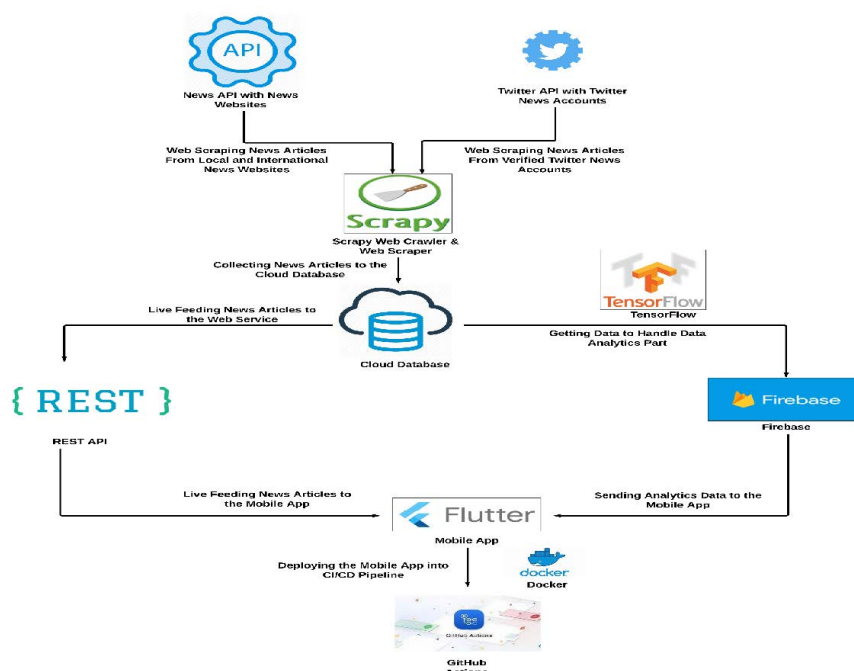
Figure 13 : The overall technology map of the system

B Fact-Checking Function

Using the bottom navigation bar the users can get to the fact-checking function where they can utilize the CNN, RNN-LSTM based hybrid model to fact check social media postings. The hybrid model determines whether it is legitimate or bogus news based on the user's inputs. For example, if the user enters the message as in figure 16 the hybrid model checks and displays a message as confirmed news by highlighting the content in green. If the user enters a text as in figure 18 then the hybrid model flags it as a forgery by displaying the text in red. By comprising various deep learning methods, the hybrid model achieves 92% accuracy. The high-level characteristics and interdependencies among the input text capture from the hybrid model. The following paper by the authors [53] provides further information regarding the CNN, RNN-LSTM hybrid model. This function is only available for social media users to reduce the effort and time to verify the legitimacy and trustworthiness of social media posts. TensorFlow is utilized to create the hybrid deep learning model followed by Firebase Machine Learning to keep the model and REST APIs [54] connect with the model when using the Flutter framework.

C Latest Fact-Checkings and Latest Twitter News Trends Function

All the users can access this function. The newest fact-checking and Twitter trends can be visible using this function. If the user wishes to learn further about certain news trends, they can follow the news story which takes them to a page with additional information about the trending news stories. To obtain the most recent Twitter trends Twitter API [55] is utilized and websites such as AFP-Fact Check is utilized to obtain the most recent fact checkings.

D News Reporting Function

Only the news reporters allow access to the news reporting function using the bottom navigation bar. News reporters can submit news to the platform by giving accurate information such as the relevant photography of the news, the reporter's identity, the caption of the news and more details about the news. Only news reporters can access this function. To collect news reports Firebase Database is utilized. Then Firebase Storage is utilized to store illustrations of the news reports.

E Daily COVID-19 Reports Function

The final function of the bottom navigation bar is daily COVID-19 reports. The latest COVID-19 updates in Sri Lanka and in Globe represents from this functionality. Based on their preferred languages users can get to know more facts. The majority of the data consists of total fatalities, total local and global cases, total recovered and hospital statistics. For all the local languages Localization is included. To retrieve the latest facts using the cloud-hosted database REST APIs are utilized. Furthermore, Localization for all the local languages is included using Google Translate.

VI EVALUATION AND TESTING

The entire project is carried out using the test-driven development process. To assure the functioning of the mobile app various automated tests are performed. To test the functionalities of the mobile app unit tests are utilized and UI is tested by performing widget tests.

Postman [56] is utilized to ensure that all endpoints function properly in various circumstances. Following that, to test the entire mobile app end-to-end tests and integration tests are investigated. When submitting pull requests to the main branch GitHub Actions CI/CD pipeline is selected to perform automated test scripts.

A suitable test strategy is required to test a system in a systematic manner. The test plan outlines how to carry out Integration Testing and Unit Testing effectively.

A Unit Testing

Unit Testing is conducted to ensure that all the system's modules are working properly before the system integration. Unit Testing covers the main modules of the system.

Following Table 1 points out Unit Testing that is carried out for different modules of the system.

Table 1. Unit testing for different modules

Module	Description
Authentication Module	The authentication module is tested by using different combinations of user names and passwords to make sure that all fields are validated properly. For user login details data are cross-checked with the database.
Administration Related Tasks	Administration related tasks are tested properly to make sure that there are no errors in the admin panel.
Latest Global News Module	Endpoint level testing is done to test this functionality to check that all the data which are calling from the endpoint are matched with the data which we can see from the front-end mobile app.
Fact-Checking Module	Fact-Checking module is tested properly with several datasets to make sure that the function is working properly. It also evaluates deeply with running several test scenarios on it as well.
Latest Twitter News Module	Both endpoints and websites are cross-checked to validate the data which we are getting to the front-end mobile app.
News Report Module	The news report module is tested to make sure that it triggers the correct crud operations to store the news reporters in the storage and store the operational data in the database.
COVID-19 Report Module	Endpoint level testing is done to test this functionality to check that all the data which are calling from the endpoint are matched with the data which we can see from the front-end mobile app. Localization is also tested properly as well.

B System Testing

System Testing is conducted to ensure that all the system's features are working properly. System Testing covers the main features of the system.

Following Table 2 points out System Testing that is carried out for all the features of the system.

Table 2. System testing for all the functionalities

Test Scenario	Description
Login Function	Test user login function for valid user name and password. User login can identify the user credentials correctly. Only the registered users can log in to the system.
Admin Related Function	Admin can add/edit/delete users and can assign the correct user to correct functionality. Test whether the admin can add/edit/delete users and can assign the correct user to the correct functionality.
Fact-Checking Function	The fact-checking function can check the new social media posts and stories. The test case can be run to check whether the function is working properly to check the fact-checking function.
Latest Twitter News Function	The Latest Twitter news function can show the latest Twitter trends and news stories with insights from trusted news agencies. The test case can be run to check whether the function is working properly to check the function.
News Report Function	The news report function can use to report the latest news updates to the portal. The test cases can be run to check whether the function is working properly for news reporters to report the news to the portal.

A recent message presented in figure 14 is utilized to test with the proposed hybrid model, the given message is la-

"Amitabh Bachchan & Abhishek Bachchan test positive for COVID-19."

Figure 14 : Experiment - message 01

belled as real news by envisioning a score of 0.9950. For the second message, as illustrated in figure 15, also evalu-

"All the universities and schools remain closed for two months due to the coronavirus outbreak in the country".

Figure 15 : Experiment - message 02

ated using the proposed hybrid model and it is forecasted as false news with a score of 0.4190. Recent news which is in figure 16 is chosen as the third message, and it is forecasted

"Dalada Maligawa website comes under cyber-attack."

Figure 16 : Experiment - message 03

as real news by giving a score of 0.8509 from the proposed hybrid model. After that, a lengthy statement consisted in a social media post in figure 17, chose to evaluate using

"A video has been shared thousands of times in multiple posts on Facebook alongside a claim that it shows a rally against coronavirus restrictions in the British capital of London."

Figure 17 : Experiment - message 04

the proposed hybrid model. And it is predicted as false news with a score of 0.0015. With that, a lengthy statement which is received via WhatsApp selected to evaluate using the proposed hybrid model in figure 18, by project-

"A photo has been shared in multiple Facebook posts alongside claims that it shows deforestation in Sinharaja, a protected forest reserve in Sri Lanka."

Figure 18 : Experiment - message 05

ing a score of 0.0050 it is once again labelled as false news. Finally, a recent message in figure 19 is tested with the proposed hybrid model, with a score of 0.9847, it is correctly

"'Black Panther' star Chadwick Boseman dies of cancer at 43."

Figure 19 : Experiment - message 06

predicted as real news.

After testing various messages using the proposed hybrid model, Table 3 points out the experiment results which are examined from the proposed hybrid model.

Table 3. Experiment Results

Input Text	Predicted Results	Label	Actual Result
Message 1	0.9950	Real	Real
Message 2	0.4190	Fake	Fake
Message 3	0.8509	Real	Real
Message 4	0.0015	Fake	Fake
Message 5	0.0050	Fake	Fake
Message 6	0.9847	Real	Real

Docker [57] is utilized to improve the performance of the mobile app during the evaluation phase. The mobile app is then compressed using app bundle packages to minimize its size. When utilizing Flutter as the front-end framework, the suggested mobile app is adaptable for both Android and IOS versions. After giving the mobile app to use as a complete system to some users for testing the authors found that

the user satisfaction and usability rates are high when compared with other related software in figure 4.

VII   CONCLUSION AND FUTURE WORK

Finally, the research proved that the suggested mobile app is a viable option for Sri Lanka as it contains various functionalities such as fact-checking, social media news trends, news reporting, daily news updates and daily COVID-19 reports. Furthermore, the key functionality of fact-checking is becoming increasingly important for everyday social media users to discern between legitimate and false news items and social media postings.

In terms of future work, the suggested mobile app is expected to be released to the public as a full system with Android and IOS versions. As a result, the authors expect to publish the mobile app freely available on both Android and Apple stores.

VIII   PROJECT REPOSITORY

Project Repository URL:
https://github.com/pathumveyron24/PG-FYP-SherLock

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CONFLICT OF INTEREST

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Prediction of Air Quality Index in Colombo

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ABSTRACT Air is always considered as the main critical factor on which human survival depends on. The AQI or long firmly air quality index is the index value that illustrates qualitatively the current state of the air. The substantial AQI will further menace the living creatures' health & the living atmosphere. Terrible air quality has been a major concern in Sri Lanka, particularly in urban cities such as Colombo and Kandy. Reliable AQI prediction will assist to decrease the health risks caused by air pollution. The goal of this study has been to find the most suitable machine learning approach for predicting accurate air quality index in Colombo based upon PM2.5 particular concentration. In this study, PM2.5 concentration in Colombo had been predicted using four correlated air pollutant concentrations such as SO2, NO2, PM2.5, & PM10. The obtained dataset was pre-processed via prediction in order to improve prediction accuracy. The gathered dataset Cross-validated as according to 80% for training & 20% for testing the prediction model. Machine learning methods such as K-Nearest Neighboring, Multiple Linear-Regression, Random Forest, and Support Vector Machines were used to train and evaluate the prediction models. In the end, we achieved 83.25% accuracy for the K-Nearest Neighboring algorithm model, 84.68% accuracy for the Support Vector Machines model, 85.17% accuracy for the Random Forest model, and 41.9% accuracy for the Multiple Regression Model. Random Forest was recognized as the best appropriate prediction model after evaluating the models, with over 85% greater accuracy.

KEYWORDS: Air Quality Index (AQI), Correlation, Machine Learning, Model, Pollution

I INTRODUCTION

Air Quality or in other words quality of the breathing air around us is a highly valuable luxury that people should have but unfortunately, more than two-thirds of the people who live on our planet do not have it. By referring to the most recent reports of the WHO, more than half of the people who live on our planet live in extremely air polluted urban areas and almost all the people who live in those areas are not aware of the quality of the air in their atmosphere. When considering the quality of the air in Colombo, it is evident that air pollution in Colombo, increases at a very rapid rate yearly. In the rush hours in the morning and evening, the Air quality Index in Colombo exceeds the 4th category level of the world health organization recommended. Unfortunately most of the people are not aware of AQI level around their living space and as a result of their unawareness, especially in areas such as Colombo, the people have developed an indifferent attitude towards the adverse effects that air pollution might have on their health [1].

This paper mainly explores air quality index prediction using various machine learning algorithms such as regression algorithm, support vector machines algorithm, k-nearest neighboring algorithm & random forest algorithm. Various machine learning models have been implemented & evaluated to find out the best accurate

machine learning model. This research mainly focuses on enhancing the methods that have been used to predict air quality index and improve the knowledge on air quality index, and to understand the effects of the bad air quality. In Colombo, the AQI value is always at the average unhealthy level. With some reliable & accurate predictions of the AQI category, the Colombo public can get necessary precautionary measures like increasing the indoor activities & minimize the outdoor activities as much as possible to protect themselves from consequences of bad air quality in Colombo. This chapter presents a very brief description of the AQI, the motivation of this research study and background details about Colombo air quality which is followed by the goal of the research[2]. Minimizing air pollution and ensuring that people have access to clean air, are major responsibilities of human beings as their actions have led to the increased level of air pollution in the world. Some human revolutions such as industrialization have mainly affected the earth's air pollution. An increase in the vehicles and machines which emit carbon dioxide into the air can be identified as another cause for air pollution. Basically, air pollution can be described as mass contamination of the air in a specific geographical area by the emission of enormous amount of harmful gases and chemical substances to the environment. Emissions from productions, industries & vehicles are the main reason for poor air quality. A highly populated urban city such as Colombo most of the time has the poorest air quality

compared to the other rural areas mainly due to the actions of human population. There is a strong correlation between air quality index value and threats to human health, these threats include both short-term & long-term side effects on the health of living beings and their environment. The people who have suffered from diseases such as asthma, and pneumonia are more prone to suffer from heart and lungs related diseases when they are exposed to polluted air. It is stated that once contaminated air is inhaled, PM2.5 particles and PM10 particles which have entered to the human body are either extremely difficult or nearly impossible to be self-purified in the immune system of the human [3]. As mentioned in many studies lack of public awareness in Colombo about bad air quality is the main problem. Therefore, with the rapid increase in air pollution, air quality index has become a very important factor to predict and to make people aware of the effects of air pollution (AQI levels) may have on health and the environment in which they live [4]. Moreover, the adverse impact which is caused by air pollution on human health and the surrounding environment can be significantly re-duced/minimized by predicting the AQI value. To identify the most suitable method to predict AQI value from avail-able techniques, and the available dataset to achieve the highest accurate prediction are important accomplishments of this study. The continual human existence is based on air. The Air Quality Index is the index value that illustrates qualitatively the current state of the air. A substantial AQI will further threaten the health of all living beings and the atmosphere. From Central Environment (CEA) Authority, a historical air concentration dataset was gathered for this research, which includes hourly concentration levels of various air pollution factors & weather factors such as PM10, PM2.5, SO2, NO2, CO, O3, wind speed, wind direction, average temperature, relative humidity, and solar radiation. To guarantee the prediction outcome accuracy, a variety of data preparation approaches were used. An already preprocessed dataset was utilized to to cross-validation technique by dividing it into 80 percent for model training & 20 percent for testing. Random Forest, K Nearest Neighbors, Support Vector Machine, & Multiple Linear Regression are the machine algorithms that have been deployed as prediction models. The best-suited model for AQI prediction is chosen based upon the performance of the machine learning model & accuracy.

The paper is structured as follows. The second chapter of this study is the literature review of the research. The third and the fourth chapters of this study highlights the method-ology and the findings of this research respectively. Finally, the conclusion of this study is presented in the final section.

II LITERATURE REVIEW

There are several AQI prediction solutions which are available. Out of these predictions, very few solutions provide general guidance to overcome the adverse effects air pollution has on human health which depends on the amount of PM10 & PM2.5 fine particulates in the atmosphere. A comprehensive literature review has been done to provide a brief overview on the existing literature on AQI predictions which ae made using different machine learning models due to the unavailability of one precise methodology to predict the within the domain of research AQI prediction. The study field differs not only in terms of methodologies and methods, but also in the terms of accessible datasets, which are frequently varied owing to the traffic, environmental factors, and climate of the chosen geographical region. Bad air quality is mostly caused by PM particulates. For example PM2.5 & PM10 like air pollutants cause air pollution in certain cities, whereas COx, SOx, and NOx are primarily responsible for polluted air in others. Due to these drawbacks, the comprehensive literature review of this study is carried out as an effort to gain a thorough grasp on the AQI prediction research scope and to locate relevant research studies that serves the same purpose as this study. The literature review chapter of this study consists of a collection of the most recent and relevant researches on AQI predictions. Here some of the current AQI prediction approaches are discussed. It's also crucial to consider which approach is best for predicting air pollution. AQI predictions which are made using a deep learning approach is one of the most widely utilized approaches out of the existing models. When it comes to predicting AQI, the most often used technique is machine learning. Machine learning approaches use a lot of data & machine learning-based algorithms to train the model. The deep learning-based neural network technique is another approach that may be used to forecast the AQI. With a basic neural network, correct predictions of the AQI can be made, and the model may be further modified using various testing settings and input parameters[7].

As per the literature of the study, there are a few flaws in the existing air quality index prediction methods, such as issues with dataset collection. The low accuracy of the predictions made by the available air quality index predic-tion models in Sri Lanka is a result of inaccurate and null data. Data preprocessing is another aspect that affect the decreased level of impacts accuracy decreases. In the light of these considerations, it is evident that the majority of Sri Lanka's existing systems have failed to provide accurate predictions. In view of the foregoing with other countries, they have been able to overcome these disadvantages and attain high accuracy.

Table 1. Literature Review Summary

Author	Application	Technique	Remark
S. Silva and others	Air quality prediction for smart cities	• Support vector regression	• Predict PM 2.5 levels variability. • Model is suitable for predict hourly air pollution. • Obtain an accuracy of 94.1%
Usha Mahalingam and others	Air Quality prediction	• Neural Networks • Support vector machine	• Accuracy of 91.62% for neural network • Accuracy of 97.3% for support vector machine
Min Lee and others	Air pollution prediction	• Deep Learning	• Predict against PM 2.5, PM 10 particulars. • Accuracy based on PM 10 is very low. • Accuracy based on PM 2.5 is very high.
Timothy M. A. and others	Air quality monitoring model development	• Naïve Bayesian • KNN • Support Vector Machines • Neural networks • Random Forest	• Highest accuracy was obtained through Neural Networks. • Sometimes Neural Networks leads to slower responses.
C. Zhao and others	Air Quality Index Prediction	• Linear regression	• AQI Prediction based on a year data of PM2.5, PM10, etc. • There is a deviation between predicted results and actual data.
Esmail Almadi	Air pollution prediction	• Data Mining • Decision Tree	• Used Clementine software for data clustering. • Data sample include climate data of 53 years
Colin Bellinger and others	A systematic review based on Machine Learning and data mining for Air Pollution	• Machine Learning Algorithms • Data Mining • Big Data	• Refer 400 research papers & reduce to 47 after the inclusion/exclusion criteria's • Divided research papers into three categories • End of the literature survey that highest accuracy levels always obtain in Machine Learning Algorithms based approaches.

III METHODOLOGY

The proposed approach consists of a sequence of phases for predicting the AQI. The sequence of phases includes collecting the dataset from Central Environmental Authority, pre-processing the collected dataset, analyzing the collected dataset to identifying the correlations among air pollution factors, applying appropriate ml algorithms, & ultimately selecting the most suitable machine learning approach & analyzing the prediction results.

A Data Collection & Pre-processing

Historical datasets containing information regarding air pollution factors' hourly concentration levels in Colombo are obtained from the Central Environment Authority(CEA) and the National Building Research Organization(NBRO). From January 2019 to February 2021, the dataset contains average concentrations of air & weather factors such as humidity, CO, SO2, NO2, PM10 & PM2.5. The obtained dataset is being pre-processed by using various preprocessing approaches to improve accuracy & assure the reliability of the values that have been predicted.

B Data Analysis

Correlation matrix and distribution charts are used to determine the correlations among air pollution variables, as well as to determine the dataset's distribution and nature. The RStudio software[11] is used for the data analysis. The most & least factors that are affected by PM2.5 can be identified using correlation matrix and distribution graphs.

C Evaluation

The Train-Test-Split technique is so far the most frequent approach used in the cross-validation of pre-processed data. The pre-processed dataset is divided into two sample sets, 80 percent of data is used to train the prediction machine learning model and 20 percent of data is used in evaluating the results that have been predicted.

D Training the Model

i. Random Forest
ii. Multiple Linear Regression
iii. Support Vector Machine
iv. K Nearest Neighbors

The dataset is trained using several Machine Learning algorithms. The default parameters have been used in each of these instances. Python[12] libraries such as pandas[13], scikit learn[14], & the PyCharm IDE[15] were used in the implementation.

E Model Evaluation

The machine learning model is utilized to predict the air quality index based on the previously pre-processed dataset. It is predicted once the machine learning model training stage is completed. The most appropriate machine learning algorithm has been identified based on the prediction accuracy of all the used machine learning algorithms. Accuracy has been calculated using the following equation.

i. $0 \leq PM2.5 \leq 30$: AQI Category 1(Good)

ii. $31 \leq PM2.5 \leq 60$: AQI Category 2(Satisfactory)

iii. $61 \leq PM2.5 \leq 90$: AQI Category 3(Moderate)

iv. $91 \leq PM2.5 \leq 120$: AQI Category 4(Poor)

v. $121 \leq PM2.5 \leq 250$: AQI Category 5(Very Poor)

vi. $251 \leq PM2.5$: AQI Category 6(Severe)

IV RESULTS

Nearly 11000 data records of air pollutants and weather variables were obtained for this research, including PM10, PM2.5, SO2, NO2, CO, O3, Wind speed, Wind direction, Average Temperature, Relative Humidity, & Solar Radiation. As per the correlation matrix graph in Figure 2, which was computed using RStudio, the correlation between PM10 & PM2.5 is the best correlation value shared between two factors. When compared with other air and weather parameters, CO, NO2, SO2, and PM10 have the highest correlation values with PM2.5, as shown in the correlation matrix. As a result, we applied PM10, PM2.5, CO, SO2, and After a comprehensive correlation analysis of all the air parameters and weather factors, four air parameters were chosen from the selected dataset. SO2 concentration, NO2 concentration, PM10 concentration, and PM2.5 concentration NO2 parameters to train & evaluate the prediction machine learning model.

are these four parameters. Apart from CO, SO2, NO2, and PM10, correlations among PM2.5 and other weather parameters and air parameter concentrations are average, as shown in Figures 1,2 and 3. To obtain a better correlation value, the correlations between PM2.5 and multiple air parameters concentrations were computed, as shown in Table 2. PM2.5 and the collection of SO2, NO2, CO, and PM10 have a correlation of 0.8644, which is really a great value.

