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ENSURING SAFETY OF PILGRIMS USING SPATIO-TEMPORAL DATA MODELING AND APPLICATION FOR EFFICIENT REPORTING AND TRACKING OF MISSING PERSONS IN A LARGE CROWD GATHERING SCENARIO

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ABSTRACT

More than two millions of pilgrims visit the holy cities of Makkah and Madinah, in Kingdom of Saudi Arabia, to perform Hajj and Umrah rituals every year. Ensuring safety of the pilgrims is the top priority of Saudi government. Therefore, kingdom considers health, safety and security a red line that is not supposed to be crossed at any extent, considering the magnitude of related consequences. A higher tendency of persons is found who get separate from their group of members during Hajj and Umrah rituals; especially in the case of children and old-aged ones. Our survey from pilgrims who lost their elders or children shows that amongst the missing 8% were elderly persons and 92% were children. The lost elderly persons and children need an efficient system to track them. Therefore, this paper proposes a system model and a prototype application for effective reporting and tracking of lost and found persons in a huge crowd gathering scenario of Al-Nabawi mosque Madinah. Our proposed system's model aims to facilitate both pilgrims and the center of lost and found persons in Madinah. It allows pilgrims to report and search lost persons effectively. It matches the reported spatio-temporal contextual information of lost persons along with integrated support of the face recognition and biometric verification techniques. We used an existing deep learning method based on a face recognition algorithm which results in high accuracy during small-scale testing on labeled faces in the Wild benchmark. The tracking procedure is made more efficient by coupling the face recognition technique employed with biometric verification and reported spatio-temporal features of lost pilgrims.

Keywords: safety and security, spatio-temporal, data modeling and application, efficient tracking, large gathering, smart assistance application, pilgrims.

1. INTRODUCTION

The Ministry of Hajj and Umrah of the Kingdom of Saudi Arabia has stated during the recent wake of the pandemic that the government's top priority is to enable pilgrims to perform rites safely and securely. Therefore, the government ensures all it takes to plan, manage, and approbation to facilitate pilgrims at any cost. In this context, various state-of-the-art information and communication technology tools and techniques are already used by the government. This includes 'Eatmana', a mobile application for Haram entry appointments aimed at pilgrims monitoring, tracking, and controlling. Another smart application 'Tawakkalna', approved by the Ministry of health mandatory to be used for the health safety and security of pilgrims and residents. This work proposed a system model and prototype application for the assistance of people in huge gathering in terms of efficient reporting and searching of lost persons. Every year the cities of Makkah and Madinah, in KSA ("Kingdom of Saudi Arabia"), witness millions of pilgrim's from all over the world to perform Hajj and Umrah. These Pilgrims arrive with their families or in the form of groups. According to the official statistics gathered for the Al-Nabawi Mosque in May 2019, it was estimated as half a million numbers of pilgrims are children below 15 years and approximately a million pilgrims are above 65 years aged people. It only takes an instance, for example, just as one turns around and the next thing you notice is your child is missing. Finding the missing person in a huge and dense population is challenging. A survey was carried out in the center for lost children and with the pilgrims in Al-Nabawi mosque. The collected data has been analyzed based on 50 responses of lost person's instances. The results, shown in Figure-1, indicate that amongst the lost ones, 46 (i.e. 92%) are children and 4 (i.e. 8%) are elderly persons.

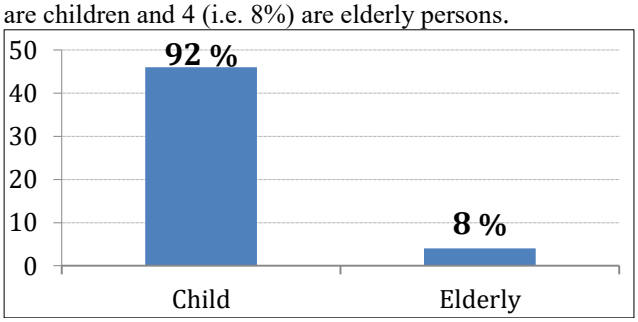


Figure-1. Statistics of survey carried out in the center for lost and found children and pilgrims in Al-Nabawi mosque.

