Monitoring Prayer Using Mobile Phone Accelerometer

Reem Al-Ghannam[1(✉)], Eiman Kanjo[2], and Hmood Al-Dossari[1]

[1] King Saud University, Riyadh, Saudi Arabia
r.g.alghannam@gmail.com
[2] Nottingham Trent University, Nottingham, UK

Abstract. The ever-increasing ability of smartphones for sensing paves the way for a new form of human-computer interaction which wasn't possible before. One of these possibilities is monitoring Muslims' prayers which consist of a set of physical activities that must be conducted in a correct way, i.e. ordered and complete. In this paper, we introduce a novel method to monitor and detect prayer activities using mobile phone accelerometers in order to evaluate the correctness of prayer. The method involves four stages: data collection, signal pre-processing, features extraction and classification.

Keywords: Mobile sensing · Accelerometer · Activity recognition · Prayer monitoring

1 Introduction

Prayer is the second most important pillar of Islam and the most regular compulsory action in a Muslim's life. If a person's prayer is accepted, then other acts of worship are accepted. Thus, Muslims must carefully perform their prayers in order to be accepted by Allah. The ability to concentrate in prayer may be improved by undertaking adequate psychological, mental and physical preparation before the prayer and by utilizing certain techniques during the prayer [1, 2]. To improve prayer performance, current technology may help to monitor and track the prayer's activities (i.e. the Muslim's body movements).

Among the huge amount of technology available nowadays, smartphones are among the most widely used devices. The success of smartphones is leading to an increasing amount of sensors in mobile phones to provide new features and services to end-users, to reduce costs through more integration or to improve hardware performance. Significant interest in smartphone sensing [3] in recent years can be attributed to several factors, including their ubiquitous nature, rapid evolution toward smartphones with several built-in sensors and their portability making them easy to use for "mobile sensing".

Not surprisingly then, mobile sensing has been used in a very creative way to produce interactive and interesting applications which have been realized or envisioned in diverse domains (e.g., transportation, social networking, health monitoring) [4].

Mobile sensing has a wide variety of types classified by their purposes. For example, accelerometers that detect translational motion, gyroscopes that detect

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rotational motion, digital compasses, barometers and proximities. The aim of this study is to utilize mobile phone accelerometers to monitor Muslims' body positions and movements in order to determine their prayer quality. To do so, the accelerometer data will be collected and analyzed to detect and discover the prayer's activities: standing, bowing, prostration and sitting.

In this paper we present a novel method for detecting prayer activities based on the mobile phone accelerometer. We discuss the related work in Sect. 2. Then in Sect. 3, we describe our activity model and the process for addressing the activity recognition task. Next, in Sect. 4, we go on to evaluation techniques that we have used to assess our system. Toward the end, in Sect. 5, we discuss our conclusion.

2 Related Work

Recent advances in computers have given rise to a large number of technologies that can be used for various purposes. For example, mobile sensors are now widely used by people to record data while they move. These sensors range from specific sensors that can be embedded in systems such as location-based sensors (e.g. GPS) to stand-alone systems such as physiological sensors that can be used to detect emotions or vital signs (e.g. Galvanic skin response), or mobile sensor accelerometers used in our study that can be embedded to devices (e.g. wearable device or mobile phone) to monitor human activities.

Mobile accelerometer sensors have been used in a wide variety of applications. They are currently the most widely used sensors in human physical activity monitoring in clinical and free-living settings [5]. For example, Ravi et al. [6] have used accelerometer data to recognize user activity and by formulating as a classification problem. In addition, accelerometer sensors could be used in fall detection and health monitoring as [7] has implemented wireless acceleration sensor module and algorithm to detect the wearer's posture, activity and fall. This system can be applied to patients, elders and sports athletes' exercise measurement and pattern analysis.

The convergence of pervasive and sensing technologies and signal processing, provides a platform for a wide range of innovative applications based on a more refined understanding of the users' context; wherever they are, whatever they might be doing and why. These applications can range from environment monitoring [3], emotion mapping [8] to religious application [9]. Nowadays, with the increase in technologies' popularities among Muslims, many developers resort to program Islamic applications to meet their religious needs. Islamic-focused mobile phone applications are not a new phenomenon. Several of these applications were available over the past few years; however most of them have focused on verses of the *Quran* such as *iQuran*, Qibla: the direction that should be faced when a Muslim prays, such as "*Find Mecca*" and other instructional applications like Athkar, Islamic Pocket Guide etc. [10].

Other important aspects should be covered in worship, besides verbal aspects. Physical movements play an important role in Muslims' lives which needs more research to be conducted technically. Indeed, many applications have monitored physical worship but they are still limited. For example, Ravi et al. [11] and Alnizari [12] have proposed an architecture using radio frequency identification (RFID) technology to track and monitor individuals during Hajj pilgrimage. Mohandes et al. [13] have outlined a system for tracking and monitoring pilgrims during Hajj in the Holy area, consisting of a mobile phone equipped with a Global Positioning System (GPS) used by pilgrims and wireless sensor networks (WSNs) installed in the surrounding environment to observe the locations of pilgrims. Mantoro et al. [14] have also proposed a HajjLocator framework for Hajj Pilgrim tracking based on mobile phone environments as it is reasonably affordable and is widely used by people. Amro et al. [15] have put together a plan for assisting the pilgrimage leader (Mutawwif) to perform his/her duties and add new capabilities and solutions for the most significant challenges such as finding lost pilgrims, predicting where they are and avoiding losing them.

