Autonomous Mobile-Based Model for Tawaf / Sa'ay Rounds Counting with Supported Supplications from the Quran and Sunna'a

Nashwan Alromema

King Abdulaziz University, Faculty of Computing and information technology, Rabigh, KSA

Summary
Performing the rituals of Hajj and Umrah is an obligation of Allah Almighty to all Muslims from all over the world. Millions of Muslims visit the holy mosques in Makkah every year to perform Hajj and Umrah. One of the most important pillars in Performing Hajj/Umrah is Tawaf and Sa'ay. Tawaf finished by seven rounds around the holy house (Al-Kabaa) and Sa'ay is also seven runs between As-Safa and Al-Marwa. Counting/knowing the number of runs during Tawaf/Sa'ay is one of the difficulties that many pilgrims face. The pilgrim's confusing for counting (Tawaf/Sa'ay) rounds finished at a specific time leads pilgrims to stay more time in Mataff bowl or Masa'a run causing stampedes and more crowded as well as losing the desired time for prayers to get closer to Almighty Allah in this holy place. These issues can be solved using effective crowd management systems for Tawaf/Sa'ay pillars, which is the topic of this research paper. While smart devices and their applications are gaining popularity in helping pilgrims for performing Hajj/Umrah activities efficiently, little has been dedicated for solving these issues. We present an autonomous Mobile-based framework for guiding pilgrims during Tawaf/Sa'ay pillars with the aid of GPS for points tracking and rounds counting. This framework is specially designed to prevent and manage stampedes during Tawaf/Sa'ay pillars, by helping pilgrims automatically counting the rounds during Tawaf/Sa'ay with supported Supplications (in written/audio form with different languages) from the Quran and Sunna'a.

Keywords:
Mobile Model, GPS, Tawaf, Sa'ay, Mobile-App, GPS, FOG.

1. Introduction

In Islam religion, Hajj is one of the five pillars for the Muslims who have the capability to perform it and it should be performed once in the lifetime [1]. Hajj is conducted once a year on the month of Dhul Hijjah ,12th month in the lunar Islamic calendar. In the other hand, Umrah is another ritual related to Hajj, and it can be performed anytime through the year. Hajj and Umrah are performed by millions of Muslims who come to the holy city called Makkah which is in Saudi Arabia as it is shown in the map in Figure 1. Hajj and Umrah include many rituals, the common rituals between Hajj and Umrah are Tawaf and Sa'ay. There are some problems pilgrims facing while doing rituals of Hajj and Umrah. These include to, many pilgrims do not have the knowledge of rituals of Hajj that include Tawaf and Sa'ay. Most of pilgrims lost counting in Tawaf runs or Sa'ay. The difficulty of remembering how many runs they did because of the loud crowd and reading supplication. Lack of knowledge in which is right in supplication for Tawaf, Sai and between them.

Figure 1: The Map of the holy city Makkah [1].

The Tawaf requires the pilgrims to circle clockwise around Al-Kaaba for seven rounds staring from the green sign as shown in Figure 2. The approximate range of Tawaf ranges from 1.6 Km to 4.5 Km depending on how pilgrims close Al-Kabaa and to which floor the Tawaf is performed [2].

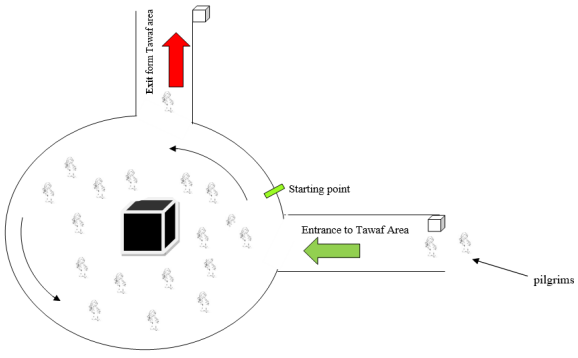

Figure 2: The pictorial representation of Tawaf.