The statistics has also shown that hardly 37% of pilgrims were aware of the center of lost and found at Al-Nabawi mosque. It has shown that a wide number of Hajj and Umrah pilgrims lack awareness and understanding of information about how to report missing persons. Currently, there does not exist any application through which pilgrims can report missing persons online.

Figure-2. Illustration of current system of lost and found reporting.

In most cases, due to the separation of family members, a huge amount of time is spent in locating and finding that causes loss of concentration and disturbance in performing religious rituals. Moreover, it is estimated that count of pilgrims may reach twenty million till year 2030 [1-4]. Therefore, this paper presents a mobile-based prototype application and a system's model to address this important issue. The proposed work is novel in a way that it uses spatial and temporal artifacts, in terms of last seen location and time, of the missing person to reduce the search space that facilitates the officials to optimize missed person tracking in a shorter time span.

This paper is structured in five sections. We discussed existing system of reporting lost and found persons in Al-Nabawi mosque in section 2. Then section 3 presents literature review and research gap analysis. Our proposed spatio-temporal modeling system and prototype application is presented in section 4. Finally, conclusion and future work is presented in section 5.

2. EXISTING REPORTING & TRACKING SYSTEM

At the moment, the center for lost children, shown in Figure-2, is working to serve pilgrims in Al-Nabawi mosque, Madinah.

The department follows a WhatsApp based group to communicate with security staff, as elaborated in Figure-3, where a pilgrim either visit the office to report a missing one or report it through police men. The majority of the pilgrims find it difficult to communicate because they are non-Arabic speakers. Therefore, a smart application supported by an online portal is needed that will not only save their time but also enable pilgrims to provide detailed information including time and location where the person was lost. Such application should address major problems for pilgrims in existing system like language barrier and lack of knowledge about reporting procedure and location of center for lost children.

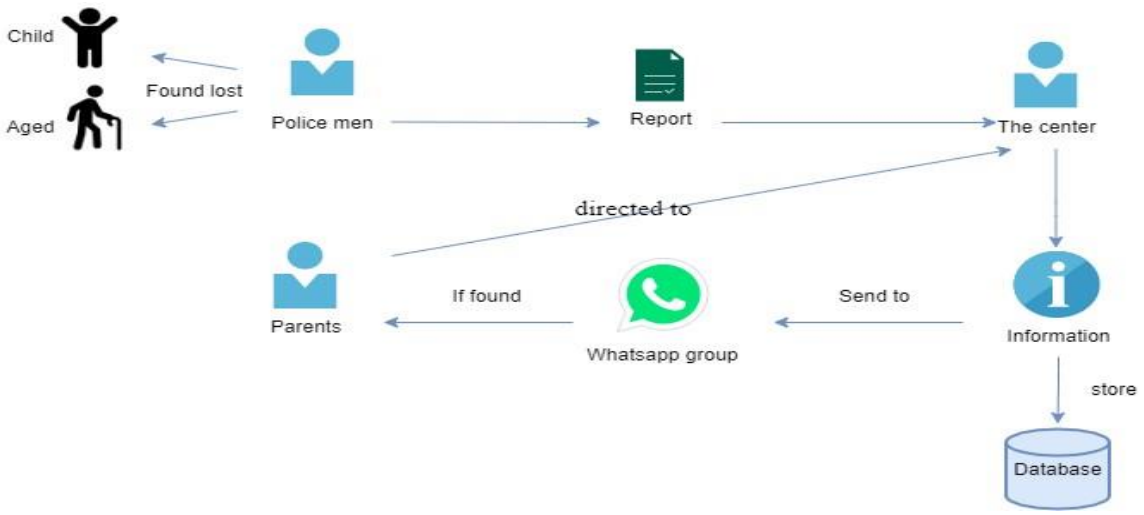


Figure-3. The department for lost children at Al-Nabwi mosque Madinah.

