Data Visualisation for Smart Farming Using Mobile Application

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Abstract

People directly or indirectly rely on agriculture to obtain food, the most essential requirement for human survival. Plantation and farming have been practised for ages and have continued to be sources of food and employment in many countries. The rapid advancement of information and communication technology, along with the increasing human needs, has led to the modernisation of traditional agriculture. The integration of technology in agriculture has introduced smart farming. Smart farming has vast potential to increase the productivity of the agriculture field and reduce the work load of farmers. However, smart farming faces a few issues, including difficulty in managing and monitoring various large farming data. To address this problem, this paper presents a mobile application that can help in visualising collected farming data. Using this application, the farmers can access the data directly through their mobile phones, facilitating farm management.

Key words:
Smart Farming, Big Data, Data Visualisation, Mobile Application.

1. Introduction

Plantation and farming have been practised for ages in Malaysia. They have been cultivated before the colonisation era and improved during the British colonisation. Agriculture contributes 12% to the national gross domestic product (GDP) and provides employment for 16% of Malaysians [1, 2]. Many well-established companies, such as Sime Darby, United Plantation and KL Kepong, are involved in cultivating and improving this field.
The integration of technology in agriculture results in smart farming, a farm management concept that utilises various technologies in measuring, monitoring, responding and collecting various farming data and introduces either inter or intra-field variable data. The use of precision equipment, such as the Internet of Things, sensors and actuators, unmanned aerial vehicles and robotics, promotes the Third Green Revolution and is prevalent in the agriculture field [3-5].
With the correct technology, tasks such as remote crop and equipment monitoring and climate monitoring and forecasting can be successfully performed. For instance, John Deere, a big tractor production company, has implemented the concept of smart farming, producing new tractors with sensors and displays that reduce work load. Smart farming saves time and money, generates more profit and manages jobs efficiently. This modern day farming method can provide a better life for the future generation and contribute in reducing poverty.
In farming, a massive amount of data must be collected and managed, e.g. fuel usage rate and performance of machines and total of yield produced. Big data are high-volume, high-velocity and high-variety information assets that demand cost-effective, innovative forms of information processing for enhanced insight and decision making [6]. Based on this definition, farming data are categorised as big data. Thus, in smart farming, data visualisation is beneficial for processing, visualising and distributing data.
Data visualisation challenges in smart farming are mainly influenced by the V characteristics of big farming data. The first V is the volume of farming data. The use of precision equipment, such as sensors, actuators and robotics, in smart farming rapidly generates a large amount of data. The massive data are difficult to handle and lead to challenges in information analysis and processing. The second V is the variety of data. As previously mentioned, using multiple kinds of devices generates various types of data, such as structured, semi-structured and unstructured data. Managing these data is challenging. Visual noise, information loss, large image perception, rapid image change and high performance requirements are other challenges encountered during big data visualisation [7, 8].
This paper presents a practical study based on the application of data visualisation in the agriculture domain. The result of the study confirms that data visualisation can play a crucial role in the analysis and management of large farming data. The proposed technique can address smart farming questions and facilitate farm management.
The remainder of this paper is organized as follows. The related work is discussed in Section 2, and the methodology is described in Section 3. The results and discussion are presented in Section 4. The paper is concluded in Section 5, along with the limitations and future work.

Manuscript received November 5, 2019
Manuscript revised November 20, 2019

2. Related Work

Data visualisation is the transformation of raw data into meaningful figures or charts which assists in understanding and discovering patterns of a complex process and relations hidden in multidimensional and multivariate data. Understanding figures is easy because it simplifies the process of finding the ratios and relations between data [9]. The basic representations used in data visualisation are charts, graphs, maps and plots [10]. Several papers related to data visualisation and big data are summarised in Table 1.

Table 1: Example of Data Visualisation Characteristics

Features	References	[11]	[12]	[13]	[14]	[15]	[16]	[17]	[18]	[19]	[20]	[21]	[22]	[23]	[24]	[25]	[26]
Method	1. TreeMap	✓			✓	✓	✓	✓			✓	✓	✓		✓	✓	
	2. Parallel Coordinates		✓	✓	✓	✓	✓	✓		✓	✓	✓	✓			✓	
	3. Scatter plot	✓	✓	✓	✓	✓			✓	✓		✓	✓			✓	
	4. Stream Graph				✓	✓	✓	✓			✓				✓		
Data Characteristics	1. High volume		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	2. Variety	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3. Veracity	✓		✓	✓	✓			✓	✓	✓		✓	✓		✓	
	4. Scalability			✓	✓	✓	✓				✓				✓	✓	✓
Tools	1. Tableau		✓			✓			✓		✓		✓			✓	✓
	2. D3	✓		✓		✓		✓	✓				✓				✓
	3. Plotly										✓		✓				
	4. Gephi				✓	✓					✓						
Application Domain	1. Agriculture				✓									✓	✓		
	2. Media		✓	✓		✓		✓	✓	✓	✓		✓	✓	✓	✓	
	3. Public	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	4. Transportation			✓			✓										✓