Figure 3 shows a snapshot of Tawaf ritual during the Hajj season in 2017. The second common ritual between Hajj

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and Umrah is the Sa'ay, in which the pilgrims walk back and forth between As-Safa hill and Al-Marwa hill. The starting point of this ritual is from As-Safa toward Al-Marwa which will be counted as one round, and from Al-Marwa back to As-Safa is counted as another round. This process continues for seven rounds with an approximate distance of 2.9 Km as shown in Figure 4. Tawaf finished by seven rounds around the holy house (Al-Kabaa) and Sa'ay is also seven runs between As-Safa and Al-Marwa which must be performed according to the sequence.

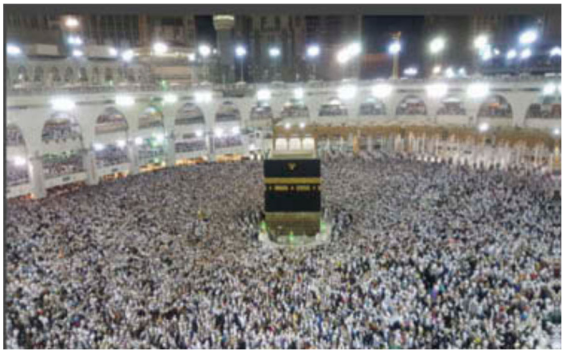

Figure 3: Snapshot of Tawaf Activity in Hajj season 2017.

In the last four decades more than twelve thousand people lost their lives due to stampedes as stated in the studies of crowd management researches conducted by many researchers [3], [4], [5] [6]. Stampedes are caused by overcrowding and mismanagement that could been minimized by better control and management [3]. The scope of the study in this research is concentrated on the stampedes during Tawaf and Sa'ay.

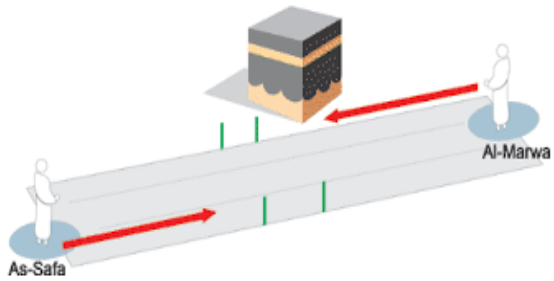

Figure 4: The pictorial representation of Sa'ay.

The rest of the paper is organized as follows: Section 2 discusses the materials and the methodology of this research. Section 3 presents the results and discussions as well as the justifications and benefits of using the proposed autonomous model, finally, section 4 concludes the paper.

2. Materials and Methodology

Now a days the available technologies like WSN, FOG Computing, Drones, GPS, Cloud Computing, smart phones and devices are used to manage businesses and real-life operations [3] [7] [8]. Table 1 lists the technologies/tools and its usage that are employed in our system. The integration of these technologies/tools (listed in Table 1) forms an important part of our proposed Autonomous Tawaf/Sa'ay Model, Figure 5 shows the system architecture and the integral parts of the system.

Table 1: Technologies and tools used for the proposed system.

Technology/Tool	Usage
Smart phones/devices	Use for the applications provided in the article
GPS	For finding and tracking global location of objects
Cloud	Storing and processing historical data into a data warehouse for the purpose of data mining and big data analytics [9].

We have divided the architecture of our proposed system into three integral parts as can be shown in Figure 5. Each of them with many services, Smart Devices is used for collecting data. The GPS will be used for tracking the moving objects. The GPS will be used by the smart devices for tracking the moving objects in Tawaf and Sa'ay, Finally, the data of all subscribed pilgrims is stored in a database system located in the Cloud for the purpose of data analysis and running data mining techniques.

