INTEGRATION OF GIS, GPS AND CCTV INTO A TRACKING APP SYSTEM: DEVELOPING A SEARCH TOOL FOR MISSING SENIORS WITH DEMENTIA

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KEY WORDS: Dementia, GPS monitor, Deviation behavior detection, CCTV, Trajectory data analysis

ABSTRACT: CCTV plays an important role in police investigation and crime prevention. Besides tracking criminals and collecting digital evidence of crimes, modern CCTV systems can also improve public safety and the quality of human life by helping law enforcement find missing seniors with dementia and conducting crash reconstructions. However, investigating officers may need to spend hours searching possible CCTV cameras and collecting CCTV videos from public and private systems close to the incident scene. In addition, the current process for finding the right CCTV video frames that might serve as digital evidence is highly inefficient and time-consuming.

Therefore, this study combines GIS, GPS tracking techniques, and CCTV to develop a more efficient system for searching for missing seniors with dementia. The first step is to define the patient's daily activity area and wandering behaviors on a GIS map. Then, a GPS tracking app can be used to record and monitor the patient's daily movement and possible deviation. When the senior leaves their normal route and thus is at risk, the app sends a warning to the family and/or police. Nearby CCTVs are identified and the key time period defined, and the corresponding videos automatically sent to the police authority. This study also defines several main dementia behavior patterns based on their GPS trajectories. Our results will contribute to different stages in the investigative process by providing key images in a short period of time and predicting the future trajectories of missing people over time.

INTRODUCTION

The ageing population is an important issue around the world. As people grow older, they are more susceptible to cognitive impairments such as dementia. According to a study by Kawas and Katzman (1999), 5% to 40% of older people suffer from dementia. Globally, this is around 50 million people (International Association of Dementia, 2017). In Taiwan, there are approximately 270,000 people suffering from dementia, based on statistics provided by the Taiwan Dementia Association. In other words, 1% of all Taiwanese have dementia-related afflictions, and this rate is expected to grow to 4% in the next 30 years. The authorities need to develop corresponding policies and design services that respond to dementia patients and their families' needs

Beside medical treatment, the most critical services involve the navigation and transportation of people with dementia (PWD), because dementia often first affects the hippocampus. This is the part of the brain primarily responsible for navigation, memory, and visualization. Therefore, the initial symptoms of dementia include loss of spatial cognition, inability to recognize familiar places, disorientation, and wandering. In the later stages, it is not possible for PWD to leave home by themselves.

Researchers and mobile system operators have already developed positioning systems for PWD, such as the "BoBee Guardian" manufactured by Far EasTone. Lin et al. (2014) reviewed more than 28 different system and methods for managing the wandering behaviors of PWD. However, existing studies and systems are mostly positioned from a single viewpoint (e.g., medical care, law enforcement), so their functions focus on providing an accurate description of the user's immediate position. Such services are more suitable for individuals in the later stages of dementia, who may need to be searched for after they go missing. These devices may not be as useful for people in the earlier stages of the disease. Relatively few studies have analyzed GPS trajectory data and tried to define when someone should be considered lost. For example, Lin et al. (2015) used GPS trajectory data to define the wandering and path deviation patterns of PWD. Their system was capable of predicting 95% of the subjects' moments of disorientation. However, the researchers did not record, calculate, or interpret their data for more advanced analysis.

Families of PWD often prevent patients from going outside, or force them to stay at home because they worry that they'll go missing or become injured, especially when the family is busy and cannot accompany them. However, dementia is a slow process that might take years or decades to run its course. Throughout this time, PWD still require transportation for shopping, medical care, and socializing. If they lose the right to go outside because of the possibility of getting lost, or their family feels the need to accompany them on any trip, this not only inhibits their mobility and overloads their family, but may also force early long-term institutionalization. This is a waste of social welfare and healthcare resources.

Therefore, the aim of this study is to develop an app to assist individuals suffering from the early stages of dementia to solve or circumvent the above problems. The design combines different technologies such as GIS, GPS, and CCTV to provide a full range of functions that operate from a variety of different perspectives. (1) Monitoring: the app uses GPS to record the PWD's trajectory and GIS to define regular paths, based on the patient's history and a buffer area. The algorithm also defines deviation and wandering behaviors when the PWD walks beyond a particular threshold. (2) Law enforcement: after a PWD is marked as missing, the system provides the PWD's path and all nearby CCTV footage for the appropriate time period. This information efficiently defines a useful time window of CCTV video. (3) Health care: the app records the PWD's long-term behavior. A doctor or nursing home can then use biomarkers to monitor the patient's condition and on-time performance, and evaluate the effectiveness of any treatment.

Different from the existing systems that emphasize accurate positioning and tracking, this app focuses on behavior detection, protecting patients' rights, reducing the load on caregivers, and making the external environment friendlier for PWDs.