After a comprehensive correlation analysis of all the air parameters and weather factors, four air parameters were chosen from the obtained dataset. SO2 concentration, NO2 concentration, PM10 concentration, and PM2.5 concentration are the four parameters. Apart from CO, SO2, NO2, and PM10, correlations among PM2.5 and other weather parameters and air parameters concentrations are modest, as shown in Figures 1,2 and 3. To obtain a better correlation value, the correlations between PM2.5 and multiple air parameters concentrations were computed, as shown in Table 2. PM2.5 and the collection of SO2, NO2, CO, and PM10 have a correlation of 0.8644, which is really a great value.

Table 2. Multiple Correlation Summary

	PM2.5
PM10 + NO2	0.8635649
PM10 + NO2 + CO	0.8623043
PM10 + NO2 + SO2	0.8642185
PM10 + NO2 + SO2 + CO	0.8644263

A Multiple Regression Model

Using Multiple regression model Mean Absolute error, Mean Squared Error, Root Mean Squared Error & default accuracy score have been computed. All of these scores are average values, as shown in the sheet which is illustrated by Figure 4. The nature & the type of the collected dataset constantly influence these values which are predicted from the regression machine learning model. For this dataset and prediction procedure, multiple regression algorithm is not a suitable machine learning algorithm.

B Support Vector Machines Model

The SVM model has been able to achieve 84.68% accuracy, as shown by the classification details sheet in Figure 5. When compared to the regression method, this Support Vector Machine model has relatively very higher accuracy. The reason for the higher accuracy is because SVM handle input parameters with polynomial properties and SVM is suitable for this prediction work.

C Random Forest Model

The Random Forest machine learning algorithm was also deployed for this prediction. Random Forest is a supervised learning technique that could be used to solve both classification & regression-based problems, and through this module it is simple to calculate the relative significance of each feature that makes up the prediction. As seen in Figure 6 of the paper, the Random Forest model has been able to achieve 85.17% accuracy. When the Random Forest model accuracy is compared to the accuracy of the Multiple Regression approach, this 85.17% accuracy rate is quite a remarkable one.

D KNN Model

In numerous research projects, the KNN machine learning model has been utilized to predict the category of air quality index. When k = 3, the KNN prediction model obtained 83.25% accuracy, as shown by Figure 7 of the paper. It's able to get a higher accuracy from using this KNN prediction model although some air pollutant factors are very weak.

```
              AT     RH SolarRad RainGauge WSRaw WDRaw     O3     CO    NO2    SO2  PM2.5   PM10
AT          1.00  -0.90     0.79     -0.07  0.60  0.01   0.48   0.08   0.22   0.25   0.04   0.27
RH         -0.90   1.00    -0.79      0.12 -0.68  0.13  -0.59  -0.01  -0.23  -0.24  -0.10  -0.31
SolarRad    0.79  -0.79     1.00     -0.05  0.66 -0.15   0.40   0.03   0.21   0.19   0.05   0.23
RainGauge  -0.07   0.12    -0.05      1.00 -0.01  0.02  -0.04   0.04   0.05   0.00  -0.05  -0.07
WSRaw       0.60  -0.68     0.66     -0.01  1.00 -0.33   0.52  -0.05   0.16   0.14  -0.07   0.10
WDRaw       0.01   0.13    -0.15      0.02 -0.33  1.00  -0.30   0.07   0.07   0.10   0.02   0.05
O3          0.48  -0.59     0.40     -0.04  0.52 -0.30   1.00  -0.24  -0.19  -0.03   0.01   0.01
CO          0.08  -0.01     0.03      0.04 -0.05  0.07  -0.24   1.00   0.50   0.19   0.48   0.48
NO2         0.22  -0.23     0.21      0.05  0.16  0.07  -0.19   0.50   1.00   0.40   0.54   0.63
SO2         0.25  -0.24     0.19      0.00  0.14  0.10  -0.03   0.19   0.40   1.00   0.24   0.32
PM2.5       0.04  -0.10     0.05     -0.05 -0.07  0.02   0.01   0.48   0.54   0.24   1.00   0.86
PM10        0.27  -0.31     0.23     -0.07  0.10  0.05   0.01   0.48   0.63   0.32   0.86   1.00
```

Figure 1 : Correlation Matrix Chart
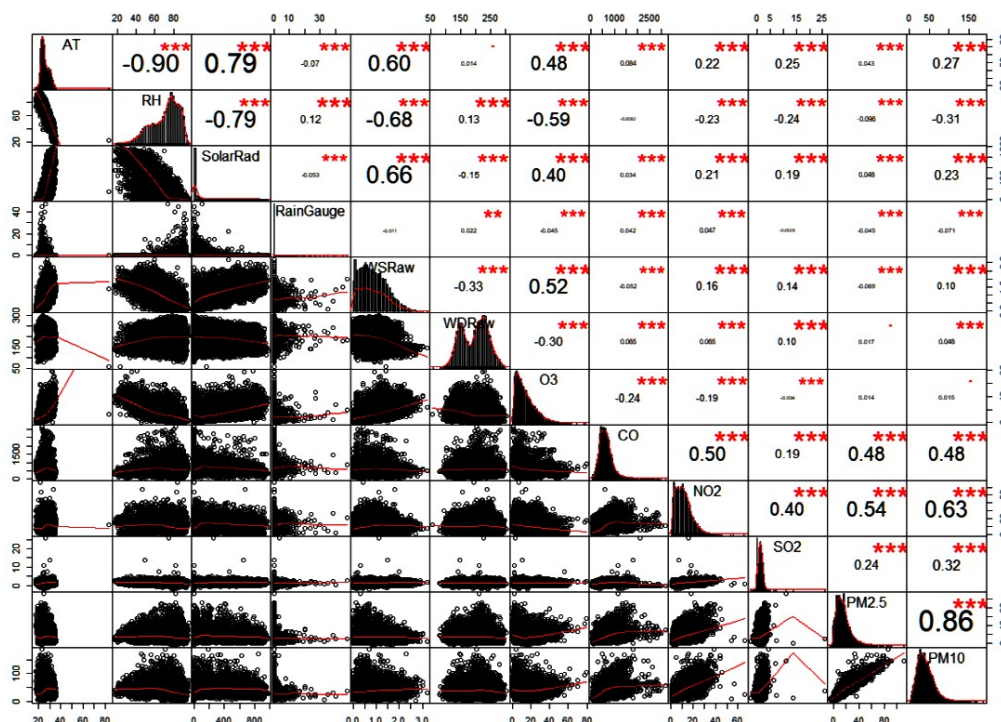
Figure 2 : Correlation Matrix
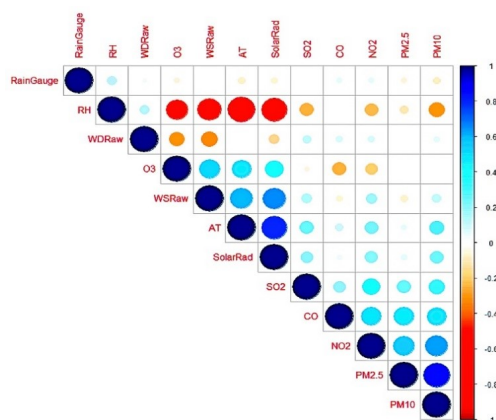
Figure 3 : Correlogram

Mean Absolute Error: 0.2694807929045523
Mean Squared Error: 0.15263856450175747
Root Mean Squared Error: 0.39068985717798904
Default Accuracy Score: 41.90964213392034

Figure 4 : Multiple Regression Classification

V   DISCUSSION

Using Random Forest, Support Vector Machines, and K-Nearest Neighboring algorithms, several existing international researches have achieved high accuracies, as shown in Table 1. The incompleteness in some records within the collected dataset is the major factor that has contributed to the poor accuracy which is produced by the Multiple Regression machine learning model. Another reason that affected low accuracy is the nature of the

Default Accuracy Score:
84.68021814576103

	precision	recall	f1-score	support
0	0.89	0.96	0.92	1601
1	0.60	0.48	0.53	350
2	0.69	0.16	0.26	57
3	0.00	0.00	0.00	9
accuracy			0.85	2017
macro avg	0.54	0.40	0.43	2017
weighted avg	0.83	0.85	0.83	2017

Figure 5 : SVM Classification

Accuracy Score:
85.17600396628656

	precision	recall	f1-score	support
0	0.91	0.94	0.92	1601
1	0.60	0.57	0.59	350
2	0.47	0.25	0.32	57
3	0.00	0.00	0.00	9
accuracy			0.85	2017
macro avg	0.49	0.44	0.46	2017
weighted avg	0.84	0.85	0.84	2017

Figure 6 : Random Forest Classification

Accuracy: 0.8325074331020813

	precision	recall	f1-score	support
0	0.91	0.93	0.92	807
1	0.49	0.53	0.51	161
2	0.50	0.18	0.27	38
3	0.00	0.00	0.00	3
accuracy			0.83	1009
macro avg	0.48	0.41	0.43	1009
weighted avg	0.83	0.83	0.83	1009

Figure 7 : KNN Classification

regression machine learning algorithms. The performance of the algorithms is affected by the lack of data records and some noisy factors in the pre-processed dataset. In an effort to improve the quality & the performance of the obtained dataset, several data pre-processing approaches were used.

The Random Forest machine learning model is the best-fitted model for this air quality index prediction process since Random Forest obtained the best accuracy rate when compared with the Support Vector Machines, Multiple Regression, and K-Nearest Neighboring models.

Table 3. Model Evaluation Summary

Model	Accuracy
Multiple Regression	41.90\%
SVM	84.68\%
Random Forest	85.17\%
KNN	83.25\%

VI CONCLUSION

Air is always considered as the main critical factor on which human survival depends on. The AQI or long firmly air quality index is the index value that illustrates qualitatively the current state of the air. The substantial AQI will further threaten the living creatures' health & the living atmosphere. Terrible air quality has been a major concern in Sri Lanka, particularly in urban cities such as Colombo and Kandy. Reliable Air Quality Index prediction will assist in decreasing the health risks caused by air pollution. To determine the most affected air pollutant concentrations air quality index prediction correlation analysis has been done. In this study after the comprehensive correlation analysis, PM2.5 concentration is predicted in Colombo using four correlated air pollutant concentrations such as SO2, NO2, PM2.5, & PM10. The obtained dataset was pre-processed via prediction in order to improve prediction accuracy. The gathered dataset Cross-validated as according to 80% for training & 20% for testing the prediction model. Machine learning methods such as K-Nearest Neighboring, Multiple Linear-Regression, Random Forest, and Support Vector Machines were used to train and evaluate the prediction models. In the end, we achieved 83.25% accuracy for the K-Nearest Neighboring algorithm model, 84.68% accuracy for the Support Vector Machines model, 85.17% accuracy for the Random Forest model, and 41.9% accuracy for the Multiple Regression Model. Random Forest was recognized as the best and the most appropriate prediction model after evaluating all the models. Under the circumstances with limited data, the model had over 85% greater accuracy.

VII FUTURE WORK

In the future, more datasets in Colombo from ambient air quality parameters monitoring stations inside Sri Lanka are expected to be collected and more appropriate pre-processing techniques for the dataset will be used. Since the Multiple Regression machine learning algorithm is inaccurate, the study team intends to develop a deep learning-based prediction model to calculate the air quality index prediction. Moreover, since the current prediction is based only on Colombo, the research team plans to predict the Air Quality Index in other districts as well in the future.

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IOT-based Monitoring System for Oyster Mushroom Farms in Sri Lanka

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ABSTRACT Oyster Mushrooms are a type of a fungus which is very sensitive to the environmental factors and vulnerable to diseases and pest attacks which directly effects local trade and export strength. Mushroom is a climacteric type of food which continues its cycle even after harvesting. The mushroom farming process still uses manual mode such as the identification of diseases uses a farmers eye visually, harvesting of mushrooms are decided based on the visual appearance while the environmental factors are decided based on gut feelings. These methods has its limitations which requires more potential to improve both the quality and capacity of mushroom production. With the advancements of technology, this farming process can be performed with the aid of an IoT device and deep learning model. This research applies Convolutional Neural Networks (CNN) with Mobile Net V2 model to detect mushroom harvest time and any disease spread with an accuracy of 92% and 99% respectively. Long Short-Term memory (LSTM) to analyze the detected environmental factors with an accuracy of 89% and this system predicts the yield of mushroom production with the support of LSTM model with an accuracy of 97%. This developed system which aids mushroom farming activities is connected with the farmers through s mobile application.

KEYWORDS: Harvest, Monitoring, Mushrooms.

I INTRODUCTION

Mushrooms are a type of edible fungi which expands to a wide range of varieties. Oyster mushrooms (Pleurotus Ostreatus) is one of the most dominant type of mushroom which is consumed within Sri Lanka. It is well known for its delicate texture. Mushrooms are being highly consumed among Sri Lankans for its national benefits [1] by which the local trade has failed to full fill the market demands.

Mushrooms are grown inside closed, thatched mud houses, in which maintaining the required environmental factors such as temperature, humidity, and Co2 is difficult with the weather changes [2]. The cultivators are still deciding when to harvest their mushroom products, by their gut feelings, which ends up in less life for their packed products. Mushrooms being a type of fungi, they are very vulnerable to diseases. When diseases spread at a high-rate, cultivators often fail to recognize the disease accurately and thereby fail to apply the correct remedy. Mushroom farmers also fail to obtain a better yield owing to the inefficiencies in the cultivation methods. These, methods require quick refinement for the farmers to obtain their profitable yields

II RELATED WORK

G.M Fuady, A.H Turoobi, M.N Majdi,, M. Syaiin conducted an empirical Study of Extreme Learning Machine, ELM to maintain the environmental factors of a mushroom farm house[3]. This research uses a Single Layered Feed Forward Neural Network (SLFN) with the moderation of H inverse matrix or ELM to create a model to maintain factors such as temperature and humidity within a mushroom farm. Together this research develops a hardware panel with a mist maker and exhaust fan to control and DHTII sensor to monitor humidity[3].

Palraj M.P, Hema C.R, R. Pranesh Krishnan and Siti Sofiah, Mohd Radzi presents a design to detect the ripeness level of a banana fruit[4]. This research manipulate a Neural Network model developed using the error back propagation. The specimen used for this research is a banana. Data for the dataset collected at difference ripeness levels of the banana from good condition to rotten level. This process is a combination of three steps Image Pre-processing phase followed by feature extraction phase and classification phase of bananas. First the image is

captured using a digital camera at a resolution of 320×240 pixels. Then the captured image is recomputed to image's color index. The RGB color component is extracted and displayed using a grey scale image. The components of the colour of the recomputed image are rescaled using simple heuristic methods. A histogram for the recomputed image is achieved and then it is used as a feature vector to recognize the level of ripeness of the banana fruit. This work proves the accuracy of ripeness detection as 96% [4].

Andi Wahju Rahardjo Emanuel has used five steps for recognizing and classification of diseases which spread on plants using Image Processing[6]. The first step is Image Acquisition using a digital device. Image resizing, smoothing, increasing contrast and image enhancement is used in the second step Image Pre-processing. The third step is removing the noise and Image Segmentation. In the fourth step, Feature Extraction is based on colour, shape, edge, and texture. The final step of image processing is Classification. Convolution Neural Network (CNN) trains the input and classifies output responsibility and has the capability of detecting disease. At this step model's accuracy is also verified [6].

According to Md Al Maruf the easiest way to accomplish provide and demand optimization is to create algorithms that forecast potential demand based on historical demand data and the variables that influence demand[5]. The paper examines three different Machine Learning Algorithms to predict a mushroom farm's future demand for mushrooms based on data from the previous few months and thus to produce the best possible algorithm for predicting mushroom sales. The paper also evaluates the type of data in each of the three algorithms that produces the best possible result, thus differentiating the algorithms based on the type of data they can best work on.

'Mangosteen' has become a significant export and trade item in the country of Indonesia. It is believed that this fruit changes with time, therefore there is a possibility of fruit ripening during transport and storage. Thereby, there is need to detect the maturity level of mangosteen before releasing to market. This process is yet to be done by manual methods, which involves in human supervision which will have a limited capacity of identification. In this research, Oka Sudana, Putu Bayupati and Dewa Yudiana demonstrates a digital system which is capable of detecting the maturity level of the fruit [22].

A study by Manish Chhabra, Rohan Gaur and Parminder Singh introduces a technique to detect the ripeness level of the mango fruit [23]. A neural network methodology is used. for the classification of mangoes according to its ripeness levels. In this study, the mangoes are classified into two classes 'Ripe Mango' and 'Unripe Mango'. The

mangoes ripeness was identified with an accuracy of 95.5% and 200 samples were considered.

There are various researches performed based on different types of fruits, but very few have assessed mushroom cultivation. However, methods used by other fruits tends to use much similar methodologies. The paper which presents temperature and humidity control of oyster mushroom based on microcontroller [3], monitors the farm house environment factors in spite of that our application has achieved to monitor the environmental conditions and also to provide control recommendations in a timely and customized format which balances the maintenance of all three factors. Determining the Ripeness of a Banana [4], research determines the maturity level however our application is able detect the maturity and provide a timely alert to harvest the mushroom which the mushroom will be plucked at the peak quality point. Plant leaf detection [5] detects the diseases but our application nevertheless has found out the most significant disease to the Sri Lankan context to give Sri Lankan farmers the best use.

III   METHODOLOGY

This research aims to address issues that the mushroom cultivators face due to the manual farming practices followed by them. Thereby, a study was conducted aiming to develop smart mushroom farming solution to the mushroom cultivators in Sri Lanka to solve the issues that are left unaddressed.

A   Data gathering for dataset training

At present, fundamental information required for mushroom farming in the Sri Lankan context is not readily available. Therefore, the research group initially carried out a survey among a group of mushroom farmers from different areas of the country and identified essential data such as the ideal environmental conditions required for farming in Sri Lanka, the frequent types of diseases which may develop with in mushrooms in Sri Lanka, criteria for harvesting mushrooms and specific yields from cultivations. Currently there is no standard database of images of unique mushroom diseases to Sri Lanka and images of mushrooms at different stages of their life cycle. Thereby the research team selected three private mushroom farms and collected a total of 748 images of five diseases on mushrooms and 1887 images of mushrooms at different stages of their life cycle.

B   System Overview

The system consists of 04 functions: Environment Monitoring function, Harvest Time Detection function, Disease Detection and Recommendation function and the Harvest prediction function. The farmer, provides the required inputs

to the respective functionalities to ease the farming methodology. The required outputs to the farmer is provided to him through a mobile application. The overview of the SMF functionality is illustrated in figure 1.
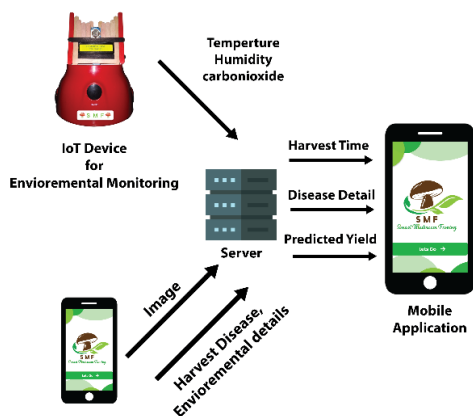

Figure 1: System Overview Diagram

This system is divided into four different segments in order for it to provide solutions to the technological spaces within the mushroom cultivations in Sri Lanka. Each segment of this system is elaborated below:

1 Monitoring of Environmental Factors and recommendation for controlling

Oyster mushrooms grow well within specific environmental states such as temperature, humidity, and carbon dioxide CO_2 in air. They grow and develop in a temperature that range from 26 to 30 °C, humidity within a range of 80 to 90 percent and carbon dioxide level in a range 800 to 1500 ppm as illustrated in Table 2.

Table 1: Environmental factors Threshold Ranges

Environmenta Factor	Threshold Range
Temperature	26 – 30 °C
Humidity	80 – 90%
Carbon dioxide	800 – 1500 ppm

The data required to create the dataset was collected by planting the hardware, IOT device developed to monitor the mushroom farms environmental factors, in the three selected local mushroom farms. Then the monitored levels of three factors were recorded every hour for 24 hours. Finally, a dataset of 4000 record were generated to train the machine learning model. The monitoring unit is setup in the farm to monitor the basic environmental factors temperature, humidity and carbon dioxide of the oyster mushroom cultivation, initiates with the detection of sensor readings as inputs. The inputs data of time, temperature, humidity, and carbon dioxide are refined using a Node

MCU as a microcontroller.