Our objective is to propose a system for the center for lost children to report missing/ found persons using his/ her photo and biometric (finger-print) features. Image recognition and biometric facility make the process simple and delicate. The proposed system's model presents a web service to collect mentioned features of missing/ found persons and apply spatio-temporal data filter and computer vision techniques side by side. Moreover, it includes a module on finding a lost person's caretaker contact details to notify them.

3. Literature Review

The related work in terms of tracking missing persons in religious huge crowd gathering is presented in this section. We also review some other applications of locating lost persons in other type of scenarios. Study by

[5], for finding a missing person, randomly assigned spatial and temporal cues to a participant to recognize missing person's whereabouts. This study elaborates that spatial features are more important than temporal features. Another work to protect school going children and mark their presence, absence or getting late is presented by [6][18-19][21]. This is an SMS based alert system using fingerprint verification. The work in [7] presented a framework, called "HajjLocator" to track people in huge crowded environment. Authors in [8] presented experiments on friction ridge. The missing person's investigation management technique is used by [9]; it uses situation calculus modelling that shows formalism to the process. In this study a scenario is discussed to investigate finding of missing person using initial state variables that includes age, medical condition, location type, risk level, mode of transport, and last seen time. Then a rule base matrix of fluents generated to indicate potential actions.

Various applications and work is studied, like "CrowdFound" [10] and an integrated recognition system for Hajj and Umrah [11], for identifying missing, dead and found. Work named "MissingFound" was presented in [12]. A real time location system is shown by [13]. Moreover, "Mutawwif-ul-Hujjaj" is proposed by [14] [27]. Some reviewed literature also proposed the solution for locating lost persons in general situations. A hybrid key item locating method is proposed in [15] to assist elderly daily life using Internet of Things. An initial level of comparative study of some articles depicts the efforts put in place to develop a system that can help find a missing child with the use of several technologies and network devices. A study by [16] presents that persons with dementia are at high risk of getting lost and, therefore, RF based and GPS based seven commercially available tracking devices were used concluding that GPS based devices resulted best. In compassion to the proposal in [17] and [2], we focus on reducing the search space and time to efficiently find missing person.

4. Proposed System Model and Prototype Application

Considering the lack of online applications for reporting and tracking missing persons, we proposed spatio-temporal system's modeling and prototype application in this work to report and track missing persons in Al-Nabawi mosque Madinah. To support our argument, we considered two scenarios. The first scenario addresses situation in which a family is headed by a family member and, the second scenario depicted the situation where a group of people or different families headed by a group leader. During the Hajj, Umrah, and five-time prayers especially in the holy month of Ramadan, it is a general practice that pilgrims moved in the form of a group. Therefore, a group leader is assigned to each group that gives directions to his group members and they are supposed to follow him to perform rituals smoothly. This group leader has the information of all his group members. A group leader can direct his group members not only from the hotel to the Al-Nabawi mosque but also inside the mosque. The proposed mobile-based application can help him in this regard. Moreover, the information of all his group members is also visible to him through it.

The proposed system model is shown in Figure-4. It shows proposed system with the flow of data for the core system processing. The head of the pilgrim's group or the family of visitors must register in this application. Then report the missing person by entering relevant details including the time and last location of the person lost with respect to our proposed geo fences of Al-Nabawi Mosque. The application then allows tracking the status of their reported lost person. Once a security personal found a reported missing person then the system will generate an alert and also reported it in the spatio-temporal database. It is supposed to notify the reporter through messaging about the person to be received from the department for lost and found in Al-Nabawi Mosque.

