

On the Comparison of Location Based Methodologies Used for Tracking Purposes in Ambient Assisted Living Applications

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Abstract—Nowadays, handheld devices such as smart phones have become an everyday necessity as more and more features and services can be provided in such small packages. The diversity of the different sensors that are embedded in these devices (such as accelerometer, light sensors, etc.) provide the required foundation for the emergence of specialized applications that are capable of serving all kinds of purposes. By taking advantage of this specialized hardware found in smart phones, not only it has become feasible to constantly sense and gather information from the device's environment, but it has also become an effortless task to transmit the collected data to any individual or organization in a plethora of forms. This paper serves as an evaluation method for a location based Android application, SeniorTracker, by presenting a comparison between two applications that are both used for tracking down a device. While both have quite a similar purpose, the way they go about it as well as the ways the application itself can be utilized, drastically differs. SeniorTracker's main purpose lies in the retrieval of the coordinates of a device in case it is located somewhere it is not expected to be, enabling this way the finding of missing persons. The comparison was mainly focused on the performance of both applications when it comes to location retrieval and energy consumption while keeping in mind the respective tasks that each of them were designed to fulfill.

Keywords—GPS, Location Tracking, Energy Consumption, Comparison

I. INTRODUCTION

Pocket-sized devices such as smart phones have advanced so far that they can now, not only provide an

extremely vast number of services, but they can do it in a mobile manner as well. There are all kinds of applications that can be accessed through a smart phone, some for entertainment, other for educational purposes, even applications that tend to fixate on the well being of the device's user. The different kinds of sensors that are embedded in such devices make possible the collection of data from their environment; data that when analyzed can provide necessary information about the surroundings or living conditions of the people using it, predicting this way any threats that could possibly occur, or quickly resolving already happened problems.

Another important aspect that is brought to the table, and shouldn't pass unmentioned, is the ability of smart devices to determine their own location using the Global Positioning System (GPS), which can swiftly provide accurate information regarding the geographical positioning of the device, thus, the owner of it. Localization services, although being highly beneficial and handy, don't come without their tradeoffs, as the constant retrieval of device's whereabouts can be quite energy consuming.

The purpose of this paper is to consider two location based applications, that both use at least GPS functionalities, and provide the results of a comparison with regards to the objective of each application, as well as how efficient each one provides its respective services.

II. REVIEW OF LITERATURE

In order to provide an evaluation for SeniorTracker, it was necessary to look into other applications with similar purposes or similar functionalities. Therefore, a number of applications that were equipped with localization capabilities, either by using a GPS sensor or any other method, were taken into consideration.

Such a software solution, that met the criteria of this research, was implemented by the authors of [1], as it is an Android application which collected speed and location data by utilizing a smart phone's embedded GPS sensor. The purpose of this application is public safety and it achieves this by sounding an alarm in case a driver exceeds the predefined speed limit near a school. Any necessary information regarding the map of an area is retrieved from the Google Maps Application Programming Interface (API).

Additionally, the project proposed in [2] also uses GPS measurements to achieve its objective. It is capable of estimating the speed of a moving vehicle without the help of an accelerometer and the generated results are compared with On Board Diagnostics II (OBD2) speed measurement.

SensTrack [3] is also a localization application which gathers information regarding the holder's location and reconstructs the path that was taken. It uses the accelerometer, and also switches between GPS and WiFi for data collection in order to minimize the device's energy consumption.

One more project that was considered was the work proposed in [4] which presents a method for determining the lane position of a car by calculating the distance between a smart phone (using GPS) and the center line on a digital road map.

After considering the aforementioned applications, it was decided that for the evaluation of SeniorTracker, SensTrack was the most suitable choice due to their similar purpose and functionality.

III. SYSTEMS OVERVIEW

A. SeniorTracker description

Senior Tracker is an application that runs on any device that can support the Android Operating system. It serves the purpose of locating missing or lost individuals, mainly senior citizens, in time before anything happens to them. This is accomplished by notifying, with the use of an SMS message, some of the user's designated peers in case they are not where they are expected to be. The message contains information regarding their location and it is sent only to chosen contacts of the device, giving the opportunity to communicate with the missing person via phone call or go and find him.

