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Understanding aspects of pilgrimage using social networks derived from smartphones



Amir Muaremi^{a,*}, Agon Bexheti^b, Franz Gravenhorst^a, Julia Seiter^a,
Sebastian Feese^a, Bert Arnrich^c, Gerhard Tröster^a

^a ETH Zurich, Wearable Computing Lab, 8092 Zurich, Switzerland

^b University of Lugano (USI), Faculty of Informatics, 6904 Lugano, Switzerland

^c Boğaziçi University, Department of Computer Engineering, 34342 Istanbul, Turkey

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ABSTRACT

The Hajj pilgrimage to Makkah and Madinah is one of the biggest annual events in the world, where millions of people congregate for religious rituals over several days. The main challenge for organizers and participants is to ensure a smooth flow through the activities and a safe, healthy and spiritual journey during the pilgrimage. A deep knowledge of how the pilgrims behave during this event is a precondition for improving these issues. One approach to understand the behaviors of pilgrims is a social network analysis based on spatial proximity information. In this work we use a proximity system to identify pilgrims' social networks and apply social network analysis to (i) estimate the experience level of the pilgrims and differentiate leaders from followers, (ii) observe how groups of pilgrims are created around prayers and (iii) identify density peaks and recognize changes in group formation over time. The suggested proximity system is created by merging ANT+ and Bluetooth, two inhomogeneous peer-to-peer systems. Merging is facilitated by using (i) social rules of pilgrims, (ii) existing wearable devices and (iii) GPS location information. Proposed methods are applied on data collected from 41 participants during their 8 day pilgrimage.

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1. Introduction and motivation

1.1. Hajj pilgrimage and its main challenges

Pilgrimage is a journey in search of spiritual relief and is important to people of many different religions. Recent statistics show that the total number of people participating in pilgrimages from various religious faiths is growing [1]. The annual pilgrimage for Muslims is called Hajj. During Hajj, millions of people from all over the world congregate for religious rituals at holy sites in the cities of Makkah and Madinah and their surrounds. Umrah, also known as the “lesser pilgrimage”, is the visit to the sacred sites outside the period of Hajj (for details see, e.g., [2]).

Even though Hajj is one of the biggest and oldest events in the world, little research has been carried out to objectively monitor the pilgrims and understand their behavior during the different stages of pilgrimage. The challenges regarding Hajj are of two broader levels. First, of the organizational – global – level; and, second, of the individual level. At the global level, the challenges are of the crowd monitoring and management type. Here, the main concerns revolve around enabling a smooth flow through the activities for the pilgrims, and transporting them from a site to another. The second level, the

* Corresponding author.

E-mail address: muaremi@ife.ee.ethz.ch (A. Muaremi).

individual one, is concerned with enabling a safe, healthy and truly spiritual journey through the pilgrimage. To ensure these, a deeper understanding of the whole event, and thus, further, broader-scale studies are needed.

1.2. Understanding aspects of Hajj using social networks

Of the roughly 3 million yearly pilgrims, the majority come from abroad. These are organized in contingents according to the countries they are arriving from. These contingents are further divided into better manageable groups of up to about 200, which are led by pre-assigned guides with thorough knowledge of the local surroundings and the itinerary of the pilgrimage. Despite this, there can be several factors that cause inefficiency in the monitoring and management process, and thus difficulties of various types, for those responsible and for the pilgrims as well. Among these factors, besides lack of information and experience, age, crowdedness, panic, etc., could be insufficient guiding. The number of guides is usually only a few, if not a single one, and this can be challenging, considering that for most pilgrims it is the very first time they find themselves in those places. One way to alleviate this burden is by delegating the responsibility of guiding and supervising onto possible leaders within the groups. And, to find these possible leaders, one needs to understand the process of leader formation, by studying the social networking within the groups. Also, it can be safely assumed that, due to the nature of the gathering, these groups have a lot in common, as far as their expected behavior. Thus, the hierarchical delegation of the responsibility of guiding and supervising could lead toward easing the tasks of maintaining the security and smooth flow of the pilgrimage. Moreover, such achievements would help in the overall well-being of the pilgrims, by providing them the safety of being closely supervised and carefully guided, in an environment in which they are most probably found for the first time in their lives.

So, as a means of learning about these aspects, including the leader/follower differentiation aspect, we utilize the monitoring of social networks of pilgrims within the group. We do this, by deciding to study the pilgrim group behavior around and during the daily prayers. The five daily prayers are the most frequent activities during Hajj. There are several rituals performed, other than the daily prayers, such as, the Tawaf and Sa'i rituals, the supplication on the mount of Arafat, etc., but we believe that the construction of social networks around prayer times is a very appropriate starting point. For this, we see the following reasons: each pilgrim performs five prayers per day; prayers have dynamic, semi-dynamic and static parts and involve re-groupings of the individuals—this ensures a high but still predictable variety of recorded proximity data; the routines around the prayers are very structured, which simplifies the annotations; the fixed and synchronized schedule concerning prayer activities enables comparison of data. Besides the aforementioned leader differentiation, another point of interest would be if – and how – group behavior changes with time. Hence, we included the analysis of the clustering property of social networks over time. Also, the time segmentation approach was meant as an attempt to find possible stages of the ritual, i.e. the prayer, that show distinct characteristics in the group behavior.

As was mentioned, the approach in carrying out the study was to utilize social networks. Social scientists have introduced social network analysis (SNA) methods to better understand and interpret relationships between individuals and between groups within communities. Having constructed these networks, we use state-of-the-art SNA features to understand the following aspects of pilgrimage:

- estimate the experience level of the pilgrims, i.e. differentiate leaders and followers,
- observe how groups of pilgrims are created around prayers, i.e. validate the separation intervals around prayer times, and
- identify density peaks and recognize different communities and sub-groups within larger groups, i.e. analyze the clustering property of social networks over time.

1.3. Social networks based on proximity data

A key question from a technical point of view is how data can be obtained to reconstruct social networks. To identify these networks one can measure the proximity between individuals within a group. Individuals who are often spatially close to each other are potentially also linked in a social sense. One possibility to estimate spatial proximity is to measure the absolute positions of individuals and then derive their mutual spatial distance. Another method is to use peer-to-peer transceivers, which are worn by the individuals. If one transceiver picks up the signal of another one, the two individuals are considered to be close to each other.

In this work we use two peer-to-peer proximity sensing systems to construct the social networks, and on top of that, we use, among others, the GPS positioning to improve these networks.

1.4. Proximity information derived from different sensing systems

We build social networks from spatial proximity data collected using two different communication protocols, ANT+ and Bluetooth (BT).

ANT+ is a proprietary wireless technology designed for sensor networks. Its low complexity, together with the low power consumption has made it to penetrate the sports and fitness equipments market, where it is mainly used for constructing

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