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Research paper

Context-Aware Crowd Monitoring with Dynamic Multi-User Tracking Data

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Abstract

Monitoring small crowd of people as tourists in different country always create recurrence issues to their tour-guides such as someone is lost somewhere, losing important documents and getting sick in the middle of the crowd. Similarly, during the Hajj season, such issues occur while millions of Muslims are gathered in two popular cities, Mecca and Medina, of Saudi Arabia. At the peak of the Hajj season, Mecca is identified as the most crowded place when pilgrims all over the world along with their respective tour-guides known as Mutawwif are resided in the city. Thus, communication between the crowd and their respective tour guides offers useful dynamic multi-user tracking data which is essential for close monitoring purposes. This study explores the usage feasibility of dynamic multi-user tracking data in order to provide a context-aware and simple communication means in the form of mobile application to both pilgrims and Mutawwifs for resolving their recurrence issues. The application can be used by the pilgrims to send current location and purpose for contacting the Mutawwif. At the same time, the Mutawwif is able to locate their respective pilgrims and aware of their pilgrims' current location and needs. The prototype of the system is developed by using software engineering approach to test the feasibility of using multi-user tracking data in such situation. The prototype has been evaluated and fulfilled the intended requirements for monitoring small crowd. As a conclusion, the prototype offers an alternative for Malaysian Mutawwifs to aware of pilgrims' issues and track their need and location at real time during Hajj season. Similarly, the pilgrims also can communicate their needs and problems to their respective Mutawwifs.

Keywords: *Dynamic Data, Dynamic Tracking, Multi User Tracking, Monitoring Small Crowd, Small Group Communication .*

1. Introduction

Mecca or Makkah is an annual Islamic place for pilgrimage visit in Hajj season (Bhat, Ardiansyah, Ally, & Ibrahim, 2015) and it involves over 180 countries to present in Mecca to perform pilgrimage which is known as Hajj (Gautret, Benkouiten, Sridhar, Al-Tawfiq, & Memish, 2015). A pilgrim is defined as a person who is capable of undertaking the trip and has enough property to perform the Hajj for at least once in their lifetime. The rule is applied for all Muslims and is stated as one of the Five Pillars of Islam policy (Hajj, 2016). The Hajj season is the largest annual gathering of people in the world in the city of Mecca (Olaitan et al., 2015) where almost three million pilgrims are gathered to perform the rituals of Hajj (Mohandes, 2011). Therefore, it is normal for the pilgrims to encounter three major problems during the season; getting lost, losing important documents and encountering health disease.

The chances for pilgrims to getting lost in the crowd are very high if they do not follow the specified rules and policy during the Hajj season. As reported in the Arab News (Jun, 2015), the large number of pilgrims during the Hajj season has caused over crowded issues and the responsible agencies unable to minimize this problem every year. Statistic shows that over 2,500 pilgrims were lost around the Grand Mosque in Mecca only (Galal, 2006). The numbers of lost pilgrims are large, especially for the non-Arabic and elderly due to lack of tracking techniques and the procedures of reporting the missing pilgrims are not efficient enough. The lost is a very critical problem since the pilgrims are mandatory to perform specific rituals, at specific time and at required place. Otherwise, their Hajj rituals might not be accepted by the Islamic rules and their Hajj is considered annulled. Thus, their journey for that year is a waste of time, effort and money. Besides lost, food poisoning is also common during the Hajj season and is caused by pollutants produced by Bacillus cereus and Staphylococcus aureus (Shafi et al., 2016). Furthermore, living together in a crowded environment exposes the pilgrims and the local citizens to health diseases. If the pilgrims do not take any action after knowing that they are not well, the spreading of the diseases will be more severe. Therefore, pilgrims are in need of direct communication means to communicate their problems to the respective Mutawwifs accurately and immediately.

Many attempts have been made to resolve issues while monitoring such crowd. The major aim of the attempts is to keep the pilgrims safe and on the right track of time and place. One approach to track the pilgrims is by using, Radio Frequency Identification (RFID) (Mohandes, 2008) via wearing wristbands. The weakness of RFID is the limited distance coverage of such device. There exists an application in Google Play called "Cek Porsi Haji" dedicated for Indonesian pilgrims. The application is able provide data for Mutawwifs at real time. However, the system uses Indonesian language and different slang and terminology to be

used by Malaysian elderly. This work is intended to improve current techniques or methodology so as to making use dynamically of available multi-user tracking data for monitoring small crowd within the huge crowd of pilgrims in the Hajj season.
This paper is organized as follows. Section 2 discusses on the related work involving data visualization techniques, then, Section 3 shows the research methodology which shows how data are clustered and visualized using particular techniques. Section 4 explains on the results while Section 5 is the conclusion.

