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A Mobile Based Crowd Management System

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Abstract: Modern technology aims not only to make people's life easier but also more safely. Being in a highly crowded place like stadium, metro stations or holy places on Hajj affects not only the human level of comfort but mainly the human level of safety. Very high Crowd may result on pushing, mass panic, stampede, crowd-crush and causing an overall control loss. The current work introduced a mobile based crowd management system. The system consists of two main parts, the first one is a server side application connected to IP cameras to detect crowd level in certain location(s) while the other one is a mobile application with different users rights to receive alarm from the server side application. The suggested frame work provides an effective method to connect and alert all of the system users immediately, preventing high crowd level danger.

Keywords: Crowd detection, Crowd Management, People Counting, Commercial Crowd Detection Applications, Surveillance system.

I. INTRODUCTION

Many countries all over the world are currently experiencing problems caused by rapidly growing populations of urban areas, the population growth rate of human beings is quite worrying in the meantime. Towns, streets, and schools have been overcrowded due to rapid population growth.

The crowd could be defined as a mass gathering of people or group of people. The crowd may result in pushing, mass panic, stampede, crowd-crush and causing an overall loss of control [1]. The crowd could be categorized into diffused crowd where individuals couldn't be recognized or tracked and the diffuse crowd where individuals and groups could be recognized and tracked [2]. The last decade has seen a great advance in crowd analysis techniques including people counting by using either pixel-level, texture-level or object-level analysis [3]. People counting used to determine the level of crowd and send an alarm if this level exceeds a certain level to avoided crowd impact. Finally, crowd analysis also includes people tracking. The mechanics of human crowds are complex because a crowd exhibits both dynamics and psychological characteristics, which are often goal directed [4]. This makes it very challenging to figure out an appropriate level of granularity to model the dynamics of a crowd. Research on the crowded scene analysis could lead to a lot of critical applications such as Visual Surveillance and intelligent environmental. The current project concerned with abnormal behavior analysis to avoid accidents in crowded public places, like what happened in Hillsborough football accident disaster [5], Love parade disaster in 2010 [6] and Al-hajj disaster on 2015 [7] if we could detect highly crowd dense and static crowd in crowd places such as stadium, malls even the holy places, we can prevent tragic accident from happening.

The current work presents a frame work for crowd management system based on mobile application. The system main contribution is to provide an effective method to connect and alert all the people categories affected by the crowd level increasing danger in a certain location(s). Providing an immediate alert through mobile app. allow uses to take the effective actions to manage the problem just a few seconds after its beginning, resulting in a good chance to solve with problem with minimum loses or damages.

The system will provide different data access rights according to user category. For example, normal users will just receive alarms to avoid walking toward certain areas or roads while others like civil defense officers or security officers will be able to access live images and more details from different locations and also send alarm messages to others.

The rest of the current paper organized as follows, Section II compare Similar Applications, Section III will cover System overview, section IV the used crowd level detection algorithm will be introduced, section V system interfaces design will be illustrated followed by section VI where the system testing and results will be shown and finally the last two sections VII and VIII introduce conclusion and future work.

II. SIMILAR APPLICATIONS

Recently many commercial Applications are available to monitor and manage crowd. In the following subsections we will demonstrate most of them and comparing their features.

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A. AllGoVision Video Analytics

1. System Description:

It is a real-time enterprise grade advanced video analytics software product developed by AllGo Systems, a leader in Multimedia technology. Being a specialist in Video Analytics, it is focuses on Accuracy and Reliable performance [8].
It is a desktop application, and it analyses the video contents in real-time and provides the crowd count with reasonably high accuracy. Based on a pre-defined threshold value [8]. The crowding threshold can be set either based on the number of people occupying the region of interest or the percentage of area occupied by crowd in the user specified region, also supports crowd flow analysis by highlighting sections of the crowd by their direction of movement. Counter flow of crowd, which happens in a direction opposite to the desired path, can also be intelligently detected and alerted against [8].

2. System Services:

Video Analytics provided crowd management solution which includes Crowd Counting, Crowding Detection, Overcrowding Alert, Crowd Flow Analysis, Crowd Counter Flow Detection [8].