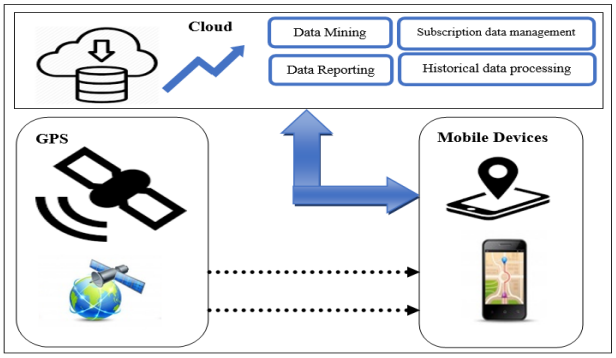

Figure 5: The architecture of the integral parts of the proposed system.

2.1 The Autonomously of Tawaf/Sa'ay

In this section we introduce the proposed autonomous mobile-based model for Tawaf/Sa'ay rounds, the proposed model is based on mobile computing and GPS system for tracking the moving objects holding the mobile device (it could be smart phone, tablet, or hand bangle as shown in Figure 7) for detecting and preventing stampedes. These objects are an integral part of the proposed system [8].

2.1.1 Tawaf

Tawaf rituals is the first activity pilgrims perform at the arrival time to Masjid Al-haram. The system should be able to detect the location of the pilgrim at the green sign (see Figure 2), the system will start the journey by notifying the pilgrim that Tawaf will start now by the aid of the GPS and the smart App. The notification can be using text alert or sound alert for the people who want the system to guide them using headphone as an example (might be appropriate for old people or crippled people). A supplication for each round will also be provided in multilanguage because most of the pilgrims are not Arab speakers. Table 2 list some of these supplication in Arabic, English, and Hindi for the first two rounds. During each round there are slight stop at Yemeni corner and black stone, the system also should notify the pilgrims about it as there is a special supplication should be said in these two points. At the end of the seventh round the system will guide the pilgrim to stop and pray at Makam Ibrahim place and to be ready for the second rituals (Sa'ay).

Table 2: Sample of Supplication for the rounds in Tawaf.

R#	Language		
	Arabic	English	Hindi
Round 1	بسم الله، والله أكبر، اللهم إيماناً بك وتصديقاً بكتابك، ووفاء بعهدك، واتباعاً لسنة نبيك محمد صلى الله عليه وسلم اللَّهُمَّ اجْعَلْهُ حجا مَبْرُورا وذنبْ مغفورا وَسَعْيًا مَشْكُوراً.	In the name of God, and God is the Greatest, O God, in faith and belief in Your Book, fulfillment of Your covenant, and in compliance with the Sunnah of Your Prophet Muhammad, may God bless him and grant him peace.	ईश्वर के नाम पर, और ईश्वर सबसे महान है, हे ईश्वर, आपकी पुस्तक में विश्वास और विश्वास में, आपकी वाचा की पूर्ति, और आपके पैगंबर मुहम्मद की
Round 2	بسم الله، والله أكبر، اللهم إيماناً بك وتصديقاً بكتابك، ووفاء بعهدك، واتباعاً لسنة نبيك محمد صلى الله عليه وسلم اللَّهُمَّ اجْعَلْهُ حجا مَبْرُورا وذنبْ مَغْفُوراً، وَسَعْيًا مَشْكُوراً.	In the name of God, and God is the Greatest, O God, in faith and belief in Your Book, fulfillment of Your covenant, and in compliance with the Sunnah of Your Prophet Muhammad, may God bless him and grant him peace.	ईश्वर के नाम पर, और ईश्वर सबसे महान है, हे ईश्वर, आपकी पुस्तक में विश्वास और विश्वास में, आपकी वाचा की पूर्ति, और आपके पैगंबर मुहम्मद की

The lack of specialized applications for helping pilgrims in counting Tawaf Rounds is considered as a challenge to pilgrims during rituals of Umrah. Although a lot of mobile APP has been used in different life style as depicted in [8] [10] less of them have been dedicated for crowd management in Makaa. The prototype of the proposed App is shown below, Figure 6 shows a snapshot of the developed App for the proposed autonomous mobile based model using multilanguage.