In order to recognize whether a person went missing or not, Senior Tracker enables the user to mark and name any number of locations from a digital map. These marked locations, or Usual Locations (UL) serve as the center of circular areas which are created automatically by the application and represent the areas in which the user is usually found in (house, grocery store, etc.). The default radius is 200

meters but for each UL this radius can be changed by the user separately at any given time. An example of a Usual Location can be seen from the figure below.

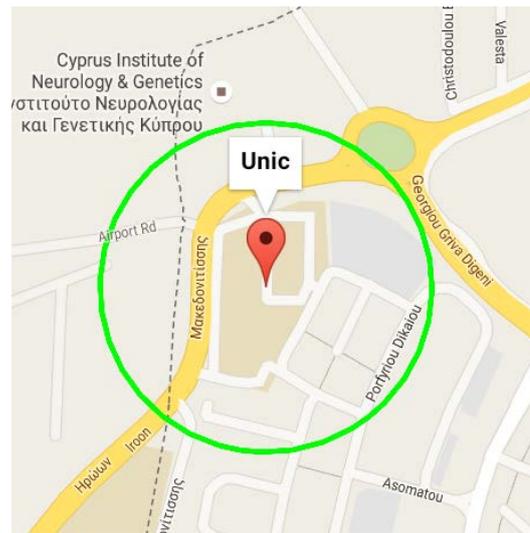


Fig. 1. Usual Location view

After specifying at least one Usual Location, the application, by using the device's embedded GPS sensor will begin to periodically retrieve the location of the device, on which Senior Tracker is installed, and check whether it is located inside any of the ULs. This is comparison is achieved with the utilization of the Haversine formula, used for calculating great-circle distances between two points on a sphere, using their coordinates in the following manner.

$$\begin{aligned} a &= \sin^2(\Delta\phi/2) + \cos(\phi_1) \cdot \cos(\phi_2) \cdot \sin^2(\Delta\lambda/2) \\ c &= 2 \cdot \text{atan2}(\sqrt{a}, \sqrt{1-a}) \\ d &= R \cdot c \end{aligned}$$

Where ϕ is latitude, λ is longitude and R is the earth's radius. After the distance between the user's current location and all the selected Usual Locations is calculated, it is compared with the predefined radius of the ULs, and if the distance is greater than the radius, for all the ULs, it means that the device is not located inside any of the Usual Locations, as shown in Figure 2.

At this point, an SMS will be sent to a number of individuals who were already selected from the contact list of the device. Whilst the user remains outside from any UL, a new SMS will be delivered for every 100 meters travelled, containing an update status regarding the location of the missing person in the form of coordinates (latitude, longitude), as well as the distance to the closest Usual Location.

The SMS transmission service was tested in order to see how different numbers of assigned contacts affect the reliability of the transmission in terms of delay. The designated contacts that were set to receive an SMS, in case the device was located outside of any UL, ranged from 5 to 25 and were used to measure and compare the time it takes for all

the messages to be successfully transmitted. The results of this testing is shown in the graph below.

