TrackMe - A Low Power Location Tracking System Using Smart Phone Sensors

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Abstract—**Tracking of locations of a mobile object or person continuously using smart phones using conventional Global Positioning System (GPS) puts a huge toll on the battery life of power-limited smart phones. The power consumption of a GPS unit is much more than any other sensors in a smart phone. Worse, the GPS unit cannot be switched off even if the smart phone is in sleep mode. GPS, in addition, is not effective in indoor locations because suitable number of satellites cannot be obtained for acceptable communication. To overcome these problems, in this work, we have proposed a low power and low cost fast location tracking system for a smart phone device that is effective in tracking continuous locations of a moving device with very good accuracy. The inbuilt sensors of a smart phone like the accelerometer, the magnetometer and the gyroscope have been utilized, instead of the costly GPS unit, to track the continuous locations of a mobile device. Distance covered between any two time instants is calculated using the accelerometer readings, while the magnetometer readings give the direction of movement of the mobile device. These sensors are used to get an initial estimate of the number of foot counts and the average foot length of the person that carries the smart phone. Basically, a pattern has been framed using the change of acceleration due to gravity when a footstep is taken. These values are then used to continuously find the location of a mobile person carrying the device. The system based on these sensor measures has been implemented on Android based smart phone devices. Implementation results have generated an accuracy level of as low as 2 meters distance. The system has been tested on both indoor as well as outdoor locations without any observable differences in performance measures. Huge savings in terms of battery power consumption, as high as 20 percent for a run of 3 hours, have been found, with savings increasing rapidly with the increase in time of run of our system. Our results strongly suggest the use of our proposed system as a good alternative for the costly GPS system of location tracking.**

Keywords— GPS; Location Tracking; Low power; Smartphone; Sensors; Accelerometer; Magnetometer.

I. Introduction

Tracking the location of any object or person, generally termed as localization, has been very interesting topic of practical application and active research. This has improved reach of persons to unknown locations with much ease. Tracking locations of an object or a person while it is moving (termed as navigating), has been very popular in the research community since very long. It involves the use of Global Positioning System (GPS) technology to continuously track mobile objects while they navigate. GPS systems work by communicating directly with at least three GPS satellites (four in case of 3-dimensional tracking) to trace the latitude and longitude coordinate values of an object's current location. Now-a-days, even moderately priced smart-phone devices are equipped with GPS units that contain an antenna that uses the battery power of the device to communicate with the GPS satellites. This communication occurs at a data rate of around 50 bits per second and for long durations to precisely identify the current location of a device. This communication is very costly in terms of the power consumption of the smart phone device and the time taken, though after delayed initial start-up, it quickens a bit. Even then, it requires continuous communication with the satellites for continued tracking of the device, or while navigating.

The smart phones now-a-days are essentially equipped with other sensor units that communicate locally to do their tasks. Some of them include the accelerometer, the magnetometer and the gyroscope. The product cost as well as operational cost of these sensors is much cheaper than the use of GPS units. We have, in our proposed work, devised a technique that uses combination of these 'local' sensors as a very cheap and efficient alternative to the costly GPS. The accelerometer, the magnetometer and the gyroscope have been used in combination to provide continuous location information of a moving object. This strategy ensures that costly satellite communication is avoided, and local calculations are used to generate latitude-longitude coordinate values of the successive locations. This process starts as soon as the initial location of the device is identified, which can be performed either using GPS initially, or by using known location points from a map.

The initialization step starts by asking the user to provide some initial information to calculate the foot-count and footstep-length. The walking or running pattern of a person is then identified using the device. After that, the latitude-longitude values of each successive step of the user movement are generated locally using smart phone sensors. This happens without using the costly GPS. One more advantage the proposed strategy provides is that it is equally capable of generating good location details even in indoor conditions where GPS suffers badly. This is true even in the case where GPS gets constrained by signal interference and cloudy weather conditions.