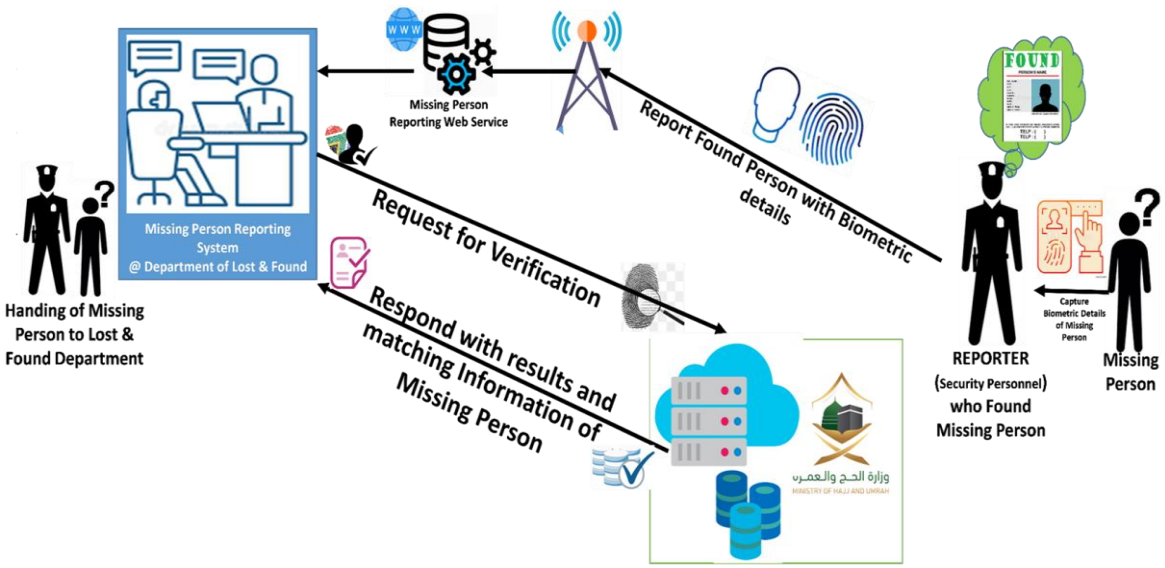


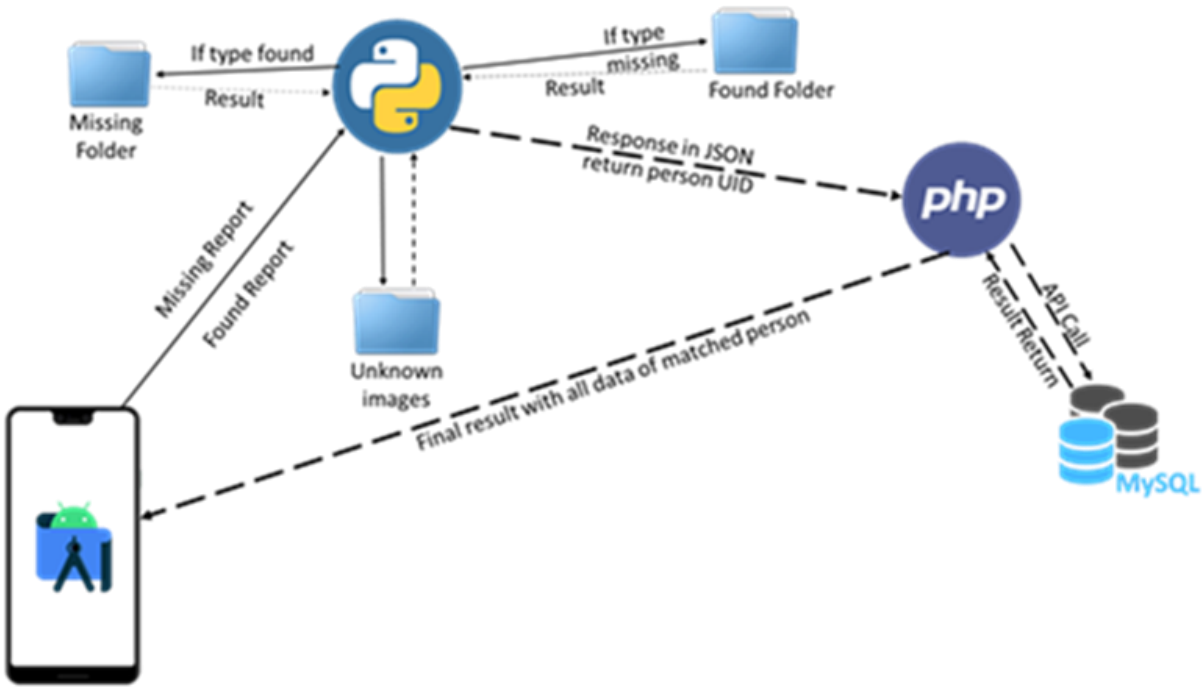
Figure-4. Proposed system's workflow model.