This circuit uses two methods to power it, the main power supply (230 v) and the auxiliary power supply. Here we need to consider two ways to finish and activate the final device according to our needs. That is, the main current (230 v) from the main supply has to be reduced to fit the circuit. (230v to 5V) and the recharging process of the auxiliary power supply. To accomplish this the main power supply is reduced to 5v using a converter circuit and then connected to the switch via an auxiliary power supply. The circuit, which is powered by these power supply processes, connects to two main sensors and detects and collects environmental factors. Namely the DHT11 sensor and the MQ-2 sensor. This DHT11 sensor is capable of detecting both ambient temperature and ambient humidity. The MQ-2 sensor will also be used to measure atmospheric gases. Therefore, CO_2 gas is measured according to our requirement through this sensor. An LCD display is attached to the device to display the factor readings at the real time. The structured diagram you can see in Figure 2 is the circuit diagram of the IOT Environment Factors Monitoring Device.
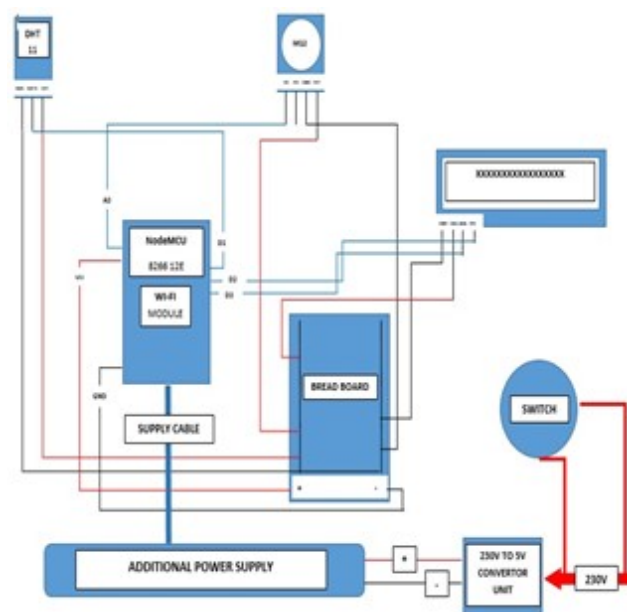
Figure 2 : Schematic Diagram of the IOT device circuit

Therefore, the device that is finally produced allows the farmer to take this device to any corner he wants in the house as per his need.

That's because this is a device that is designed to be packed together and carried in the hand which makes it fully portable as illustrated in Figure 3 (final deice image).

The environmental factors of the farm are monitored for 12 hours, every hour. Then by learning the pattern changes with respective to time by a trained model by Long short-term memory (LSTMs), the output in Figure

Figure 3: IOT Environment Factors monitoring Device

4 will be given as a timely recommendation for how long the control equipment's needs to operate to bring back the environmental factor back to normal which will cut down the resource wastages. This recommendation is customized as in the time recommended for a particular equipment will only effect the factor needed to be changed while keeping other two factors unaffected In the specialism of

Figure 4 : Final LSTM output

deep learning, LSTM is an Artificial Recurrent Neural Network (RNN) [13]. LSTM networks are ideal algorithms in making predictions, classifying objects and processing based on time series data [14]. LSTM's were evolved to handle the dispersing gradient problems which can be experienced when training traditional RNN's. A usual LSTM contains a cell an input gate (x,1) and output gate and a forget gate.

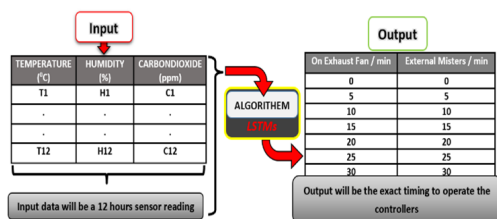The model created for this system to train the collected data was LSTMs was used. The user data is passed through an API into the LSTMs [15]. After data set was created, second step was to train the data set, select the future values in data set then it scale down to min, max. The scale down, transfer 1D array to column vector. A dataset of 5000 data records were created. Then this data is broken

down to windows of 12 record (12 rows). This resulted in 417 data records. Then out of 417 records 90% was used for training and 10% was used for testing purposed. Then the model was tested.

Using this part of the project a farmer receives a customized recommendation, to bring the particular factor to its normal levels having the other two factors remain unchanged. If any of the environmental factors changed, the farmer will be notified immediately on his phone, and with that notification, the farmer is notified how and for how long to use his equipment to bring the mushroom farm back to its normal environmental conditions.

The timely recommendations are given respectively. If humidity increase more than the required levels the function generates the timely recommendation to on the exhaust fans in order to reduce humidity. If humidity decreases than the required levels the timely recommendation will be generated to turn on the external misters. If the temperature increase than the required levels the timely recommendation will be generated to on the exhaust fan to control temperature and on the external misters to make sure the humidity levels are not affected. If CO_2 level increases than the required levels, the timely recommendation will be generated to on the exhaust fans to maintain CO2 and on the external misters to make sure humidity and temperature levels are unaffected.

Receiving the notification at the correct time enables them to manage the resources inside their mushroom farm by working as they see fit. This comes from other types of algorithms, but here using this LSTMs algorithm can be used to reach a higher level of accuracy level.

2 Mushroom Harvest Time Identification

A dataset containing 1887 images in total was collected at 05 different stages of a mushroom life from two agro-processing mushroom farms. The images collected to create the dataset were captured using a phone camera consisting a resolution of 4160 * 3120 pixels. The five stages are displayed with one of its respective images in Figure 5:

The user data is passed through an API into the Convolutional Neural Network (CNN) model that runs to obtain the harvest time of mushrooms.

To train the collected data a CNN was used. Substantially, in order to achieve real time predictions and accurate results the Mobile Net Version 2 model of CNN was applied. CNN was constructed based on the concept of an human brain architecture [16]. CNN embody particular nodes called neurons and they are arranged onto different layers. The Mobile Net Version 2 performs significantly

Figure 5 : Stages of mushrooms from growing, harvesting to post- harvest phase

the data 20 epochs were used in order to train it 20 times to get an accurate result. The model was tested after the data was trained using the created model After the data was trained using the created model, the model was tested. For testing out of 1887 mushroom images 80% was used for training and thereby 20% was used for testing.

Using this part of the research, the farmers are alerted when to harvest their mushrooms, their suitability for consumption and the expiry date. The farmer needs just to capture an image of the required mushrooms through the mobile application and then to let the application to analyze the image for them and then alert them with the detected harvest time.

3 Identification of diseases and recommendation on appropriate remedy

A dataset containing 710 images in total was collected of 05 different types of diseases which are likely to grow in a mushroom cultivation from two agro-processing mushroom farms. The images collected to create the dataset were captured using a phone camera consisting a resolution of 4160 * 3120 pixels.

There are 5 main identified Oyster Mushroom diseases on cultivation bag and mushroom bud that are most available in Sri Lanka as shown in Figure **??**. Convolutional

Figure 6 : Diseases on mushroom flowers and cultivation bags

on mobile devices [16]. Therefore, it is used for its effectiveness in feature extraction.

The model of the proposed system was created using CNN with the Mobile Net Version 2 model. Applying transfer learning, the image sizes were resized into a uniform resolution of 224 x 224 and normalized [17]. Then the RGB images were converted into grey images. Creating the model, Mobile Net Version 2 was used with an input shape of 224 x 224 using 03 channels. A new model was created and sutured into CNN [17]. The rest of the model was constructed by adding the required layers. Average pooling layer, of pooling size 4 x 4 to down sample its input images by taking the average value over an input window of pooling size. Flatten layer, to transform data into a one-dimensional array to pass onto the next layer. Dropout layer, to reduce over fitting by preventing complex co-adaptions of training data. The dense layer, being a fully connected layer completes the classification. To train

Neural Network, a deep learning algorithm was used to diagnose Black Mould, Green mould and Mite Attack diseases and Image Processing method was used to diagnose Neurospora and Thali Makka attack.

The total of 710 images was used to identify the diseases of the mushroom. The images which include their symptoms are taken from two mushroom farms. The dataset carries 216 images as 'Black Mould', 268 images as 'Green Mould' and 226 images as 'Mite attack'. The image which needs to be checked for diseases will be captured through

the mobile application.

The best advantage of using Mobile Net V2 architecture is that it perform faster than a consistent convolution and more suitable for mobile applications. The architecture began with 3×3 convolution kernels and then progressed to 16 depth wise separable convolution blocks to offer a mobile model that is effective. The input images processed through several convolution layers, pooling layers and eventually a fully connected layer that displays the classification results as illustrated in Figure **??** [18]. The dataset
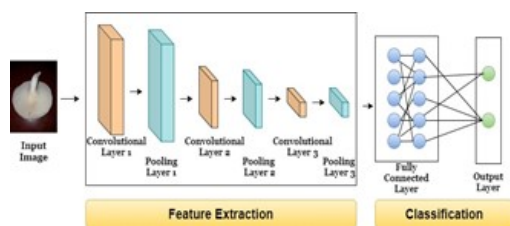

Figure 7 : CNN Architecture

used average pooling layer with size 4×4 and 1280 neurons to reduce dimensions and spatial variance. To achieve more successful accuracy, the Dataset was trained to 100 epochs. [8]. Mainly, the disease is segmented according to an object in the image, depending on colour. The images come in three types: colour (RBG-Red, Green and Blue), grey and binary. In image processing the RGB images were transformed to the HSV colour format [23].

- Hue - The pure colours. It is distributed in a circle ranging from 0-180 in OpenCV.

- Saturation – Controls the amount of colour used with white.

- Value – Controls the brightness of the colour.

Numpy, a highly efficient library for numerical computations, is used by OpenCV-Python to process images and identify the objects[7]. The diseased image took a mask of the image and the range between the upper color and lower color of the mask was white, and the rest was black. The upper color is determined from the color of diseased image from the Hue values by getting the best range. The lower_colour varies with the upper_colour. Furthermore, using 'contour Area' can remove unwanted objects from the image.

4 Harvest Prediction

There is a lack in supply of mushrooms in the food market. This is due mushrooms' fluctuated production yield [20]. This functionality focuses developing a segment, which will notify the farmer through a mobile application regarding the yield of the mushroom cultivation at four stages of the cultivation based on the environmental

factor conditions, mushroom harvested time and diseases that has spread. For this a dataset of 500 plus records with the manual monitoring of environmental factors, harvested times, and the presence of diseases from an oyster mushroom farm was collected. These data are passed through a RNN long short-term memory to forecast the production yield of mushrooms. Temperature, humidity, Co2 level, diseased, right harvest time & yield per day were monitored hourly for 12 hours a day their average values are obtained for each day. Then those values for 5 consecutive days are considered to estimate the total expected yield for particular month.

Figure 8 : LSTM Architecture

A RNN layer's output includes an individual vector per sample by default. This vector contains the information of the entire input sequence and it is the output of the RNN unit corresponding to the last time step. This output has the shape, where units is the unit's argument passed to the layer's constructor. Furthermore, an RNN layer can return its final internal state or states and the returned states can be used to resume the RNN execution or to start another RNN. This is a frequent configuration in the encoder-decoder sequence-to-sequence architecture, where the encoder final state is utilized as the decoder's initial state. Set the return state argument to True when establishing an RNN layer to have it return its internal state and there are 3 state tensors in LSTM [27].

Reasons for choosing LSTM over other techniques, because it's best suited for using experience to identify, analyze, and predict time series with unknown time lags. LSTM prediction technique was created to assist network operators in detecting and reacting to network traffic fluctuations in near real-time before they become congested. According to the findings, by many orders of magnitude, LSTM beats standard linear approaches and feeds forward neural network.

IV RESULTS

The trained models were tested on the test data to get the corresponding accuracies of classification of collected data from local mushroom farms through the developed IOT device and phone camera. The accuracies obtained are illustrated in Table 2.

Table 2 : Accuracy table

Function Name	Accuracy
Environment Factor monitoring(LSTM)	89%
Harvest Time Detection (CNN)	92%
Disease Detection (CNN)	99%
Yield Prediction (LSTM)	95%

The number of epochs committed is directly affecting the accuracies of the models. For the Environmental factor monitoring, Figure 9 displays the accuracy acquired in training the previously collected data using the model. Figure 10 displays the loss that occurred during the training. The Figure 9 and figure 10 plots explains an event of overfitting, since the validation loss decreases up to a certain point and increases and decreases again. By using more data to train the model it will be able to increase the accuracy more.
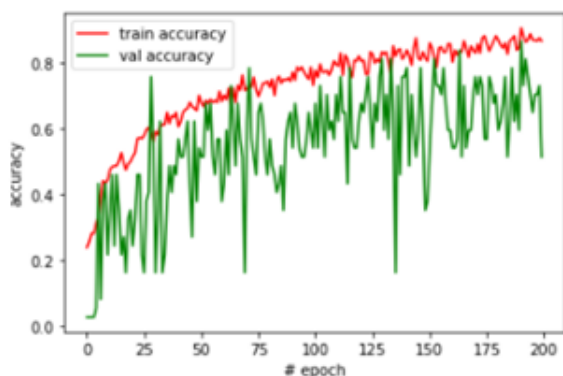
Figure 9 : Accuracy Graph for Environmental Factor Monitoring and Recommendation

The training accuracy of employing the CNN model for harvest time detection was 92% as shown in Table **??**. For the Harvest Time Detection, Figure 11 displays the accuracy acquired in training the images used in the model

For the Disease Detection, Figure 13 displays the accuracy achieved in training the images used in the model. Figure 12 describes the accuracy achieved in training the images used in the model for the harvest prediction. Figure 14 the loss that occurred during the training.
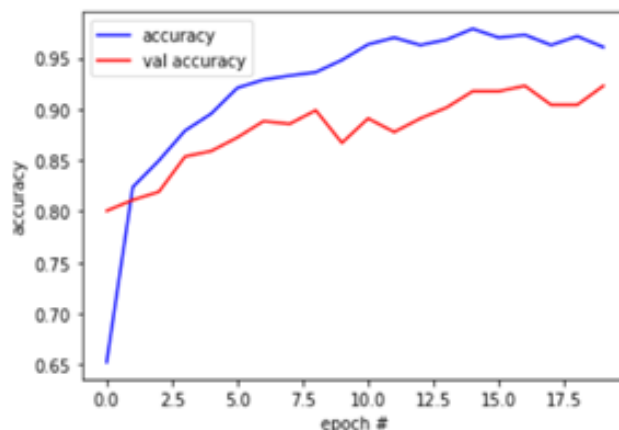
Figure 10 : Accuracy Graph for Harvest Time Detection
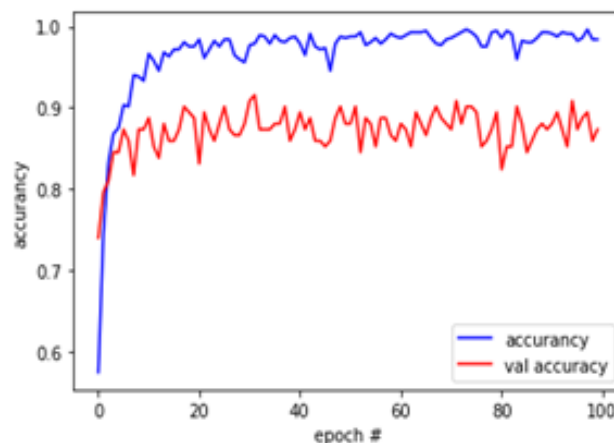
Figure 11 : Accuracy Graph for Disease Detection

The authentication system has the following accuracies of each function: The system analyzes and recommends environmental factor controls with an accuracy of 82%, Identifies the mushroom harvest time with an accuracy of 92% and detects the diseases within mushrooms with an accuracy of 92% and Predicts the mushroom yield with an accuracy of 95%. Validation accuracy linearly changing with the training accuracy indicates high accurate predictions of independent data. This indicates that the model was successful in memorizing the data.

V LIMITATIONS AND RECOMMENDATIONS FOR FUTURE WORK

This research's main limitation in scope of its functionalities was that the disease detection functionality limits for the detection of only five disease types.

This study can be further elaborated to develop the system to detect the disease spread within mushroom farms at early stage. Also further development could be done with a robotic arm to pluck mushrooms at detected harvest
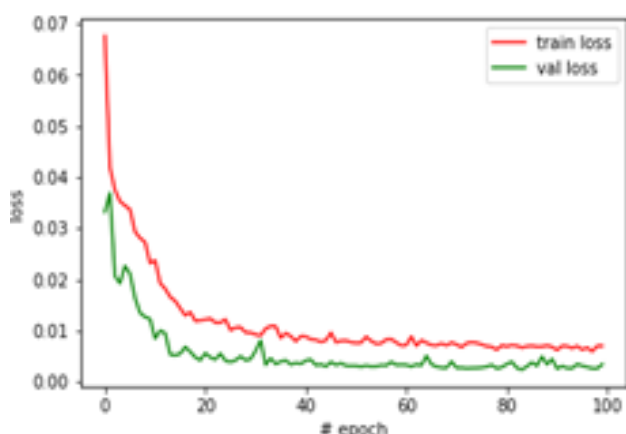
Figure 12 : Loss Graph for Yield Prediction


```
test_r2_score: 0.9467178124464929
train_r2_score: 1.0
```

Figure 13 : Accuracy of Harvest prediction

times using cameras place in the farm rather than capturing through the mobile phone for real time harvest alerts. Also the limited scenario of monitoring and providing control recommendations can be further developed to build a mechanism to control the factors using a control unit.

VI CONCLUSION

This paper presents a solution to the problems faced during mushroom farming in Sri Lanka. The solution presented comprise of four functionalities each serving a different issue faced. Identification of mushroom Harvest time and diseases are introduced to solve issues regarding the harvesting and disease spread within a mushroom farm house build based on a CNN model. The analyzation of environmental factors and providing a control recommendation functionality serves to solve the issue related in maintain farms climatic changes with the aid of an LSTM model. For the purpose of being able to serve the market demands farms yield is predicted to the farmers with the aid of LSTM.

Replacement of manual farming strategies with the designed technological farming approach farmers are directly benefited from achieving high yield in turn increasing their revenues. Thereby farmers expanding businesses, respective governments are benefited indirectly with taxation revenues. Buyers purchasing products grown under exact requirements receive high quality items.

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ABBREVIATIONS AND SPECIFIC SYMBOLS

- LSTM - Long Short Term Memory

- CNN- Convolutional Neural Network

- RNN- Recurrent Neural Network

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Smart Contract Based Electronic Cheque Settlement Protocol

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ABSTRACT Blockchain and smart contract technologies can be used to build a significant impact on financial transactions. This research initiatives the potential of applying blockchain and smart contract technologies for the traditional cheque clearing method. The new protocol is designed based on electronic cheque concepts, blockchain, and smart contracts. As a result of this research, a new secure cheque settlement protocol is designed and implemented. It provides several rewarding features compared to the traditional cheque clearing methods. The new protocol reduces the cheque dishonoring rate and has the possibility of handling a dated cheque. Further, it can be implemented without any exceptional hardware such as heavy-duty scanners.

I   INTRODUCTION

An innovative, blockchain-based secure cheque settlement protocol is designed and presented in this research paper. It holds several rewarding features such as high security, good usability, support for both macro and micropayment, and dated transactions.

The protocol design is based on an electronic cheque concept, blockchain, and smart contracts. Furthermore, the security is highly considered in this protocol as most of the cheque payment technologies offer no inbuilt security other than the standard password and communication layer protection.

A Proof of Concept (POC) of this protocol implementation is carried out with Android smartphones and Mystiko blockchain [4].

Blockchain is a peer-to-peer distributed storage that stores chronological series of transactions in a tamper-resistant manner [5]. However, when implementing a financial application with a typical blockchain, one encounters many challenges as follows [6,7].

- It does not support high transaction throughput;

- It does not scale in terms of big data storage and management;

- It does not provide keyword-based search and retrieval.

Mystiko blockchain supports high transaction throughput, high scalability, high availability, and full-text search features. Thus our Proof of Concept (POC) application is deployed and tested on Mystiko[4].

In addition, reference implementation of the settlement contract written in Solidity was published in Github [10].

II   CHEQUE SYSTEMS

Although credit cards are a popular payment system, statistics show that cheques are still the fund transfer method used by the majority of Sri Lankans [9].

The reason behind this could be the following:

- History of cheque usage (people have been using cheques for decades, whereas credit cards entered the show quite recently)

- The exorbitant amounts that get debited from bank accounts due to credit card usage and especially improper credit card usage

- The fees that transfer out of the country to organisations such as Visa, Master, American Express etc. for every usage of the credit card.

A Dated Cheques

Through the survey conducted, it was observed that more than 75% of daily transactions are done through cheques, which confirms that cheques are still the preferred payment method in the Sri Lankan Business Community [9] and many other Asian countries. The main reason for the popularity of cheques in Sri Lanka is the possibility of issuing dated cheques [8]. The dated cheque is an agreement to pay the money on a particular date.

B Dishonour of Cheques

Cheques presented for payment through a bank counter are dishonored due to two reasons:

- Technical Defects

- Technical Defects

- Lack of funds

The decision to dishonor should be taken by an officer if the defect is technical. If the account does not have sufficient funds, the cheque should be referred to the Manager.

Cheque dishonoring decreases the value of a bank's cheques, which leads to less usage of the banks' cheques.

In Sri Lanka, an average daily cheque dishonoring percentage is an alarming 7.2% [9]. This leads to the denial of cheque payments. This negatively impacts the cheque payee, the cheque payer and the payer's bank.

If we can reduce the cheque dishonored rate:

- Cheque users will benefit.

- The organizations will benefit.

- The banks will benefit.

- The government will benefit (less tax to visa, master, etc)

Thus our protocol solves the cheque dishonoring issue while providing the dated cheque facility.

III PROTOCOL ARCHITECTURE

A Participants

To fully explain how our protocol works, we need to explain the relationships between the parties involved in the system.

Payer: The person/organization who purchases goods and services using cheque payments.

Payee: Goods and services provider who accepts cheque payments.

Issuer Bank: Bank or financial institution that issues a cheque facility to the Payer.

Smart Contract: The blockchain platform that executes the functions of Payment Settlement Smart Contract between Payer, Payee and Issuer Bank.

B Preliminaries

The payment settlement Smart Contract should be deployed in public or permission blockchain such as Ethereum and Mystiko, respectively [4]. This smart contract has a fixed amount of crypto tokens to be distributed among the participating banks and protocol developers.

A reference implementation of the settlement contract was published in Github [10]. This contract can be deployed in Ethereum, and it was written in Solidity. The settlement contact, which was written in Scala for Mystiko blockchain cannot be published since it is copyrighted to a commercial bank in Sri Lanka.

Initially, banks enroll in the system and receive a fixed amount of crypto tokens free of charge for their contributions. The setBank function [10] of the smart contract performs this action. The bank also receives the token when a customer deposits a cheque, as explained later on. If this system gets popular, banks may need additional crypto tokens. The additional tokens can be purchased from the developers who maintain the system.