One of the major applications of location tracking can be found in a post-disaster rescue and relief operations where relief workers use smart phone devices to communicate to each other for sharing critical information. To track the location and the movement of a relief worker is of utmost importance in such scenarios, as is navigating on known or unknown paths. Because of limited battery power of the Smartphone devices and limited energy resources, GPS seems an inappropriate option for localization in a post disaster scenario. The strategy proposed in this works proves to be a very good alternative as a solution in such situations. Use of local sensors produce minimum delay and consume very low power as compared to GPS. Crippling of existing networks after a disaster minimizes the possibility of using other alternatives to location tracking like the AGPS, RSSI technique, etc.

In this paper we have reviewed the measurement techniques and evaluated the effectiveness of smart phone's sensors like the accelerometer, magnetometer, etc. for indoor and outdoor location tracking and navigation purposes. Our major challenges have been to reduce the power consumption of smart phone devices, to track location and to navigate in both indoor and outdoor locations, to minimize delay in getting precise location information, and to produce better and accurate results. We have, in the current work, proposed a novel method to track the location of a person carrying a smart phone in terms of latitude-longitude coordinate values. The movement pattern of a person, whether walking or running, has been identified using local sensors of the smart phone. This results in very small delay and huge power savings, as power consumption of in-built sensors is much lesser and it is much faster than the GPS system. Distance covered between two time instants has been calculated with the help of accelerometer, gyroscope, and magnetometer of the smart phone. While the accelerometer measures linear acceleration and angular acceleration separately, the magnetometer gives the direction of movement of the mobile device. One problem incurred in the measuring process has been due to amount of vibration produced while a person walks or runs carrying a smart phone. This creates a challenge to measure accurate reading from the sensors. We have analyzed the vibration of each foot step of a person and found some common patterns in the Z-axis (axis perpendicular to the earth surface) accelerometer reading. Using this, we have identified walking and running patterns of a person. First, the strategy calculates the average distance covered by each footstep of a person by asking to walk or run for a predefined number of footsteps. The total distance covered here is found using the initial and final GPS coordinates. This distance is divided by the number of footsteps to obtain average footstep length. The GPS unit is disabled thereafter. The next locations are calculated only by the accelerometer and the magnetometer readings of the smart phone.

We have implemented the proposed strategy in the Android platform. We have correctly identified the walking and running patterns of various users. The implemented system has been tested in both indoor and outdoor locations without any observable differences in performance. Huge savings in terms of battery power consumption, as high as 20 percent for a run of 3 hours, have been found, with savings increasing rapidly with the increase in time of run of our system. Our results strongly suggest use of our proposed system as a good alternative for the costly GPS system in case of location tracking.

The rest of the paper is organized as follows: section II describes the related major works that have already been done in the context of location tracking and navigation. Section III presents the details of our proposed strategy to perform location tracking and navigation using local sensors easily found on the smart phone devices. Section IV shows the experimental set-up used to perform our implementation and experiments, followed by the results obtained from performance of our proposed system. Finally, section V ends the paper with conclusions drawn from our research work, and some future tasks.

II. Related Work

The topic of location tracking (localization) and navigation has been so interesting in the research community that huge work has already been done in the area. Localization approaches rely on some form of communication between reference points with known positions and the receiver node that needs to be localized. Localization scenarios are of two types namely Indoor Localization and Outdoor Localization. Important and related research work done in these fields hasve been discussed next.

Any wireless technology [1, 2, 3, 4] including GPS [10, 13] can be used for localization. Many different systems take advantage of existing wireless infrastructure for indoor positioning. There are three primary system topology options for hardware and software configuration, network-based, terminal-based, and terminal-assisted. Positioning accuracy can be increased at the expense of wireless infrastructure equipment and installations.

Due to signal attenuation caused by building materials, satellite based GPS incurs significant power consumption and delay in indoor environment. Also, non-availability of sufficient number of GPS satellites prevent the GPS system to work precisely. People inside a building are localized using Indoor Positioning Systems (IPS). Instead of using GPS satellites, IPS systems rely on other technologies like radio waves, magnetic field, acoustic signals and other sensory information collected by mobile phones. Indoor localization is also achieved by Inertial Measurement Unit (IMU), Simultaneous Localization and Mapping (SLAM) using monocular camera and Wi-Fi SLAM. Indoor localization techniques are further classified into two types namely the non-radio based techniques, and the wireless techniques.

a Magnetic positioning

Magnetic positioning [9] generally relies on the iron inside buildings that create local variations in the Earth's magnetic field. Various sensors present inside smart phones are capable of sensing and recording these magnetic variations and is used to map indoor locations. This technique provides an indoor accuracy of 1–2 meters with 90% confidence level, without using the additional wireless infrastructure for positioning.