4.1 PROPOSED SPATIO-TEMPORAL MODELING

The relationship established between the events (report missing) and the objects (Missing person). The artifacts for the event of a reported person missing or found has confirmed to the appropriate time constructs. For example, the valid time, transaction time and existence time etc. The person missing is associated with a specific clock time which can be approximated while reporting via the proposed system. The event of reporting a person, being missed, leads to invoking the beginning of a valid time interval (pre-condition to TT) and the transaction time interval also begins. The existence of transaction time start is the post condition. The valid time ends with the transaction time of the event when the aforementioned missing person is reported as 'found'. Hence, the search is bound to seek data about the target person being missing within a valid time interval. Here, we do not consider multiple transaction time stamps for beginning as more than one relative can initiate the event of reporting the same person being missing. Similarly, the end of valid time in this scenario will remain open even the same person found, due to multiple valid time intervals.

4.2 PROPOSED APPLICATION IN A NUTSHELL

We have developed a mobile-based application to report and track missing persons. The user can report a missing person by entering 6-tuple information including pilgrims name, ID, spatial features, temporal features, fingerprint, and facial features as shown in Figure-5(b). The core functionalities of the application are illustrated in Figure-5(a), where a missing person report is received by the web service developed in python. The application then marks the person as missing and adds the 6-tuple record in the database. When a child or elderly person is found by the police, it takes the fingerprint and facial features through the application and sends a query using JSON to match found person features with the list of reported missing persons as shown in Figure-4.

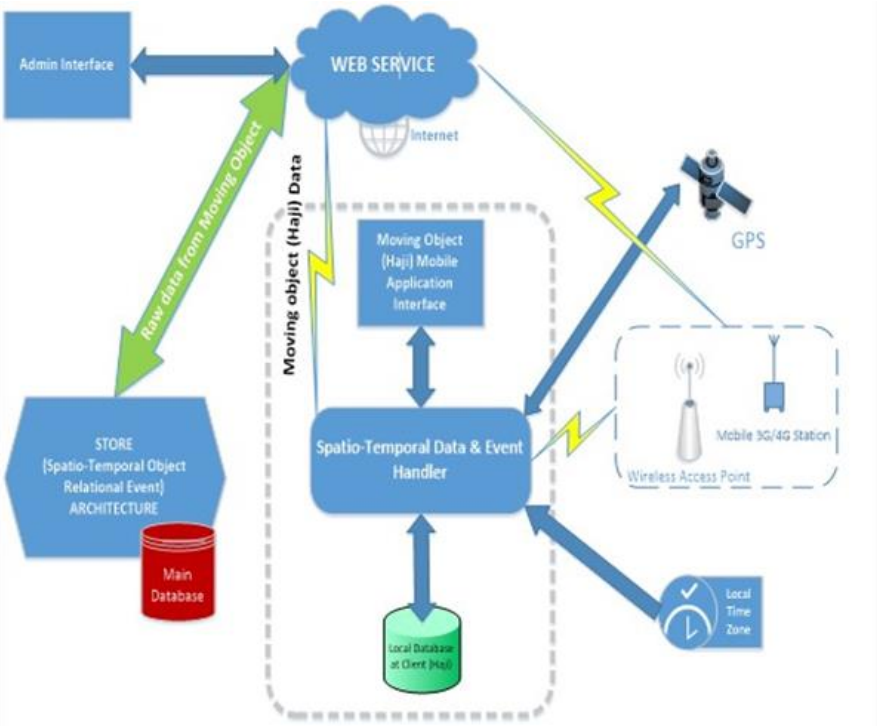


(a) Flow of information

Pilgrim's Name	Policeman's ID	Date/Time	Location	Fingerprint features	Face features
Abd'Allah	78910	1-1-2020, 5:01:01	24.470901, 39.612236		

Any (or Both) features may be required

(b) 6-tuple data snapshot about found (or missing) person



(c) Sample model for spatio-temporal event and information logging [26]

Figure-5. Proposed data deployment model.