As well as the studies conducted into the potential of technology in assisting pilgrimages, a small range of projects have been developed regarding prayer practice. El-Hoseiny et al. [16] have worked on a system capable of recognizing major postures and actions performed by a Muslim normally during the prayer. The core of their scheme was based on video-processing which contained a basic module known as the *front end*. The action recognition phase was implemented as a customized module using a special model developed specifically to fit this purpose. Muaremi et al. [17] have also presented their work to differentiate, in the first case, between congregational prayers and individual prayers, and in another case, between silent prayers and loud prayers by using two wearable sensors namely chest belts and wrist-worn devices. They collected data from bio-physiological responses of people performing different types of prayers during an Umrah pilgrimage. Nonetheless, none of the previous works have monitored physical activities during prayers. Using the technology in the Islamic applications is still in the stages of early development and there is a space to utilize the technology to support Islamic worships. The focus of this work is on investigating the use of mobile phone accelerometers to monitor and recognize the prayer's activities in order to assess its correctness.

3 Prayer Activities Detection System

In this section, we present a novel method for detecting prayer activities. The work presented in this paper comprises six components as illustrated in Fig. 1.

For further illustration, in this work, different techniques have been manipulated to analyze and detect prayer movements' patterns in collected data. Mobile phones are commonly used as a sensor for a wide range of applications. Most of off-the-shelf smartphones offer built-in sensors including accelerometer, gyroscopes and vibration monitoring. These sensing capabilities can provide a rich source of information about body movements and physical behavior. This study utilizes mobile phones as a means of data collecting and analysis of body movement during prayer (i.e. prayer here refers to Muslim prayer). In order to record the sequence of movements, a mobile phone application needs to be used to capture the data. A number of applications have been reviewed and the application with the best performance has been adopted for this study. Android has been adopted as the main platform for data collection, since Android applications are easy to access and easy to use and does not require the application to have special permission to use it [18]. In order to monitor prayer activities the mobile phone is attached

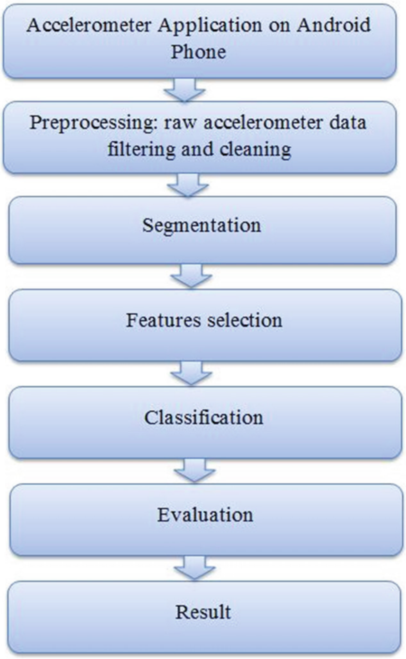

Fig. 1. System components.

to the worshipper before the start of the prayer in a convenient and comfortable fashion. A preliminary set of experiments have been conducted in order to figure out the best place to locate the mobile (e.g. on the chest, the hip, the back or the arm). The upper back was the best location we have selected because it provided a clear pattern of movement and usability combined with comfort. The best position was chosen for the rest of the experiments and data collection stages. During the prayer activity, the body of a person will change between six possible positions, as illustrated in Fig. 2, from the person standing still (No. 1), to the person's forehead touching the ground (No. 6). For this task, we examined the posture and acceleration data of the mobile phone. The application monitors the body movements by collecting data using some methods to analyze it followed by measuring the correctness of each activity in every round.

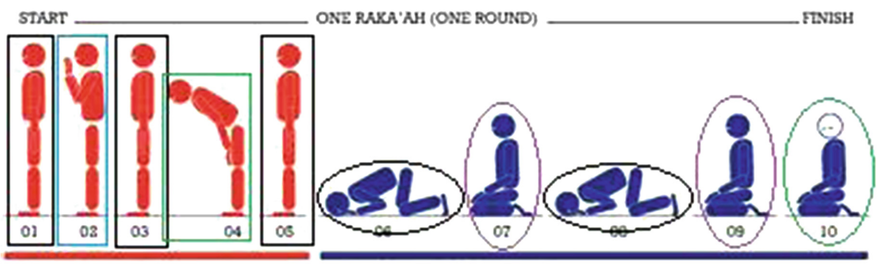

Fig. 2. A sequence of the prayer covering all the possible positions of the subject's body.

