A Review of Tracking Technologies in Hajj and Umrah Research

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ABSTRACT

Hajj and Umrah are unique events that experience the clustering of millions of people in a limited area. The safety of pilgrims and visitors, in addition to, ensuring the quality of provided services are among the most important issues to make sure that Hajj and Umrah rituals are carried out smoothly.
Over the past few years, technological developments have produced a range of sophisticated and readily available digital tracking technologies. Despite this remarkable progress in technology, researchers in the field of Hajj and Umrah services have failed to take full advantage of what these relatively new systems offer. This leads to a strong need to utilize tracking technologies to develop new applications that facilitate the different services presented during Hajj and Umrah. The type of developed applications depends primarily on the characteristics of each type of tracking technology.
This paper focuses on reviewing prominent tracking technologies that can be customized to Hajj and Umrah. Examples of such tracking technologies include satellite-based global positioning system, land-based antennas, radio frequency identification and near field communication systems, Bluetooth, Wi-Fi, barcode systems, scene analysis based on image examination systems, and hybrid solutions. The main aspects of the review are possible uses, installation cost, coverage range, localization accuracy, and advantages and disadvantages, in terms of suitability to Hajj & Umrah related services and applications.

Keywords: tracking technologies, Hajj & Umrah research

1. Introduction

Several millions of Muslims visit Makkah and Madinah to perform Hajj, Umrah, and Ziyarah every year. Hajj is considered as the one of the most important acts of worship in Islam. It is the fifth pillar of our glorious religion, and it is an obligatory worship for Muslims who are able to perform it. Hajj and Umrah are unique events that show the clustering of millions of people in a limited area. The safety of pilgrims and visitors, in addition to, ensuring the quality of provided services are among the most important issues faced by Saudi authorities to make sure that Hajj and Umrah rituals are carried out smoothly.
Therefore, it is necessary to manage crowd's movement and maintain high quality services presented during Hajj and Umrah journey, starting from the arrival to airports, following by performing the acts of worship, and finishing the journey by departure from airports.
During the past decades, many investigations have been made to produce a range of sophisticated and readily available digital tracking technologies [1]. Despite this remarkable progress in technology, research in the field of Hajj and Umrah services have failed to take full advantage of what these relatively new systems offer. This leads to a strong need to utilize

tracking technologies to develop new applications that facilitate the different services presented during Hajj and Umrah. Tracking technologies can provide high resolution spatial and temporal data that could potentially help in improving the quality of presented services in various areas of Hajj and Umrah research. The type of developed applications depends primarily on the characteristics of each type of tracking technology.

This paper focuses specifically on pioneer tracking technologies that can be customized to Hajj and Umrah, based on analysis of the current technologies. These tracking technologies can be classified into large-area techniques and limited-area techniques, as shown in Fig. 1.

The tracking technologies considered in the paper, include satellite-based Global Positioning System (GPS), land-based antennas, Radio Frequency Identification (RFID) and Near Field Communication (NFC) systems, Bluetooth, Wi-Fi, 1D and 2D barcode systems, scene analysis based on image examination systems, and hybrid solutions. The main aspects of the review are possible uses, installation cost, coverage range, localization accuracy, and advantages and disadvantages, in terms of suitability to Hajj & Umrah related services and applications.

The paper is organized as follows. Section 2 reviews the current prominent tracking technologies. Section 3 discusses tracking technologies and its suitability to Hajj & Umrah applications. Finally, conclusions are drawn in Section 4.