4.2.1 Matching Algorithm

We used Python's face recognition algorithm for recognizing and matching the face. We exploited mobile phone camera for the compliance of proposed model. The Python face recognition algorithm release 1.2.3 [22] is used for face recognition purpose in this proposed work. We built a web service that works as an agent between this Python algorithm and our web application. It gets query image from web application and forward it to Python engine, and vice versa, for fetching results. This algorithm contains face recognition API that includes built-in functions some of which are listed below:

- batch face locations
- compare faces
- face distance
- face encodings
- face landmarks
- face locations
- load image file

The technique we used, store all pilgrims faces in a database. Then a module fetches the query image from database based upon the reported lost person's details. Our geofence algorithm gives the possible estimated locations of missing person. Then 'compare faces' function compares the query image's face with the acquired faces of video images from cameras placed at estimated locations. Face distances are measured to get the smallest distance with the query image. This distance is used to populate results in matching percentage with the reported query image of missed person.

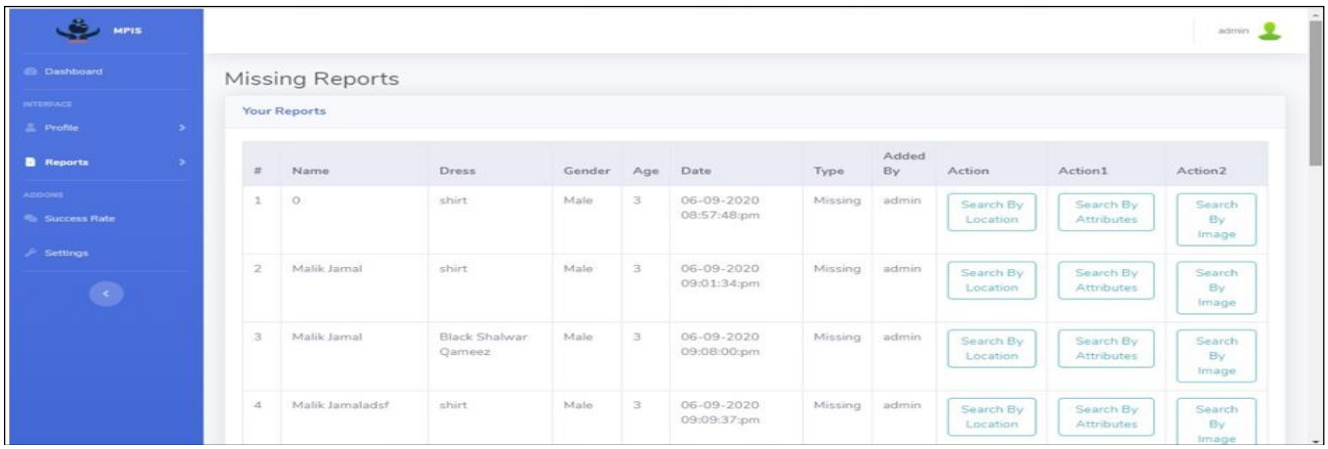
4.2.2 Geofence Algorithm and Results

Covered area is calculated using Google map that is 29.7 hectare (i.e. 2.97×105 sq. meters) approximately including the courtyard and perimeter is 2.18 Sq. kilometers approximately. We divided fences further in a 5x5 matrix of sub-geofences. The division based on 560 m x 540 m in approximation. We estimate further that the traveling velocity is around 1 m/s (at the rate of 550 meters in 7minutes). This approximation calculated during no crowd. Nevertheless, we propose varifocal cameras with 60 mm lenses that have 35-meter range. On 1080 resolution system range is doubled [20]. Geolocation base construct are represented as spatial features as the geofences of Haram Al-Nabawi mosque and nearby in Madinah city. The geofences coupled with the information containing name of enterance gates is used as nearest point of reference (landmark) for reporting lost and found person. So, if a person lost his/her relative or group member then he/ she would report using proposed mobile application. The spatial feature and the time construct improve efficiency of the system.