METHODOLOGY

This study used the Android studio to develop our app combined with built-in sensors, and general software package. The data analysis procedure was separated into three steps: (1) using the built-in sensors to gather GPS location data, (2) employing GIS and historical trajectory data to define regular paths and abnormal behavior, and (3) after detecting deviations or other wandering behavior, sending warning messages transmitted via Google's Firebase cloud service. The system also records distances walked and paths taken in local system, which can be used by medical professionals. A flow chart describing the system is shown in Figure 1.

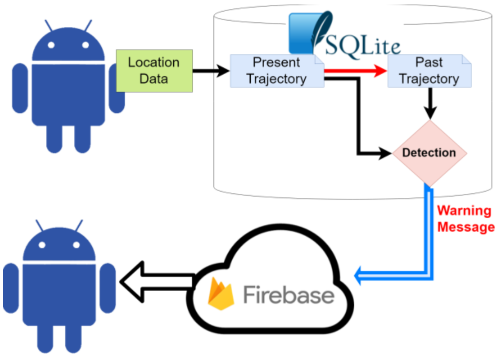

Fig. 1 System architecture.

The most challenge part of this research was to develop an algorithm for defining regular paths that could instantly detect when a user became lost. The default settings and parameters significantly affected the system' s accuracy. Below, each step is described in detail.

1. Regular path construction:

The algorithm is based mainly on a study by Lin and colleagues (2015), in which they used a square grid to record trajectory data. They first cut the study area into a grid of equal-sized squares. Then, they counted the frequency of trajectory points in each grid, deleted the noise, and eventually obtained a regular trajectory grid. This was used as the regular path, the basis by which they judged users' movements as normal or abnormal. However, they first needed to build a mesh grid, and their grid size was fixed.

Different from Lin's study, we built our regular path based on the user's trajectory data. Our grid size and buffer distance were flexible and could be updated based on the user's behavior and setting. Our platform uses Android's built-in Location-Change-Listener mechanism to obtain GPS information (i.e., coordinates with GPS accuracy). The Android service package was executed in the background to record the location data to Android's local database, sqlite database. For different time period record, this system saves records by two table. Present is used to save recently location record to detect wandering and historical table for regular path.

We set a training time for our app to build the regular path. Only the trajectory that occurred within this time period was input as a historical trajectory to define the regular path. Other trajectory data were ignored in order to save memory space and add subsequent processing speed. For grid size, previous studies have suggested 150m X 150m. However, we chose a circle with 50m X 50mdiameter because our study area was smaller and GPS accuracy higher. In other words, other studies set different grid sizes for their regular paths, or even set their regular path by hand. Our 50 meter2 area of historical trajectory points was our regular path, and other points outside this boundary were seen as new points.

2. Instant detection:

After building the regular path grid, our app is capable of estimating the Euclidean distance of the current position from Android's background location listener and the historical trajectories (or regular paths). If the distance is higher than the threshold, the current position is represented as a deviation. In Figure 2, this is illustrated as a blue line. In the same figure, the black icons represent recent coordinate points outside of the safe range. Wandering behavior is detected if a PWD stays in one place (e.g., a busy intersection) for a long time (e.g., more than 15 minutes).

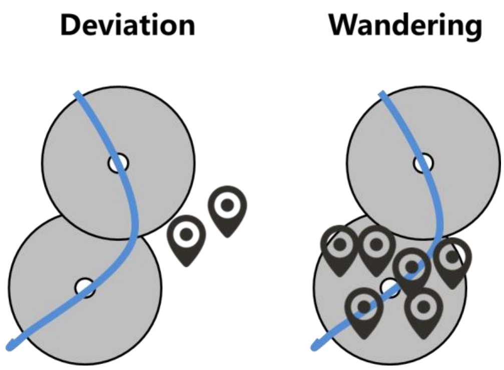

Fig. 2 Detection figure.

The pseudocode of trajectories detection is shown below. These processes are calculated through the SQL with sqlite. Deviations are calculated by the newly added coordinates and distance from the historical trajectory points. When detecting wandering behavior, the system uses the recently collected points and time differences between recent and current locations. In this part, the system determine user wandering by whether there are 150 present trajectory points, which are recorded during 15 minutes, in the safe range of current location. “diff_min” is the time difference of present trajectory record and current location.

```
STRUCT Position contains
        Double X, Y;
        Datetime Time;
        String Status;

Past ← LIST < Position >
Present ← LIST < Position >

WHILE (MONITOR_ON) AND (GPS _ON) Then
        status ← "Normal"
        Compute GPS ← get_GPS_data
        Compute Current_time ← get_Current_Time
        Now  ← new Position
        Now.X  ← GPS.Longitude; Now.Y  ← GPS.Latitude; Now.time  ← Current_time
        FOR past_item IN Past
                Compute dist = (Now.X − past_item.X)^2 + (Now.Y − past_item.Y)^2
                IF (dist > Threshold) Then
                        status ← "Deviation"
                ENDIF
        FOR present_item IN Present
                Compute diff_min = DATEDIFF(now.Time,present_item.Time)
                IF (dist  < Threshold  AND diff_min < 15 min) Then
                        status ← "Wandering"
                ENDIF
        Now.Status = status
        Present.insert(Now)
        Compute  First_Position_Time ← getFirstItem(Present).Time
        IF DATEDIFF(now.Time, First_Position_Time) > 1 Day THEN
                FOR present_item IN Present
                        Past.insert(present_item)
                Present.free()
        ENDIF
```