A customer (Payer/Payee) has zero crypto token at the registration. The setCustomer function [10] of the smart contract performs this action. At any given time the token amount may be positive, negative or zero. The positive amount indicates the pending funds, and the negative amount indicates the liability level.

C Protocol Messages

The business logic of the entire system is deployed as a smart contract. A reference implementation was published in Github [10]. A payer and a payee of the system should use cheque payment mobile application. Standalone application was developed for banks.
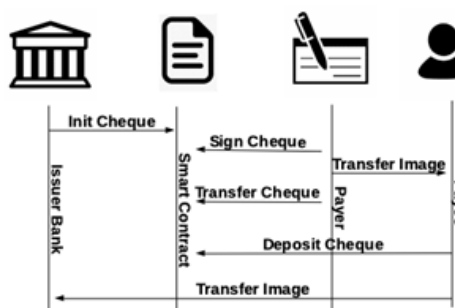

Figure 1. Message Sequence

The physical image of the cheques is transferred from the payer to the payee and finally to the issuer bank. The protocol messages are shown in the figure 1. Each participant of this protocol calls the relevant function of the smart contract as follows.

(A) On the request receives from the payer's mobile application, the electronic cheque is generated by the Issuer bank. It has the same look and feel of the physical cheque. The data relevant to the cheque such as cheque number, bank number and amount is written into the smart contract on the blockchain by calling initCheque function [10]. The Issuer Bank transfers the equivalent amount of crypto tokens associated with the cheque to the payer's address. By transferring the crypto token, the Issuer bank assures the payment.

(B) The payer authorizes payment by signing an electronic cheque using the mobile Application. The date and electronic signature are written into the smart contract on the blockchain by using the signCheque function [10]. In addition to that physical signature of the payer is embedded into the cheque image to give the same look and feel.

(C) The payer transfers the signed cheque image to the payee by using the Mobile application and call transferCheque function [10] of the smart contract. It transfers the cheque to the payee. When the electronic cheque is transferred to a payee, the payer transfers the equivalent amount of crypto tokens associated with the cheque to the payee's address. By transferring the crypto token, the payer assures the payment on the mentioned date.

(D) The payee claims the payment by presenting the signed cheque to the issuer bank on the relevant date by calling the depositCheque function [10]. When the payee executes the depositCheque function, an equivalent amount of crypto tokens associated with the cheque transfer from the payee to the issuer bank. It verifies the authenticity, and the Issuer Bank releases the funds to the payee via an inter-banking transfer.

(E) In the case of a cash cheque, the payee can also transfer the signed cheque to the third party. Then the equivalent amount of crypto tokens associated with the cheque transfer from the payee to the third party with the signed cheque image. Then the third party claims the payment by presenting the signed cheque to the Issuer Bank on the relevant date as mentioned in step 4. The cheque can be transferred to any number of third parties before it deposits to the relevant bank.

Figure 2 shows the crypto token transfer between the issuer bank, the payer, the payee and the third party. In order to complete the transaction, the payer must deposit the funds in his account on the settlement date.
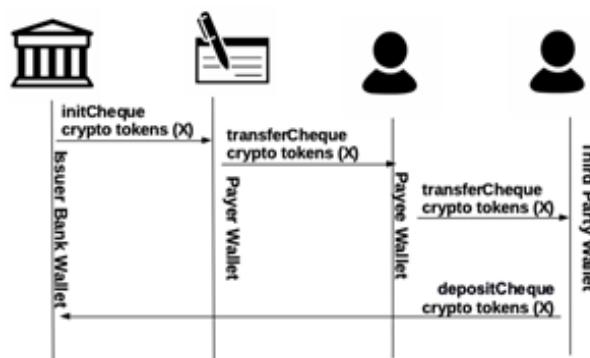
Figure 2. Crypto Token Transfer Sequence

D Transaction Settlement

In order to facilitate the settlement, the payer must deposit the funds in his account on the settlement date. If a payer does not have sufficient funds in his account on the settlement date, the Issuer Bank calls the settlementDelay smart contract function [10].
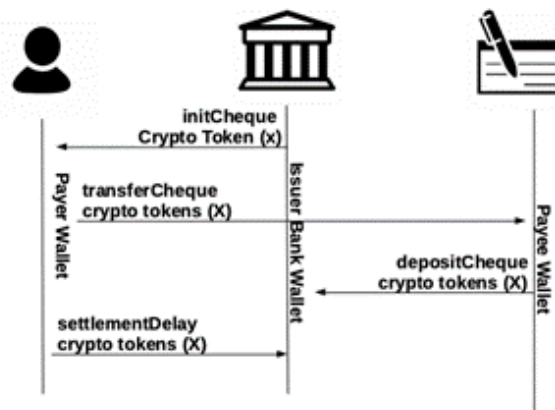
Figure 3. Settlement Delay

As shown in the figure 3 **settlementDelay** function transfers crypto tokens equal to the cheque amount from the payer account to the issuer bank account.

The following status may occur after calling the *settlementDelay* function:

(A) The crypto-token amount of the payer is zero. If he/she has some cheques to be deposited, he/she cannot do it until he/she purchases crypto token from the bank or until he/she receives some cheques. The bank can charge a fee for such settlement delays.

(B) The crypto-token amount of payer is positive. If he/she has some cheques to be deposited, he/she can deposit cheques less than or equal to the crypto token balance.

(C) The payer must settle the account balance and purchase a crypto token to deposit the other cheques. The Issuer bank can charge the fee for settlement delay.

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(D) The crypto-token amount of payer is negative. The negative figure shows insufficient funds, and the payer cannot deposit any cheque if he/she has a negative balance. In addition, interest can be charged for such negative balance and settlement delays.

These actions block the payer's pending funds until the payer physically settle the funds. If he/she settles the funds, the equivalent amount of crypto tokens is transferred back to the payer's address. The bank can charge a fee for such settlement delays. These actions encourage the payer to deposit sufficient funds on the settlement date.

As previously mentioned, The payee can transfer the cash cheque to the other person or keep it until the settlement date. The present owner of the cheque can deposit the cheque, and it terminates the life cycle of the cheque.

IV EVALUATION

This protocol was evaluated by implementing a Proof Of Concept (POC) application. The POC application was evaluated under various possible use cases. Five such use cases are described in the following section.

A Case – 1

Amal issues a cheque to a Nimal equal to Rs. 5000/=. Amal deposits Rs. 5000/= to settle this cheque. Amal receives 5000 crypto tokens from the bank for his cheque, and he transfers these 5000 tokens to Nimal with the cheque. Amal has zero crypto tokens at this stage, and Nimal has 5000 crypto tokens.
Nimal deposits the cheque to the bank with these 5000 tokens and claims the money. Since Amal deposits Rs. 5000/= for his cheque, the bank does not take any action on Amal's account.

B Case – 2

Amal issues a cash cheque to a Nimal equal to Rs. 5000/=. Nimal transfers it to Saman, and he deposits it. Amal deposits Rs. 5000/= to settle this cheque.
Amal receives 5000 crypto tokens from the bank for his cheque, and he transfers these 5000 tokens to Nimal with the cheque. Nimal transfers the cheque to Saman with 5000 tokens. Thus Saman has 5000 tokens, and he can deposit the cheque to the Bank. Since Amal deposits Rs. 5000/= for his cheque, the bank does not take any action on Amal's account.

C Case – 3

Amal issues two cheques to Nimal and Kamal equal to Rs. 1000/= and Rs. 2000/=. Amal deposits Rs. 3000/= to settle these cheques.
According to the protocol, Amal receives 3000 crypto tokens from his bank at the initial stage. When he transfers the Rs. 1000/= cheque to Nimal, 1000 crypto tokens are transferred to Nimal. When he transfers the Rs. 2000/= cheque to Kamal, 2000 crypto tokens are transferred to Kamal. At this stage, Amal has zero crypto tokens, Nimal has 1000 crypto tokens, and Kamal has 2000 crypto tokens. When Nimal deposits Rs.1000/= cheque, he transfers 1000 crypto tokens to the bank. When Kamal deposits Rs.2000/= cheque, he transfers 2000 crypto tokens to the bank. Thus the bank receives 3000 crypto tokens, and both people receive the money. Since Amal deposits money on time, the bank does not claim any crypto token from Amal.

D Case – 4

Amal issues two cheques to Nimal and Kamal equal to Rs. 1000/= and Rs. 2000/= as described in case 3. However, in this case, Amal fails to deposit Rs. 3000/= to settle these cheques.
Initially, Amal receives 3000 crypto tokens for his cheques, and he transfers all 3000 crypto tokens to Nimal and Kamal. Thus he has zero tokens, as described in the previous case. Nimal deposits Rs.1000/= cheque and transfers 1000 crypto tokens to the bank. Kamal deposits Rs.2000/= cheque and transfers 2000 crypto tokens to the bank.
Thus Nimal and Kamal received their money. Since Amal fails to deposit Rs. 3000/=, the bank claims 3000 crypto tokens from Amal. Then his crypto token balance becomes -3000. At this stage, let us assume Amal receives two cheques equal to Rs. 5000/= and Rs. 2000/=. Then he gets 7000 crypto tokens, and his crypto token balance is 4000 (7000-3000). Now he can deposit Rs. 2000/= cheque but cannot deposit Rs. 5000/= cheque. In order to deposit it, he must settle Rs. 3000/= and purchase 3000 crypto tokens. The bank can charge a commission for this delay.

E Case – 5

Amal issues a cheque to a Nimal equal to Rs. 2000/=. Amal receives a cheque from Saman equal to Rs. 5000/=. Amal fails to deposit Rs. 2000/= to settle his cheque.
Amal receives 2000 crypto tokens from the bank for his cheque, and he receives 5000 crypto tokens from Saman. Thus he has 7000 crypto tokens. When he transfers Rs.2000/= cheque to Nimal 2000 crypto tokens are transferred to Nimal. Thus Amal has 5000 crypto tokens. Since he fails to deposit Rs. 2000/= for his cheque, the bank takes 2000 crypto tokens from his account. Thus he has 3000 crypto tokens, and he cannot deposit Rs. 5000/= cheque. Either he has to purchase 2000 crypto tokens by depositing Rs 2000/=, or he should receive a cheque greater than Rs. 2000/= from someone else.

V FEATURES

Feature comparison of the proposed solution and physical cheque system is given in Table 1.

Table 1 : Features Comparison

Physical Cheques	Proposed Solution
Printed Cheque Book is used	Not necessary to issue a cheque book
Physical signature is applied	Physical and Electronic signatures are used
Signed on the paper	Signed on the device screen
Support inter-bank cheque clearance	Support inter-bank cheque clearance
Scanned the physical cheque and submit the cheque image to clearance	Cheque image is generated and directly submitted to clearance
Clearance may delayed	Immediate clearance
Issue cheque with future dates (dated cheques)	Issue cheques with future dates
Banks are not aware about dated cheques	Banks knows the volume of dated cheques
Cheque may dishonor	Cheque dishonoring rate can be reduced
Possible to issue cash cheque and transfer to third parties	Cash cheque is supported and electronically transfer to third parties
Banks are not aware such transfer	Banks can trace the transfer
Manually archive for dispute resolutions	Electronically save on a Blockchain for dispute resolution

VI CONCLUSION

In the existing paper-based cheque system, the Issuer Bank has no information regarding the volume of dated cheques issued by a particular customer. With our protocol, the Issuer Bank knows it, and therefore it can maintain the maximum limit of such cheques. It reduces the cheque dishonoring rate. The overhead of cheque clearing, such as scanning of the paper cheque, can be eliminated with this protocol. Thus the bank can save the cheque clearing cost. In addition, the bank can offer a credit facility to their customers based on their credibility and earn extra income. With this protocol, the customer should not need to visit a bank and manually fill a deposit slip. Thus it improves customer convenience. This protocol can coexist with the paper-based cheque system.

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E-Learning Platform for Hearing Impaired Children with Handwritten Character Recognition using CNN

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ABSTRACT Hearing impairment is an example of a disability that can affect a child's education in a variety of ways. E-learning has been proved to be an excellent learning approach for students as it provides many advantages. One advantage is that children can save their time as it provides the opportunity to engage in studies from anywhere in the world. Although the e-learning method may have various advantages, it also has several disadvantages that need to be addressed. This online learning technique may not be as helpful for children under the age of five as it is for the older generation. For children with hearing impairment, this strategy of education will be even worse. Hence, these children should have an appropriate alternative for learning letters and numbers during crisis situations. The major goal of this study is to critically evaluate the need for an alternative solution. The suggested e-learning platform helps children learn letters and numbers step by step. This platform also teaches children to write numbers and both Sinhala and English characters. In order to recognize the letters and numbers children write, the system uses convolutional neural networks (CNN). In addition, the system provides basic quizzes and activities to ensure an engaging/interesting learning process. This study was conducted with the goal of improving the effectiveness of e-learning for hearing impaired children.

KEYWORDS: CNN, Crisis Situations, E-Learning, Handwritten Character Recognition, Hearing Impaired Children

I INTRODUCTION

Every person on earth should have access to education and every child should have access to education and school regardless of where they live. Children with hearing loss should also have access to such facilities but those children go through various difficulties when engaging in the process of education. Sociocultural attitudes and crisis conditions such as public health, and environmental catastrophes are all major impediments to learning for hearing impaired children.

Distance education, often referred to as e-learning, was introduced as a new approach as a result of the advancement in technology in the field of education. E-learning is an important component as the younger generation relies on technology to go through challenging times. In e-learning, students and teachers are physically separated. However, at the same time, students and teachers have the ability to communicate with each other online and offline. One of the most common methods of distance education is video conferencing. Video conferencing is the most common way for students to interact directly with their teachers during live lessons [1]. Students with disabilities can benefit greatly from this technology as they can complete their education at home without having to leave home. Due to their socio-cultural realties, some students with disabilities are reluctant to attend standard classes to complete their studies. As a result, distance learning or e-learning may be beneficial for students like them [2].

World health organization stated that almost half a billion people worldwide have hearing impairments and more than 30 million of them are children [3]. One of the most significant and contentious problems in deaf history is deaf children's capacity to obtain and access education [4]. For many years, deaf or hard-of-hearing children were counseled primarily through sign language. Deaf individuals communicate with others via sign language. It is thought to be one of the most recent research topics in the history of science.

E-learning is known as a modern method that can be used for education. It does not require physical presence of students in a classroom. It can be considered as a great opportunity to engage in education remotely anywhere in the world. E-learning is known as a method of education that is based on student-student interaction (SSI), student-content interaction (SCI) and finally the most common relationship, student-instructor interaction (SII) [5]. However, this method requires several electronic devices such as laptops or smartphones or tablets and Wi-Fi. Those who are unable to afford to find such devices will have to face some difficulties in engaging in their education [6]. Many people nowadays benefit from e-learning, including differently abled people. This method can only adversely affect anyone's life if they are not familiar with the newest technologies [7]. Hence, it is important to keep people informed about the latest technologies and upcoming trends.

Differently abled children require more attention than other children. A typical online classroom for them would not be as effective as it would be for other children, specifically when it comes to learning letters and numbers. A structured environment is highly required for hearing impaired children to succeed in their education. Some of the researchers who are in the field of e-learning have found several methods and techniques that can be used to overcome the above mentioned barriers. The issues they have faced when developing those systems and the advantages of the techniques and the methods they used will be discussed in this study. The major goal of this research is to provide a mechanism for hearing-impaired youngsters to complete their education even in the face of a crisis. This study will present a way for learning numbers and letters in both English and Sinhala.

The significance of this research is that this study is based on e-learning platforms for hearing impaired children. The idea of e-learning platforms for children with disabilities is an emerging trend in the field of e-learning. Therefore, this study pays a careful consideration on the existing e-learning platforms for hearing impaired children and the technologies and trends used by other researchers to solve existing problems. Also, this study presents a developed model that can be used to solve the existing problems.

II LITERATURE REVIEW

Researchers have observed various techniques and methods that can be helpful for hearing impaired children in their education. Researchers working in the field of e-learning have seen the usefulness of e-learning for them from several angles. This section of the study attempts to identify the proposed perspectives of researchers which can later be

used to analyze the technologies and the newest trends they have used. According to Saunders, Lewis and Thornhill, the literature will support the research question and objectives providing a complete justification for the research aim and objectives, gaining insights as per the outline of the research and providing important information and ideas for other researches [8]. Therefore, this section is structured in accordance with the research objectives.

A Existing Systems

There are many e-learning platforms currently available for hearing impaired children and the content of most platforms is based on Math, general education and communication. Some of the studies that were done by researchers are as follows,

Table 1 : Existing studies on e-learning for Hearing Impaired Children

Name of the Study	Participants	Areas Based On
"A Gamified E-learning Framework for teaching Mathematics"	Deaf students	Mathematics
"Adaptive Learning System and an Academic Advisor Agent"	Deaf students	General Education
"Design an Application for the Hearing Impaired People"	Hearing Impaired People	Communicate with others
"Deaf Students Higher Education using E-Learning"	Deaf Students	Higher Education
"E-learning course based on AdAPI"	Deaf and hard of hearing participants	Computer literacy

Table 1 covers a wide range of subjects taught to hearing impaired children and adults. The system implemented by Samaa M. Shoheib is a gamified e-learning framework that can be used to teach mathematics to hearing impaired students. According to the author, Gamified is an approach to accelerate the experience curve of teaching, learning and thinking in education. Simply, gamification is an application of game planning elements and game principles in non-game contexts. The general contents of the implemented system were, content, Arabic sign language avatar, quality standards, learner support as well as characteristics, and gamification components. The content of this study contains the course syllabus, structure, quantity, depth and activities. The learner support includes grading, feedback and guidance. Grading and feedback are given using score and instant feedback. These are included in the

gamification components. Special guidance is provided using the Arabic sign language avatar. Gamification components that were used in this study were, points and performance graphs, challenges, badges and achievements, leader modes, levels, time based activities, stories and characters as well as freedom to fail [9].

The main objective of the adaptive learning system proposed by [10] was to monitor the student's achievement in the learning program and instruct them to do better. They proposed this system to overcome the difficulties hearing impaired learners face. According to the researchers, some of the challenges hearing impaired people face are, difficulties in writing and reading online and being compared with other normal students, grammatical errors they make when writing, and not having tutors who are willing to educate them without any hesitations as most of the tutors find it difficult to teach hearing impaired students. For the above mentioned problems, authors proposed a solution based on a set of defined skills that would help hearing impaired children to enhance their knowledge in writing and reading. These skills were specified as DSLO's ("Deaf Students Learning Outcomes") [10].

Matjaž Debevc and others have created an e-learning environment that is adapted for people with hearing disabilities. In this study, the utility and educational effectiveness of the e-learning curriculum were evaluated using an inventory and adapted education index system that measures software usage. The researchers have used sign language videos to teach hearing impaired students to make the system more effective for them [11].

Researchers were able to design an application for smooth communication and for an easy life of the hearing impaired people. For this, sign language, voice to text translation features were included. In addition, a vibration alarm was added for the safety of the people[12].

B Approached Techniques

This section contains the technologies and the approaches used by the above mentioned authors to implement the systems they proposed.

According to Samaa M. Shoheib, Gamified is an approach to accelerate the experience curve of teaching, learning and thinking in education. Simply, gamification is an application of game planning elements and game principles in non-game contexts [9]. This is known as a game based method. Hence the goals of the system are presented to users as games. A study was undertaken, to assess the usefulness of this strategy by using a gamification plugin in a learning management system. The results show that the gamification method has better effects than the traditional

Table 2 : Technologies used in Proposed Systems

Name of the Study	Approached Techniques
"A Gamified E-learning Framework for teaching Mathematics"	Gamification, Arabic Sign Language (ArSL), Animation
"Adaptive Learning System and an Academic Advisor Agent"	N-tiers, Multi-Layer architecture, Multi agent system, Model View Controller pattern maintenance
"Design an Application for the Hearing Impaired People"	Sign Language, Voice to text translation
"Deaf Students Higher Education using E-Learning"	Cloud Computing, Big Data, Video Streaming, Text
"E-learning course based on AdAPI"	Video Streaming (sign language and subtitles), Animations

education system.

C Effectiveness of E-learning for Hearing Impaired Children during Crisis Situations

With the development of the world, distance education also known as e-learning has started growing rapidly all around the world. It has also become the major solution to provide education to the younger generation in difficult times. The effectiveness of e-learning cannot be analyzed just by comparing it with the traditional education system as both the systems have many advantages as well as disadvantages, especially in times of crisis.

According to the authors, the distance education system is the most effective and efficient way to continue education in crisis situations. During crisis situations people are stuck at home unable to go anywhere. There are times when people are not able to get the essential products for themselves. In such situations, advanced technology is needed in order to manage the situation. As a result, distance education was developed to address all the barriers that affect the education sector in a country.

According to Oliveira, in a crisis situation, schools and institutions are closed to prevent external damages. Hence there won't be a place for students to do their studies. In the distance education system, a specific place is not required for students to engage in their studies [13]. Students are able to engage in their education at home. In the traditional education system, the teacher may have to teach the same subject to different classes at different times but with the distance education system the teacher or the tutor has the ability to conduct only one session (video) and can ask students to join that at the same time. It is much easier than teaching the same lesson at different times.

According to the researchers, distance education requires 40-60% less time to learn than in the traditional learning system [14]. The main reason for that is that students have enough time to self-study and clarify the queries on their own. According to the authors, the effectiveness of distance education varies among age groups. Since young children require more attention they require physical activities as well as in depth guidelines.

III METHODOLOGY

The architecture of the system was broken down into four main components and they are, software architecture, database, modular architectures as well the interfaces of the system.

A Data Gathering

To gather the required data for the development of the system were done using data collection protocols such as interviews, questionnaires and documentary reviews. The main purpose of this system is to deliver an effective learning method for hearing impaired children that can be used to ensure that they gain education even in their difficult times.

B Data Analysis

Data required for the implementation of the system were analyzed using charts and diagrams. In the analysis process, problems and difficulties faced by hearing impaired children were identified. This helped the authors to discover the need for a new learning method for hearing impaired children in times of crisis.