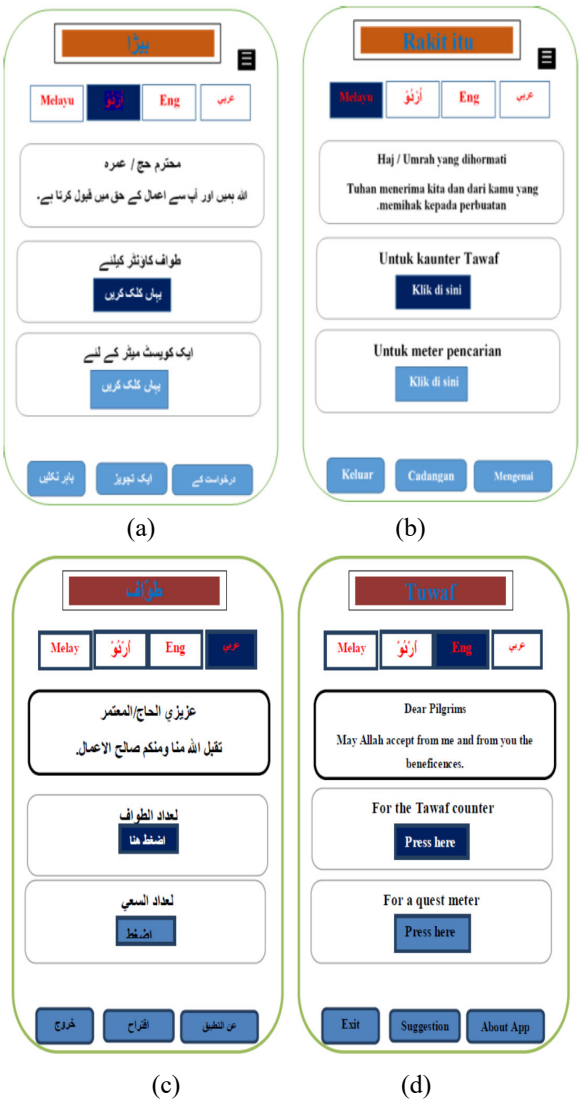

Fig. 6 Snapshot of some screens of the developed App using multilanguage. (a) Hindi (b)Turkish (c) Arabic (d) English

The main aim of this research project is to develop a smart system that can is installed on smart phones or small device that is carried on a bracelet as shown in Figure 7. Another method of controlling the crowd is to use the autonomous hand bangle device that will have smart application and it connect to the GPS. hand bangle device has the light indicator for rounds number as shown in Figure 7, autonomously the green light will continue for the rounds from 1 to 6 which means the Tawaf rounds not finish yet, once it become red it gives the Haram security the right to

catch the pilgrims and enforce them to leave the Sahan Al-Kabaa. The system contains a counter and a luminous background. The bracelet starts counting as soon as the pilgrim reaches the starting area of the circumambulation.

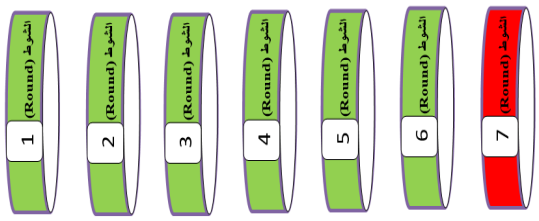

Fig. 7 autonomous hand bangle device for Tawaf Round counts

2.1.2 Sa'ay

Sa'ay rituals is the second activity pilgrims perform after finishing Tawaf. The system should be able to detect the location of the pilgrim at the starting point of Sa'ay (As-safa) as shown in Figure 4. the system will start the journey by notifying the pilgrim that Sa'ay will start now by the aid of the GPS and the smart App. The stating point of this ritual is form As-Safa toward Al-Marwa which will be counted as one round, and form Al-Marwa back to As-Safa is counted as another round. This process continues for seven rounds with an approximate distance of 2.9 Km. Table 1 list some of these supplication in Arabic, English, and Hindi for the first two rounds. During each round there are slight stop at Yemeni corner and black stone, the system also should notify the pilgrims about it as there is a special supplication should be said in these two points. At the end of the seventh round the system will guide the pilgrim to stop. Table 3 list some of the supplication of Sa'ay in Arabic, English, and Hindi for the first two rounds.