B. iOmniscient and vedioIQ

1.System Description:

Omniscient offers the most comprehensive range of video analytics in the industry. From the most complex behaviour analysis to the recognition of vehicles and humans, from simple video management to automated response systems, if any analysis can be performed using Video, iOmniscient provides it. The iQ-120 is the Crowd Management, which is a very smart system [9].
It gives a live count of the number of people within one or more regions of interest that have been drawn on the screen. It is a desktop application and it combine crowd estimates from multiple cameras to gauge the total crowd size [9].

2. System Services:

It is will Counting in a Crowd, Crowd Density Analysis, Overcrowding (people), Traffic Congestion (vehicles) [9]. It is can be used to monitor an area and alert staff if it becomes overcrowded and it will raise an alarm if the figure reaches a pre-defined occupancy limit [9].

C. IPSOTEK Proven Video Analytics

1 System Description:

IPSOTEK has successfully deployed numerous solutions for crowd management in venues, public spaces and areas with capacity requirements. Typical crowd management operations include; queue management, which provides performance statistics for use in key performance indicator reports and management analysis [10].
The analytics algorithms used by IPSOTEK were specifically designed for use in congested areas; areas where other systems struggle to count accurately due to the tendency of people to bunch together while moving through doors. With this technology, IPSOTEK crowd counting solution provides accurate data in real-time [10].
The crowd analytics can also provide crowd density estimation, whereby IPSOTEK capabilities provide a measure of occupancy in a given space without the need for defined entry points, exit points or pinch-points, as the measure originates from the individual camera view itself [10].
Journey time measurement is a solution which uses Ipsotek's accurate crowd counting solution at various checkpoints throughout a large area to measure the mean journey or queue time. This can be combined with Bluetooth technology to further increase the detail of information that is collected from crowd CCTV video analytics.
Smoke detection has been developed through a Visual Smoke Detection (VSD) algorithm that can be used to detect signs of smoke on the same cameras that are providing Ipsotek's other solutions [10]. This crowd counting solution provides an accuracy of 95-99%
Journey time measurement combined with Bluetooth technology. It is a desktop application only.

2. System Services:

The system provides accurate real time picture of total occupancy and alerts when capacity or predicted queue time reaches an unacceptable level. The system used to monitor the flow of people to avoid potential bottle necks, gridlocks and overcrowding, improve crowd management and Improve safety management and evacuation plans by monitoring occupancy levels [10].

D. Qognify

1. System Description:

Some of the world's busiest mass transit hubs use Qognify video analytics to ensure security, safety and a positive customer experience. Using Qognify crowd management and people count video analytics applications provides accuracy rate of over 90%.

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As Walking against the flow in certain locations, such as airport security checkpoints and gates, can be a sign of something much bigger the current system provides this functionality. It can potentially result in terminal shutdowns, along with significant financial and security implications. Qognify's Counter-Flow Detection alerts operators to individuals breaking airport and security regulations by walking in an unauthorized direction [11].

2. System Services:
It provides Suspect Search software help to locate and track specific people in near real time. Perimeter Intrusion Detection System (PIDS) works with or without a physical fence, and can also be a part of a smart fence configuration. This system provides alert to intrusions anywhere along your perimeter in real time, it is a Desktop application only depending on picture analytics [11].
Crowd management and people count Qognify analytics to ensure security, safety and a positive user experience.
Counter-Flow Detection alerts operators to individuals breaking airport and security regulations by walking in an unauthorized direction [11].

E. VISIOINGENII Crowd Management Systems
1.System Description:
VISIOINGENII crowd management systems used for both the retail and government sectors. This solution is proven to assist retailers in innovative marketing through effective activity analysis and improved store safety. With the help of vision-based analytics, the implement effective customer counting and crowd counting systems [12]
It uses crowd counting systems and it is also a Desktop application only. Crowd Management from Visio Ingenii they can craft a bespoke crowd management system that is tailored to meet any of the complex and critical security challenges that user can face [12]**.**

2. System Services:
It is used for multiple user both the retail and government sectors. It is also analysis and improved store safety.
VISIOINGENII crowd management systems can be optimized to work for you whether user looking for crowd counting in a busy public place, or to track customer footfall in a large retail environment [12].
Table I summarize the comparison between the reviewed applications. As it is notable all of the popular commercial applications depend only on desktop application which provides the service without guarantee whenever the alert received on a timely mannered to users.