C Approach

Main users of this system are hearing impaired children and lecturers or teachers of hearing impaired children. There are two types of inputs for the system. They are basic information such as the name, date of birth etc. of hearing impaired children and uploaded course materials by teachers.

D Technology Adapted

To gather user inputs through sign in and registration modules, the system has been implemented using HTML, CSS, JavaScript and firebase. These technologies were used by considering the functional and non-functional requirements of the system. It is important to develop a system that satisfies the requirements of the users. Proposed e-learning platform for hearing impaired children is a web based system. Non-functional requirements such as availability, security, learnability and usability were mainly considered when developing the system. To develop the frontend of the system,

Html, CSS, JavaScript were used with visual studio code. To develop the backend of the system, CNN, python, Jupyter notebook and firebase were used. Since the main goal of this system is to teach hearing impaired children how to write letters and numbers, CNN was used to recognize the handwritten text and digits.

E Proposed Design

The architecture of the system was broken down into four main components and they are, software architecture, database, modular architectures as well the interfaces of the system.

1 Overall System Architecture
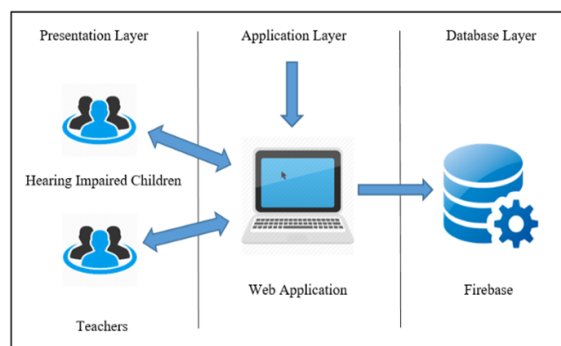
Figure 1 : Overall System Architecture
Source: Author

Presentation Layer - This shows information about the system and the web application. It is a user friendly layer and is the front part of the system. In this layer, user interfaces of the system are largely considered. User interfaces of this system are eye catching and graphical.

Application Layer - The application layer consists of the web application. The application layer presents the functional logic that shows the basic functionalities of a web based system. It is an abstracted layer that connects to the other two layers as it acts like the central part of the entire system. This layer presents a detailed configuration of the system.

Database Layer - The database layer consists of databases, tables, records, etc. It has database servers that can be used to store all the required information. This layer is independent of the application layer and the presentation layer. This storage will be used to ensure the efficiency of all operations related to the database of the e-learning platform.

2 Modular Architecture

Overall modular architecture of the e-learning platform is shown using figures. The modules of the system are

mentioned below with related interfaces.

User Profile - Every user will have their own user profile. The details which were entered by the user will be displayed in their user profiles. Details such as, name, age, and courses they follow on the platform.

Course Selection - There will be several course materials for hearing impaired students to access. They can choose to follow any of the included courses in the system.

Letters and Numbers Identification - This module includes an algorithm to identify the handwritten texts and digits entered by the users. The recognition of handwritten characters and letters is done using convolutional neural networks.

Feedback - Users can send their feedback on the course material they follow or regarding the system. They will be given a section to add their comments on the platform. For this a feedback form will be provided.

The developed e-learning platform for hearing impaired children is based on colorful themes and colors because children require eye catching interfaces. Figure 2 displays the home page of the platform and figure 3 displays the course selection interface of the system. Figure 6 is the sign up interface for children.
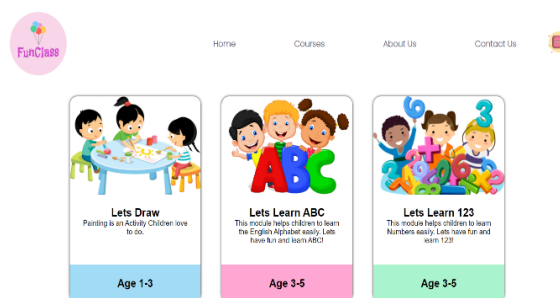

Figure 2 : Home Page of the System
Source: Author

IV   RESULTS AND DISCUSSION

Hearing impaired children are in need of an effective solution to continue their education in times of crisis. A typical online classroom where teachers talk and students listen would not be effective for them at all. Therefore, an e-learning platform was proposed to be used as an alternative which hearing impaired children can use to learn letters and numbers with proper guidelines. This allows children to draw letters and numbers on their own.

To recognize the numbers and letters written by children, CNN is used. For this, a dataset consisting of 100 images

Figure 3 : Course Selection Interface
Source: Author

Figure 4 : Sign Up Interface
Source: Author

per digit was used. This data set was split into two sets. 20% were used for the training process of the dataset and 80% were used for testing. For English and Sinhala character recognition the same approach was used. 100 images were used for each letter. The entire data set was then split into two sets for training and testing process.

V   CONCLUSION AND FUTURE WORK

The main purpose of this research is to provide HIC with a better way to complete their education in times of crisis such as public health, political and environmental disasters. In times of crisis, learning letters and numbers has proven to be a daunting task for young people. Some of the existing e-learning systems are inefficient and inefficient compared to traditional school education. We were able to overcome these challenges by creating an e-learning platform that teaches hearing challenged youngsters how to learn and write letters and numbers in a step-by-step manner.

This article recommends a web-based e-learning platform with a variety of course resources for teaching students how to write letters and numbers. This system will be expanded to accommodate more course content for other age groups and for other differently abled youngsters. Furthermore, this way of learning will be offered to a group of youngsters who are suffering from hearing impairments and their feedback will be taken. The system will be
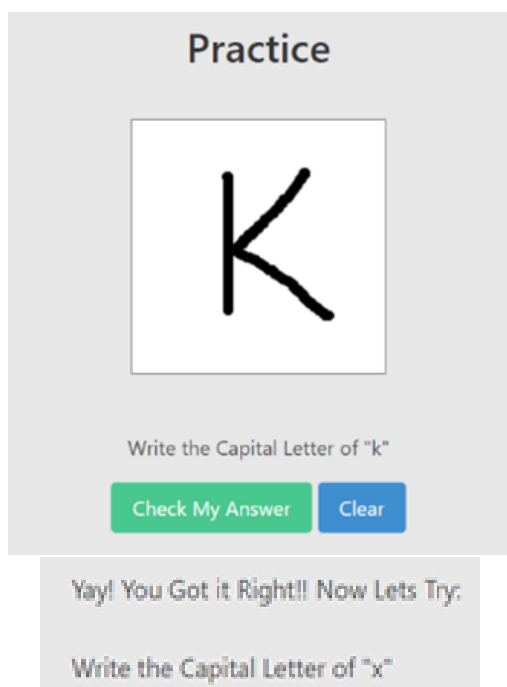
Figure 5 : Prediction of Characters
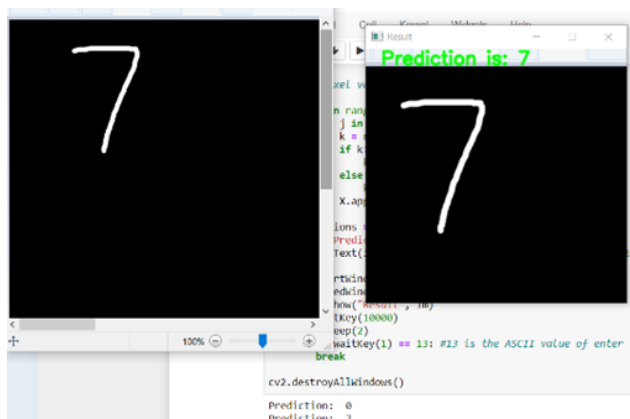Source: Author

Figure 6 : Prediction of Handwritten Digits
Source: Author

improved based on the comments received to make it more beneficial for children.

This platform can be very useful for children who struggle with learning letters and numbers in times of crisis. Some parents find it difficult to persuade their kids to sit in one place and study, especially when they're at home. Children seek entertaining activities. Hence, this platform will help not only children but also parents in educating their children.

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ABBREVIATIONS AND SPECIFIC SYMBOLS

- CNN – Convolutional Neural Network

- HIC – Hearing Impaired Children

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Investor Driven Adaptive and Automated Stock Market Portfolio Management Platform with Stock Prices Prediction for Colombo Stock Exchange of Sri Lanka

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ABSTRACT Over the past few years various studies have been conducted to develop an optimum stock market related portfolio management platform that will assist investors to actively perform the portfolio management process. Risk and level of investor participation is considered to be one of the challenging aspects identified for optimum portfolio management. Along with portfolio management, stock price prediction is one of the key contributing factors that helps an investor to make mid and long-term strategic investment decisions. Various concepts are evaluated and studied thoroughly to determine the most accurate algorithm to implement a stock price-based prediction system. Currently, Colombo Stock Exchange have identified a desperate requirement of a portfolio management system with prediction capabilities to support the local and foreign investors to actively engage in trading activities in different stock exchanges in different countries. A critical study has been conducted using supportive research papers, studying similar applications which are developed so far and using various requirement elicitation techniques to determine the functional requirements, non-functional requirements, investor requirements and User Interface/User Experience (UI/UX) considerations. The paper further describes various technological mechanisms implemented and system architectures used to develop the portfolio management and stock price prediction system. Accordingly, the implementation of Brownian Motion algorithm-based model and LSTM (Long Short-Term Memory) model are presented in detail by the author. Finally, evaluation and testing results of the completed system and stock price prediction models are presented to prove the successfulness of the completed application and accuracy of the models implemented.

KEYWORDS: CSE, LSTM, portfolio, prediction, stock

I INTRODUCTION

[1] Stock market portfolio management can be defined as a technique or an art of analyzing or overseeing, selected number of interested group of shares in order to achieve long term financial goals and objectives. The ultimate requirement of the portfolio management is to weigh the strengths, weaknesses, opportunities, and potential threats over selected number of stocks. In portfolio management an investor is intended to increase the investment returns under a deuterated risk level within a specific period of time. In the non-automated process, an investor requires to re-balance his/her stock portfolio manually according to the trading activities conducted over the time. Following are the actions or tasks that needed to be performed by an investor in the manual process to manage the stock market related investments:- re-evaluate the financial value of the current stocks if purchased before, re-evaluating the investor depending on the investment strategy by analyzing the stock selection criteria used previously

such as stock purchasing sectors e.g.-health care, leisure and entertainment, business etc., manually analyzing the current market value of stocks which are preferred to be purchased by each public listed company, summing up the total investment and deciding the percentages of possible returns expected, calculating and evaluating the expected returns with real returns and deciding sectors to add or drop based on returns[2].

Stock prices prediction is an act of forecasting the future stock prices of a particular public listed company. Currently many countries including NYSE (New York Stock Exchange) provide predictions to the investors to increase the profits or return of investors by investing at the present time. There are various arguments related to success of prediction, since there could be various macro and micro economic factors influencing to fluctuate the stock prices. Stock market related operations are uncertain in nature and most of the investors feel insecure and unconfident when managing their investment portfolio on

stock exchanges among different countries. One of the prime concern of investors, stakeholders and any other individual in the financial market is to successfully manage the stock market portfolio. On the other hand, investors face various difficulties in identifying public listed companies which have a sound growth prospects for investment.

In the current situation, Colombo Stock Exchange would not offer a feasible platform for the investors to manage, view, analyze and forecast the future behaviour of the stocks purchased by an investor. Currently many investors driven stock purchasing platforms are introduced in Srilanka and as well as in other foreign countries where investor could directly engage in buying/selling without any assistance from stockbroker or brokerage firm. With the development of said platforms, a need of a stock portfolio management and prediction platform are identified. Web and mobile responsive application is developed to facilitate the investors to manage and analyze local and foreign stock portfolio by including stock prices prediction module which support the investors to make decisions based on predicted behaviour of a particular stock.

II   PROBLEM DOMAIN

Currently in Sri Lanka, investors obtain assistance from various stock-brokering firms where stock broking advisors would assist an investor by advising, predicting the market, and managing the portfolio for the best investment return. On each transaction conducted on behalf of the investor a certain amount of brokerage is charged by the stock-brokering firm. If a local investor is interested to invest on international stock market either an investor could start purchasing stocks through an online platform using an E-wallet with dollar account or through a stock-brokering firm who is specialized in with international stock market transactions [3]. On considering the local/international situations if an investor needs to obtain a quick analysis or update of the current portfolio status, gains, loss, or any other information, he/she needs to request a portfolio summary through the broker or through the portfolio management access granted by the stock brokering firms. [4] CSE and Central bank of Sri Lanka have identified various frauds or illegal attempts actioned by stockbrokers due to lack of proper concertation, lack of knowledge on share market activities or lack of updated portfolio analysis knowledge with the investor. Due to the continuous fraud, malpractices and untransparent actions conducted by stockbrokers, CSE have identified a reluctance of potential investors to invest on share market and actively engage in large volumes of shares. One of the most popular incidents is Securities and Exchange Commission (SEC) filing a court cases against four well known stock brokering firms that have been operating over past few years. According to the SEC, these stocks brokering firms had involve in

certain manipulation or creating abnormal/misleading situation with regard to a share price named "Radiant Gems International PLC" in 2011 which have interfered the smooth functioning of the share market. This has result in losing the credibility with regard to the shares among investors who have currently purchased shares or intended to purchase in the future.

At present Colombo Stock Exchange does not facilitate investors with an official stock market portfolio management platform with prediction capabilities. In the course of addressing the above-mentioned problems one of the drawbacks CSE has identified is the unavailability of fully responsive, functional, user friendly, ubiquitous, and free platform to add and manage the stocks own by an investor in his/her local or international portfolio. Stock prices prediction system would also assist an investor to make the most accurate financial strategic decisions before investing in a particular share according to the predicted data. This development will be the first official stock market portfolio management and prediction system for CSE in Sri Lanka.

III   LITRETURE REVIEW

A thorough analysis of previous literature has been conducted prior to the design and development of the system to obtain an in-depth knowledge on related theories, concepts that are related to the study.

A   A. Stock Price Prediction Using LSTM, RNN AND CNN-Sliding Window Model

[5] Forecasting could be defined as predicting the future behaviour or trends based on analyzing the relevant past historic data. Predictions are used in various systems in the industry such as in business sector, health care, education, time related activities etc. According to the paper forecasting could be divided in to three types- short term, medium term, and long-term forecasting. The main difference between forecasting types is the duration predicted in the future. To provide prediction a variable is considered, in the paper **"price"** is considered as an important variable. Stock price forecasting could be performed using various methods such as technical analysis, fundamental analysis, and time series-based forecasting. In Fundamental analysis the investment on a particular stock price is decided based upon the analysis on profits/returns, sales and other economic (micro and macro) factors. This is mainly suited for long term forecasting. Technical analysis uses the previous data (past stock prices) in order to predict the possible future price. Average/Mean is considered to be the main algorithm used to provide the predictions on the said type of analysis. It is mainly suited for short term forecasting. Time series-based forecasting mainly involve two types of algorithms namely, linear model and non-linear model.

Series of time related data are analyzed and studied along with algorithms to predict the future. Based on the two types of algorithms the paper has stated linear models are not capable to identify a pattern or trend in a set of considered data. Inability to identify the latent dynamics within the data is considered to be the main reason for the above said drawback. Nonlinear model utilizes methods such as deep learning, neural networks and various other algorithms in order to provide predictions. The paper further evaluates concepts such as Multi-Layer Perceptron (MLP), Recursive Neural Networks (RNN), Convolutional Neural Network (CNN) and other types of machine learning techniques such as image processing, natural language processing which are utilized in testing the suitability to stock price predictions. One of the most feasible and proven method suggested by the paper is algorithms based on deep learning concepts. After completing several levels of self-learning process, deep learning has been able to identify a pattern, hidden trend and dynamics underlying with in the data analyzed.

Based on results of an experiment conducted by the author the paper recommends Convolutional Neural Network (CNN) predictions are more accurate when compared with the predictions from Recursive Neural Networks (RNN) and Long Short-Term Memory networks (LSTM). Since CNN does not rely on previous/historic data or information for prediction CNN model has been able to provide proven results. The CNN prediction process understands the patterns/dynamic changes in the current window. This is considered as one of the prime reasons for providing more accurate prediction results. LSTM and RNN depends on the historic information or data to predict the instances of the future. However, for short term predictions RNN and LSTM model were able to provide more accurate predictions according to the results of the experiments concluded by the author.

B MobiMine-Stock market monitoring platform

[6] MobiMine is an intelligent cross platform accessible system for monitoring and analyzing stock market related data through a distributed data mining process. Investors could store the current portfolio related data on the application to manage and monitor the stocks. One of the important factors identified through the research paper is watchlist feature that allow investors to concentrate the stocks that they are interested to buy in the near future. The application is capable of constructing relationships between the data collected from various finance related data sources and the ultimate objective of identifying specific focus area of the investor to provide an enhance analysis process based on one's interest. Using the datamining process, details of a customized wish stock list will be delivered through the application. Existing

portfolio management system depends on a manual input of wish stocks (stocks that are expected to purchase in the future). Manual based construction of watch list feature using the predefined focus area of the investor is often cumbersome and unpractical since investor cannot keep watch and analyze the market for a longer period of time when he/she is on the move. Investor based customize focus area development is the main requirement addressed through the application and it is focused on improving the watch stock list feature. Challenges faced by the author on developing above process are- difficulties on handling continuous flow of data from many incoming data streams, managing the limited wireless/ GSM network bandwidth when conducting the data mining process, representation of highly informative data within a limited small screen and managing the battery consumption when conducting high computational and processing tasks.

The application has been developed according to the client-server architecture where investors run the application on any type of handheld devices where as Mobine server sources the financial data streams. To ensure the smooth functioning of the application, it is designed to work without any issues on wireless low bandwidth network connections.

The main functional requirements addressed by the MobiMine application are as follows-

Portfolio Management- each investor is provided with a dashboard to manage, analyze stocks and to evaluate between different stocks performance, gains, losses etc. The investor could edit or delete details related to their stored portfolio from the application.

Area of Focus/Interest- The application delivers a more unique approach to track and monitor changes in the market by dividing the selected events as "interested to investor". The following are delivered through the focus area of the application- **Watchlist feature-** Each stock added by the investor on this section is assigned with a score. A higher score means more interesting and lower score means less interesting. The higher score marked stock are given more priority when delivering related data specific to that stock. Modules such as stock connection, stock nuggets and reporting module are different collection of services provided by the application to understand the dynamic and volatile nature of the market. MobiMine application employs various datamining techniques to collect and deliver stock market related data from variety of sources. One of the main function performed by the MobiMine server is, it collects related financial data from various related data sources available on the internet and stores them in the database in order to be used in the data mining process. The server receives the data feed in XML format. In order to perform the datamining various techniques such as clustering, statistical based algorithms, decision trees and Bayesian nets are used.

C Predicting Stock Prices Using LSTM

[7] Due to the changing nature of various financial indicators the prices of stocks would fluctuate unexpectedly. This has been a difficult and a challenging factor for many stock analysts, investors and researchers who are keen on knowing the future behaviour or situation of the stock prices [8]. With the rapid development of technology and correct/appropriate utilization of important and informative indicators, behavioural predictions could be performed up to certain aspects. According to the author a significant explanation has been provided on the RNN (Recurrent Neural Networks) which is described as one of the powerful and well proved models on processing sequential related data. On the in-depth analysis of RNN, LSTM (Long Short-Term Memory) is identified as the most successful RNN's architecture. LSTM consists of memory cells which could be described as a computational unit that replaces hidden layer artificial related neurons among the networks. This structure helps to dynamically identify the data structure and associated patterns to provide more accurate high-capacity predictions. The overall paper is focused on presenting an in-depth idea on developing a prediction system on predicting the returns of NIFTY (50) using an LSTM model. Using historic dataset which contain 5 years of past stock prices the model training and validation activities are conducted [9].

The methodology section of the paper is explained using the background research activities conducted on experimenting the prediction activities of the NIFTY (50) stock prices. The following series of activities are conducted by the author when developing RNN and LSTM based model.

Step 1 -Preparation activities of the historic stock prices data. According to the paper, the window size of the dataset is 22 days and stock prices related data ranges between 01/01/2011 and 31/12/2016. **Step 2- Pre-processing stage of data-** At the pre-processing stage the following activities are conducted such as discretization of data- sorting filtering and determining the important features to be used when developing the prediction model, transformation of data, cleaning and integration of data. After the pre-processing stage, the dataset is divided as testing data and training data. When selecting data for training, the most recent data values are used. **Step 3- Extraction of features-In** feature extraction process more refined and most relevant features are selected in order to be used as input for the neural network. **Step 4- Neural Network Training process-** By assigning random weights and biases the neural network is trained in order to conduct the experiments. According to the paper the author has developed a LSTM model with sequential input layer. Along with sequential input

layer two dense layers and LSTM layers are used. Further LSTM model consists of activations namely **"ReLU"** and linear activation function with an output dense layer. **Step 5- Prediction of results-** In this final step the author evaluates the model by cross comparing the targeted values with the output values generated from the RNN output layer. Backpropagation algorithm could be identified as a significant action carried out by the author to reduce the difference between the derived results from the final model and targeted results. In here the initial biases and weights of the network set at earlier steps are readjusted to reduce the difference between the results. The paper highlights the analysis phase by which efficiency of the model is evaluated. In order to test the efficiency of the model a statistical equation namely, Root Mean Square Error (RMSE) is used. Using the value of the said equation the difference or error between the derived results and targeted results could be minimized. Accordingly, the figure below is extracted directly from the research paper to demonstrate the experimental results of the model outcomes. Various test cases with different parameter numbers and EPOCHS are stimulated by the author. Moreover, the stimulation conducted with the selected features such as High, Low, Open and Close along with 500 EPOCHS has provided the best results of 0.00983 and 0.00859 (testing with RMSE). Results of different parameters and EPOCHs is shown using the Figure 1.

Parameters	No. of Epochs	Training RMSE	Testing RMSE
Open/ Close	250	0.01491	0.01358
Open/ Close	500	0.01027	0.00918
High/Low/Close	250	0.01511	0.014
High/Low/Close	500	0.01133	0.01059
High/Low/Open/ Close	250	0.0133	0.01236
High/Low/Open/ Close	500	0.00983	0.00859

Figure 1 : Results on different Epochs. Source: Research Paper [7]

On concluding the paper, the author proposes Long Short-Term Memory (LSTM) and Recurrent Neural Network (RNN) as a successful approach on predicting more accurate stock prices.