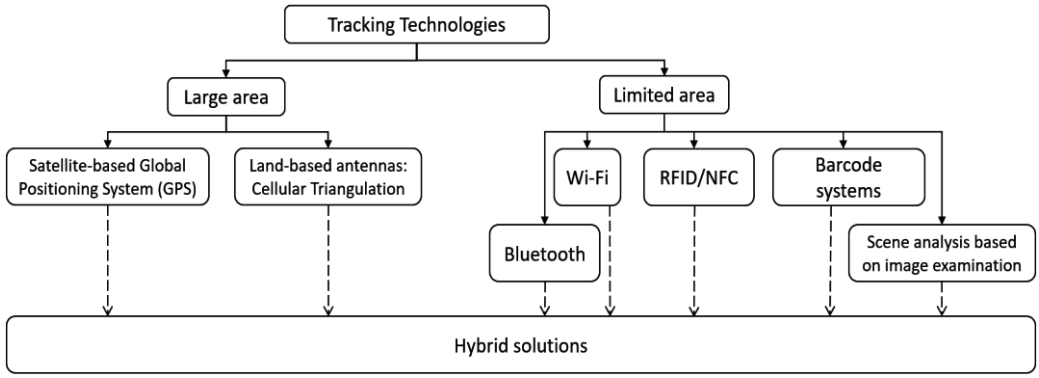

Fig. 1: Classification of tracking technologies.

2. Tracking Technologies

Tracking technologies can provide high resolution spatial and temporal data that could potentially help in improving the quality of presented services in various areas of Hajj and Umrah research. The type of developed applications depends primarily on the characteristics of each type of tracking technology. In the following, some prominent types of the tracking technology are briefly discussed.

2.1 Satellite-based Global Positioning System (GPS)

The Global Navigation Satellite System (GNSS) is an area of growing significance in the field of wireless communications [2]. It is a network of satellites that transmits high-frequency radio signals containing time and distance data that can be picked up by a receiver, allowing the user to pinpoint their geographic location (Longitude, Latitude, and Altitude), along with other information, anywhere around the globe. GNSS is a rapidly growing field and systems continue to be refined. The technology is now readily available at low cost via different forms of devices used daily, such as mobile phones and GPS-enabled handheld devices. These potentials make satellite navigation technology open for exploitation for real-time location and routing awareness in applications requiring the user to be located in a city map or model in real time.

Global Positioning System (GPS) is basically a series of satellites that orbit the earth broadcasting signals picked up by a system of receivers. By triangulating the data received from at least four satellites, is possible to determine a receiver's location.
The GPS is a one-way broadcasting system that can support an almost unlimited number of end users. The accuracy of the data supplied by it varies greatly, depending on the nature of the local terrain (exposed rural plains or dense urban environments), weather conditions, and the degree to which the GPS receivers are exposed to the sky. A receiver will provide an accurate reading only if exposed directly to the satellites' signals. Any kind of obstruction, regardless of whether it wholly or even partially blocks the signal, will produce an inaccurate reading.
As a tool for tracking, the main advantage of GPS lies in being global. An accurate reading requires direct line of sight between receiver's antenna and orbiting satellites. Moreover, error intensities of the GPS receiver vary from one location to another. Position information as well as error intensities are different at different times for same area. Therefore, precise pedestrian positioning only by conventional GPS receiver appears to be limited. Consequently, other wireless technologies can be used to enhance GPS positioning information to provide more precise, acceptable and reliable positioning information.

2.2 Land-based antennas: Cellular Triangulation

Although GPS-based travel data collection systems are suitable for monitoring vehicular traffic, it is not always applicable for observing human behavior since the GPS requires an open sky environment to detect signals from multiple satellites. This problem may be resolved if auxiliary signal transmitters are distributed in the areas where satellite signals are not available.
Apart from GPS-based studies, another research investigated the application of a cellular phone system to monitor individual travel behavior. Thus, Global System for Mobile Communication (GSM) based tracking methods have been developed [3,4]. It has emerged with the spread of cellular communications networks. It identifies the location of an end unit by triangulating adjacent cells within a single cellular communications network. The variation in this method's accuracy is dependent on the number and density of the network's cells and the volume of activity at any given moment. Accordingly, the more active cells on the network, the smaller each cell is, thus allowing greater accuracy.
Land-based tracking technology has several advantages. As there is no need to expose the end unit directly to the radio frequency station, it can be placed in a bag or even carried around in a pocket, hence leaving the subject free to go about business without manipulating the unit. Moreover, with no need for direct line of sight between antennas and end units, this technology can be used in dense urban areas, tracking people as they wander in and out of various buildings.