TABLE I CROWD MANAGEMENT COMMERCIAL APPLICATIONS FEATURES

Application Name/ Feature	AllGoVision	Iomniscient and vedioIQ	IPSOTEK	Qognify	VISIONGE NII
Desktop Application	✓	✓	✓	✓	✓
Crowd dictation /counting	✓	✓	✓	✓	✓
Crowd management	✓		✓	✓	✓
Overcrowding (People) alert	✓	✓	✓	✓	
Crowd density analysis		✓			
Traffic congestion		✓			
Crowd flow analysist	✓		✓		
Crowd counter flow dictation	✓			✓	

III.SYSTEM OVERVIEW

The proposed system consists mainly of two main parts as shown in figure 1. In the proposed prototype system, we select the Hajj holy places to be our desired scope for system design so, the system main users would be civil defense officers, pilgrim's groups supervisors and also pilgrims. The main IP camera locations would be Mena, Mozdalefa and Afafat. The system main components are: mobile side application, server side application, database, IP surveillance camera and Google Map (external system). The first main part of the system is a server side application connected to IP surveillance camera(s). The second main part is a mobile side application. Firstly, the IP camera(s) capture real time

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images periodically from selected locations where we would like to detect, monitor and manage people crowd then these images passed to the server side application where image analyzed and crowd level detection is detected through crowd level detection algorithm. In case of very high crowd dense detection or static crowd detected alert messages will be send to all the users through the mobile application. The crowd level indicator mark will be marked on the corresponding image from Google Map on user side application, the marker would be red for dangerous and very high dense location, orange for medium level dense and green for low level dense. All the system users could perform a query about the crowd level in any of the IP camera(s) location at any time. The Civil defense could receive real time images from selected
location. Civil defense and pilgrims' supervisors can create lists to send group alert messages in emergency cases in order to prevent the upcoming pilgrims from reaching very high dense dangerous locations or cluttered places. Figure 2 shows the proposed system use case. The proposed system prototype titled with Crowd Detection Application (CDA).