IV   METHODOLOGY

As the primary data source research papers were critically studied, analyzed, and evaluated to understand the functionalities, challenges, theories, and concepts to obtain an in-depth knowledge on the research area. Along with the critical literature review various requirement elicitation techniques were used as secondary data sources to identify the functional and non-functional requirements of investors/users and officials of Colombo Stock Exchange.

Several interviews were conducted to obtain detailed information from the CSE officials since the ultimate development is intended to be developed on behalf of CSE. By conducting an interview informative and detailed information from a broad perspective were collected from different type of stakeholders of the CSE. Several officials of CSE including head of R&D (Research and Development), Head of Public Relations Department and Chief Information Officer (CIO) of CSE were interviewed to obtain in-depth information on investor behaviour's, legal factors, functional requirements, and non-functional requirements. Questionnaires are used as the medium of collecting data from the investors. Questionnaire comprises of 17 questions covering a broad context with regard to system development including functional requirements, non-functional requirements, visual design aspects, UI/UX (User Interface/User Experience) and content management. Questionnaire was presented to a sample of 233 respondents and obtained their responses. As the participants investors who are currently engaged in various professions are selected such as doctors, engineers, judges, businessmen, teachers, accountants, architects etc. Responses derived from the questionnaire were subjected to a statistical analysis, which helped to determine functional requirements, non-functional requirements, important designing aspects considerations and user requirements. The responses from the questionnaire and information gathered from interviews are mainly considered when developing the proposed portfolio management and prediction system. After a comprehensive gap analysis, the following requirements and process were recognized as essential to the proposed system when addressing the important requirements identified throughout the study.

A A. Functional requirements

Initially an investor could sign up and login to the system. First user could add stocks details by entering stock code name and selecting the Stock Exchange (New York stock exchange, Colombo Stock exchange). Along with the stock code, user can include the buying price of the share and volume of the shares purchased. Similarly, user could add the entire portfolio to the system which could be diversified between different shares belonging to various countries. Once the system is updated, each user will be provided an analysis of profit returns/losses, updated stock price details etc. Portfolio will automatically be updated once the market transaction goes online on country wise/stock market wise.

- Live and summarized stock market transaction dashboard presented based on user's selection.

- Ability to generate a detailed summary report on current portfolio in PDF format.

- Delivery of E-mail and SMS-text messages notifications on profits and losses incurred on current portfolio.

- Ability of adding and removing stocks of different countries/stock exchange and conduct portfolio-based customizations.

- Informative analysis of a particular share using candle stick chart filtered according to different time slots such as monthly, weekly, 30 days, 90 days, 180 days, and 360 days.

- "Wish Stock list feature" is integrated to analyze the stocks that are intended to invest in the near future.

- Future stock prices predictions using line graph representations, provided on each share based on user selection.

- Ability to update and change user/investor account related details such as personal information and password.

Administrator-
Ability to obtain detailed analytics of the investors/users who are currently enrolled with the platform, Ability to obtain an overview of currently logged and active users and Ability to create new users and update personal information of existing users.

B Non-Functional requirements

Availability (24x7), user friendly and highly interactive platform, privacy/security, and high performance to cope up with large workloads.

C Design and Development of the Application

The following section of the paper provides a thorough insight of the developed application as a proposed solution to the stated problem. This sections deeply justifies various technological mechanisms implemented in order to develop and embed the previously identified requirements in the system.

Web based platform is developed using Hyper Text Markup Language (HTML), Materialize CSS, Bootstrap and React.js as frontend framework and back ended using PHP with required 3rd party libraries. MySQL relational databases will be used for managing and storing data. The whole application runs on the base of four API endpoints. Two JSON based API's will be used to retrieve data on international stock exchange and another XML based API is used to retrieve data from Colombo Stock Exchange (Officially provided by CSE to fulfill the current development purposes). The logic behind the portfolio management and stock analyzer goes along with the data return in JSON

format. Relevant data will be retrieved and passed to data structures where manipulation activities will be carried out and lastly will be stored on the database.

Machine learning based prediction system will be developed and implemented using API driven data sets. Two types of models are developed to provide price prediction categories based on short term (1-7 days) and midterm (15-30 days). For short term predictions stacked Long Short-Term Memory cell (LSTM) model is used to provide the predictions since LSTM is extremely powerful in providing solutions to sequence-based prediction problems by analyzing the past information. As well as for long term predictions Brownian Motion algorithm-based model is developed. Both models will be trained, tested and deployed on Azure Machine learning studio to avoid any difficulties or delays on model processing and rendering. Python language along with supportive libraries such as MatPlot libraries, Tensor Flow (Keras), Pandas Data reader will be used to implement the model training and other model-based manipulation tasks. One of the challenges identified when developing the stock price prediction module is the update factor of the dataset used to train the model. For example, if a particular investor uses the stock prices prediction system today, the dataset should contain yesterday's stock prices related data when training the model as it is used for forecasting the future stock price of a particular stock based on the perspective of today.

[10] In order to perform long-term stock price prediction Brownian motion model is developed using hyperparameters. When conducting the expected formulation of stock prices, a confidence level of 95% is determined. Initially the dataset is retrieved using the Pandas yahoo finance data reader by specifying the stock symbol of the particular stock which is required to be predicted. In order to specify the range of the time period the current date is fetched using **current=datetime.now ()** function. Along with current date and time details, **current.year-3** is used to specify the starting year of dataset and **current.Month** and **current.Day** are used to specify the latest time period which the particular stock related dataset needs to contain. The main parameter from the dataset- **"Adjust Close"** is mainly used to train the model. After the fetching process the data normalization is performed using logarithm function. On completing the normalization process the following calculations are generated- Mean, Standard deviation, Variance, Volatility and Drift value are calculated. The Brownian motion algorithm along with hyper parameter are applied in order to forecast the stock price after completing the previous computational step. In order to obtain meaningful representations using the Mat plot library a graph is plotted and saved in .PNG format in order to render and display in the portfolio management system once an investor/user requests the prediction results.

Final graph generated using Brownian Motion algorithm on APPLE Inc (AAPL) stock Original stock price and Predicted Output is represented using the Fig 2.

For short term stock price prediction Deep learning Artificial Recurrent Neural Network (RNN) architecture based Long Short-Term Memory (LSTM) model is developed. On elaborating the process of prediction initially using an API driven end point data source named Tiingo is used to download the relevant stock related dataset in CSV format. Every dataset downloaded from Tiingo consists of information related to stock prices ranging from 2016 to present. Accordingly, the following attributes are provided from the dataset which are as follow-**symbol, date, close, high, low, open, volume, adjClose, adjHigh, adjLow, adjOpen, adjVolume, divCash and splitFactor.**As the main parameter **"close"** value of the concerned share is used to train the model. In next step the dataset is split as training data and test data in order to avoid overfitting. This will also help to determine the model generalization ability as well. After implementing the splitting process feature scaling process is implemented, since the LSTM is sensitive to the scale of data. Therefore, before model fitting the data are normalized using scikit-learn pre-processing package named **Min-Max Scaler** and NumPy. One of the advantages of feature scaling could be the increase of performance. Since LSTM expect all the data to be in one specific arrangement using NumPy the data are transformed in to 3D dimension array. Once all the above-mentioned steps are fulfilled the LSTM model could be build using the followings- **Keras** imports, **Sequential**-neural network initialization, **Dense**- to add a densely connected neural network layer, **LSTM**- to add a Long Short Term Memory layer. After importing the required modules, the model is compiled using popular optimizer named **adam** and the loss is set as **mean_squarred_error** in order to calculate the squared errors mean. Next the model will be fit to run 100 Epoch with the batch size of 64 and verbose 1. Epoch is specified here to define the number of times the learning algorithms would work on the entire training dataset. After completing the model compiling process the future stock prices could be predicted using the test data set. In here some of the actions performed earlier are conducted again such as transforming the new dataset using MinMaxScaler and reshaping the dataset. **Inverse_transform** function is used here to obtain the readable format of the stock prices after completing the predictions. Finally using **Matplotlib** predicted stock prices are visualized. LSTM model prediction developed to Microsoft Corporation (MSFT) stock is shown using the Figure**??** .

After completing the development and testing phases the entire project is hosted on Microsoft Azure platform (IaaS, PaaS) deployed and implemented on a virtual machine to ensure the platform performances are guaranteed during

Figure 2 : Apple Stock prediction using Brownian Motion
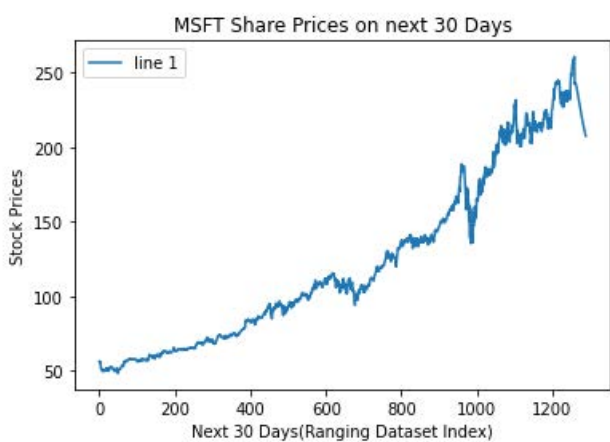Algorithm
Source: Author

Figure 3 : MSFT Stock prediction using LSTM.
Source: Author

times when the workload is at peak. The finalized system architecture is represented using the Figure**??**.
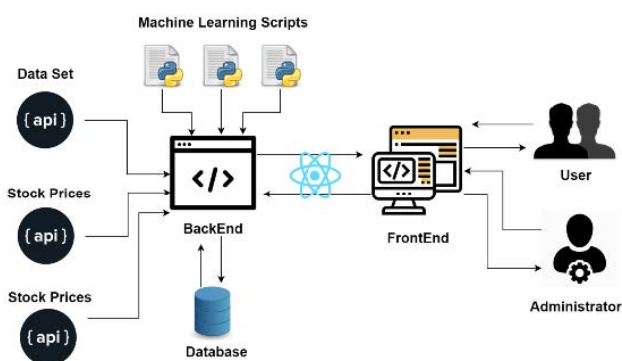

Figure 4 : System Architecture
Source: Author

V RESULTS AND DISCUSSION

A comprehensive system testing, and evaluation was conducted to verify the results/output of the finally developed system. System testing and user acceptance testing are conducted on the 95% completed system by the author as well as from the higher officials of CSE. The Fig 5. provides the results of the test conducted on each and every functional component which is developed in the system using manual as well as automation testing mechanisms (e.g.- Selenium and Katalan Studio tools). The sole purpose of system testing, and evaluation is to ensure the reliability of the system and the appropriate arrangement of newly developed functionalities.

On deeply evaluating the stock price prediction module, it was identified that the accuracy rates of the Long Short-Term Model (LSTM) and Brownian Motion algorithm-based stock price prediction model are more than 85% when these models are used to forecast the future stock prices. According to the testing conducted on different types of Stocks using the Brownian motion algorithm-based model the differences are as follows, On Microsoft Corporation (MSFT) stock the difference between the original stock price and predicted stock price was 4.88%. When evaluating the model on Nike Inc (NKE) stock the difference between the original stock price and predicted stock price was 12.1%. On APPLE Inc (AAPL) stock the difference between the original stock price and predicted stock price was 18.51%. It can be concluded that when different types of stocks are tested using the Brownian motion algorithm-based model, the difference between the original stock price and predicted stock price value of these stocks varies based on the type of the stock. Moreover, based on the outcomes of these tests, it is evident that the accuracy rate of Brownian Motion algorithm-based stock price prediction model is generally more than 80%.

Functional Requirements	Pass/Fail	Score
Investor/User		
Login and Sign-up Function	Pass	98%
Live and summarized stock market transaction dashboard	Pass	97%
Summary report generated in PDF format	Pass	95%
Delivery of E-mail and SMS-text notifications on profits and losses incurred	Pass	92%
Ability of adding and removing stocks from portfolio	Pass	100%
Informative analysis of a particular share using Candle stick chart	Pass	100%
Wish Stock list feature	Pass	96%
Future Stock prices prediction using line graph representations, provided on each share based on user selection	Pass	97%
Ability to modify user/investor account related details	Pass	97%
Administrator		
Detailed analytics on the investors/users who are currently enrolled with the platform	Pass	95%
Ability to obtain an overview of currently logged and active users	Pass	95%
Ability to create new users and update personal information of existing users	Pass	98%

Figure 5 : Test Case Results
Source: Author

VI CONCLUSION

In conclusion, it can be stated that throughout the study a highly interactive, fully functional portfolio management system has been developed. Its specialty is marked by its abilities to engage in thorough analysis of the market and to predict the future stock values. The system would be beneficial for the highly engaged investors to actively participate in the stock market transactions with high volumes of investments at low risk levels and obtain maximum possible returns from the investments. Higher levels of investor participation on stock market activities would ultimately leads to achieve the goals and objectives of the CSE. Accordingly, this would contribute to boost the overall volume of market transactions and ultimately contribute to improve the country's GDP (Gross Domestic Production) in mid and long terms.

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Information Management for Sri Lankan Vegetable Farmers: Effectiveness of ICT Applications

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ABSTRACT The scenario behind Sri Lankan agriculture sector is that one-third of the country's population who engage in agriculture contributes only 7% of the GDP. The distribution of smaller amounts of income among large communities increases poverty among farmers in Sri Lanka. This limited income shrinks further due to sudden price drops, wastage, damages and oversupply. Various types of ICT-based solutions have been provided to eliminate poverty among farmers in Sri Lanka. However, research findings and literature show that most farmers are still suffering in poverty in an age of information even with the availability of many forms of information sources required for farmers. Due to some issues or reasons, farmers do not continuously use information systems and available information systems become obsolete within a short period due to lack of continual use. The research explores reasons for the limited use of information and communication technology-based agricultural information systems among Sri Lankan farming community. The research collected data using literature review, questionnaires and interviews from 76 farmers in four districts of Sri Lanka. Weekly average prices of three selected vegetables and selling offers received for a digital classified AgriApp were observed for one year and collected data was analyzed to identify farmers' and market behavior patterns. Research findings will help to increase ICT practices in agriculture, reduce wastage, control price fluctuation, and eliminate oversupply. It will ensure a continuous supply of vegetables and food security of the nation.

KEYWORDS: ICT adoption in Agriculture, Agriculture in Sri Lanka, Vegetable farmers.

I INTRODUCTION

Sri Lanka is a country where 33% of the population is engaged in agriculture or agriculture related livelihoods but they only contribute 7% for the Gross Domestic Production (GDP) of the country [1], [2]. The Sri Lankan agriculture sector consists of several subsectors and vegetable subsector directly influences the entire population since it is mainly for the consumption of the citizens [3]. The main stakeholders of vegetable cultivation are farmers and they require various types of information throughout the crop cycle. The accuracy level of information must be high to engage in a successful crop selection, preparation, cultivation, maintenance, harvesting and post-marketing activities in agriculture. Cultivation will be profitable with proper use of information at the right time in the correct way [4]. There are many ICT-based agricultural information systems available in Sri Lanka which are dedicated to farmers, with objectives such as eliminating vegetable wastage, controlling price fluctuations, ensuring the prosperity of farmers, and minimizing poverty rate [5]. Findings of published literature and preliminary research show that critical issues in the Sri Lankan vegetable sector continue even though there

are various types of information systems. Excess stock generation, uncontrollable price fluctuations and vegetable wastage have become everyday situations in the sector [6]. This indicates that functioning information sources are not adequate; their contribution is not substantial enough for the sustainability of the vegetable agriculture sector in Sri Lanka or the farmers might have rejected using the provided systems for some other reason.

II RESEARCH PROBLEM

A large number of information systems are available in Sri Lanka to assist farmers in obtaining information required during the crop cycle. These systems have been developed by government organizations as well as private sector companies. However, the lifetime of interactive informational systems has become very short due to underutilization. The main problem that is investigated in this research is "What are the factors which lead to farmers' refusal to the continuous use of interactive agricultural information systems in Sri Lanka". Interactive information systems become more robust and reliable with increasing use and interactions. Agriculture information systems have been estab-

lished after conducting researches with considerable investment. The research aims to identify reasons behind the continuous rejection of the use of interactive information systems by Sri Lankan farmers.

III   LITERATURE REVIEW

According to Walisadeera, Ginige, and Wikramanayake [4], farmers require various types of information during their farming activities. The nature of information required depends on the stage of the crop cycle [7]. Farmers in Sri Lanka obtain information via formal information sources such as AI (Agricultural Instructors), informal sources such as family members and neighboring farmers, digital information sources such as online systems and traditional information sources such as TV, radio and newspapers [8]. In addition, most of the Sri Lankan farmers have access to mobile phones and use mobile-based information systems mainly to obtain crop advices, market information, and weather details [9].

According to Sivagnanasundaram, Ginige, and Goonetillake [2], a large amount of food produced for human consumption gets wasted annually due to many basic errors of farmers. About 1,300,000,000 (1.3 billion) tons of food get wasted per year; it is almost 33% of the annual production. This wastage is a result of crop damages caused by pests, diseases, excess use of pesticides and incorrect handling of crops. The situation in Sri Lanka is not much different from the typical situation in the world and even in Sri Lanka a large amount of food wastage is reported every year. Sri Lankan farmers used to cultivate vegetables without using proper information sources. They used to cultivate as they wished with a very little amount of unreliable information in hand, which led to cultivation of less demanded crops. Farmers used to gather information via neighboring farmers, expert farmers or agrochemical merchants. They used to contact agricultural offices for pest and disease control information via very basic ways. Farmers use pesticides and fertilizers according to their experiences, without having any expert advice. It causes a high cost of production as well as crop losses. It was found that incorrect agricultural practices lower the quality of products and production [10]. Farmers fail to make the right decisions at the right time due to the lack of information or their inability to utilize the available information accordingly. This increases non-demandable commodities in the marketplace and increases vegetable wastage [11]. Finally, farmers face difficulties selling their products and they suffer with financial losses [12]. According to [13], farmers suffer losses due to incorrect crop selections, lack of professional advice, technologies, seeds, best practices and proper agricultural knowledge. This situation may occur due to financial issues, marketing difficulties, cultural or social problems, transport issues

and poor literacy levels (language and ICT) [11].

According to Sivagnanasundaram, Ginige and Goonetillake [2] there is a considerable knowledge gap between farmers and researchers. Therefore, the knowledge of researches must be directed into practice through farmers and other stakeholders. Unfortunately, this academic-industrial collaboration is not visible in Sri Lanka, but most of the developed countries have formed strong field-level collaborations and have gained favorable results.

Not only developed countries but developing countries also use ICT in the agriculture sector with positive results. According to a research done in Tamil Nadu state in India, farmers use a system that provides pest information and details about the disease [14]. Tologbonse, Fashola, and Obadiah [15] have mentioned that Nigerian farmers also have an ICT-based information system to obtain details regarding crop losses and pests. Research done by Hashemi, Hosseini, and Damalas [16] in Iran have described that they have identified that farmers have knowledge on pests/diseases and their effects on crops. They have further identified that farmers required proper training to handle situations.

The Sri Lanka paddy marketing board developed www.pmb.lk and department of agriculture developed www.goviya.lk which are the two available systems for farmers to obtain information regarding cultivation [17]. Silva, Goonetillake, Wikramanayake, and Ginige [18] mentioned that Govinana, a system introduced by the department of agriculture, Dialog Trade Net of Dialog mobile and 6666-Agri price index of Mobitel are active agriculture information systems available in Sri Lanka. These information systems provide timely information for farmers about crop prices, but farmers are reluctant to use these information systems since they need more efficient and timely information to make the most suitable decisions. The information system developed and introduced by Sri Lanka paddy marketing board was not popular among farmers due to the lack of basic ICT knowledge among farmers, unavailability of signal and other ground-level facilities and the non-user-friendly nature of the system [17]. Welandapola, Badumila and Govipola are classified AgriApps that are available for farmers to directly access the vegetable market by avoiding intermediaries [1]. Further, as per Ekanayake, and Sirisuriya [17], Dialog TradeNet and Mobitel price index provide only price information. The price becomes an unimportant matter after harvesting since they have to sell at any price as soon as possible. Therefore, farmers use these systems very rarely.

Jayathilake, Mudalige, Gow, Waidyanatha, and Perera [19] mentioned that the high cost of information is a barrier

to access the ICT systems of the agriculture sector of Sri Lanka. Narmilan [20] describes that due to constraints such as lack of infrastructure facilities, and training, different research priorities, lack of skills, community and political issues, farmers may be reluctant to use ICT information systems in Sri Lanka. Subashini and Fernando [21] also mentioned that lack of knowledge is the biggest constrain for the use of ICT in the agriculture sector in Sri Lanka. In addition, language barriers and high costs also have a negative impact on the use of ICT among farmers. As a result, farmers do not use farming information systems. Moreover, reasons such as the lack of awareness, inaccessibility of systems and difficulties of handling systems further affirms their decision to not to use these farming information systems [22]. Jayathilake, Mudalige, Gow, Waidyanatha, and Perera [17] also say that cost of technology, lower trust regarding systems, no training, infrastructure issues, non-availability of support services resistance and limitations in adopting new technologies are also some of the constraints for the use of ICT systems for agriculture purposes in Sri Lanka. Pemarathna [23] mentioned few more reasons for not using ICT systems by Sri Lankan farmers and they are; lack of knowledge, training issues, problems related to language and unawareness about benefits. Apart from that, complications in the sector, issues regarding the level of outside support, farming experiences, infrastructure, information availability, farmer's personality, ability to learn new things, ICT knowledge, cost of ICT equipment, user-friendliness, trust about ICT systems, training issues, system integration issues and availability of software also have become reasons to not to use ICT enabled agriculture systems in Sri Lanka [17].

According to Wijerathna, Dissanayake, Navaratne, and Gunawardena [9] government operating information centers are not formally receiving information. Offices in some particular subject areas are not willing to provide information properly. This may be due to the bureaucratic nature and politics of government offices in Sri Lanka. Technical issues such as the non-availability of systems are also an issue in the access of information. The poor coordination between farmers, economic centers and buyers, is the biggest issue in the Sri Lankan agricultural sector.