2.3 Radio Frequency Identification (RFID) and Near Field Communication (NFC) systems

Near Field Communication (NFC) combines two established technologies, which are tags and wireless readers. In the latest analysis of NFC market, most of mobile handsets have built in NFC capabilities. One advantage of NFC technology is the ability to work under harsh environmental. They also have a fast response time, long life time and low maintenance. A new set of applications and services are opening up as NFC integrated into mobile phones, given their ability to have many features.
Radio Frequency IDentification (RFID): is a general term for a set of technologies that use Radio Frequency (RF) to communicate data [5]. RFID technology has been available for several decades, the current century has marked the beginning of a new era in RFID development and usage. The RFID is a technology enabling automatic identification of objects at a distance without requiring direct lineof-sight between tag and its reader. This allows real-time data

exchange. Some of the current uses of RFID technology include: point of sale, automated vehicle identification systems, restrict access to buildings or rooms within buildings, asset tracking including buildings as assets, warehouse management and logistics, product tracking in a supply chain, people tagging and many more.
An RFID system is always made up of two basic components, Transponder (RF tag) and Interrogator (RF reader). Transponders used in RFID are commonly called tags, chips, or labels. Tags can be extremely small, thin and easily embedded within packaging, plastic cards, tickets, etc., as shown in Fig. 2.

Fig. 2: Examples of RFID/NFC tags.

Transponder is the actual data carrying device of an RFID system. It normally consists of a coupling element and an electronic microchip. A tag is located on the object to be identified. Information related to a given object is stored on an affixed tag and transmitted to a reader over an RF connection. Transponders are classified as active or passive depending upon the type of power supply they use.
Many models of reader are handheld devices, but readers can also be fixed in place (e.g. on buildings or in doorways) and even hidden, e.g. embedded into ceilings or walls. There are also readers that can be incorporated into handheld devices such as mobile phones.
NFC technology: is a short-range wireless connectivity technology that uses magnetic field induction to enable communication between electronic devices, in close proximity. The interfaces operate in operating distances of 0~20 centimeters in air. Currently, it offers data transfer rates of 106 Kbit/s, 212 Kbit/s and 424 Kbit/s, and higher rates are expected in the future.
The NFC can operate in either of two modes: active and passive. In active mode, both devices generate their own radio field to carry and transmit the data. In passive mode, only one device generates a radio field. The passive mode of communication is very important for battery-powered devices like mobile phones and PDAs that need to prioritize energy use.
NFC devices' mode of operation, as illustrated by Fig. 3, can be categorized as, ticketing and payment, peer-to-peer, and service initiation. Transportation is the initial leading use of NFC technology. Contactless tickets have already begun to revolutionize the speed and ease with which all consumers can use public transport and access controlled environments like parking garages. Numerous NFC payment and ticketing projects are being held around the world. Peer-to-peer mode of operation of NFC system takes advantage of the data sharing capability to enable simple and seamless transfer of data from one device to another, simply by touching the devices together.

Fig. 3: Uses/modes of NFC systems.

NFC systems can also be used in recording waiting (or service) times. A user touches or wave over an NFC-enabled device, such as PDA or mobile phone, against a specially located RFID tag, this then typically provides a small amount of information to the device. This can be few textural lines or a specific ID that connects handheld device with backend database of information. Also, the tags store information that can be accessed by touching them with NFC enabled digital handheld devices, as illustrated by Fig. 4.

Fig. 4: Communication between mobile phone and RFID/NFC tags.