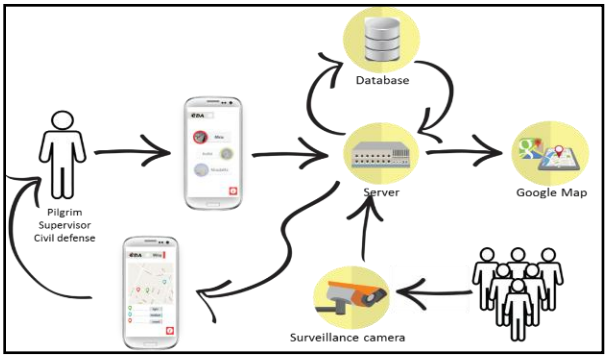

Fig. 1 High Level System Architectural Diagram

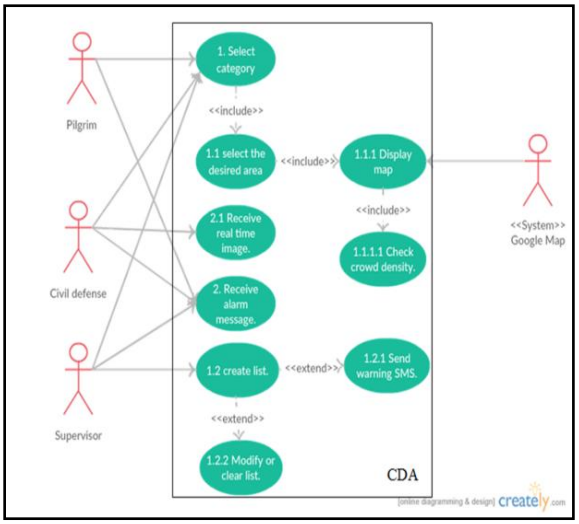

Fig 2. Proposed system use case

IV. CROWD LEVEL DETECTION ALGORITHM

One of the image properties which have received high attention from many researchers is texture. Texture based methods explore a coarser grain and requires the analysis of image patches compared to pixel-based methods. It is mainly used to estimate the number of people rather than counting persons in a scene [3].
The aim of CDA project is to detect the level of crowd (high, medium or low) and the static crowd situations in extremely dense people crowds. The effective method that work well for dense crowd is to use texture-based methods that rely on texture modelling through the analysis of image patches. However, there are several texture methods for counting from an image [13], [14] and [15].
The current work used the texture based method for people counting that proposed in [16] and [17]. This method based on Fourier analysis as shown in figure 2 [16].
We test the performance of the used people counting method on the UCF crowd counting dataset of 50 images containing between 96 and 4633 people per image [18]. Further, we complement the dataset with 10 images taken from flicker web site, representing low and medium crowd as it is not represented enough in UCF database [18].

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A. Algorithm overview

When a crowd image contains thousands of individuals, with each individual occupying only tens of pixels, especially those far away from the camera in an image. However, a crowd is inherently repetitive in nature, since all humans appear the same from a distance. The repetitions, as long as they occur consistently in space, crowd density in the patch is uniform, can be captured by Fourier Transform where the periodic occurrence of heads shows as peaks in the frequency domain [16] and [17].

Fourier Analysis

Fourier analysis can be used to capture the repetitions in crowds. Since we are dealing with small cells and not the complete image, we can safely assume that the crowd density in a cell is uniform. In this case, the Fourier transform, f(ω), will show the repeated occurrence of people as peaks. For a given cell, P, in an image, we calculate the gradient , (P), and apply a low pass filter to remove high frequency components. Then we apply inverse Fourier transform to obtain the reconstructed image patch, Pr. The local maxima in the reconstructed image give an estimate of the total person count in that cell. We also calculate the several other statistical measures, such as entropy, mean, variance, skewness and kurtosis for both Pr and the difference | (P) – Pr| to use it for patches segmentation which means if these values below a certain level the patch not used for people counting as it will be background [16] and [17]. Figure 2 illustrates how Fourier methods is applied to count from image patches.

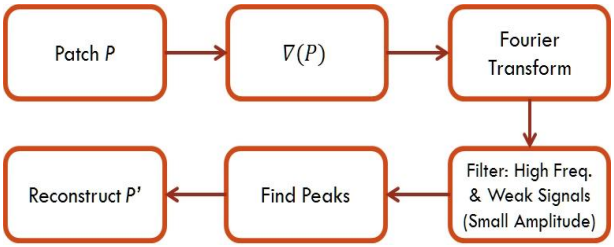


Fig.2 Fourier based crowd analysis block diagram [16].

Figure 3 shows two original patches, the second column shows gradient image, while the third column shows the corresponding reconstructed patches. The positive correlation is evident from the number of local maxims in the reconstructed patch, and the counter shows in the last column [16].

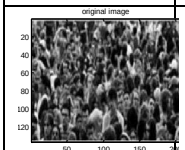
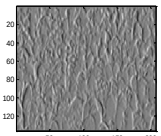
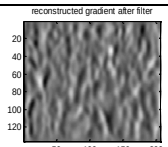
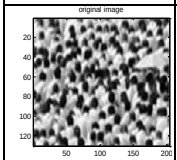
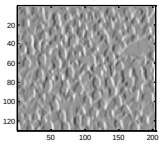
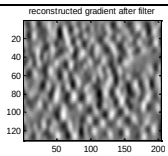
Patch	Gradient	Reconstructed	Count
			129
			135

Fig3. Examples of patches, gradient, reconstructed images and their corresponding count.

V. SYSTEM INTERFACES DESIGN AND DIFFERENT USERS FEATURES

A. System Interface

The system was implemented using C#, SQL, and XAMPP Server for server side application. Android Studio for mobile application implementation and finally Matlab for implementing crowd level detection algorithm.

The system starting interface will ask the user to select if he/she is a pilgrim, supervisor or civil defense, then he/she can press on the enter button and the next window which is the places list will be displayed directly, Figure 4 (a). The pilgrim can choose any location from holy places location to check the crowd density figure 4 (b). The user can click any of the locations (Mena, Arafat or Mozdalefs) to check the level of crowd as shown in figure 5(a).