Table 3: Sample of Supplication for the rounds in Sa'ay.

R#	Language		
	Arabic	English	Hindi
Round 1	إِنَّ الصَّفَا وَالْمَرْوَةَ مِنْ شَعَائِرِ اللَّهِ فَمَنْ حَجَّ الْبَيْتَ أَوِ اعْتَمَرَ فَلَا جُنَاحَ عَلَيْهِ أَنْ يَطَّوَّفَ بِهِمَا وَمَنْ تَطَوَّعَ خَيْرًا فَإِنَّ اللَّهَ شَاكِرٌ عَلِيمٌ	Al-Safa and Al-Marwa are among the rituals of Allah, so whoever performs Hajj or Umrah, there is no sin on him if he circumambulates them.	अल-सफ़ा और अल-मरवा अल्लाह के कर्मकांडों में से हैं, इसलिए जो कोई हज्ज या उमरा करता है, उसके लिए कोई पाप नहीं है यदि वह उनकी परिक्रमा करता है।
Round 2	اللَّهُمَّ عَافِنِي فِي بَدَنِي، اللَّهُمَّ عَافِنِي فِي سَمْعِي، اللَّهُمَّ عَافِنِي فِي بَصَرِي، لَا إِلَهَ إِلَّا أَنْتَ، اللَّهُمَّ إِنِّي أَعُوذُ بِكَ مِنَ الْكُفْرِ والفقر, اللَّهُمَّ إِنِّي أَعُوذُ بِكَ مِنْ عَذَابِ الْقَبْرِ، لَا إِلَهَ إِلَّا أَنْتَ.	O God, forgive me in my religion, O God, forgive me in my hearing, O God, forgive me in my eyes, there is no god but you	हे ईश्वर, मेरे धर्म में मुझे क्षमा कर दे, हे ईश्वर, मेरी सुनवाई में मुझे क्षमा कर दे, हे ईश्वर, मुझे मेरी दृष्टि में क्षमा कर दे, कोई ईश्वर नहीं है, लेकिन आप

During each round there are fast running should be performed at green sign as shown in Figure 4, the system also should notify the pilgrims about it as there is a special supplication should be said in this point. At the end of the seventh round the system will guide the pilgrim to stop and finish the Umara.

3. Results and analysis

Consequently, the developing of an appropriate and suitable intelligent mobile-based system is a paramount issue to prevent and manage stampedes during Tawaf/Sa'ay pillars, by helping pilgrims automatically counting the rounds during Tawaf/Sa'ay. Therefore, in this section, we investigated the need and the importance of having an intelligent mobile-based system that will reduce the stampedes and serving lager number of pilgrims. The area of the circle surrounding Al-Kaaba is roughly (the radius of the circle is about 50m as shown in Figure 8 and referenced in [11], and since the area of the circle is $A = \pi r^2$ then $A = \pi\ 50^2$) equals to 7,854m^2, the circumference of circle is $C = 2\,\pi\,r$ therefore the circumference of circle surrounding Al-Kabaa is roughly equal to $C = 2\,\pi\,50 \approx 314.16$ m, the distance of each round in this circle (around Al-Kaaba) is equal to 314.16 m and the total distance for the seven round is equal to (314.16 X 7) 2,199.12 m ≈ 2.19 Km for the farest point from Al-Kaaba (worst case) and ranges from 0.79 Km to 2.19 Km depending on how pilgrims close Al-Kaaba. Using the counter for rounding around Al-Kaaba will reduce the estimated time to finish the seven rounds and control the coward in Sahan Al-Kaaba (circle around Al-Kaaba) for the following reasons: The pilgrims sometimes confused in which round they are in during the Tawaf and based in the Tawaf ritual instructions in this case, pilgrims should base on the lowest number and continue, leading to more time stay in Sahan Al-Kaaba and causing stampedes.