2. Related Work

There are many types of tracking techniques available for public used.

2.1 Tracking Mechanism

This section presents three selected tracking mechanisms; Radia Frequency Identification, Global Positioning System, and mobile phone.

2.1.1 Radio Frequency Identification (RFID)

Radio Frequency Identification (RFID) is an Automatic Data Collection (ADC) that uses radio frequency waves (Shah & Kulkarni, 2015) for identification and tracking uses. An RFID tag is sometimes called an RFID transponder consisting of chip, memory and antenna. This RFID tags are embedded in many things which can be applied for business purposes, particularly warehousing, retail and livestock. The components of RFID tag is shown in Figure 1.

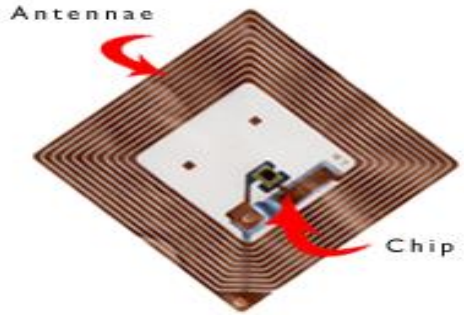

Figure 1. RFID Tag Components

From Figure 1, RFID tag composed of wireless transducer with encapsulating material and an antenna. In addition, the tags can either be passive or active in which the passive tags use the power induced by the magnetic field of the RFID reader whereas the active tags have on-chip power (Mohandes, 2008).
RFID also allows mobile objects to be tracked accurately which gives a lot of advantages for many applications (Binsalleeh, Mohammed, Sandhu, Aljumah, & Fung , 2009). With its good accuracy of tracking objects, it is beneficial for tracking lost pilgrims in Mecca. There are also more advantages using the RFID. One of the advantages is that more information can be stored compared to using bar codes as it follows the reader instruction. In addition, ID of each RFID provides location to the reader whenever it is near to the RFID tag. Therefore, it can be used to track luggage and also to monitor health conditions of patients in hospitals (Yang et al., 2014).

2.1.2 Radio Frequency Identification (RFID) and Mobile Phone

Every year, there are millions of pilgrims came to Mecca for Hajj and the amount is expected to increase in the future (RF Wireless World, 2017). Due to a massive amount of people, pilgrims tend to be lost and it will be a challenge to track family members and friends when the situation happens. Therefore, RFID chip is implemented in wristbands but this has also becomes inconvenient whenever pilgrims are taking the wudhu'. The wristbands were tend to lay around and cause for it to be missing, thus, it is then embedded in mobile phones to prevent any losts. Moreover, it is more convenient when this technology is embedded in mobile phones as the web service can transmit data more easily. Even though RFID technology can track lost objects, Global Positioning System (GPS) allows a wider range of navigation system.

2.1.3 Global Positioning System (GPS)

Global Positioning System (GPS) is a radio-based navigation system with an augmented technology that has uneven accuracy and flexibility to monitor, search, send and track location (Mohandes, 2010; Varshney, Goel, & Qadeer, 2016). It has the ability to cover three dimensional positions with an accuracy of approximately a meter and gives nano-second unambiguous time worldwide (Mahoharan. 2009). In addition, GPS is able to determine elements such as weather condition, military broad range, velocity range for sprinting sport, commercial and consumer applications anywhere in the world (Brown, Dwyer, Robertson, & Gastin, 2016).
With such technology that can be used 24 hours a day, mobile phones and cars are embedded with this system in this era, thus, it is widely used in law enforcement, vehicle tracking and person monitoring. Moreover, GPS functions to obtain the shortest path with time arrival to reach the desired destination (Moloo, & Digumber, 2011). General architecture for the GPS tracking consists of three components – user, mobile phone and GPS. The process starts by reporting the location from the user via mobile phone which has the capability to communicate through text messages. Then, the GPS will be activated to retrieve the current location from the satellite and enables the location to be sent to others by the user.
GPS has been used to perform data mining on spatial data (Alispahic & Donko, 2014). The research involves information transmission regarding current position of mobile device and processing of the spatial data using database warehouses. Besides the typical GPS coordinates and timestamps, research shows that GPS can be used to track personalized movement and used the patterns as the context associated with the users past activity patternsto make recommendations (Kumar, Jerbi, & O'Mahony, (2017). Thus, GPS is the potential candidate to be used in this project as it provides easy navigation by showing the directions taken by the user as well as the suggested directions to reach the desired destinations without worrying about the weather condition during the time. In comparison with other navigation systems, GPS is a low cost system with 100% coverage on Earth. With this facility, it is easier to get to certain places as it is embedded into devices such as mobile phones.