In case of very high dense or static crowd the users will receive an alarm on their mobile side application figure 5(b), when he clicks on it, the application will open a window that shows the map of the intended location, marked with red marker (figure 7(a)).

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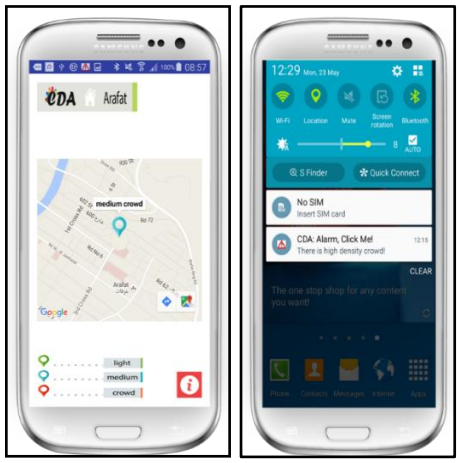
(a) (b)

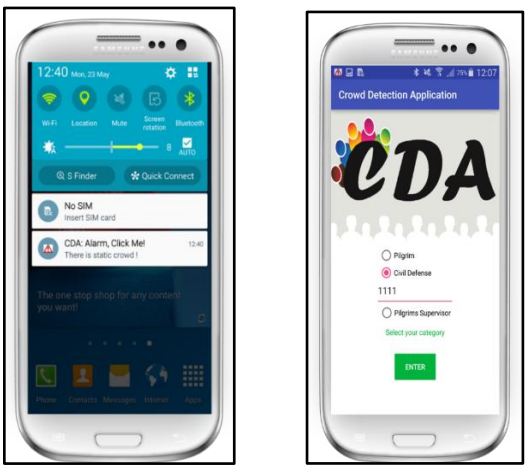
Fig. 4 (a) Pilgrim's login window, (b) Pilgrim's Locations list



(a) (b)

Fig. 5 (a) Arafat location marked with medium crowd dense, (b) Extreme crowd alarm

If the user was civil defense, he need to enter the id in the input field, and press the enter button, figure 6(b). As soon as the enter button is pressed, the application will connect to the external database to chick if the inserted id exists or not. Indeed, civil defence member will be provided with additional functionality which is receiving a real-time image in case of high density or static crowd, figure 7 (a) and (b).



(a) (b)

Fig.6 (a) Static crowd alarm (b) Civil defense's login window with wrong ID

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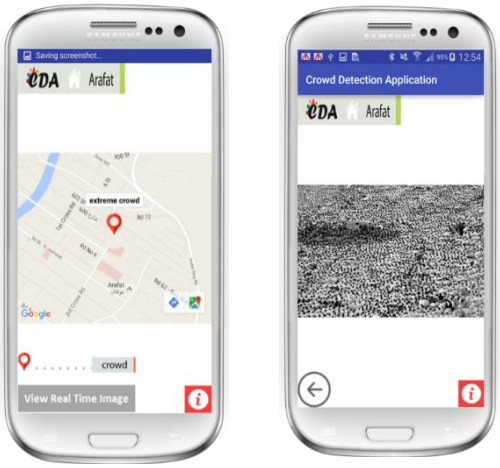
Civil defence officers and Supervisor have other feature to open list window contains many options that allow the supervisor to handle a list smoothly and sending SMS alarm to a group of people in case of dangerous situations.



(a) (b)

Fig. 7 (a)Arafat location marked with high crowd mark with the ability to view on line image from the location, (b) Arafat location on line image

The current system main features can be summarized as follows.

B. Different Users Features

In this section, the system different features listed based on the different categories of users(pilgrim, supervisor or civil defense officer).

1. Pilgrims' side:

- The crowd detection application gives the pilgrims the ability to check holy places crowded level.
- In case of static or extremely crowd, the pilgrim will receive an alarm along map that indicates the dangerous place.

2. Civil defense's side:

CDA help the civil defence in facilitation their responsibilities such as helping them to locate the crowded scene and get there easier and faster.

