User Requirements for Localization and Positioning During Hajj

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Abstract— **Hajj is a unique annual ritual event that pours around 3 million Muslims from all over the world into the Holy City of Makkah in Saudi Arabia. This massive crowd of people moves synchronously between three distant locations and environments from outdoor plain areas to huge indoor concrete buildings. Many location-based services could be provided during Hajj to help and guide pilgrims. However due to the unique user and location characteristics, careful consideration need to be taken when designing these services. In this paper, we shed some light on the user requirements for indoor localization and positioning that should be accounted for when designing location-based service for Hajj and pilgrims.**

Keywords—**Hajj, Localization, Indoor, Local-based services**

I. INTRODUCTION

Hajj is a unique annual ritual event that pours around 3 million Muslims from all over the world into the Holy City of Makkah in Saudi Arabia. It is considered as one of the largest pilgrimage events in the world. It is a physically demanding ritual where the massive crowds of pilgrims move between three distant geographical locations from concert buildings to plain lands. They perform series of similar rituals in a span of 6 days at the same time in the same locations. Providing basic services to those pilgrims during Hajj season resembles a great challenge to the infrastructure and authority of the city due to the unique characteristics, locations and sociological issues related to Hajj.

Many location based-services can be provided to help and guide pilgrims during Hajj. However, due to the uniqueness of this event, many requirements need to be provided to guarantee the success of the provided location based-service. The objective of this paper is to shed some lights on the challenging requirements of Hajj in terms of indoor localization and positioning. The paper is organized as follows. Section II gives a background of the rituals of Hajj that are performed by pilgrims. Section III briefly describes the main indoor environments and locations that are used by all pilgrims during Hajj. Section IV discuses three important location-based services that could be implemented in Hajj. The user requirements for indoor localization and positioning are provided and discussed in Section V. Finally, we conclude this paper in Section VI.

Figure1: Pilgrims performing Tawaf around Ka'bah

Figure 2: Pilgrims Performing Sa'I Between Safa and Marwah

II. BACKGROUND

Although Hajj is associated with Islam, the ritual of pilgrimage to Makkah was established even long time ago. Nowadays, around 3 million Muslims come to perform Hajj from around the globe. For most of them, it is a once in a lifetime journey. The following would give a brief description on the level of physical activities associated with Hajj.

During Hajj, pilgrims perform a series of activities. Once they arrive to Makkah, they perform Tawaf where they walk counter-clockwise seven times around Ka'bah, the black cubic-shaped building Figure 1. Pilgrims then perform Sa'i which is walking seven times back and forth between the hills of Safa and Marwah for a total distance of 3.5km, Figure 2.

Figure 3: Pilgrims in Arafat
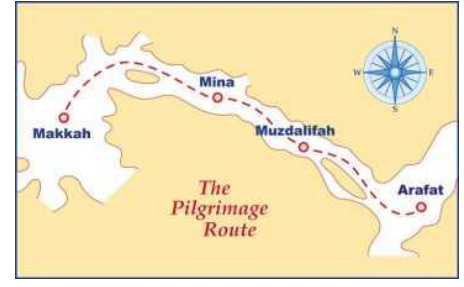

Figure 4: Pilgrims in Mina

Figure 5: The Pilgrimage Route

On the 8th day of the last month of the lunar calendar, pilgrims move from Makkah to Mina which is 8km away from Makkah [2]. They spent the day and night at Mina and move on the sunrise of the next day (i.e. the 9th day) to the plain of Arafat which is 14 km away from Mina Figure 3. During this day from morning to sunset, pilgrims pray to Allah (i.e. God) for forgiveness and mercy.

After sunset, the mass crowd of pilgrims moves back to Mina stopping in Muzdalifah, an open area between Mina and Arafat, to collect throwing pebbles. On day 10, pilgrims celebrate the biggest Eid for Muslims by throwing the pebbles at the stone monument in Mina which symbolizes the devil Figure 4, sacrifice a healthy animal (i.e. sheep, cow, camel), and perform Tawaf again. On the following three days, pilgrims camp in Mina and on each day they throw the pebbles at the three stone monuments in Mina. After the 13th day, pilgrims are considered to be done with their Hajj.