Therefore, by having GPS technology, not only it can track lost pilgrims but it can show directions more accurately for both the lost pilgrims as well as the people who are trying to track down the lost pilgrims.

2.2 Comparison of Tracking Mechanisms

This section presents the comparison of the three researched mechanisms in Table 1.

Table 1. Comparison of Tracking Mechanism

	Global Positioning System (GPS)	Radio Frequency Identification	RFID And Mobile Phone

		(RFID)	
COMPONENT	All smart devices that embedded with GPS.	RFID tag and RFID reader.	RFID chip can placed inside the mobile phone to tracking pilgrims.
USED	GPS is also used for personal convenience such as travellers, especially trampers, can carry GPS in order to form a digital trail.	Used for inventory tracking, animal tagging, timing marathon runners, secure automobile keys, and access control for secure facilities.	Used for tracking pilgrims. It combined chip into mobile phone because using wristband of RFID it may lose when to clean his hand.
RANGE	GPS will hard to define the location of the places is underground.	• Active RFID less than 100m • Passive RFID less than 10m.	Long range, and higher speed of data transfer.
ABILITY	Exact current location, velocity and time 24 hours a day	RFID is fast, reliable, and does not require physical sight or contact between reader and the tagged item.	Short Message Service (SMS) and wireless network can communication and updated the server .
DESIGN	• Embedded with mobile application. • Embedded with device such as Garmin Drive 51 LMT-S.	Wristband containing a unique numbers for every pilgrim.	Using mobile phone and Google Maps.

Based on Table 1, the best tracking mechanism is GPS because all smart devices have embedded with the GPS. Therefore, the pilgrims need not to worry about the location. Next, it can retrieve the current location, velocity and time accurately 24 hours a day with an Internet connection. RFID is good but it has its own limitation such as it must be worn all the time doing Hajj. In addition, it will be much costly if the number of pilgrims is huge in oder to provide additional device.

3 Research Methodology

There are five main phases for this project which are requirements, design, coding, testing and deployment.
The first phase in mobile application development is requirements. This work uses abstract scene analyses methodology (Omar, 2014) for extracting users' requirements for the system. Statements from expert Mutawwifs are taken in terms of how they handle communication for three recurrence issues (missing pilgrim, lost valuable items and sickness) during Hajj seasons. More than 50 experience and 50 inexperience pilgrims in random selection from rural areas are interviewed in order to extract pertinent communication experience with their Mutawwifs. Based on the analyses of the qualitative data, the pilgrims can be categorized into eight categories:

i. Have previous experience in Mecca, literate and can self-navigate if loss.
ii. No experience previous experience in Mecca, literate and can self-navigate if loss.
iii. Have previous experience in Mecca, illiterate and can self-navigate if loss.
iv. No experience previous experience in Mecca, illiterate and can self-navigate if loss.
v. Have previous experience in Mecca, literate and cannot self-navigate if loss.
vi. No experience previous experience in Mecca, literate and cannot self-navigate if loss.
vii. Have previous experience in Mecca, illiterate and cannot self-navigate if loss.
viii. No experience previous experience in Mecca, illiterate and cannot self-navigate if loss.

This work is focused on helping the last category of pilgrims which are in need of effective communication to express their problems in relation to the three recurrence problems.

Based on therequirements, use case diagram is drawn as in Figure 1.

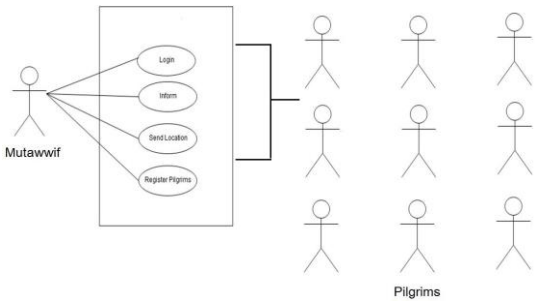

Figure 1. Use Case Diagram of the System

Figure 2 shows that the proposed system be allow Mutawwif to handle many pilgrims which are assigned under him and should allow him to monitor his group of pilgrims virtually. On the other hand, the less advantage pilgrims are able to communicate with their assigned Mutawwif at real-time and anytime with minimal clicks away. The second phase involves designing the architecture, flow and graphical user interface for the system. Figure 3 presents the architecture of the system.