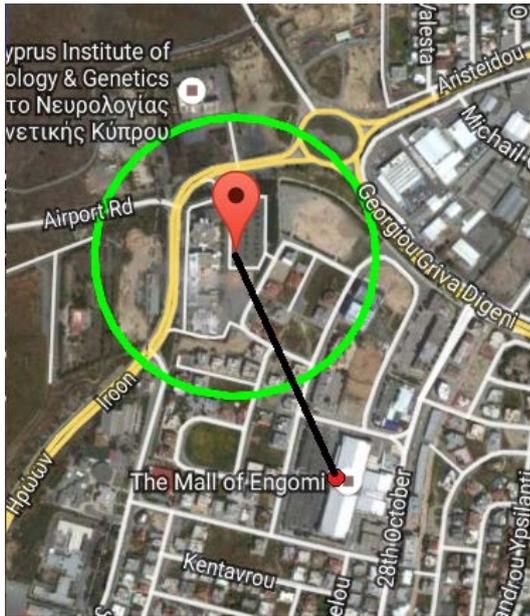


Fig. 2. Example of location check

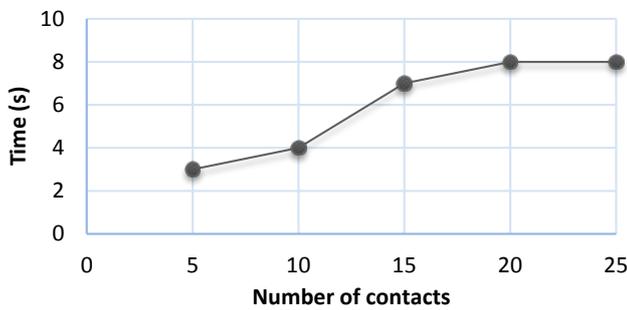


Fig. 3. SMS delay for different number of contacts

As shown in the graph, as the number of designated contacts increases, so does the time of the successful reception of the message. However, the difference between 5 contacts and 25 is merely 5 seconds, and therefore, the delay can be considered negligible as it does not affect in any way the performance of the message transmission.

While the main objective of the application is swiftly locating individuals in case they are lost, it also offers a few more features. One of such is the recognition of certain hand motions that can be performed by the user, and in turn depending on the gesture, a certain action will be fired. In total there are three different hand movements, or Gestures, that can be performed and each of them is designed to send a customizable SMS message when activated, to any phone number of the user's choosing, giving this way a context awareness aspect to Senior Tracker. Each gesture can be edited as well as be enabled or disabled individually as shown in the Figure 4.

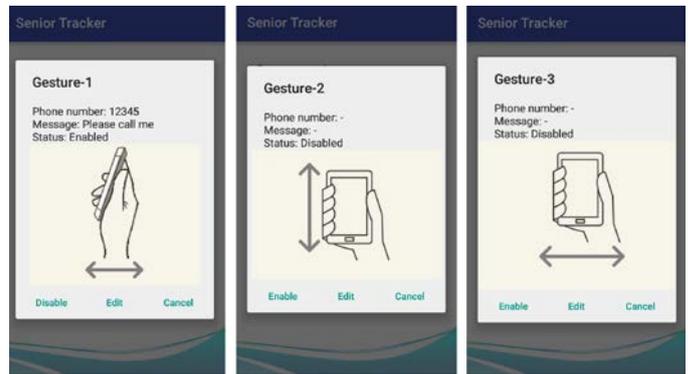


Fig. 4. The three available gestures

Moreover, the application is able to retrieve the battery level of the device and if it is below a certain threshold it will send another SMS to the predefined contacts, warning them that the device is about to run out of battery. The threshold is set at 15% by default but it can be changed at any time by the user.

Finally, Senior Tracker was made to be a persistent application that always runs on the background. It starts itself as soon as the device boots up, so that the services that it provides are operational at any given time.

B. SensTrack description

SensTrack is a service that is used for location tracking purposes by switching between two different location retrieval modes (GPS and WiFi) in order to conserve energy on a device. It enables a device to gather location information, by either using the embedded GPS sensor, or by connecting to the Internet using Wifi, and reconstruct the path which the user has taken using all the information that was gathered during the time the application was active as seen in Figure 5.

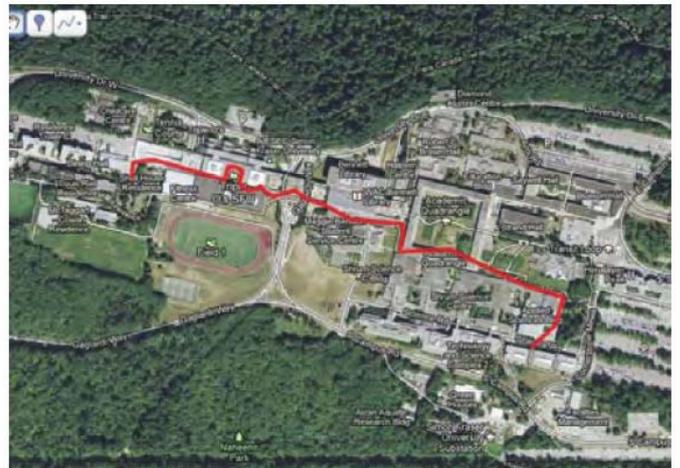


Fig. 5. Track reconstructed by SensTrack [3]

SensTrack is able to periodically sense data from a device's accelerometer and GPS in order to produce an estimation of the user's speed, calculate the distance from the previously recorded location and detect whether the user has taken a turn or not. However, whenever the signal of a GPS

satellite is low or non-existing, location information is gathered from the network using wireless communications. Additionally, all the data that is gathered is uploaded to an online server whose objective is to analyze the received samples using a machine learning algorithm and recreate the traversed path.