Table 1 indicates that the studies conducted by [14, 15, 21, 22, 25] claim that traditional methods of visualisation do not keep up with the pace and volume of data. Big data characteristics and few visualisation techniques, such as tree map, parallel coordinates, scatter plots and stream graph, are discussed. A few popular visualisation tools are also identified in these studies.

According to Satyanarayan, Wongsuphasawat [11], declarative visualisation can accelerate development, facilitate retargeting across platforms and allow language-level optimisations. For example, a visualisation (such as tree map and scatter plot) specification can be rendered in a browser using HTML5 canvas or scalable vector graphics or as a static image for print-based media simplified retargeting. This paper outlines the function of D3, such as offering standard interaction techniques with black boxed event processing and limited customisation via exposed parameters. Gao, Dontcheva [18] states that visualisation makes data analysis easier by allowing users to look at more data simultaneously and see patterns more easily. This paper explains the characteristics of big data. Visual analysis tools, such as Tableau, creates visualisations automatically based on variables of interest. Similarly, Healy and Moody [13] claims that differences in visualisation methods help in exploring datasets and presenting results in the sociology field. Effective data visualisation has introduced big changes in social sciences wherein data are more easily available and high-quality graphical work can be produced and shared easily [13].

Fiaz, Asha [23] focuses on making the usage of data visualisation more efficient and valuable. The concept of big data is incomplete without terminologies, such as volume, variety, veracity and velocity. The relation between big data and the Hadoop distributed file system together with the map reduce framework is explained in detail. Nguyen, Nguyen [24] presents a comprehensive study related to the techniques for collecting, storing, analysing and visualising big data. Visualisation techniques have been proposed to address important questions and challenges in the agriculture domain. The paper mentions that the most traditional data visualisation approaches and tools are often inadequate to handle big data.

Chen, Guo [16] provides an overview of visualisation techniques applied in the context of traffic analysis and presents the common data flow in traffic data visualisation. Chen, Guo [16] also elaborates the existing methods for depicting the temporal, spatial, numerical and categorical properties of traffic data. The data visualisations techniques have been highlighted in [12, 17, 19, 20]. The authors in [12, 19] focus on explaining parallel coordinates and scatter plots in media and the public domain. Meanwhile, the authors in [17, 20] discuss data visualisation in the public domain. Visualisation techniques (e.g. tree map and parallel coordinates) are covered in these two papers. Finally, Zhiyuan, Liang [26] explores the application of big data visualisation in the passenger flow analysis of the Shanghai Metro network. Techniques of big data visualisation, such as 3D tech and graphics-based tech, are studied. Low and

high visualisation tools are also briefly discussed in the paper.
Moreover, Table 1 indicates that scatter plot and parallel coordinates are preferable big data visualisation techniques, and D3 is a popular visualisation tool. However, the tools have drawbacks in terms of cost as most of these tools' functions for visualising data are not free.

3. Methodology

The methodology is divided into three phases as shown in Figure 1. The first phase is literature review and analysis, and the second and third phases are application development and evaluation, respectively.
In the first phase, related papers are studied to collect information about smart farming and data visualisation. From the studies, the smart farming process, issues and challenges are identified and understood. Issues in smart farming data are recognised, and a solution to overcome that, i.e. a farm management android application, is proposed.
The second phase consists of requirement analysis, design, implementation and testing. In the requirement analysis cycle, the functional and non-functional requirements of the application to be developed are identified by collecting data using the observation method and studying the written documents. The second cycle is where the application interface is designed. The step starts by drafting the application interface which contains all the functionalities that the application requires. A storyboard which provides an idea on how the application works is then designed and modified until all the functionalities are included. Once the design is confirmed, the application interface is designed by considering the usability factor. Application implementation involves migrating the process in the cloud (Google Drive). The tool used to implement data visualisation is GraphView. Google Drive is used as the cloud storage platform for the tools in this study. The visualisation tool pulls data from the source and applies a graphic type to the data. The output, which are line graphs and scatter plots, are then displayed in the format supported by the application. The application is developed using Java as main language and Android Studio as the tool to build it.
Application testing is the last cycle. The application's functionalities are tested using various tests to ensure a bug-free application.
The last phase is application evaluation. Verification aims to check whether the application meets its specification is carried out by comparing the developed application with existing applications. The ability of the application to complete the functionalities required, such as creating visualisations, is compared with Microsoft Excel as it possess the same functionality as the proposed application.