The drawback of this type of localization technique is that it is only applicable in indoor scenario such as inside a building. Moreover the position of the iron inside the buildings must be known. The dependency of this technique on irons limits its usage to few indoor regions, mainly buildings. Our proposed method does not depend on any such material and moreover our method performs well in both indoor and outdoor scenario.

A. Inertial measurements

Inertial measurement unit is an electronic device consisting of a combination of sensors, accelerometer, gyroscope and magnetometer. It is used for measuring velocity, orientation and gravitational forces.

In [11] authors used double integration of momentary accelerations to determine the position of a pedestrian. The inertial unit MTi of Xsens Technologies, and its variant MTi-G, which integrates a GPS and a barometer was used. They divided each footstep into two phases, swing and stance. The inertial measurement unit is attached to the foot of the pedestrian. The inertial unit measures the linear as well as angular velocity of each footstep for determining the displacement and direction of movement. The main drawback of this method is that the angular velocity measurement is reliable only for short interval of time (a few seconds) because of the inherent error of the sensors. Direction may be miscalculated because the foot may rotate during a walk.

III. PROPOSED METHOD FOR LOW POWER OBJECT TRACKING

We have proposed a method to calculate the GPS coordinates of a walking or running person carrying a smart phone without using the GPS sensor. We have calculated the distance covered by the person using the inbuilt sensors of a smart phone, such as accelerometer and magnetometer. We have analysed that while a person is walking or running with a smart phone, a certain amount of vibration is generated at each foot-step. We have identified those patterns by accelerometer value along the axis perpendicular to the ground which can be considered as a footstep as shown in Fig1(a) and Fig 1(b):

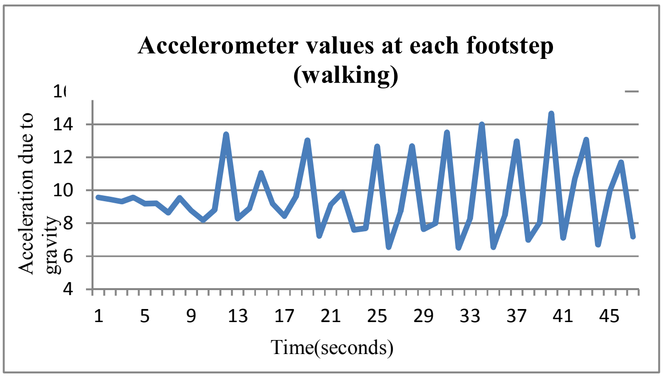

Fig 1(a): Pattern in accelerometer values while walking.

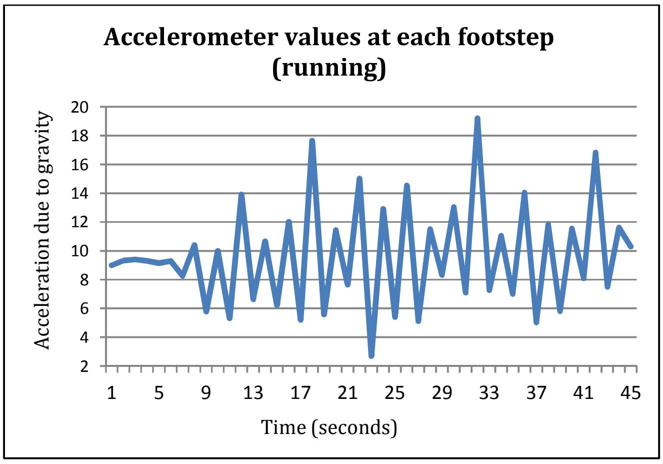

Fig 1(b): Pattern in accelerometer values while running.