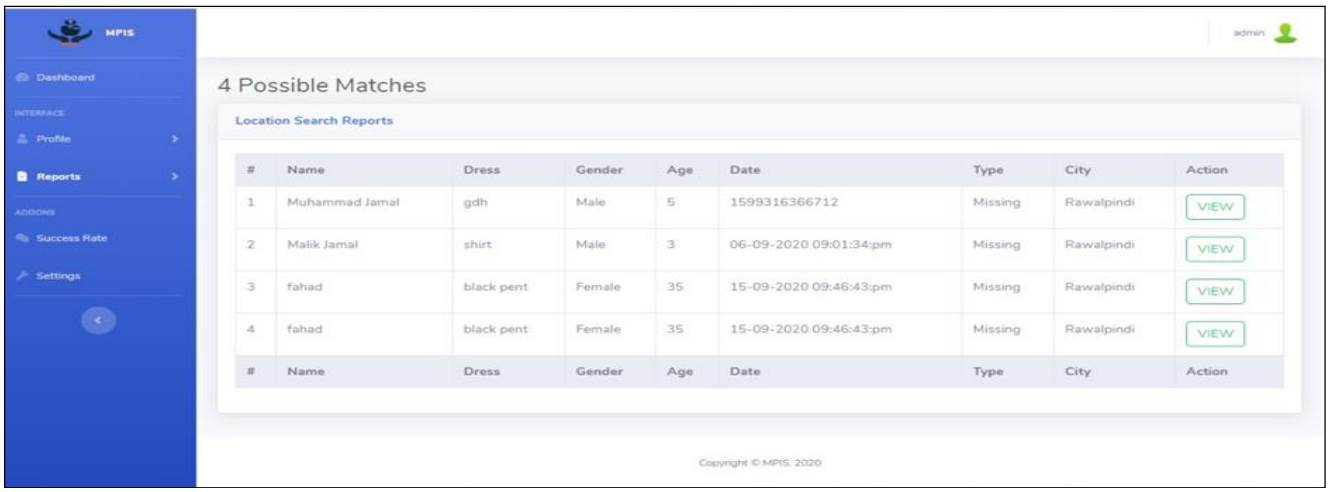
The temporal features along with spatial features help efficiently in searching the missing person. The device of policeman work as a seed value information to formally register the report of missing person depicted in Figure-5(a). The group or family head report an event ro record a person being missing in his/her group. Then, spatio-temporal data and event handler save the reported information in the database. The staff of 'center of lost and found' also has the option to report the event on behalf of the family head or head of pilgrims group. The proposed

database handler post data about the missing person in 6-tuple form as shown in Figure-5(b) from the mobile application's interface, inclusive of space (location) and time stamped data. The spatio-temporal data is extracted and parsed by the spatio-temporal data parser and pass on to data handler. Then received event procedures and constraints are checked as shown in Figure-5(c).

The constraint is to be marked that the person would be reported in valid time. The spatio-temporal relationship manager may be mended to relate parsed data with the event's domain. Then application performs physical storage of data in three instances; (a) contain spatial feature, (b) stores temporal features and (c) stores information related to the person (found and/or missing). We observe that the overlapping of valid time-start has a variation with respect to reporting. The reports registered at server end to be summarized at administrator application shown in Figure-6. The system is compatible with cross-platform. We are using powerful tools such as HTML5, CSS3, JavaScript, MySQL, PHP, Android Studio, XML, Java, PYTHON, Visual Studio 2010, Web forms and Bootstrap. The proposed system is also responsible for identifying or finding missing persons by using image processing techniques.