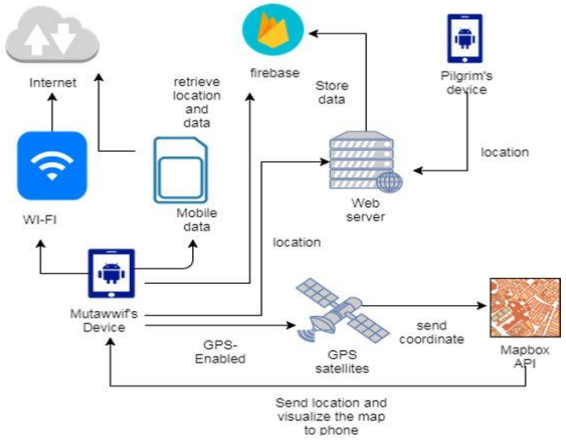

Figure 2. Architecture of the System

Figure 2 shows the overview of necessary components involves to support the system and the overall overview of how the components are interconnected with one another. Firstly, pilgrims have to connect to Wi-Fi or mobile data. Next, the proposed mobile application will enable the GPS on the mobile phone with the Location Based Services. GPS satellites will send coordinate magnitude and longitude to Mapbox API and visualize the location in the mobile phone. The location that has been visualized will be sent to the database once the user press button send. The

magnitude of the location will be saved in database and pilgrims will get the location from the database. Pilgrims or Mutawwif are able to retrieve each other's location while the Mutawwif is taking the advantage of knowing multiple pilgrims' location from the database once the pilgrims send their location to the Mutawwif.
The flow for the overall process can be further described in the following flowchart in Figure 3.

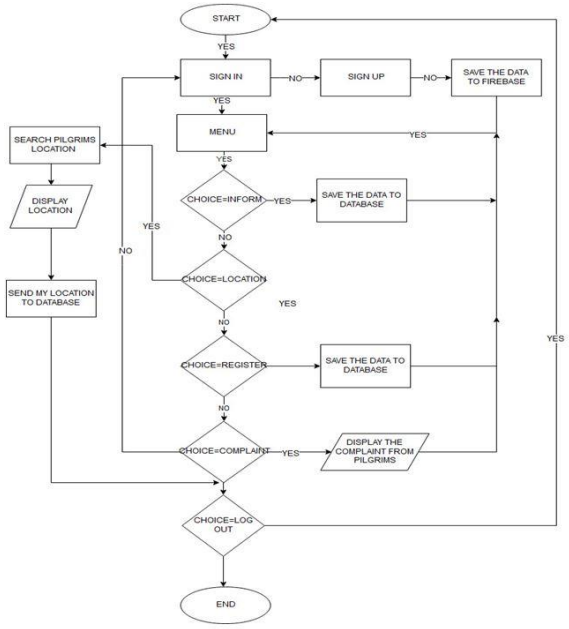

Figure 3. The Flow of the System

Figure 4 shows the flow of the system for a Mutawwif's use (referred to as user). When a user log in, the user will go to the user menu. If user is not signed in yet, the user has to sign up. On the menu page, the user will able to register new pilgrims, choose location and then track any lost pilgrims, or identify complaints from the pilgrims. If the user chooses location, user will able to track location of the pilgrims and the location will be displayed, and the same time user also can send their location to pilgrims. On the other hand, the menu for the pilgrims is much simpler. They are presented with three buttons and they press the button to communicate their problems to their Mutawwifs. In this phase, the graphical user interface (GUI) of the system is designed. The design is presented with multiple GUIs to cater different category of pilgrims. Nevertheless, the prototype of this system starts by having the GUI for the last category of pilgrims.
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The third phase is the implementation of the system. The system uses Firebase as the database. All data in this system will include the latitude and longitude of the locations as part of the fields in the Firebase records. The database is a real-time database that can be accessed anytime and anywhere but it uses directory file that consists of parents and child. In order to use and access the firebase database, a project has to be created in Firebase website. Once the project is created, a Firebase API will be given. The Firebase API is needed in order to access the authentication, real-time database and cloud storage. This Firebase API share the same API with the pilgrim's system.
In this phase, Map Box important parameters are needed in order to display map on the user interface. Map Box API, Map Box access token and HTML file are needed. A Map Box account needs to be created first in order to get Map Box access token. When a Map Box account is created, an access token will be obtained from Map Box page.
The algorithm for tracking multi-user locations and retrieving data that have been stored in the database is embedded in the system. The algorithm consists of several sections; tracking current Mutawwif's location, sending current Mutawwif's location, tracking various pilgrims location, adding marker to the pilgrims' location and retrieving pilgrims' data from the database.
The GUI for the application is designed and implemented. Figure 5 presents the design and the implemented GUI for the application.