SensTrack minimizes the utilization of location sensing activities by avoiding the constant gathering of the location of users if they are moving in a straight line. Rather, by taking advantage of the orientation sensor, it is able to detect the moment when the direction the user is moving in drastically changes and that is when the location of the device will be sensed.

Furthermore, the accelerometer is also used for calculating the user's location, since distance can be derived from acceleration by integrating it twice. Even though the readings from an accelerometer are packed with noise, especially during activities that involve lower speeds, the estimations that are gathered regarding distance and speed can be meaningfully utilized since they are calibrated by using the location and velocity readings of the GPS.

As aforementioned, when inside a building, and GPS cannot be used, SensTrack switches to network based localization if there is an available WiFi connection. During this time, the accelerometer and orientation sensors stop collecting data in order to avoid wasting energy on them since WiFi location updates in a less frequent manner.

Finally, the last phase of SensTrack consists of the track reconstruction using Gaussian Process Regression. All the data samples that were collected are uploaded to an online server and there the machine learning algorithm is applied for a smoother track reconstruction.

IV. COMPARISON

A. Concept

The core feature of both SeniorTracker and SensTrack, which involves location tracking, is quite the same but both systems go about it in a dissimilar way, serving entirely different purposes. SensTrack can be used to reconstruct the path which a particular device has taken over some time by uploading all the collected data samples to an online server. For the device to communicate with the server though, it requires some sort of Internet connection therefore it doesn't necessarily mean that this will happen in real time, as a connection could be unavailable at any given time. On the other hand, while SeniorTracker's method of notifying someone of the whereabouts of a lost person is not of the latest technological advance, since it is performed simply by sending an SMS containing geographical coordinates, it is in fact performed swiftly in real time.

Additionally, SeniorTracker offers a few extra features besides tracking down a device that is located somewhere where it is not expected to be. Although the main purpose of the application revolves around quick location retrieval, it also makes itself more appealing due to its context awareness nature. Since the application's target users are

senior citizens, who most of them are not very proficient in operating a smart phone, it makes the transmission of simple SMS messages easy for them by utilizing the previously mentioned Gestures feature of the application.

B. Location retrieval method

While SeniorTracker only uses GPS to constantly retrieve the location of a device, SensTrack takes advantage of other features of a smart phone to do so. It uses the accelerometer in order to obtain information regarding the speed and travelled distance of a device (noisy but can be recalibrated using GPS info) along with an orientation sensor to detect whenever the user has taken a turn, i.e. the direction of the user has changed drastically. The use of the orientation sensor allows the requirement of less GPS samples since there is no need to collect coordinates in case the user is moving in a straight line. However, by taking into consideration that senior citizens tend to move slower than others (except when they are in a vehicle, but most occurred cases when they are lost, happen on foot) the noise that is received from the accelerometer is significantly higher.

Furthermore, SensTrack is capable of locating a device even within a building, where GPS sensor cannot collect location data, by utilizing the WiFi capabilities of a smart device. SeniorTracker cannot perform such task, and while it would be a nice feature to have, at least the dangers inside a building, in case a person goes missing, are relatively less than wandering in the streets.

C. Energy efficiency

In terms of energy efficiency, SensTrack has proven to be more energy conserving than simply using the GPS since according to its testing, for the same path (1km) SensTrack required 38 location samples to reconstruct it, while by using the naive approach (only GPS) required 568 samples. Since the purpose of SeniorTracker is simply location retrieval, and not path reconstruction like SensTrack, it is only natural that the required GPS samples would be less, at least from the naive approach, and therefore the frequency in which the location of a device is retrieved is smaller. SeniorTracker was tested with the help of three senior citizens to identify the number of GPS samples that are required for tracking them. The distance in which a new SMS message was to be sent was left to the default value (every 100m). As far as their walking paces they were measured to be 3.1km/h, 3.9km/h and 4.4km/h and for completing the distance of 1km, each device retrieved 61, 41 and 34 GPS samples respectively, as shown in the graph below.