Based on vibration readings, the raw accelerometer data has the following attributes: timestamp, acceleration along x axis, acceleration along y axis and acceleration along z axis [19]. All collected data was subject to inspection and analysis to remove any corrupted data using various techniques including moving average filter in order to obtain only higher values which are the most representative for movements. Thus, we obtained smoother acceleration values to work on, which allow more accurate results compared to just raw data. After the process of noise removal, further processing of the data was carried out to partition the acceleration values into small segments based on their approach for visual pattern inspection. The segmentation of acceleration signals made it easy to highlight the prayer activities patterns, as shown in Fig. 3 (Standing tagged with no. 1, Bowing no. 2, Prostrating no. 3 and Sitting no. 4). Also, this segmentation helps to understand and identify the main features in the collected data for classification. For each of the segments, the features were extracted which made the signal distinct. We have generated average values for all three axes (x average, y average and z average). The features selection process is followed by feature reduction in order to run and compare different machine learning techniques to classify prayer activities. After that, the labeling was performed manually, choosing from one of the four prayer activities available.

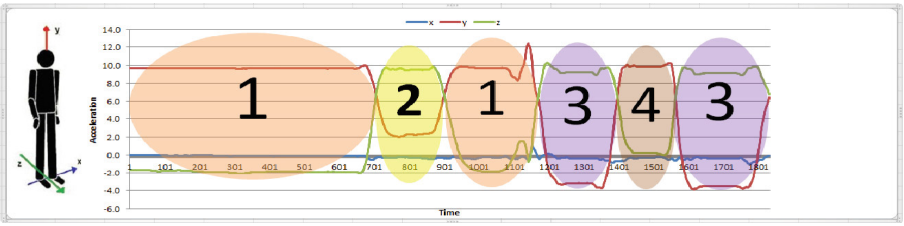

Fig. 3. Prayer activities patterns in one round of prayer.

Regarding the classification step, many different approaches have been used in the literature in the context of activity recognition [20]. In our study, we have applied supervised classification methods and training phases because of the nature of prayer activities. Previously, various classification models have been adopted in order to detect physical activities. Here, appropriate classification algorithms have been exploited to classify body movements into different categories e.g. standing, bowing, prostrating and sitting, as shown in Fig. 3. Classification of acceleration segments into a given number of classes using the segments' features can be achieved by various statistical and predictive methods. Naïve Bayes, K-Nearest Neighbor or IBL and J48 Decision Trees algorithms were chosen due to their good performance and high accuracy to detect prayer activities. There is no universally accepted method of detecting a particular range of activities and all techniques have associated benefits and limitations [21].

4 Evaluation and Results

To evaluate our system, we have used two groups of datasets in our experiments: training and testing datasets. The training set was implemented to build a model, while a test (or validation) set is to validate the model built. For the training model, the data has been collected from thirty rounds; each round consists of eight stages with the following order: long standing, bowing, and short standing, first prostrating, first sitting, second prostrating and second sitting. During the classification stage, we have implemented Naïve Bayes, IB1 and J48 Decision Tree algorithms available in Weka, which is a machine learning workbench that supports many activities of machine learning practitioners. After the feature reduction process, the dataset used 10 Cross-Validation evaluation technique provided by Weka and achieved a mean classification accuracy of $\bar{x} = 100\,\%$ using Naïve Bayes. The IB1 algorithm was tested and achieved a mean classification accuracy ($\bar{x} = 100\,\%$). The J48 Decision Trees algorithm was also tested and achieved the lowest mean classification accuracy ($\bar{x} = 94.9153\,\%$). This suggests that the prayer activities can be classified relatively accurately. By observing the results, it appears much more difficult to recognize the standing and sitting patterns; we find that this is because those two similar activities are often confused with one another. After applying different machine learning algorithms to the prayer activities dataset, another dataset containing the prayer activities (testing dataset) was tested using an evaluation technique known as a "Supplied Test Set". In this evaluation technique, we test the learning model using a dataset that has not been seen previously. To evaluate our learning models, we have used ten subjects. Table 1 shows the mean classification accuracies to classify prayer activities for all testing subjects using all three algorithms.

Table 1. Mean classification accuracies for testing subject using all three algorithms.

Classification algorithm	Classification accuracy
Naïve Bayes	91.8462 %
IB1	87.7692 %
J48 Decision Tree	89.8462 %

By comparing the classification accuracies that resulted from the three algorithms, we notice that Naïve Bayes performs better than both the IB1 and J48 algorithms since the Naive Bayes algorithm is based on conditional probabilities that might be more suitable given the nature of our data. However, the results presented here are optimized after several trials were made to enhance the classifiers' performance.

5 Conclusion

Our preliminary experiments and results showed a noticeable pattern in accelerometer signals in relation to different prayer activities. The prayer activities sensed are a rich source of information and could be used in monitoring prayers in order to determine prayer quality regarding its order and completeness of different prayer positions. Moreover, it could also be used to develop learning and educational applications to advise people praying on the accuracy of their prayers.

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