IV METHODOLOGY

Published literature was used to identify the nature of vegetable cultivation, associated issues and ICT solutions available in the agriculture sector in Sri Lanka. There were several ICT-based agriculture information systems identified during the literature review. According to literature, www.pmb.lk, www.goviya.lk, Govinana, Dialog Trade Net, 6666-Agri price index, Welandapola, Badumila and Govipola are some of the available agriculture information systems and applications for Sri Lankan farmers. The research investigated how frequently these listed systems were used by farmers by studying the facilities these systems offer to gain a direct access to the market. In addition, the ability to sell vegetables via each of the listed information systems is also considered.

The research selected one application for further investigation. The selected App was the only system that facilitates selling vegetables online. The observed App was one of the most promoted agriculture apps in 2019. This App is available for farmers to forward their selling offers and buyers can purchase vegetables through the system without any influence of intermediates. The research observed the behaviour of few vegetables. Selected vegetables were Carrots, Cucumber and Brinjal. The number of selling offers received for selected commodities was recorded during 53 weeks of the year 2019. In addition, the research obtained weekly market prices of the same selected three vegetable commodities during 53 weeks of the year 2019 by accessing the online weekly price index of Hector Kobbekaduwa Agrarian Research and Training Institute (HARTI).

Apart from that, a field research was conducted in Wadagolla and Sonuththara villages in Matale district, Hiswalla and Butpitiya villagers in Gampaha district, Magammana in Kegalla, and Ambagaha Palassa in Mahanuwara district. The questionnaires were given to 105 farmers in Wadagolla, Magammana, Ambagaha Palassa, Hiswalla and Butpitiya villagers and collected 76 responses. In addition, direct unstructured interviews were conducted with 16 farmers in Sonuththara village to obtain information regarding ICT-enabled technologies. MS Excel was used as the analytical tool since there were no many complicated data to be analyzed. The same package was used to create charts and graphs required for the demonstration of collected data.

V DATA ANALYSIS

Average weekly wholesale prices of carrots, cucumber and brinjal during 52 weeks of the year 2019 were observed and drastic price fluctuations were identified.Figure 1 describes the average weekly price of carrots in 2019 at Dambulla Dedicated Economic Centre (DDEC).

Figure 2 describes the average weekly prices of cucumber in 2019 at DDEC. Figure 3 shows the weekly average prices of brinjal during 2019 at DDEC.

A similar pattern can be observed in all these 03 commodities during the research period. Price hikes can be observed during the 4th week, 16th to 19th weeks and 46th –50th weeks, with some slight drops in the middle.

The survey identified that only 120 selling offers were received from farmers for carrots, cucumber and brinjal.
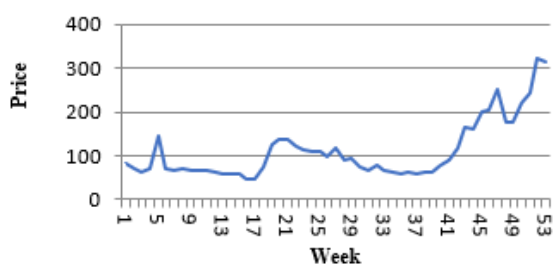
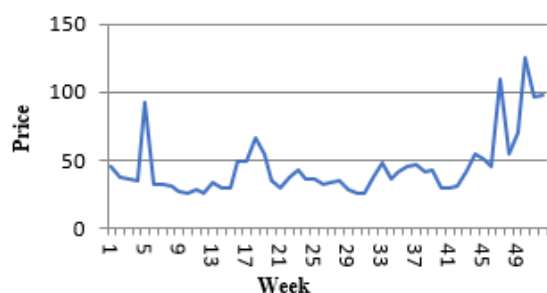Figure 1: Carrot weekly average price details in 2019 at DDEC

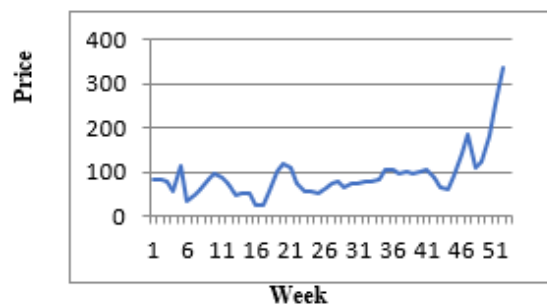Figure 2: Cucumber weekly average price details in 2019 at DDEC

Figure 3: Brinjal weekly average price details in 2019 at DDEC.

There were 53 selling offers for carrots, 26 selling offers for cucumber and 41 offers for brinjal during the period. These price patterns show that vegetable prices are fluctuat-
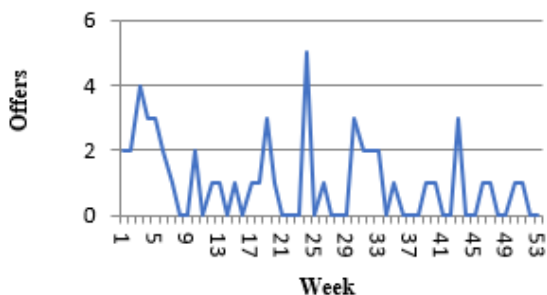

Figure 4: Carrots weekly selling offers in 2019.

ing during the year. Sudden price drops, as well as extreme price hikes, are also visible within short intervals.
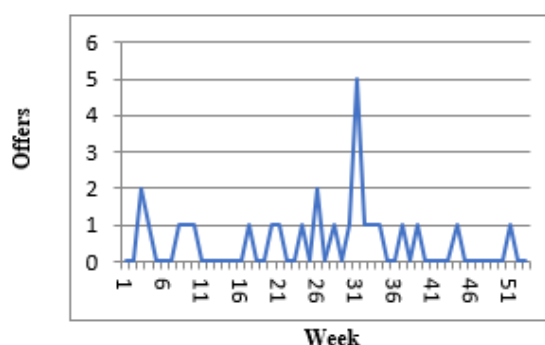

Figure 5: Cucumber weekly selling offers in 2019.

The recorded selling offers for the same commodities during the same period are illustrated through graphs.

Figure 4 shows that farmers have only received a very few selling offers for carrots during the year. There is hardly any change in other commodities as well. Figure 5 depicts the situation of cucumbers.

Figure 6 presents weekly selling offers received by farmers for brinjal during 2019 via the selected application.
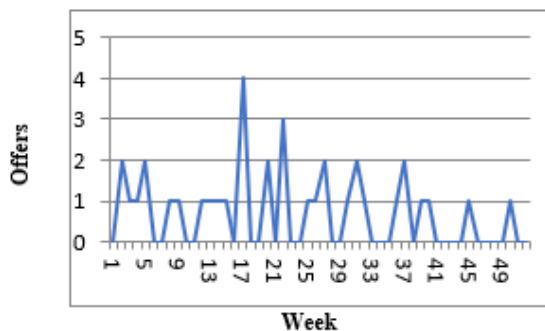
Figure 6: Brinjal weekly selling offers in 2019..

Table 1 summary the answers given by farmers for the questions that were directed at them.

According to their responses, most farmers are not using the internet but have mobile phones. They are not aware of agricultural information systems and they are hardly showing any interest in using them.

Table 1: ICT awareness among farmers

Question	Yes	No
Are you using Internet	11	53
Do you know about Agriculture IS	16	48
Have you used agriculture IS	5	61
Do you trust agriculture IS	4	44
Do you have a mobile phone	69	7

The most important factor that was identified during the private discussions that were carried out with farmers was that they used to contact their regular merchants at DDEC to get price details. If the price is satisfactory, the crop will be harvested and taken to DDEC. Otherwise, they were in the habit of leaving the crops in the field without harvesting them. Farmers do this because the farmers find it difficult to recover the harvesting costs and transportation costs from the profit they gain due to the low prices of the vegetables.

The Table 2 shows how frequently farmers use the agricultural information system which was identified during the literature review.

Table 2: Web-based agriculture information systems and Apps

App/Web site	Can sale vegetables?	Observation
www.pmb.gov.lk	No	Informational web site with price details
www.goviya.lk	No	Cannot access
Govinane App	No	Underdevelopment and cannot access
DialogTradeNet	No	Only provide price details
666 AgriPrice Index	No	Only provide price details
Weladapola App	No	Cannot access and very complicated
Badumila App	No	Only provide price details
Govipola App	Yes	Possible to add selling offers

VI DISCUSSION

According to the published literature, there is a requirement to introduce ICT-enabled information systems for farmers in Sri Lanka. It is possible to solve most of the critical issues regarding proper crop selection, obtaining the required information, selecting an accurate market, minimizing stock wastage, optimizing prices, and eliminating poverty among farmers theoretically. However, when it comes to practice, the situation is much different. Issues due to lack of awareness, literacy issues, lack of ICT skills and many other factors can be considered as barriers for the use of a technology based information system by farmers in Sri Lanka.

Price details of selected commodities are showing the general market patterns in Sri Lanka. This nature of the market does not show an impact of provided ICT solutions on vegetable cultivation in Sri Lanka. Effective ICT-based agricultural information systems must support market stability. Elimination or control of price fluctuation is one of the main objectives of all the provided information systems. Price increments occur due to high demand, low supply and the price drops due to low demand and high supply. The demand for vegetables in Sri Lanka increases only during festival seasons. There are no many variations in demand during other periods of the year. According to this scenario, low supply can be considered the most influencing factor for vegetable price increment. Similarly, oversupply leads to price drops in the market.

During the time period, the farmers rarely used selected application. Farmers showed no interest in selling their products via apps. Since the farmers seldom use the application, the level of the reliability of the system will also be reduced. As a result of the minimal use of the application, it may wipe out from the system within a short time period. This may cause not because of the non-availability of mobile devices but due to unawareness, lack of trustworthiness and lack of ICT skills of farmers. Farmers consider the use of ICT-based interactive information systems as something which is beyond their understanding. They do not face any difficulties during time periods when the market price of vegetables is high but they suffer during time periods when the price is low. They do not have any reason to use ICT-based information systems when the demand for vegetables is high. Farmers need assistance only in situations where the price drops. It is required to use these systems continuously to increase their reliability. Since farmers do not have any motivation or a reason to use the systems, they simply start neglecting them within a short time.

Table 2 describes the nature of available web-based agricultural information systems and AgriApps. A stranger can interact only with Govipoala App as Govinane is still under construction. Furthermore, Weladapola App and www.goviya.lk are also not accessible. All the other systems are only providing information.

VII RECOMMENDATION

Most of the farmers use mobile devices merely for communication purposes. Therefore, there should be effective awareness campaigns along with the promotion of interactive agricultural information systems. Farmers must be empowered with benefits that can be obtained from such systems. Simple, straightforward systems with native language will increase interactive mobile systems in farmers' communities. It is recommended to use innovative marketing strategies during the introduction and research further the nature of factors that can be influenced to increase the use of ICT systems among farmers in Sri Lanka.

VIII CONCLUSION

At the time being, farmers are suffering due to their low income levels. Their income levels lowers with price drops, increased wastage, marketing issues and crop damagers. Incorrect crop selection, wrong agricultural practices, crop destructions due to pests and diseases, non-availability of timely information lead to these issues. The use of a proper agricultural information system can solve these issues, but most farmers are reluctant to use them due to unawareness, low-level ICT skills, language barriers, and lack of trust in ICT-based information systems. It is not possible to obtain benefits from ICT-based agricultural systems without using them. Awareness programmes, ICT skill development programmes and systems with native languages will increase the use of ICT-based information systems among farmers in Sri Lanka.

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ABBREVIATIONS AND SPECIFIC SYMBOLS

- GDP: Gross Domestic Production
- DDEC: Dambulla Dedicated Economic Centre
- ICT: Information Communication Technology
- HARTI: Hector Kobbekaduwa Agrarian Research and Training Institute

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Employee Knowledge Sharing Behaviour: The Role of Workplace Cyber Incivility and Personality Traits

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ABSTRACT Knowledge sharing behaviour can achieve a greater level of innovation and creativity. Employees victimized with computer-mediated workplace incivility may hinder knowledge with rational justifications. The purpose of this paper is to identify the role of workplace cyber incivility on knowledge sharing behaviour. Additionally, this study identifies the mediating effect of personality traits (Extraversion, Agreeableness, Conscientiousness, Neuroticism, Openness to experience) and the relationship between them. This study is predominantly designed as a quantitative study based on the positivistic paradigm. Data were obtained from an online self-administered questionnaire from permanent employees in software development organizations in Sri Lanka and 251 responses were analysed using correlation and SEM bootstrapping. The findings of the study demonstrated a negative association between cyber incivility and KSB ($r = - 467$) consistent with previous studies; KSB was positively associated with extraversion ($r = 0.937$), agreeableness ($r = 219$), conscientiousness ($r = 219$), neuroticism ($r = 228$), openness ($r = 243$). Succinctly, this study draws attention towards the workplace cyber incivility victims who may negatively respond to knowledge sharing behaviour, creating hostile work environments. The theory of trait activation can be used to explain the individual differences of said relationship. We have also proposed partial mediation of personality traits (extraversion, conscientiousness, neuroticism, and openness) on workplace cyber incivility and knowledge sharing behaviour. The findings of the study have several theoretical and practical implications. It advocates the necessity to address workplace cyber incivility to ensure employee knowledge sharing behaviour.

KEYWORDS: knowledge sharing behaviour, workplace cyber incivility, personality traits, online miscommunication

I INTRODUCTION

In this prodigiously turbulent and dynamic world, organizations are striving to achieve a competitive advantage. Organizations achieve a competitive edge by developing and using knowledge and information which develops products, services, ideas, and information. Knowledge is a strategic asset (gain through continuous learning) for any organization to boost the efficiency and ability of the decision-making process [2]. Knowledge sharing behaviour (KSB) can be identified as the transmission of explicit and tacit knowledge from knowledge providers to receivers [3, 16]. In particular, tacit knowledge is the most important knowledge to win the battle in the market [1]. Modern organizations are fuelled with a new set of knowledge and mutually shared knowledge among members of the organization [1]. Surprisingly, it is not always guaranteed, as it does not occur automatically with employees at the workplace [3, 4].

In this study, the researchers propose that cyber incivility could be the reason to hinder knowledge sharing behaviours at the workplace. Workplace incivility is one of the most frequent less-detrimental behaviours in the workplace, employees experience a variety of face-to-face discourteous behaviours. However, modern technology has transformed the medium of communication in the organization into an electronic communication system that is easy, efficient, and speedy. Besides, emails are the most preferred and commonly used mode of communication in organizations that expedite organizational coordination and productivity [4]. Yet, emails can be a double-edged sword due to non-face-to-face communication, that spill uncivilized work practices into online activities such as email and

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text messages [4]. Indeed, computer-mediated communication steered and furnished new avenues to engage in workplace less-detrimental behaviours; examples of such behaviours are hurting comments, gossips, scheduling or cancelling meetings without further notice, irritable emails, and short or no response for emails. Further, online communications pave many avenues for perpetrators of such behaviours through anonymity, for example, posts in an online forum [5]. This can be identified as uncivilized cyber practices in organizations. It is evident that when employees are disregarded or mistreated, it will affect their psychological well-being [6]. Hence, that prevents employees from sharing knowledge with others, especially between supervisors, and co-workers.

A   Problem Statement

Organizations onboard employees who are rich in knowledge sharing behaviour. However, employees do not share knowledge as expected which is puzzling [3]. Knowledge hiding between supervisors and co-workers are differed victim to victim, based on their individual differences as well as the severity of the experienced cyber incivility at work. In this study we concentrate mostly on an ignored individual aspect in knowledge sharing literature: further, we examine which personality trait plays as a mediator in cyber incivility and KSB. Most of the previous studies focus on the facilitators of KSB, however, there is less research on barriers to KSB [7]. Moreover, there is a growing concern to identify possible barriers for KSB, hence, we propose that workplace cyber incivility is one of the possible barriers for KSB.

B   Research Objectives

This study aims to identify the role of workplace cyber incivility and personality traits that play in the knowledge sharing behaviour of software development employees. Further, we focus on addressing the below-listed objectives.

First, we identify the impact of workplace cyber incivility on employee knowledge sharing behaviour. Second, investigating the role of personality traits as a mediating factor between cyber incivility and KSB. Further, there is a dearth of research focusing on cyber incivility and individual-level knowledge sharing behaviour [8]. Finally, this study may contribute to the information system and organizational behaviour knowledge through the theory of trait activation by combining the mediating role of personality traits

The next section of the paper reviews substantial existing literature on knowledge sharing behaviour to identify pertinent aspects, which is structured according to the theoretical framework of workplace incivility and personality traits. Based on the literature review, four main hypotheses (Figure 2) were derived and analysed through structural equation modelling (SEM). To do so data were collected through an online self-administered questionnaire from software development employees in Sri Lanka. This paper ends with a discussion of the findings, conclusion, practical and theoretical implications, and avenues for future research.

II   THEORETICAL BACKGROUND

A   Knowledge sharing behaviour

Knowledge is the most valuable intangible asset which expedites competitive advantage, change management [9], and leads to the expansion of Information Technology (IT) [10]. Knowledge is regarded as the justifying personal notion towards the veracity gained through experience, values, and information [1] that originates in the minds of the knowers [3]. This definition encompasses two dimensions of knowledge (1) explicit; facts, rules, and policies (which is objective) that can be articulated and codified in writing or symbols shared easily [11] and (2) implicit; the knowledge which is embodied in practices and routine which is difficult to share [1]. Implicit knowledge and explicit knowledge affect organizational performance and they can differ significantly; explicit knowledge leads to efficiency while tacit knowledge improves task quality and innovation [12].

Tacit and explicit knowledge has become one of the most important assets in the organization, therefore, they remarkably invest in effective knowledge management systems [12]. Knowledge sharing has potential benefits to the organization such as, increase team performance, reducing cost, developing new products and services, improving creativity and innovation [1], strengthening the decision-making process, increasing efficiency and effectiveness [10], wealth maximization, increasing firm performance, and competitive advantage [12].

Knowledge sharing is a communication process between two or more individuals who exchange knowledge to create new knowledge [13]; that is decisive for organizations to develop knowledge, skills, attitude for creativity and innovation. Therefore, KSB can be defined as "the degree of one's positive feelings about sharing one's knowledge" [3]. This is a conscious behaviour (voluntary, proactive, behavioural awareness) shaped by the organisation's culture, ethics, and code of conduct [14].

There are contextual, group, and individual antecedents which affect the KSB such as technology, procedural justice, creativity, shared norms, personality, intrinsic motivation, and social capital [13]. Nevertheless, there is less research on barriers for KSB such as workplace mistreatment and workplace incivility [14]. Moreover, knowledge

sharing behaviour is determined by an individual's personality traits [7], knowledge sharing attitudes (employees may share knowledge when they perceive pleasure and meaning for helping others, besides they are reluctant to share knowledge when they perceive their knowledge is not important to others), subjective Norms (the degree to which subordinates and co-workers persuade to share knowledge through psychological contracts), and intention to share implicit/ explicit knowledge [15]. Nevertheless, knowledge is considered as a source of power and fuel to obtain political mileage; employees deliberately hinder their knowledge in order to achieve individual competitive advantage and growth [2]. Moreover, it is found that diversity driven misunderstanding and mistreatments affect technology-mediated knowledge sharing behaviours [15].

B Cyber incivility

Workplace incivility is identified as any rude or discourteous behaviour that drives psychological or physical consequences for both victims and bystanders of such behaviours, creating hostile workplaces, almost 90% of employees are experiencing workplace incivility [15]. Particularly, workplace incivility can be defined as "low-intensity deviant behaviour in a workplace with ambiguous intent to harm the target, violating the social norm of mutual respect towards both individuals and organizations" [6].
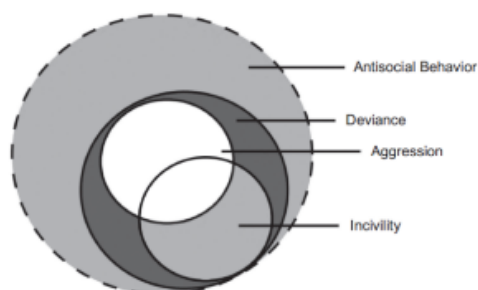

Figure 1. Workplace incivility and other constructs
Source: Andersson and Pearson, (1999)

Figure 1 demonstrated the different quantum of workplace negative behaviours based on the severity scale [6]. Therefore, workplace incivility shows a less severe detrimental behaviour towards their victims. Examples of such behaviours include not saying please or thank you, demeaning remarks, credit taking, unreasonable insulting, not responding or short response to emails, and withholding essential information by showing ignorance, and unawareness. Therefore, victims of such behaviours negatively result in physical and psychological harm such as work withdrawal or intention to leave the organisation, lack of job satisfaction, commitment, and productivity.

Cyber incivility can be defined as computer-mediated less severe detrimental behaviour that violates mutual re-

spect and norms [4]. Further, Lim and Teo [16] stated that cyber incivility is electronic aggression that occurs in workplaces through email communication [17]. Examples of such behaviours include condescending through emails, sarcastic comments in email paragraphs, cancelling or scheduling a meeting on short notice, failing to acknowledge emails, using emails that require face to face conversation, paying little attention in email, and not replying at all for emails [3]. There is a growing concern to address cyber incivility because of the anonymity of the perpetrator. Consequently, there is research focusing on cyber harassment but very few on cyber incivility [16]. If managers overlook addressing cyber incivility, that may escalate to the next level of aggression. Researchers stated that abusive supervision and deviant behaviours can reduce KSB [15]. Therefore, we have identified that cyber incivility is a predictor of knowledge-sharing behaviour. Victims may camouflage knowledge by playing ignorant, evasive hiding, and justifying their hiding behaviour [18]. This has led to our first hypotheses. H_1: There is a negative impact between workplace cyber incivility and KSB

C Personality traits

Personality demonstrates individual differences based on their behaviour, cognition, and emotions which are conceptualized through personality traits. Personality traits are the intrinsically characteristics of a person exposed to a particular pattern of demeanours for different situations. Personality traits can be defined as "the individual characteristics and behaviours, organized in a way that reflects the unique adjustment the person makes to his or her environment" [19]. Personality traits of Conscientiousness, Extraversion, Neuroticism, Agreeableness, and Openness to experience leads to certain attitudes and behaviours. This has led to our second hypothesis,

H_2: There is a relationship between workplace cyber incivility and personality traits (Extraversion, Agreeableness, Conscientiousness, Neuroticism, Openness to experience)

Extraversion includes traits such as convivial, loquacious, gregarious, assertive, active, zealous, and expressive individuals who have a vigorous desire for the accolade, convivial apperception, status, and power. Hence, extroverts may not be victims of workplace cyber incivility because they have more positive social interactions. Therefore, we hypothesized that workplace cyber incivility may negatively relate to the extrovert trait.