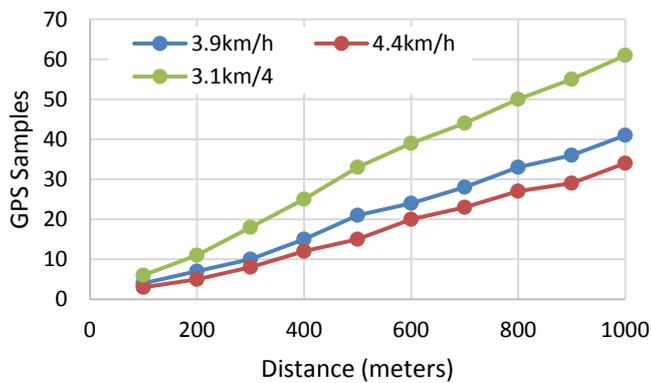


Fig. 6. GPS samples in regards to distance

The location samples that were retrieved were in the proximity of those of SensTrack. Of course this heavily depends on the speed of the user.

The naive approach that is utilized by SeniorTracker, while highly accurate it can be very energy consuming. According to the authors of [3] though, "if the user's movement is very unstable and the direction changes frequently, SensTrack inevitably activates GPS sensor more frequently and consumes more energy". By considering this fact, in the case of SeniorTracker where actual lives are at stake, it is wise to consider that the path to be taken by a missing individual could be highly unstable, therefore, by utilizing the same technique in tracking down a device as SensTrack could backfire and result in higher energy loss in a few occasions. It should be noted also that the purpose of SeniorTracker is finding quickly missing persons therefore energy conservation comes in second place when compared to the lives of lost individuals, that's why the constant and accurate location retrieval using the GPS could be considered a more suitable solution when someone's life is on the line.

Finally, in terms of a device's battery life, SeniorTracker provides a notification/reminder feature which enables the user to specify a battery threshold, and when the level of the battery falls below that threshold, an SMS will be sent to anyone who is designated in order to remind the user to charge their smart phone.

D. Location accuracy

During the testing and measuring phase of SensTrack, the locations that were retrieved had to be checked in order to evaluate the accuracy of the provided coordinates, and in a distance of 1 kilometer, the location samples that were recorded had an average error of 3.128 meters.

In order to provide a more complete comparison of the two systems, the accuracy of SeniorTracker's GPS data had to be measured as well. Therefore, the application was installed on a smart phone that supported GPS functionalities and several measurements were taken for the purpose of testing the accuracy of it. For this evaluation, 50 GPS samples were taken and the location that was specified in the received SMS message was compared to the actual location of the device. In the Figure below, the format of the SMS that is sent

can be seen for four of the measured locations (the numbering of each message corresponds to the coordinates shown in the figure after that).



Fig. 7. SMS received upon location notification

A small part of this measurement can be seen from Figure 8, where the blue spots on the map denote the coordinates noted in the SMS message and the red ones the actual location of the device.

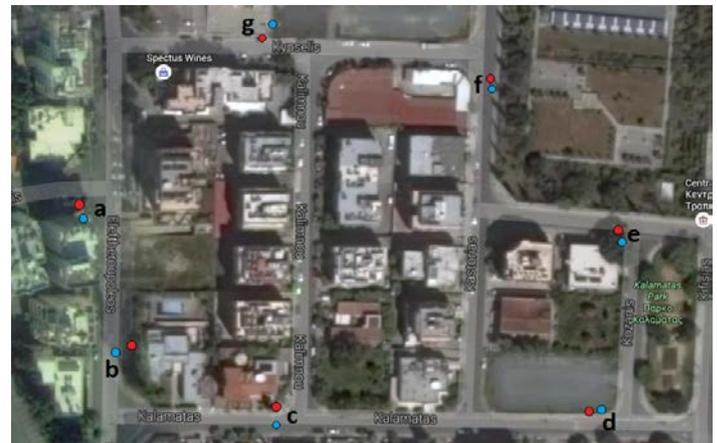


Fig. 8. Accuracy of SeniorTracker

As shown in the Figure above, there is a slight deviation between the measured and actual locations. A more detailed representation of the accuracy measurements can be seen from the graph in Figure 9, which compares all the measurements that were taken (50 samples) with their location deviation (in meters). The average error between the actual location and the measured one was calculated to be 2.7328 meters.