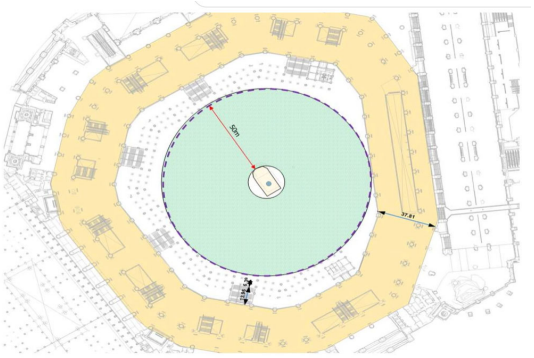

Fig. 8 Satellite shot of Al-Kabaa [11]

Let us Calculate the speed, distance, and time for each round, we assume Ψ is the largest distance = 314.16 m (with

the circle radius = 50 from Al-Kaaba) μ is the lowest distance = 31.4 m (with the circle radius = 5 near to Al-Kaaba) as the distance varies depends on how the pilgrims close Al-Kaaba we can take the average distance between Ψ and μ, therefore the new distance will be α = average (Ψ, μ) = 172.78 m. the normal velocity of a human as mentioned in Wikipedia is equal to 5 Km/h ≈ 83.33 meter/minute, in our case 172.78 m can be completed in 2.07 minutes. Based on our experience and based on our visiting to Makkah and performing this Tawaf ritual we think 5 minutes (with walking speed ≈ 34.6 meter/minute) is fair to finish each round with the regular case (no confusion in counting). The area of Sahan Al-Kaaba as mentioned in above is equal to 7,854m^2, based in the report in [11] and as shown in Figure 9, the total number of pilgrims reached to 28,700 pilgrims in Sahan Al-Kaaba with a density of 3.6 pilgrims per square meter (Ramadan season in 2017). The density of 3.6 pilgrims per square meter is considered between the second and the third level of dungarees cases of stampedes. It can be shown in Figure that level 4 and 5 represent the high level of density in which we target to avoid reaching this situation using our proposed solution which treat one of the reasons of these crowds.

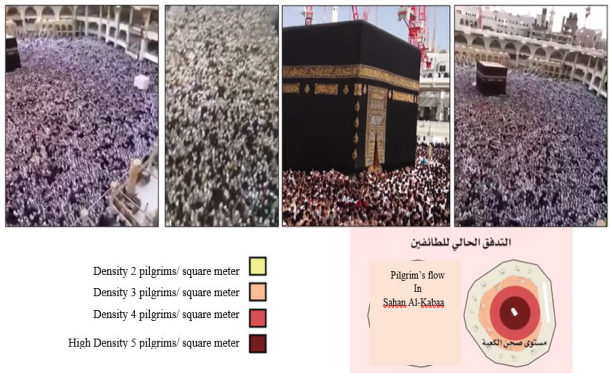

Fig. 9 The flow of pilgrims in Sahan Al-kabaa Ramadan season 2017 [11]