2.4 Bluetooth

Bluetooth is a wireless technology standard for exchanging data over short distances from fixed and mobile devices, and building personal area networks. Because the devices use a broadcast communications system, they do not have to be in visual line of sight of each other [6-8].
A master Bluetooth device can communicate with a maximum of seven devices in a piconet (an ad-hoc computer network using Bluetooth technology), though not all devices reach this maximum.
Officially Class 3 radios have a range of up to 1 m. Class 2, most commonly found in mobile devices, 10 m, and Class 1, primarily for industrial use cases,100 meters. Bluetooth Marketing qualifies that Class 1 range is in most cases 20–30 m and Class 2 range 5–10 m.
The effective range of a Bluetooth-based communication varies due to propagation conditions, material coverage, antenna configurations, and battery conditions. Most Bluetooth applications are for indoor conditions, where attenuation of walls and signal fading due to signal reflections make the range far lower than specified line-of-sight ranges of the Bluetooth products. Most Bluetooth applications are battery powered Class 2 devices, with little difference in range whether the other end of the link is a Class 1 or Class 2 device as the lower powered device

tends to set the range limit. In some cases, the effective range of the data link can be extended when a Class 2 device is connecting to a Class 1 transceiver with both higher sensitivity and transmission power than a typical Class 2 device. Mostly, however, the Class 1 devices have a similar sensitivity to Class 2 devices. Connecting two Class 1 devices with both high sensitivity and high power can allow ranges far more than the typical 100m, depending on the throughput required by the application.
Bluetooth has several applications. For example, it can be used in communication between a mobile phone and a handsfree headset, communication with iOS and Android device phones, and for low bandwidth applications where higher USB bandwidth is not required and cable-free connection desired. Moreover, it can be used in real-time location systems that are used to track and identify the location of objects in real-time using tags embedded in the objects tracked and readers that receive and process the wireless signals from these tags to determine their locations.

2.4.1 Bluetooth Low Energy (Bluetooth LE)

Bluetooth Low Energy (also called Bluetooth 4.0 or Bluetooth Smart) is the specification for the type of signals that beacons (small Bluetooth radio transmitters) transmit. Bluetooth LE has the advantage that it is low energy and is 'native' to most modern phones and tablets.
Bluetooth Low Energy is a part of Bluetooth 4.0. A dual mode device like a smartphone can support classic Bluetooth (BT) and Bluetooth Low Energy at the same time. A smartphone could be connected to a Bluetooth 2.1 headset and stream audio, and at the same time be connected to a heart rate belt or other sensors. Single mode devices like the heart rate belt will run in the Bluetooth Low Energy (BLE) peripheral mode and the smartphone will run in the central mode. In the classic Bluetooth, this is still called master and slave.
BLE has a higher modulation index and needs 2 MHz bandwidth instead of 1 MHz like classic Bluetooth. The other reason is the very fast time of BLE for pairing and reconnecting. BLE needs 6 ms and classic Bluetooth up to 6 seconds. Older BT chips will be too slow, thus unable to support the 6 ms BLE.
Bluetooth Low Energy contributed scientifically in Beacon technology, which is fast gaining momentum for efficient solutions across multiple domains today. Beacons are being used in almost every sector. Beacon technology uses small low-cost, low-powered transmitters equipped with Bluetooth Low Energy or BLE that can be used to deliver proximity-based, context-aware messages. The typical range of Bluetooth low-energy radio module is up to 70 m. Majority of beacons are battery powered and last for up to one year before they need to be replaced.

2.5 Wi-Fi

Wi-Fi provides high-speed access to the Internet [9]. Wi-Fi (802.11x)-based systems accuracy is about 3–5m. One of the advantages of this system is the use of existing IEEE 802.11 infrastructure that results in a reduced cost of deployment. However, in multi-floor and dense indoor environments the performance of the system decreases because the signal reflections and dynamic network conditions may affect signal readings. Besides, minor network changes may require recalibration of the whole location system. Wi-Fi has some similar applications to Bluetooth, such as setting up a network or printing and transferring files. It is also a wireless standard, but rather than being designed to communicated between devices, it serves to wirelessly connect devices to the Internet or Ethernet networks such as a corporate local area network (LAN). Its range is quite a bit larger than the very short range within which Bluetooth

devices communicate. This means that a Wi-Fi-enabled device, such as a PC or smartphone, can connect to the Internet wirelessly when in a Wi-Fi "hotspot," or area in which a Wi-Fi signal may be accessed. This hotspot can be a small area such as a single room, or may cover several miles if hotspots are allowed to overlap.
Wi-Fi is available in most devices, and Wi-Fi hotspots continue to proliferate across companies, university campuses, airports etc.