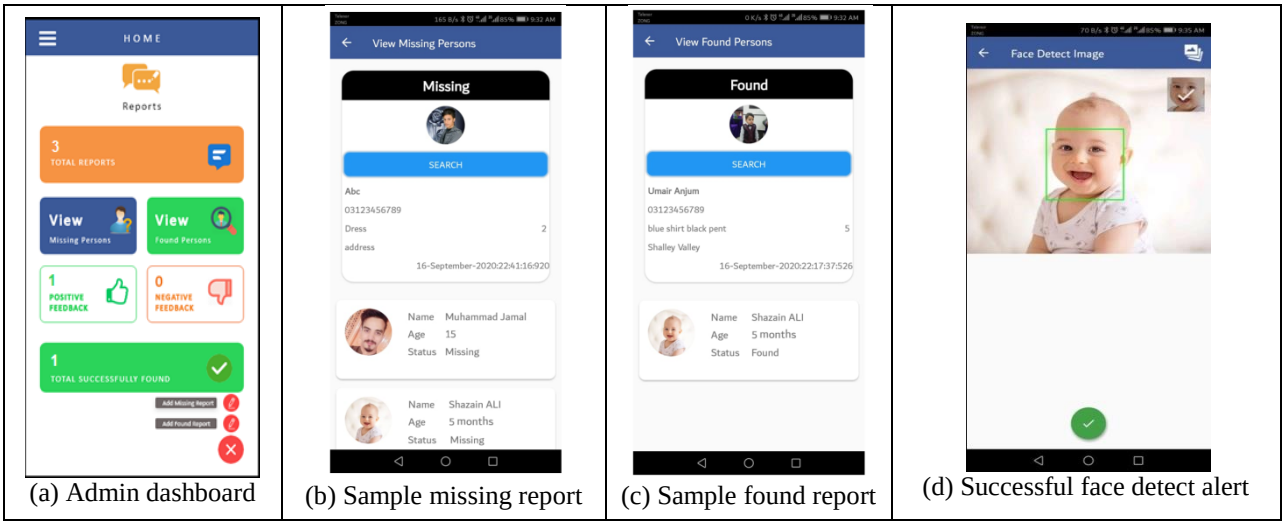
a) Sample missing report



b) Sample possible matches report

Figure-6. Web based prototype application (sample screenshots)

There are two main modules of the web application; the first is 'Missing Report' shown in Figure-6 (a), which covers those reports in this system that will be registered by the people who lost their loved ones. For that purpose, they must provide some mandatory data or information about the missing person i.e. his/her photo, name, age, dress (optional), height, etc. The system will store all the data in the database. The second is Found Report as shown in Figure-6(b). It will cover those reports in this system that will be registered by the individual who will find the missing person. Like the missing report that individual will provide information about the missing person as much as possible. It may involve the missing person's photo, name, height, age, etc. if possible. This system will get all the data from these reports and store them in the database and then the system will match the individual missing report data with all found report data and vice versa. Sample snapshots of prototype mobile application are shown in Figure-7 that shows the lists of reported persons being missed and found respectively.



(a) Admin dashboard (b) Sample missing report (c) Sample found report (d) Successful face detect alert

Figure-7. Mobile based prototype application (sample screenshots).

5. CONCLUSIONS AND FUTURE WORK

In this paper, we address an important issue of efficient reporting and tracking of missing persons in large gathering. We took the muslim pilgrims visiting site Al-Nabawi mosque as an example in this paper and a survey with sample of pilgrims clearly suggests the importance of this issue and an effective solution such as the one proposed could help them perform their religious ritual with peace of mind. We propose a spatio-temporal model and a prototype application to effectively report and track the missing persons. We proposed the spatial distribution of Al-Nabawi mosque's entire area into 25 smaller regions and apply the geofence algorithm to reduce the search space and time required to track the missing person. The initial testing results of the proposed model are presented through a prototype application. We observe a limitation that the fingerprint matching in children of zero to six years is difficult due to growing finger ridge structure and displacement of minutiae. In future, we have planned to consider artificial growth models, as studied in [23-26], to improve our proposed model. In addition, we are also planning to optimize this model by incorporating state-of-the-art computer vision techniques for locating the missing person.

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CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest to report regarding the present work.

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