We based our work in the area of Sahan Al-kabaa and the analytical study reported in [11], we assume the capacity (C) of the Sahan Al-kabaa (as in level 2 of density) is equal to 28,700 pilgrims, in the normal case this number of pilgrims can finish the Tawaf in a time minutes τ = 35 minutes (The estimated time for each round = 5 minutes, for the seven rounds 5 X 7 = 35 minutes), therefore in 35 minutes roughly 28,700 pilgrims will finish the seven rounds, in one hour and ten minutes around 57,400 will finish and so forth. when some mistakes happened like we assume some pilgrims confused the counting at any round, there will be a delay as well as crowd yielding to a smaller number of served pilgrims. We can define the number of served pilgrims in given time as a function with four variables $R_c, T_m, \beta_n, \beta_c$ as declared in Table 4 and as defined in equation 1.

$$f(R_c, T_m, \beta_n, \beta_c) = \left(\frac{T_m}{\tau} * (\mathrm{C}\,\beta_n)\right) + \left(\frac{T_m}{5R_c+\tau} * (\mathrm{C}\,\beta_c)\right) \quad (1)$$

Table 4: the variables of calculating number of served pilgrims

Symbol	*Meaning*
R_c	Number of confused rounds
T_m	Input time
β_n	Percentage of pilgrims who did not confuse the counting
β_c	Percentage of pilgrims who confused the counting
τ	The time to finish 7 rounds (Constand)
C	The capacity (Constand)

The use of the autonomous mobile-based systems is a paramount issue for the crowed management in Almasjed Alharam [12] [13]. Therefore, we investigated the need and the importance of having an intelligent mobile-based system that is connected to GPS for tracking pilgrims Tawaf and Sya'a to manage the crowd and to satisfy higher number of served pilgrims by increasing the number of served pilgrims [14]. We have used the statistical data collected from Almasjed Alharam and by using the data that is reported in [11]. As it can be shown in Table 5 the number of served pilgrims outnumber the number of served pilgrims when no use the mobile technology of the aid systems for tracking and helping pilgrims in finishing the Tawaf in smooth way.

Table 5: Number of served pilgrims per minutes when 50% of the pilgrims got confused for rounds counting.

	Estimated time			
# Confusions	35 minutes	70 minutes	105 minutes	140 minutes
0 round	28,700	57,400	86,100	114,800
1 round	14,350	43,050	71,750	100,450
2 rounds	14,350	43,050	71,750	100,450
3 rounds	14,350	43,050	71,750	86,100
4 rounds	14,350	43,050	57,400	86,100

Figure 10 is visualizing the number of served pilgrims per minutes when 50% of the pilgrims got confused for rounds counting. The performed data visualization is used to further understand the experimental dataset. These visualization results show the importance of having intelligent mobile-based system with the proposed model.

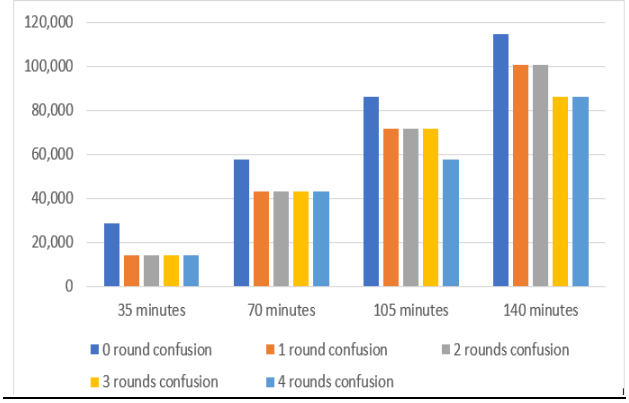

Fig. 10 The varying of served pilgrims per minutes when 50% of the pilgrims got confused for rounds counting

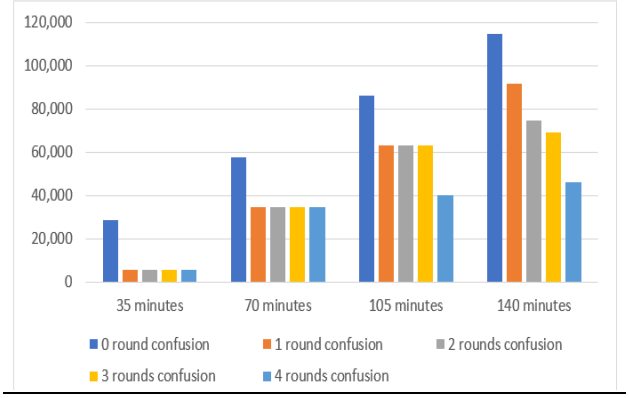

Fig. 11 The varying of served pilgrims per minutes when 50% of the pilgrims got confused for rounds counting