2.6 1D and 2D Barcode Systems

Another technology used for accurate and reliable real-time position and routing information is the 2D barcode system [10]. 2D barcode system also has ability to deliver any information, which may include text, audio, and video on location.
Their use is widespread, and the technology behind barcodes is constantly improving. However, 1D barcodes only store a key to the relevant database entry and when it is scanned the information is retrieved by running a database query. The need for a barcode to be a portable database rather than just a database key leads to the development of 2D barcode. The main advantage of using 2D barcodes is that a large amount of easily and accurately read data can ride with the item to which it is attached. Fig. 5 shows different kinds of 1D and 2D barcode symbols.

Fig. 5: Examples of 1D and 2D barcode symbols.

One-Dimensional (1D) barcode represents data by varying the widths and spacings of parallel lines, and may be referred to as linear or one-dimensional. While, Two-Dimensional (2D) barcode represents data using two-dimensional symbols and shapes. They are similar to a linear 1D barcode, but can represent more data per unit area. These include some newer barcode types such as the QR Code type.
Special barcode generation software is needed to create 2D barcode images. These barcode images can then be printed using a printer. Mobile phones and barcode technologies have been combined to the advantage of user. A mobile phone, programmed to interpret barcode images, generates the barcode value which is used to identify the object. By connecting online, user can then get access to a wealth of information about the object. To operate barcode reader, the user photographs barcode with camera phone. The barcode reader then scans and decodes the data embedded in the codes and can display, manipulate, and store the information on the mobile device. Alternatively, a 2D barcode may be displayed on a device's screen while another device is used to read the tag.
Applications and capabilities of 2D barcode systems show the potential for many fields to take advantage of them. 2D barcodes can be used as a key to access a database of location and routing information. 2D barcode system allows user to scan 2D barcodes affixed on objects and places with camera phone in order to retrieve information and services related to these places, such as the geographic location of a building, location based information including textual, graphic, audio, and video information.

2.7 Scene Analysis based on Image Examination

Scene analysis techniques are based on image examination and tracking people with multiple cameras [11]. The camera is placed at high elevation and only head is tracked. One advantage of using these techniques is that top view cameras solve occlusion issues and it gives high accuracy tracking. In addition, it is robust to illumination condition. On the other hand, one disadvantage of this techniques is that the object identity is lost because only the head is observed. Moreover, this method is not suitable for extremely dense situations because the height of the person cannot be detected.
Another approach for Scene analysis is by using thermographic cameras [12]. A thermographic camera (also called an infrared camera or thermal imaging camera) is a device that forms an image using infrared radiation, similar to a common camera that forms an image using visible light. Instead of the range of the visible light camera, infrared cameras operate in wavelengths as long as 14,000 nm. Thermographic cameras can be effectively used for crowd density and behavior estimation in real-time. The thermal camera output is processed, as video sequences, in real-time and produce an estimation of the crowd density. In addition, by comparing the density against time, crowd movement behavior can be determined.

2.8 Hybrid Solutions

This technology combines several tracking technologies, seeking to utilize the benefits of each, while minimizing their various disadvantages [13]. Of the diverse hybrid solutions available today, is assisted GPS (AGPS). It uses GPS in combination with a land-based antenna network to pinpoint specific locations. It was originally conceived to locate mobile phones within a cellular network with greater accuracy than had been possible with cellular triangulation alone. In this method, the land-based stations are equipped with GPS units, which are used to predict the signals picked up by the radio frequency receivers. This means that end units can be fitted with only a partial GPS receiver. This integration of the system and land-based networks has the advantage that it provides much more precise readings indoors

3. Discussion and Summary

Tracking technologies can provide high resolution spatial and temporal data that could potentially help in improving the quality of presented services in various areas of Hajj and Umrah research. The type of developed applications depends primarily on the characteristics of each type of tracking technology. Therefore, based on the aforementioned discussion in Section 2, several remarks have to be made concerning the characteristics of each type of technology and its suitability to Hajj and Umrah related services and applications, as follows.