- The civil defense will receive an alarm attached with a real time image of the crowded place in case of static or extreme crowd situations in Arafat area.
- The civil defense can check the crowd density in holy places.

3. Supervisors' side:

Supervisors can take the benefit of the application to manage the flow of the pilgrims during performing Al-Hajj.

- The supervisor can check the crowd density in holy places.
- In application, the supervisor can create a list of his supervisees.
- The supervisor can add or delete members smoothly.
- The supervisor can clear the list and create a new one in easy way.
- The supervisor can view the list of supervisees.
- In case of static or extremely crowd, the supervisor can send his list members a warning SMS.

VI. TESTING AND RESULTS

The current section demonstrates the system different tests. The testing phase include Interface test, unit test and usability test.

A. Interface Test

In CDA project, all components of each interface such as: buttons, input and output displaying areas were tested. Also, the layout was tested since its format can affect the user interaction. Moreover, the size of the map was checked to make sure that the user can see it clearly. In fact, the eight golden rules of interface were in mind while testing, because if they were existing this means the system's interfaces design is perfect. As a result of this testing, CDA has user friendly interfaces.

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B. Unit Test

The unit test was performed for the crowd level detection on the UCF crowd counting dataset of 50 images containing between 96 and 4633 people per image [18]. Further, we complement the dataset with 10 images taken from flicker web site, representing low and medium crowd as it is not represented enough in UCF database [18]. The performance test was 90% of correct crowd level detection.

C. Usability Test

Usability testing has done with thirty-three adult persons divided into three categories pilgrims, civil defense and pilgrims' supervisors. Each group has its own specific tasks to do. Also, after the testing there was a questionnaire distributed, in order to take their feedback about CDA.

Performance Managements

1. Number of Clicks,
2. Number of wrong clicks.

Subjective Performance Measures

These measures are affected by the users' perceptions, opinions and judgments. CDA developers need to take their rating. The measures are:

1. Ease of use.
2. Clarity of labels and buttons names.

The levels of criteria

The levels of criteria used in usability testing are:

Excellent

This means that the application is clear and easy to use according to the performance of this task.

Acceptable

This means that the user is satisfied with performance of level of this task.

Unacceptable

This means the user encountered some problems while performing the task.

Group 1: Pilgrims Testing

The results of usability testing which is done with pilgrims' category are listed below. Table II shows the three levels of criteria for CDA for pilgrims' category.

TABLE II THREE LEVELS OF CRITERIA FOR CDA (PILGRIMS' CATEGORY)

Criteria	Excellent	Acceptable	Unacceptable
Task(1) Login			
Number of clicks	2	3	4
Number of wrong clicks	0	1	2
Task(2) select desired place			
Number of clicks	1	2	3
Number of wrong clicks	0	1	2
Task(3) get information about CDA			
Number of clicks	1	2	3
Number of wrong clicks	0	1	2
Task(4) back to home			
Number of clicks	1	2	3
Number of wrong clicks	0	1	2
Task(5) open alert message			
Number of clicks	2	3	4
Number of wrong clicks	0	1	2

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The results of the usability testing done with pilgrims are shown in Table III. All participants successfully completed tasks

TABLE III RESULT OF USABILITY TESTING (PILGRIMS' CATEGORY)

Task	Average Number of Clicks per user	Task Performance
Task (1)	2	Excellent
Task (2)	1	Excellent
Task (3)	1	Excellent
Task (4)	1.2	Excellent
Task (5)	2	Excellent

Group 2: Civil Defense Testing

The results of usability testing which is done with civil defense category are listed below. Table IV shows the three levels of criteria for CDA (civil defense category).

TABLE IV THREE LEVELS OF CRITERIA FOR CDA (CIVIL DEFENSE'S CATEGORY).