Fig. 1 Methodology

3.1 Data Collection and Analysis

Various types of farming data require different visualisation and analysis methods. Real-time data collected through sensors and devices are typically raw and inaccurate. They contain outliers, ambiguities, missing values or mismatched items. Thus, the raw data must be processed for visualisation and analysis [27]. Data analysis starts from studying the sample of raw farming data collected. The following steps are shown in Figure 2.

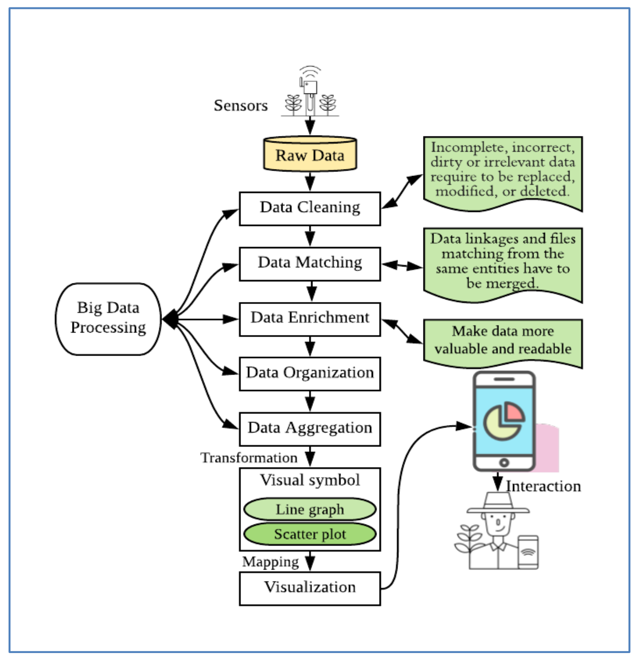

Fig. 2 Data Analysis and Visualisation Framework

3.2 Implementation of Data Visualisation in Farming Application

Data visualisation is the process of representing data and information that are generally in the form of numbers and statistics as graphical charts. Effective visualisation helps discover unknown facts and trends that users analyse to determine the rationale of the data. It makes complex data more accessible, understandable and usable. Data visualisation can also highlight areas that require focus, clarify the important factors and predict values for respective factors. The visuals used to represent data in this paper are scatter plot and line graph. The processes of implementing visualisation in the application are shown in Figure 3.

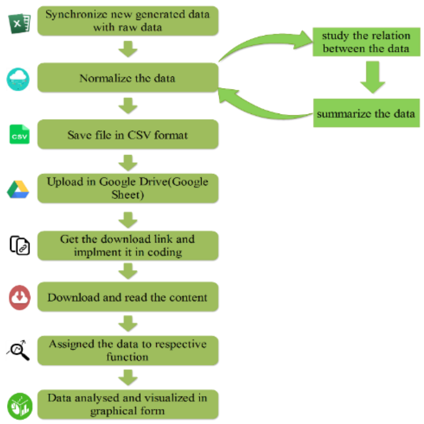

Figure 3 Visualisation Implementation

3.2.1 Two-Dimensional Visualisation and Graphview

To represent and examine large amounts of data, many visualisation techniques that address usability, interactivity and interface have been developed. The visualisation techniques include 1D, 2D, 3D, temporal, semantic network, tree map and parallel coordinates [22]. The techniques are easy to use in visualising data as they have an evaluation mechanism. The technique chosen for this study is 2D visualisation. Two dimensions, i.e. two variables, are used to visualise the data set. Visualisation can be performed easily by knowing the relationship between the two variables [28]. The 2D visualisations can be represented in the form of line graphs, bar charts, area charts, pie charts, maps, scatter plots, stream lines and arrow visualisations.
GraphView is chosen as the tool to implement data visualisation in the SmartFarm application. GraphView is an open source graph plotting library for Android that programmatically processes and creates flexible graphs and charts. It is easy to understand, integrate and customise. Compared with other available android graphing libraries, GraphView relatively bug free.

3.2.2 Line Graph

Line graphs were invented in 1786 by William Playfair and have been used widely to visualise the relationship between variables on a graph. Line graphs are utilised to simultaneously compare two or more data categories. Stacking lines are used to distinguish between trends for multiple variables and facilitate the identification of patterns. Line graphs can be used in a situation where variable changes must be displayed over the time or against other variables. Specific symbols and icons are used to represent data points in a line chart.