- Overall, the decision on using one technology over another should be based on important technical criteria (e.g. coverage range, localization accuracy, line of sight, etc.), in addition to other logistic issues such as availability and the associated implementation costs.
- The following table shows a comparison of systems for large areas (GPS with antenna-assisted GPS systems and Land-based tracking systems):

Availability	Worldwide.	Only in areas with the appropriate infrastructure.
Region of use	Works well in open areas, where the sky is unobstructed.	Suitable for environments, which contain a large number of potential users.
Usage costs	None: since satellite signals are used	High. The cost of the service varies from place to place.
Cost of end-unit	Low, and can be used anywhere.	Low. But end units are not system transferable, and can be used only with a specific system.
Real-time	Traditional GPS systems cannot track in real-time.	yes
Accuracy/precision	moderate	low

- The following table shows a comparison of systems for limited areas (RFID/NFC, Bluetooth, Wi-Fi, and Scene analysis based on image examination systems):

	RFID/NFC	*Bluetooth*	*Wi-Fi*	*Scene analysis based on image examination systems*
Availability	limited-rang	limited-rang	medium-rang	medium-rang
Region of use	Indoor/outdoor	Indoor/outdoor	Indoor/outdoor	Indoor/outdoor
Cost	low	medium	medium	high
Real-time	yes	yes	yes	yes
Accuracy/precision	Depends on the cluster size	Depends on the cluster size	3-5m	Depends on the settings

- In practice, 2D barcode and RFID/NFC systems are quite similar. However, comparison of 2D barcode and RFID/NFC systems shows that RFID/NFC systems have some advantages over barcode systems. 2D barcode systems have low cost, can be attached to almost all physical objects, and can be read with camera phone. However, it needs direct line-of-sight, usually need a half second or more for successful read, read only, surface mounted, subjected to more wear and tear, cannot be read when affixed on irregular surfaces, cannot be read in direct, bright or poor light conditions, and reader needs to be oriented properly to read barcode. On the other hand, RFID/NFC systems need no direct line-of-sight, poses both read and write capability, typical range varies from a few millimeters to above 15 m, high read-speed rate, greater environmental resistance, RFID tags can function properly in problematic environments (such as extreme temperatures, high moisture levels) and with rough physical handling, and easy to use. However, its cost is a little higher than barcode and for NFC system, touching or bringing devices into close proximity is required.

3.1 Recommendations

- As a Global Positioning System (GPS) is basically a Satellite navigation system that provides location information pretty much anywhere in the world, it can be effectively utilized in many applications. For example, tracking the buses and vehicles during transportation in Hajj and Umrah journeys.
- Several reasons make counting and thermal cameras suitable technique for the Hajj and Umrah events. First, images capturing is non-contact, i.e. uses remote sensing so it keeps the user out of danger. Also, the produced images allow for excellent overview of the target without the need of intelligent recognition of faces or body parts.
- As RFID/NFC systems are easy to use, flexible, and relatively low cost, it can be utilized in many application, for example, tracking the waiting (services) times during different stages of Hajj and Umrah journeys, and in guiding people in Al-Masjid Al-Haram and Al-Masjid Al-Nabawy, using mobile phone applications.

4. Conclusions

In this paper, a review of some prominent tracking technologies that can be customized to Hajj and Umrah has been presented. Examples of the discussed tracking technologies were satellite-based global positioning system, land-based antennas, radio frequency identification and near field communication systems, Bluetooth, Wi-Fi, barcode systems, scene analysis based on image examination systems, and hybrid solutions. The main aspects of the review were possible uses, coverage range, localization accuracy, and advantages and disadvantages, in terms of suitability to Hajj & Umrah related services and applications. The discussion showed that Several tracking technologies can be to utilize in many applications that facilitate the different services presented during Hajj and Umrah.

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