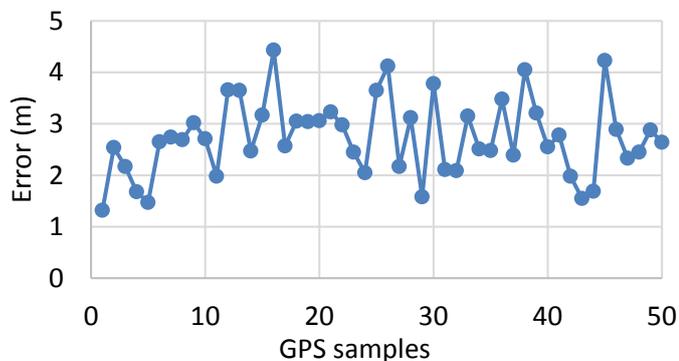


Fig. 9. Accuracy error of GPS samples

The accuracy measurement of SeniorTracker had similar results to those of SensTrack as they both had an error of approximately 3 meters. The maximum error of both is ~3m and therefore can be considered negligible as does not affect the proper functioning of any of the two applications.

V. CONCLUSION

As both systems can be used for location tracking purposes, the way they gather location information is quite different. On one hand, SeniorTracker uses a naive approach by simply collecting the coordinates of a device using only the GPS sensor of a smart phone, while on the other hand, SensTrack uses a more flexible approach by utilizing GPS, WiFi and the embedded accelerometer and orientation sensor.

Also, when it comes to connectivity tolerance, SeniorTracker constantly retrieves GPS coordinates and as soon as it is necessary one or more SMS messages will be immediately transmitted. SensTrack though, as it collects less GPS samples and still having high accuracy, the data that is gathered needs to be transmitted to an online server to be analyzed. Even if this makes it more energy conserving, it is not as reliable as SeniorTracker since if no Internet connection is available the location samples cannot be transferred to the

server. Of course, it should be noted that since SeniorTracker deals with the lives of individuals it is expected of it to provide with the necessary information in real time but that is not the case when it comes to SensTrack.

Moreover, when it comes to the accuracy of the retrieved GPS coordinates, both systems have shown similar results as they both have a slight deviation between the actual location of the device and the measured one. This error though, as it is no more than 3 meters, can be considered insignificant since it does not impede with the proper operation of the systems whatsoever.

To conclude, even though SeniorTracker and SensTrack are both location-based systems, they serve two vastly different purposes and therefore the way of providing their services are more suited to fulfilling their own respective tasks rather than stating that one is better than the other.

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REFERENCES

- [1] John Whipple, Whilliam Arensman and Marian Starr Boler, "A Public Safety Application of GPS-Enabled Smartphones and the Android Operating System", IEEE International Conference on Systems, Man, and Cybernetics, October 2009.
- [2] Arijit Chowdhury, Tapas Chakravarty and P. Balamuralidhar, "Estimating True Speed of Moving Vehicle using Smartphone-based GPS Measurement", IEEE International Conference on Systems, Man, and Cybernetics, October 5-8, 2014, San Diego, CA, USA.
- [3] Lei Zhang, Jiangchuan Liu and Hongbo Jiang, "Energy-Efficient Location Tracking with Smartphones for IoT", IEEE, 2012.
- [4] Yoshide Sekimoto, Yutaka Matsubayashi, Harutoshi Yamada, Ryuichi Imai, Tomotaka Usui and Hiroshi Kanasugi, "Lightweight lane positioning of vehicles using a smartphone GPS by monitoring the distance from the center line, 15th International IEEE conference on Intelligent Transportation Systems, September 16-19, 2012.