The Design	The Implemented GUI
	

Figure 5. The Design and Implemented GUI

It has five buttons that a pilgrim can choose; Lost ('Sesat' in Malay language), Sick ('Sakit'), Loss Item ("Kehilangan Harta Benda"), Get Mutawwif's Location ('Terima Lokasi Mutawwif) and contact Mutawwifs on Duty ("Mutawwif Bertugas"). The five buttons is easy and fast to learn for pilgrims especially elderly, the focused group of this research.
If a pilgrim clicks on 'SESAT' button, a map will be shown to him map. Next, he has to click button 'HANTAR LOKASI', then, the location will be sent to database as latitude and longitude values. The specific Mutawiff is alerted with notification and able to track the location of the pilgrim's latitude and longitude values from database. The same actions are applicable for every button on the pilgrim's GUI. On the other hand, on the Mutawwif's GUI, he is able to view list of pilgrims' reports for all the issues based on the available buttons respectively and starts providing support and help services immediately.

4 Result and Analyses

The context aware prototype has been tested to ensure sure all the function work well based on the user requirement. Table 2 shows the test cases for this system.

Table 2. Test Cases of the System.

No	Definition	PASS	FAIL
1	Verify whether the application has been launched successfully or not	√	
2	If your application has buttons (e.g. Submit, OK, Cancel, etc), ensure that the buttons appear in a consistent order from screen to screen.	√	
3	Verify the login is successfully log into the system	√	
4	Verify the data have been submit are stored in database	√	
5	Verify the logout button is succesfully out from the system	√	
6	Verify the notification will pop up if not open the system	√	
7	Verify system is easy to understand	√	
8	Verify the direction or navigation to place work perfectly		√
9	Verify the current location has store in database	√	
10	Verify whether the splash screen is displayed for long enough	√	
11	Verify that the application's display is adapted to the screen size and all buttons and menus are easily clickable.	√	
12	Check that each screen is appropriately displayed in each display mode (landscape, portrait).	√	
13	Verify that after submit the form, it will go to submit page again	√	
14	Verify the location is always accurate		√
15	Verify tap on the screen ten times at different positions, the application should work normally and not freeze.	√	
16	Verify that all spell check are correct on Alert	√	
17	Verify that Font size should be consistent.	√	
18	Verify that error messages in the Application must be clearly understandable	√	
19	Verify that any function selected in the Application should start within 5 seconds.	√	
20	Verify that If the screen contains dates, numeric, currency or other specific data types, ensure that only valid data can be entered	√	
21	Ensure that screens do not use different color sets as to cause an inconsistent.style guide should define header colors, body background colors,screen background color, footer colors, etc.	√	

Table 2 shows the test cases for the prototype. There are two issues are needed to be investigated and rectified. Nevertheless, the results shows that the context aware communication between pilgrims and their respective Mutawwifs are feasible via usage of multi-user tracking data and provide immediate response and services to the struggling less advantaged pilgrims.

5 Conclusion

Mecca is the largest annual gathering of people in the world during with about three million of pilgrims gather to perform the rituals of Hajj. There are three recurring issues while handling a group of pilgrims from the same countries. There is a need to have context aware communication between pilgrims and their respective Mutawwifs. The advancement of smartphones features embedded with default GPS allows us to make use of multi-user tracking data to provide dedicated real-time context aware communication between the two parties especially to the less advantage people with lack of literacy and navigation skills. The proposed communication alternative uses four dependent components with five buttons for pilgrims to select depending on their problems; lost location, missing valuable item, report sickness, detect location of Mutawwif, and contact Mutawwif at any time. The communication means has been tested. Nevertheless, there exists some limitations such it cannot show the pathway to Mutawwif location. It shows the location of pilgrim and the specific Mutawwif, but does not show the path to the Mutawwif location. Next, the location is not constantly accurate due to the pilgrims' / Mutawwif's location that is at underground or blocked by surrounding buildings. Currently, further investigation is needed and the improvements will be reported in the future.

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