We used the proposed formal in equation 1, where we have a function with four variables $R_c, T_m, \beta_n, \beta_c$ as declared in Table 4. The number of served pilgrims as an example in 35 minutes is equal to 28,700 (the capacity of Sahan Al-kabaa as in Figure 9) for no round counting confusion (0 round confusion), in the other way when 50% or 80% of pilgrims have round counting confusion for the first round, second, third,….,or the seventh round, the number of served pilgrims in 35 minutes is equal to 14,350 (for 50% of pilgrims have round counting confusion as in Table 5) and 5,740 (for 80% of pilgrims have round counting confusion as in Table 6). The number of served pilgrims is increasing by 50% in the first case and 80% in the second case.

Table 6: Number of served pilgrims per minutes when 80% of the pilgrims got confused for rounds counting.

	Estimated time			
# Confusions	35 minutes	70 minutes	105 minutes	140 minutes
0 rounds	28,700	57,400	86,100	114,800
1 round	5,740	34,440	63,140	91,840
2 rounds	5,740	34,440	63,140	74,620
3 rounds	5,740	34,440	63,140	68,880
4 rounds	5,740	34,440	40,180	45,920

Figure 11 is visualizing the number of served pilgrims per minutes when 80% of the pilgrims got confused for rounds counting with different time. The performed data visualization in Figure 11 shows the number of pilgrims in 35, 70, 105, and 140 minutes.

The number of served pilgrims in 35, 70, 105 and 140 minutes is equal to 28,700, 57,400, 86,100 and 114,800 respectively for no round counting confusion using the proposed autonomous model), in the other way when 80% of pilgrims have round counting confusion for the first round, second, third,….,or the seventh round, the increased percentage of served pilgrims is rang form 50% to 80% as shown in Table 6 above.

4. Conclusion

The proposed autonomous mobile-based system is targeting to help pilgrims for performing Hajj/Umrah activities efficiently. We present an autonomous Mobile-based framework for guiding pilgrims during Tawaf/Sa'ay pillars with the aid of GPS for points tracking and rounds counting. This framework is specially designed to prevent and manage stampedes during Tawaf/Sa'ay pillars, by helping pilgrims automatically counting the rounds during Tawaf/Sa'ay with supported Supplications (in written/audio form with different languages) from the Quran and Sunna'a. according to the analytical study the use of the proposed model will increase the number of served pilgrims by the range between 50% to 80% based on a variant time range between 35 minutes to 140 minutes according of our experimental study conducted in this research.

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Nashwan A. Alromema has earned his bachelor's degree in Computer Science from Zarka'a University, Jordan, in 2004, M.Sc. in Computer Science from Jordan University, Jordan, in 2009. In 2017 he earned PhD in computer science from Universiti Teknologi Malaysia, Malaysia. He has worked in several places with different positions, including technical project team leader, data service engineer, software engineer, database designer, and programmer. In 2009 he started his academic career as a lecturer at the Faculty of Computing and Information Technology-Rabigh (FCITR), King Abdulaziz University, Saudi Arabia. He is currently serving as an Assistant Professor in the afore-mentioned university. He is an excellent teacher and talented researcher with over twelve years of teaching and research experience in database, computer science, Artificial intelligence, and Machine Learning. He has produced many publications in the Journal of international repute and presented articles at international conferences. His main research interests include database analysis, design and modeling, temporal database models, temporal data mining, and time-varying medical data, Image processing,