3.2.3 SCATTER PLOT

A scatter plot is described as a type of 2D plot or mathematical diagram using Cartesian coordinates to identify and display the associations between explanatory and response variables. Data are displayed as a collection of points where the position of each point on the horizontal axis represents the value of one variable, and the position on the vertical axis denotes the value of another variable. The relationship between the two variables is known as the correlation. The closer the data points come when plotted, the stronger the relationship between the variables. A positive correlation is indicated by an upward trend (positive slope), and a negative correlation is indicated by the opposite effect (negative slope). In certain cases, a scatter plot does not indicate any trend. A scatter plot can be used when one continuous variable is in control and the other depends on it or when both continuous variables are independent.

3.2.4. Smartfarm Application

The SmartFarm application is developed as mentioned in the methodology section. Figure 4 shows the visualisation pipeline of the application. Meanwhile, Figure 5 shows the interfaces of the SmartFarm application. The main function interface of the SmartFarm application is shown in Figure 6.

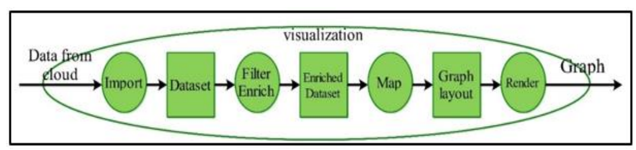

Fig. 4 Application Visualisation Pipeline

Fig. 5 SmartFarm Application Interface

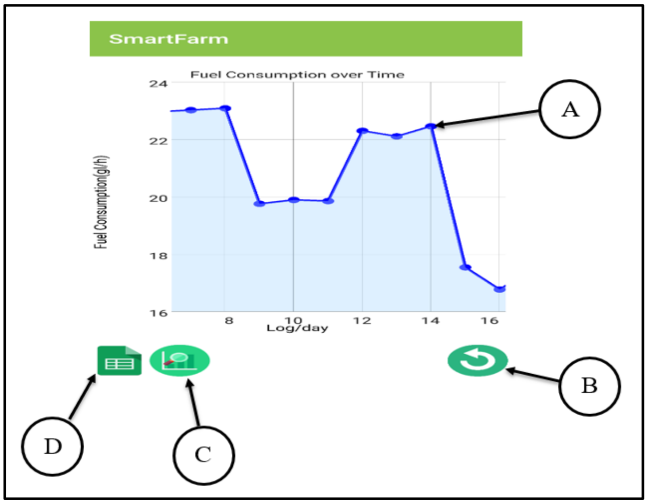

Fig. 6 Main Function of SmartFarm Application

The part labelled ‘A’ visualises the farming data, such as fuel consumption, engine speed, engine power, area productivity and wheel slip, for inventory, such as tractor, combiner and truck, with a line graph. The graph visualisation process initiated by pressing button ‘B’ to start the data downloading process. Button ‘B’ also triggers the reload function which considers the change in data in the cloud and syncs it to the graph created. This functionality endows the application with ‘real-time’ capability as the data in cloud and in application that are synced can also change. Button ‘C’ starts another activity to visualise a scatter plot of the chosen category against another data category, e.g. a scatter plot of fuel consumption against engine speed. This shows how the data are analysed from a vast amount of meaningless numbers to meaningful visuals. Button ‘D’ is responsible for simple calculation, showing the average, minimum, maximum and mode of the selected data category values. Figure 7 depicts the functionalities of buttons ‘C’ and ‘D’.

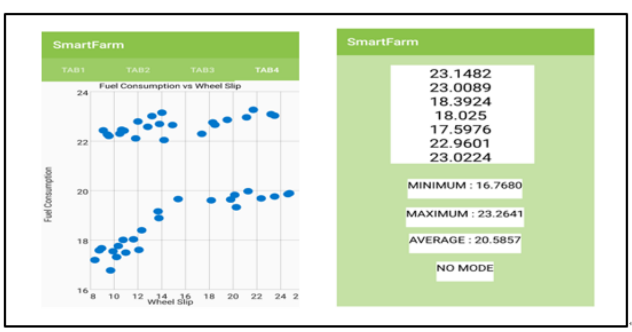

Fig. 7 Data Visualisation Result

4. Result And Discussion

This application is compared with Microsoft Excel which has the same functionality of visualising data. A similar dataset is used to create graph visuals in Excel and the SmartFarm application. The results are then studied and compared.