H_{2A}: There is a negative relationship between workplace cyber incivility and Extraversion
Agreeableness includes traits such as courteous, flexible, trusting, good-natured, cooperative, forgiving, soft-hearted, and tolerant. It is predicted that those high in agreeableness

may be less likely to be a victim of workplace cyber incivility. Therefore, we hypothesized that,

H_{2B}: There is a negative relationship between workplace cyber incivility and Agreeableness
Conscientiousness personality type includes traits such as hardworking, meticulous, exhaustive, responsible, organized, and persevering. Further, these individuals are attentive to detail and spot the subtle deviations as uncivil. Therefore, there is a positive relationship between said variables. We hypothesized that,

H_{2C}: There is a positive relationship between workplace cyber incivility and Conscientiousness
Neuroticism includes traits like apprehensive, dispirited, exasperated, disconcerted, emotional, worried, and insecure. Neurotic employees experience a greater deal of negative life experiences. Therefore, we hypothesized that,

H_{2D}: There is a positive relationship between workplace cyber incivility and Neuroticism
Openness to experience includes traits like imaginative, cultured, curious, pristine, broad-minded, perspicacious, and artistically sensitive. Individuals with openness traits are more likely to embrace challenges and enable innovative work behaviours [20]. Therefore, openness to experience individuals is providing favourable responses for the absence of evidence for less detrimental behaviours. Therefore, we hypothesized that,

H_{2E}: There is a negative relationship between workplace cyber incivility and Openness
A personality trait is a most studied individual-level predictor in KSB literature [8]. Literature demonstrated that extroverts have positive emotions and feeling for team and group efforts. Therefore, they prefer to share knowledge among other team members in order to ensure work efficiency. It is argued that extraversion people tend to demonstrate themselves as knowledge distributors. Further, it is argued that individuals with high agreeableness and consciousness traits are more likely to share knowledge among others [11]. Moreover, neurotic people reflect anxiety, lack of trust, and fear negatively impacted on knowledge sharing behaviour with others. Nevertheless, openness to experience is the most significant predictor of the big five personality traits that facilitate knowledge sharing [8]. It is evident that people with openness traits are knowledgeable and always willing to share their knowledge than low openness individuals. Therefore, it is argued that knowledge sharing behaviour is a helpful social interaction; hence, there is a positive relationship between Extraversion, Agreeableness, Conscientiousness, and Openness to experience and KSB. However, there is a negative relationship between neuroticism and KSB. This has led to our third hypothesis,

H_3: There is a positive relationship between personality traits (Extraversion, Agreeableness, Conscientiousness, Neuroticism, Openness to experience) and KSB
Additionally, the conceptual framework (figure 2) was developed based on the Theory of Trait activation, which elucidates the individual traits that are activated to respond to the situation [21]. Succinctly, traits and situations are the two-sided of the same coin. Determinately, we propose that personality traits mediate the relationship between workplace cyber incivility and KSB. This has led to the fourth hypothesis,
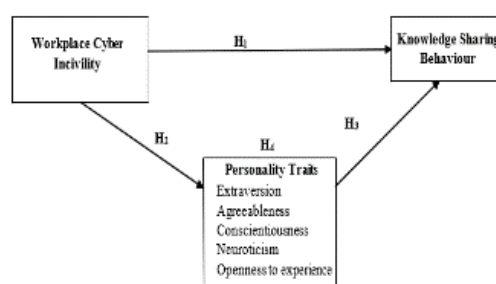H_4: Personality traits mediate the relationship between workplace cyber incivility and KSB

Figure 2. Conceptual Framework
Source: Andersson and Pearson, (1999)

III METHODOLOGY

This study is extravagant to designed as a quantitative study predicated on the positivistic paradigm, with the purpose of identifying employee cyber incivility and personality traits that lead to employee knowledge-sharing behaviour in organizations.

A Respondents and Procedure:

The target population was identified as male and female permanent employees working in Information Technology (IT) sector organizations (Software Development) in Sri Lanka. The sample compromised of a wide range of employees including trainee programmers, programmers, associate software engineers, and software engineers. A convenient sampling method was used to collect data from the target population via an online self-administered questionnaire. We have distributed 350 questionnaires among the sample proportionately and 251 usable responses were obtained after replacing the missing values, yielding a 74% response rate. The pilot study was conducted to ascertain the internal consistency of the scale and to ascertain validity before distributing the final questionnaire to the respondents.

B Measures

Based on previously developed and validated measures were used to assess workplace cyber incivility, personality

traits, and KSB, and it was pre-tested and revised with 25 respondents. Demographic information was collected for respondents' gender, age group, education, tenure, and marital status through a questionnaire. The Cronbach Alpha reliability coefficients were computed as a measure of internal consistency for the variables and measurement items used.

Knowledge sharing behaviour: dependent variable was measured using sixteen items adapted from Bock, et al. [3] through a five Likert point scale (1- very rarely to 5- very frequently). The three types of knowledge sharing behaviour were measured through; Attitude toward Knowledge Sharing (Cronbach's Alpha = 0.918), Subjective Norms (α = 0.823), Intention to share explicit knowledge (α = 0.924), and Intention to share implicit knowledge (α = 0.933). Cyber incivility: the independent variable was measured with ten questions adapted from Lim and Teo's [16] anchored on a five-point Likert scale ranging from (1) Not at all to (5) All the time, with 0.942 of internal consistency (α = 0.942).

Personality traits: we used 30 items personality traits short scales adapted from Soto and John (2017) through a five Likert point scale (1) disagree to (5) agree. It consists of five personality traits: Extraversion (α = 0.939), Agreeableness (α = 0.696), Conscientiousness (α = 0.876), and Negative Emotionality (α = 0.893), and Openness to experience (α = 0.891).

Data analysis involves descriptive statistics using SPSS and structural equation modelling using AMOS structural equation modelling. In this study, AMOS 23.0 is used to investigate the causal relationships, where the path coefficients are tested for significance and goodness of fit. Model goodness of fit was estimated using the normed chi-square ($\pi^{2/df}$), IFI (incremental fit index), CFI (comparative fit index), RMSEA (root mean square error approximation), and GFI (goodness of fit index).

IV RESULTS

Parametric assumptions of normality, linearity, multicollinearity, and common method bias are met, and the parametric test is fitting in this study. First, demographic data analysis is presented; the sample consisted of 62% male and 38% female employees. Besides, the sample represents a younger and educated population (below 25 represents 23%, 26 to 35 represents 31%, 36 to 40 represents 31, and more than 40s age group represents 25%) with 23% postgraduate, 59% bachelors, and 18% of professional qualifications. Ostensibly, there were fewer tenure employees due to the nature of the industry; 23% of the employees have more than ten years of experience while the majority had 1 to 3 years of experience (43%) and

34% have 3 to 5 years of tenure in the same organization.

Descriptive statistics including mean and standard deviation were used to assess basic characteristics of data in our paper. Table 1 indicates the descriptive output data; mean values for workplace cyber incivility, Extraversion, Agreeableness, Conscientiousness, Neuroticism, Openness to experience, and KSB are 2.90, 2.63, 3.13, 3.47, 3.40, 3.73, and 2.65 respectively. A low standard deviation indicates that the data points are inclined to be very proximate to the mean. However, KSB values are spread out over a substantial range.

Table 1. Means, standard deviations, correlations

Construct	Mean	SD	1	2	3	4	5	6	7
1. WCI	2.90	1.12	(0.86)						
2. PE	2.63	1.13	.502**	(0.76)					
3. PA	3.13	0.76	0.42	.221**	(0.54)				
4. PC	3.47	0.99	-.216**	-.310**	.681**	(0.98)			
5. PN	3.4	0.95	-.193**	-.244**	.630**	.637**	(0.82)		
6. PO	3.73	0.87	-.135*	-.200**	.551**	.687**	.548**	(0.82)	
7. KSB	2.65	1.00	-.467**	.937**	.219**	.292**	.228**	.243**	(0.70)

Note: N = 251

WCI (workplace cyber incivility), PE (Extraversion), PA (Agreeableness), PC (Conscientiousness), PN (Neuroticism), and PO (Openness to experience), and KSB (Knowledge Sharing Behaviour)
**p<0.001, **p< 0.01, *p< 0.05
The square root of AVE values is in diagonal parenthesis
Table 1 demonstrated the correlation analysis of the data and data found that workplace cyber incivility has a negative significant relationship with knowledge sharing behaviour with 0.467 (r = -0.467, p< 0.01). Consequently, personality traits demonstrated a positive relationship with KSB. Accordingly, extraversion positively influences KSB with 0.937 (r = 0.937, p< 0.01); agreeableness positively influences KSB with 0.219 (r = 0.219, p< 0.01); conscientiousness positively influences KSB with 0.292 (r = 0.219, p< 0.01); neuroticism positively influences KSB with 0.228 (r = 0.228, p< 0.01); and openness to experience positively influences KSB with 0.243 (r = 0.243, p< 0.01). Among the five personality traits, extraversion is the most frequently investigated and received consistent support to encourage KSB with relates to team efforts [14]. There is a weaker relationship between cyber incivility and KSB (Table 1), this has led to identifying the missing link between cyber incivility, personality traits, and KSB. The below sections demonstrated the output results

for structural equation modelling (measurement and structural model).

A   Measurement Model

Confirmatory factor analysis (CFA) was used to ensure the validity and reliability of the measurement scales. Table 2 average variance extracted (AVE) ensures convergent validity with greater than 0.5 output value. In this study, AVE ensures the convergent validity of the model which is demonstrated in figure 3. Conscientiousness had the highest discriminant validity among all the constructs. However, agreeableness and KSB did not achieve the threshold value for discriminant validity. However, we have achieved an optimum level of discriminant validity by sequentially removing items from the model.

Table 2. AVE, Composite Reliability, and Discriminant Validity

Construct	AVE	Composite Reliability	Discriminant Validity
Cyber Incivility	0.57	0.94	0.70
Extraversion	0.61	0.93	0.60
Agreeableness	0.66	0.69	0.59
Conscientiousness	0.70	0.87	0.70
Neuroticism	0.66	0.89	0.70
Openness to experience	0.73	0.89	0.72
KSB	0.70	0.90	0.57

Note: N = 251

AVE – Average Variance Extraction

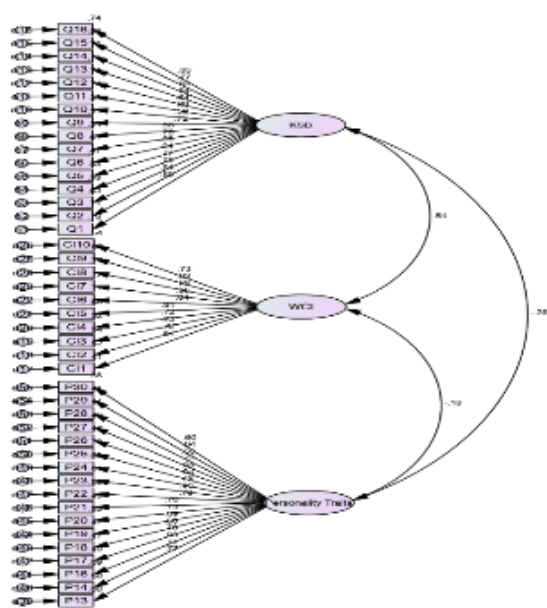Measurement model fit indices were tested to check the fitness of the SEM model.

Figure 3. Confirmatory factor analysis

B   Structural Model

The goodness of the fit indicates; $x^{(2/df)}$ = 2.899, RMSEA = 0.076, CFI = 0.862, GFI = 0.705, and TLI = 0.849 ensures the best fit with output data. The goodness of fit indices ensures that the model is well fitted with the data.

We have hypothesized a negative relationship between cyber incivility and KSB (H_1); according to output data, it ensured a negative relationship supporting the first hypothesis (β= - 0.507, p< 0.01). It is argued that if employees experience cyber incivility behaviour by one unit, they may decrease or hinder their explicit and implicit KSB by 0.507. Further, 26% of the KSB variations (R_2 = 0.26) can be explained through the selected cyber incivility behaviours.

To test the second hypothesis (H_2); we have hypothesized that there is a relationship between workplace cyber incivility and personality traits (Extraversion, Agreeableness, Conscientiousness, Neuroticism, Openness to experience) among employees. Output data for workplace cyber incivility ensures a (H_{2A}) positive relationship with workplace cyber incivility and extraversion (β= 0.502, p< 0.001), it is expected to increase extraversion trait by 0.502 if employees experience cyber incivility; negative relationship with (H_{2C}) workplace cyber incivility and conscientiousness (β= - 0.216, p< 0.001), it is expected to lose or reduce conscientiousness by 0.216 when employees experience workplace cyber incivility; (H_{2D}) workplace cyber incivility and Neuroticism (β= - 0.193, p< 0.01), it is expected to reduce neuroticism by 0.193 when employees experience cyber incivility; (H_{2E}) workplace cyber incivility and Openness to experience (β= - 0.135, p< 0.05) when employees experience cyber incivility it is expected to decrease openness to experience trait. Yet, there is no relationship between workplace cyber incivility and agreeableness (H_{2B}).

To test the third hypothesis (H_3); we have hypothesized that personality traits (Extraversion, Agreeableness, Conscientiousness, Neuroticism, Openness to experience) positively relate with KSB. According to output data, extraversion ensures a positive relationship with KSB (β= 0.906, p< 0.001), rejecting all four-sub hypotheses. It is expected to increase 0.906 of KSB if we increase extraversion personality traits. Finally, we have hypothesized (H_4) that personality traits (Extraversion, Agreeableness, Conscientiousness, Neuroticism, Openness to experience) mediate the relationship between workplace cyber incivility and KSB. We have used bootstrapping to test the mediation effect.

WCI (workplace cyber incivility), PE (Extraversion), PA (Agreeableness), PC (Conscientiousness), PN (Neur-

oticism), PO (Openness to experience), and KSB (Knowledge Sharing Behaviour)

Table 3. Total Effect

Path	Direct effect	Indirect effect	Total effect
H4A: WCI→ PE → KSB	0.05	0.35	0.40
H4B WCI→ PA → KSB	0.04	0.06	Rejected
H4C: WCI→ PC → KSB	0.47	0.04	0.49
H4D: WCI→ PN → KSB	0.48	0.03	0.51
H4E: WCI→ PO → KSB	0.49	0.02	0.51

Note: N = 251

According to table 3 output data; H_{4A} is accepted and there is a partial mediation of 0.35 (β= 0.35, p = 0.08) and the mediation effect is significant under 95% of bootstrap confidence level. 37% of the KSB variations (R_2 = 0.37) can be explained through the extraversion mediation. Second, H_{4B} rejected, there is no evidence to ensure mediation effect under 5% of bootstrap significant level (p = 0.51). Third, conscientiousness ensures a partial mediation between cyber incivility and KSB (β= 0.04, p = 0.002). Further, 29% of the KSB variations (R_2 = 0.29) can be explained through conscientiousness mediation. Fourth, H_{4C} ensures a partial mediation of 0.03 between Neuroticism and KSB (β= 0.03, p = p< 0.01) with significant bootstrapping. Moreover, 27% (R_2 = 0.27) of the KSB variations can be explained through Neuroticism and cyber incivility. Fifth, openness ensures a 0.02 (β= 0.02) of partial mediation between cyber incivility and KSB and the bootstrapping significance is 0.019 (p< 0.01). Moreover, 29% (R_2 = 0.29) of the KSB variations can be explained through openness mediation. Finally, we can conclude that personality traits mediate the relationship between workplace cyber incivility and KSB. Succinctly, 89% (R2 = 0.88) KSB variations can be explained through cyber incivility and personality traits (Figure 4).
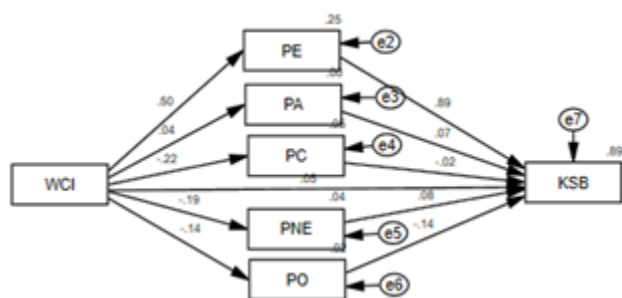

Figure 4. Results of the structural model for direct, and bootstrap indirect effect
Note: N = 251

V DISCUSSION

The purpose of this study was to identify the role of workplace cyber incivility and personality traits on KSB of IT sector employees in Sri Lanka. The first objective of our study was to identify the impact of workplace cyber incivility and KSB. The findings are consistent with the previous studies. When employees perceive workplace cyber incivility; they tend to hinder KSB (Farrukh, et al., 2018; Santoso & Anggraeni, 2020). Consequently, despite different initiation to encourage knowledge-sharing behaviours, employees may not share knowledge due to their barriers and situational factors [10].

The study's second objective was to identify the mediating effect of personality traits on workplace cyber incivility and KSB. According to the theory of trait activation, individuals tend to hinder knowledge by playing ignorant and justifying such behaviours based on experienced situations. In aligning with the previous studies, if employees with extraversion personality traits are less likely to perceive workplace cyber incivility [7]. Yet, workplace cyber incivility negatively relates to employees' conscientiousness, neuroticism, and openness personality traits. Additionally, the literature suggests that extraversion, conscientiousness, neuroticism, and openness personality traits employees are more likely to share information [11]. Finally, the findings of the study show the negative indirect effect of personality traits (extraversion, conscientiousness, neuroticism, and openness) between workplace cyber incivility and KSB [17]. Nevertheless, employees with traits such as positive social interactions, cooperative, hardworking, responsible, and imaginative [21] employees are more likely to share knowledge though they perceived less-detrimental cyber behaviours [8]. Therefore, we have concluded that personality traits partially mediate the said relationship.

VI THEORETICAL AND MANAGERIAL IMPLICATIONS

Implications of the study are twofold, stating with theoretical implications followed by implications for managers. Workplace cyber incivility is a relatively new detrimental behaviour that impedes knowledge sharing behaviour among others. This study sheds light on organizational behaviour and information management literature by unveiling the relationship between cyber incivility, personality traits, KSB directly as well as indirectly. Consequently, we have made a contextual contribution to the IT sector addressing rarely studied predictors of KSB. In addition to the theoretical implications, there are several managerial implications for practitioners and organizations.

Knowledge-sharing behaviour generates substantial positive consequences for organizations and employees such

as competitive advantages, survival, innovations and creativity, and interpersonal relationships [10]. Therefore, it is of utmost importance to identify and address workplace cyber incivility; ignoring less detrimental behaviours may create a hostile work environment that demoralizes KSB. First, practitioners should ensure a civilized workplace; this can be done through proper orientation, training programs, and awareness sessions to use technology wisely. Second, create policy, procedures, code of conduct, and shared norms to ensure civilized culture. Nevertheless, it is the organization's responsibility to continuously update its policies and communicate them among all the members of the organization. However, such initiations should start from the top management when they use computer-mediated communication and knowledge management. Third, we have identified that though employees experienced workplace cyber incivility, their personality traits guide them for their behaviours. Hence, practitioners can recruit employees who are rich in personality characteristics and ethics. Last but not least ample employee engagement programs and knowledge management systems would help to encourage KSB among employees. Whoever, who is interested in KSB should focus on developing knowledge management systems with gamification and more engaging tools addressing individual differences and potential cyber incivilities.

VII LIMITATIONS, FUTURE RESEARCH, AND CONCLUSION

The current study's limitations generally helped future studies to open new avenues. Several limitations of this study need to be addressed; we have measured KSB and workplace cyber incivility based on a measurement scale which is mental constructs. Therefore, there can be the possibility of occurring common method bias, we have addressed this using different scales to measure the constructs [22]. Moreover, the reason for optimum discriminant validity could be the contextual differences; these measurements were developed in a western context.

There are many research avenues for future researchers. First, we have conducted our study on cross-sectional nature which lacks in-depth exploration. Therefore, these constructs can be used to identify in-depth barriers for KSB among employees. Second, longitudinal studies may help to identify employee KSB. Moreover, it is better to identify the most significant personality trait which encourages KSB and identify moderating variables such as gender, generational differences, and educational level. In this study we have identified potential issues in knowledge sharing behaviour, therefore future researchers and practitioners shall identify the aforementioned barriers when developing and implementing knowledge management systems. Moreover, future researchers can identify potential security issues when adopting new technology for know-

ledge management systems.

In conclusion, knowledge-sharing behaviour is critical for organizational survival and competitive advantage. However, negative feelings and experiences may hinder employee knowledge-sharing behaviours. Therefore, this study attempted to identify the negative relationship between workplace cyber incivility and KSB via the mediating role of personality traits including Extraversion, Agreeableness, Conscientiousness, Neuroticism, Openness to experience. The findings demonstrated that perceived workplace cyber incivility practices can negatively impact not only employees but also teams and organizations; if employees are reluctant to share knowledge among others. Consequently, addressing and mitigating workplace cyber incivility behaviours could be an antidote for hindrances of knowledge. We believe that this study will stimulate the discernable views of researchers and practitioners to give more attention to deliberate less-severe detrimental cyber behaviours in organizations and KSB.

Disclosure statement

No potential conflict of interest was reported by the authors.

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