III. PILGRIMS CHARACTERISTICS

There are certain sociological characteristics that make this event a unique experience for pilgrims and a challenging duty for service provides in Saudi Arabia. We can summarize these characteristics as follows:

- ❖ According to statistics, the majority of pilgrims perform Hajj when they are 45 years or older which requires more health care consideration and high probability of sudden medical problems [4].
- ❖ Around three million pilgrims come from all over the world from different countries and raves and speak different languages making communication a very challenging task.
- ❖ Pilgrims have different educational and cultural backgrounds.
- ❖ For most pilgrims Hajj is a once in a lifetime opportunity creating emotions and unexpected behavior.

IV. INDOOR ENVIRONMENTS DURING HAJJ

During the rituals of Hajj, the massive crowd of pilgrims moves between different indoor and outdoor sites through a massive network of roads and tunnels. During Hajj, there are three main indoor environments that most of the pilgrims go through 1) Al-Masjed Al-Haram, 2) Jamarat and 3) Road Tunnels. In this section, a brief description on each environment and its importance during Hajj is discussed.

A. Al-Masjed Al-Haram

Al-Masjed Al-Haram (a.k.a The Grand Mosque), is Located in the city of Makkah, it surrounds the Ka'bah, the place which Muslims worldwide turn towards while offering daily prayers and is Islam's holiest place. The current structure covers an area of 356,800 m^2 (88.2 acres) including the outdoor and indoor praying spaces and can accommodate up to four million Muslim worshippers during the Hajj period. Around 60% of the mosque space is covered to provide a prayer place for Muslims. Moreover, Sa'i is performed in a cubical tunnel shaped path between the two mountains Figure 2.

B. Jamarat

Pilgrims stay in Mina for three days. One of the rituals performed in these three days is to throw the three symbolic devil monuments with pebbles. These monuments were reconstructed in 2010 within a huge building called Jamarat Building shown in Figure 6. Figure 7 shows the building from inside.

C. Road tunnels

Makkah is located in a valley between big mountains and tunnels were used extensively in the road network to reduce distance and time for traveling from/to the grand mosque. During peak times, these tunnels are dedicated entirely for pedestrians Figure 8.

V. LOCATION BASED SERVICES

There are many essential location based services that can be provided to enhance the quality of Hajj with respect to pilgrims [3,5]. We are going to list two potential applications:

Application 1: Locating lost people within the Grand Mosque, during peak times many pilgrims get lost due to crowd force or direction confusion. As mentioned in Section III, the problem exaggerated when the lost person is an elderly or a child. Using advance GPS and GIS solutions [1] will not be practical due to coverage problem. On the other hand, using, using advance wireless technologies such as RFID or WIFI, we can build systems to track and localize pilgrims within Haram.

Figure 6: Jamarat Building

Figure 7: Inside Jamarat Building

Figure 8: Walking in a road tunnel

Application 2: Decreasing medical intervention response time. Localization techniques can be used in medical intervention by locating and prioritizing medical emergency requests. Localizing urgent medical situations within Jamarat building or a road tunnels can save many lives during peak times.

VI. User Requirements

For localization algorithms and mechanisms to be successful with Hajj applications, many system requirements should be addressed. We can abstract the technical requirements as:

- ❖ Large Scale System: Hajj is a large scale application in terms of number of users and geographical area,
- ❖ Dense Environment: In certain time-location combinations, pilgrims' density might reach more than 6 persons per square meter [1].
- ❖ Operation Security: Due to its diverse social environment, technological solutions should provide high operational security.
- ❖ User privacy becomes a major issue with many users. Users
- ❖ Hybrid Indoor/Outdoor Environment: During Hajj, pilgrims moves between concrete buildings and infrastructure-less plains.
- ❖ Mobility: Pilgrims are always on the move.
- ❖ Seamless integration with different wireless technologies.
- ❖ Accurate Positioning: Due to critical situation, the exact location of a missing child or an injury pilgrim is essential in providing the service.

VII. Conclusion

Hajj is a very unique experience for pilgrims where most of them are going to perform it once. Special consideration need to be accounted for when localization algorithms are designed for Hajj Due to its unique characteristics, Hajj requires that many challenging problems should be solved before the practical and sustainable RFID system can be implemented. In this abstract, we have listed the main challenges that should be addressed by the RFID research community.

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