4.1 Comparison Result

Figures 8 and 9 shows the graph visualisation produced by Excel and the SmartFarm application, respectively, for the same type of data. Based on the figures, the graph created by the application is similar in pattern as the graph created by Excel. This outcome indicates the correct implementation of data visualisation methods and shows that the application can perfectly replicate he function of existing visualisation tools, such as Microsoft Excel. Furthermore, this application can replace existing tools and provide better visualisation.

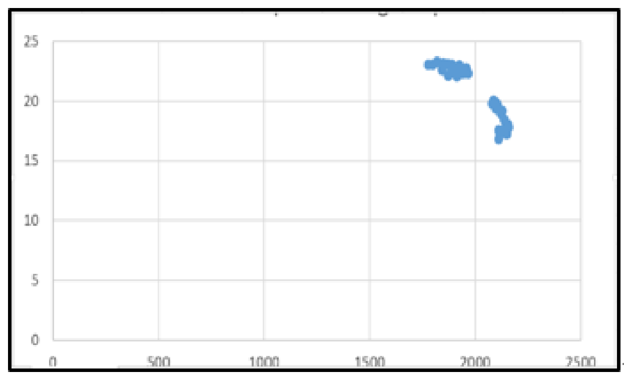

Fig. 8 Scatter Plot by Excel

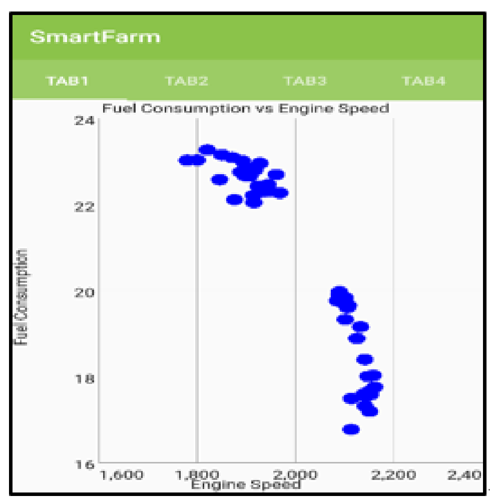

Fig. 9 Scatter Plot by SmartFarm Application

4.2 Discussion

In accordance with Figures 8 and 9, the SmartFarm application performs well in terms of creating the same type of visualisations as Excel. The outcomes reveal that the data visualisation method is correctly implemented.

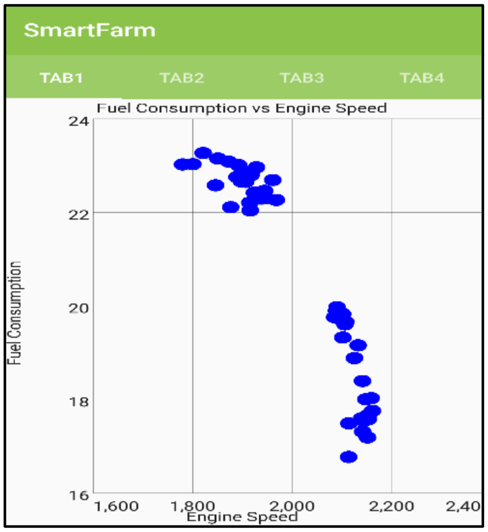

Fig. 10 Scatter Plot by SmartFarm Application

Figure 10 shows the scatter plot created by the SmartFarm application for fuel consumption against engine speed. The figure indicates that the fuel consumption ranges from 22 to 24 gallons per hour for the engine speed variation range of 1800 to 2000. Given the visual form, the data are easier to digest than when in numerical form. With Figure 10 as basis, the graph created by the SmartFarm application is easy to understand as the scale and placement of the data are clear. In addition, the clustering of data is more significant in the graph created by the application which can help users understand the relation between the data and make a prediction. The application has an advantage over Excel because it is easier to use for visualisation as it is easily accessible using a mobile phone than Excel which requires a computer.

5. Conclusion

The massive amount of farming data requires precise methods and tools to obtain correct analysis results. The method presented in this paper is data visualisation which aims to help farmers or farm managers gain a better understanding of farming data. The application developed can perfectly replicate the function of existing visualisation tools, such as Microsoft Excel. By visualisation, this application can help in reducing the work load in the farm data management process. Using the graph created, farmers can gain a better understanding of the relation between data. Farmers can also use graph visualisation to make a prediction, e.g. fuel consumption of a tractor for the coming week. This process can help increase the productivity and work quality of farmers. An increase in productivity can ultimately help boost the economy of the country. This study can be further improved in the future by replacing Google Drive with more organised and reliable databases. More functionalities, such as prediction, can be added to the application by implementing machine learning.

Acknowledgement

This research is supported by the Department of Research and Innovation of University Malaysia Pahang under RDU190365.

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