Criteria	Excellent	Acceptable	Unacceptable
Task(1) Login			
Number of clicks	3	4	5
Number of wrong clicks	0	1	2
Task(2) Select desired place			
Number of clicks	**1**	**2**	**3**
Number of wrong clicks	**1**	**2**	**3**
Task(3) get information about CDA			
Number of clicks	**1**	**2**	**3**
Number of wrong clicks	**0**	**1**	**2**
Task(4) Back to home			
Number of clicks	**1**	**2**	**3**
Number of wrong clicks	**0**	**1**	**2**
Task(5)Open Alert Message			
Number of clicks	**2**	**3**	**4**
Number of wrong clicks	**0**	**1**	**2**
Task(6) Open Real Time Image			
Number of clicks	**1**	**2**	**3**
Number of wrong clicks	**0**	**1**	**2**

The results of the usability testing done with civil defense are shown in Table V. All participants successfully completed tasks.

TABLE V RESULTS OF USABILITY TESTING (CIVIL'S DEFENSE CATEGORY)

Task	Average Number of Clicks per user	Task Performance
Task (1)	3	Excellent
Task (2)	1	Excellent
Task (3)	1	Excellent
Task (4)	1	Excellent
Task (5)	2	Excellent
Task (6)	1	Excellent

Group3 Pilgrims'Supervisor Testing

In this section, the results of testing with pilgrims' supervisor category are listed. The test was done with criteria similar to that used with civil defense group as shown in table IV. Table VI shows the results for usability test for pilgrims' supervisor category. All participants successfully completed tasks.

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TABLE VI RESULTS OF USABILITY TESTING (PILGRIMS' SUPERVISOR'S (YROGETAC

Task	Average Number of Clicks per user	Task Performance
Task (1)	3.1	Excellent
Task (2)	1	Excellent
Task (3)	1	Excellent
Task (4)	1.1	Excellent
Task (5)	2	Excellent
Task (6)	1	Excellent
Task (7)	4	Excellent
Task (8)	4	Excellent
Task (9)	2	Excellent
Task (10)	2	Excellent
Task (11)	1	Excellent
Task (12)	1	Excellent

Usability Survey

After the usability test session done a survey was performed for all of the three categories users. The survey questions concerned with the degree of:

1. Ease of use
2. Clarity of meaning of buttons and icons
3. The consistency of user interface

The results of the survey questions 1,2 and 3 shown in figure 8,9 and 10 respectively.

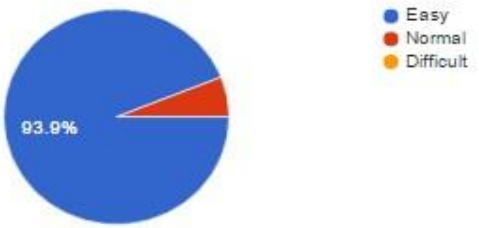

Fig. 8 The results of Ease of use Question

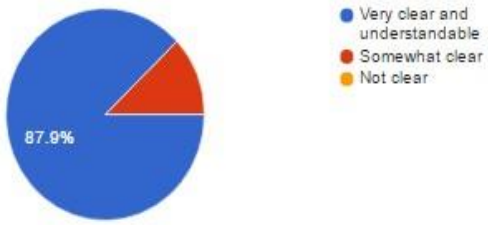

Fig. fo sluseR ehT 9 Clarity of meaning of buttons and icons.noitseuq

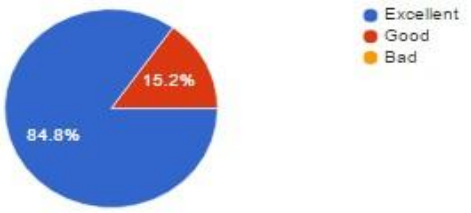

Fig. fo tluseR ehT 10The consistency of user interface question.

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VII. CONCLUSION

The current work presents a frame work for crowd level detection system based on mobile application in order to provides an effective method to connect and alert all of the system users immediately. The early alert just seconds after the level exceeds the defined limits resulting in a good chance to solve problem with minimum loses or damages and preventing high crowd level danger. The system was tested using Interface, unit and usability test to guarantee that the system working probably and the users react with it in an efficient way. The tests results show a promising result.

VIII. FUTURE WORK

In future, we aim to implement the system using Multilanguage and detecting not only the crowd level but also any abnormal behavior causes or resulting from any violence to increase the safety level. The system needs also to be tested with huge number of users and take this consideration in system design to simulate the expected real situations.

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