In sum, if the user's trajectory is outside of the safe range (i.e., if the user deviates far from the regular path) or the user is wandering in the same general area, the app instantly detects the irregular behavior and sends a warning to the user, family members, and related medical institutions. In addition, if the PWD doesn’t reply and a family member designates the individual as missing, the police receive a warning message with trajectory data and nearby CCTV information. In terms of long-term monitoring, the system records the distance and frequency of the user’s deviations and wandering behavior, so medical institutions can evaluate the PWD’s performance as part of an extended medical care plan.

EQUIPMENT

We chose the ASUS Z00ED mobile phone for the experiment. The position monitor used a minimum time interval of 1 second, and the position update distance threshold was 0.1m. The GPS accuracy threshold was set to 30m in order to verify that our datapoints were outdoors with better GPS signal. Figure 3 offers an example of our experiment results. In Figure 3(left), the points indicate the first trajectory taken to establish a regular path. For comparison with the existing grid method, we selected the NCKU campus as the research area and divided it into a 50m X 50m square. We then counted the trajectory points to obtain the purple grid. In Figure 3(right), the red dots indicate the abnormal trajectory, as judged according to our research method. However, some points (i.e., those inside the green circle) were considered to be a part of the regular path, based on the grid method. Therefore, it was clear that the grid size and cutting method directly affected the identification results. If the track points were close to the edge of the grid, the detection was underestimated and a deviation was missed. The grid method ignores the geometry of the road and user behavior, so it cannot accurately describe the path. Our algorithm searched for each coordinate point via SQL. This required a large amount of storage, but made it possible to identify the trajectory without a grid limit.

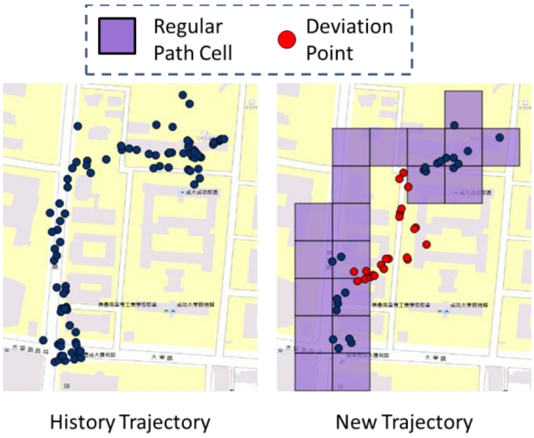

Fig. 3 Equipment results.

After defining the deviation and wandering behaviors, our app searched the nearby CCTV footage for the corresponding time period. (In Figure 4, the CCTVs view area are indicated by blue circles.). In this figure , elder want to go NCKU hostpital(right red triangle) from school gate(left red triangle), and he has wander (green line) and deviation(red line) in his trip. If a family member marked the PWD as missing, verifying that this was not a system failure, our app sent all of this information the police station for further attention.

Fig. 4 Defined wandering and deviation behaviors (red triangles: the origin and destinaiton of user; blue circles: CCTV visual area).

CONCLUSION

This study developed a friendly space-assisted app for patients in the early stages of dementia. We used the Android system and built-in listener function to obtain the user's location and stored the data in the mobile phone’s database in order to calculate the distance between the instantaneous coordinates and past trajectory. This allowed us to judge the user’s status and provide early warnings to interested parties. This study successfully developed an app that combines GIS, GPS, and CCTV techniques to record PWD behaviors. A new algorithm was developed to improve the accuracy of software for recognizing wandering behavior. In future work, our app will be extended to evaluate potential PWD in the early stages of the disease by recording the frequency of their path deviations and wandering behavior.

There are some limitations to this study. We used the maximum GPS accuracy threshold to remove the abnormal points, which usually were indoor points spread across an excessive range. This was attributable to a weak GPS signal. However, the threshold value will also cause certain correct coordinates to be discarded. Our app may not perform well in areas with weak GPS signals. Also, we set the time interval of the listener at 1 second to collect a dense set of coordinate points, but the high frequency update rate consumed a lot of resources. For long-term usage, we must balance accuracy with efficiency.

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