Our method has been divided in two phases. In the first phase initially we are detecting footsteps for both walking (see algorithm 1) and running (see algorithm 2) using smart phone sensors, then we are obtaining the average foot-step length of the person (see algorithm 3).

A. Algorithm 1:

(Detecting footstep while walking)

Input : "ACC" = Accelerometer value, "Trig" = Boolean variable (initialised to FALSE).

Step 1 - Get accelerometer value in "ACC".
Step 2 - If "flag" less than or equal to 9.02, goto Step 3 Else goto Step 5
Step 3 - Set "Trig" = TRUE.
Step 4 - Goto Step 1.
Step 5 - If "flag" value greater than 9.8 and "Trig" is true, goto Step 6 Else goto Step 8.
Step 6 - Count 1 footstep.
Step 7 - Set "Trig" = false.
Step 8 - Go to step 1.
Step 9 - End

B. Algorithm 2:

(Detecting footstep while running)

Input : "ACC" = Accelerometer value, "Trig" = Boolean variable (initialised to FALSE).

Step 1 - Get accelerometer value in "ACC".
Step 2 - If "flag" less than or equal to 8, goto Step 3 Else goto Step 5
Step 3 - Set "Trig" = TRUE.
Step 4 - Goto Step 1.
Step 5 - If "flag" value greater than 10.1 and "Trig" is true, goto Step 6 Else goto Step 8.
Step 6 - Count 1 footstep.
Step 7 - Set "Trig" = false.
Step 8 - Go to step 1.
Step 9 - End

The constant values used in algorithm 1 and 2 have been found by analysing different values from accelerometer while both walking and running. In both the cases (walking and running) we have two threshold values, one smaller than the other. By experiments we found that when the accelerometer reading goes below the smaller value and then gradually starts rising and crosses the larger value, we can assume it as a footstep (both for running and walking). In the first phase the GPS location is fetched by the GPS receiver, and the person is asked to walk or run depending upon his choice for a predefined number of foot-steps, which should be greater than or equal to 25. After completion of that event the GPS location is fetched again using the GPS receiver. Then the distance between these two coordinates is calculated using the formula (1). As the accuracy of inbuilt GPS is about 5 to 8 meter (a circular area of radius 5 to 8 meter), by practical experiments we found that to get fairly accurate distance between the two initial GPS coordinates we need to take 25 or more steps. Lesser number of footsteps during the initialization may result in imprecise average foot-step length values.

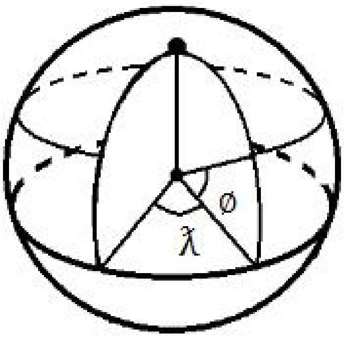

Fig 2: Surface of earth divided into latitude and longitude

$$D = R\sqrt{(\Delta\emptyset)^2 + (\cos(\emptyset_m)\Delta\lambda)^2} \quad (1)$$

Where:

$\Delta\emptyset$ And $\Delta\lambda$ are in radians. (As in Fig 2)

To convert latitude or longitude to radians we have used:

$1^0 = \frac{\pi}{180}$radian.

Differences in latitude and longitude are labelled and calculated as follows:

$$\Delta\emptyset = \emptyset_2 - \emptyset_1$$
$$\Delta\lambda = \lambda_2 - \lambda_1$$

It is not important whether$\Delta\emptyset$ and $\Delta\lambda$is positive or negative when used in the formulae (1), because the method uses the magnitude of difference in latitude ($\Delta\emptyset$) or longitude ($\Delta\lambda$).

"Mean latitude"$\emptyset_m$ is labelled and calculated as follows:

$$\emptyset_m = (\emptyset_2 + \emptyset_1)/2$$

Now by dividing the total distance (initially covered by predefined number of foot-steps) calculated using equation (1), the average foot-step length - AFL is calculated.

AFL=Total distance/total number of footsteps.

At the starting point "A" and ending point "B" as shown in

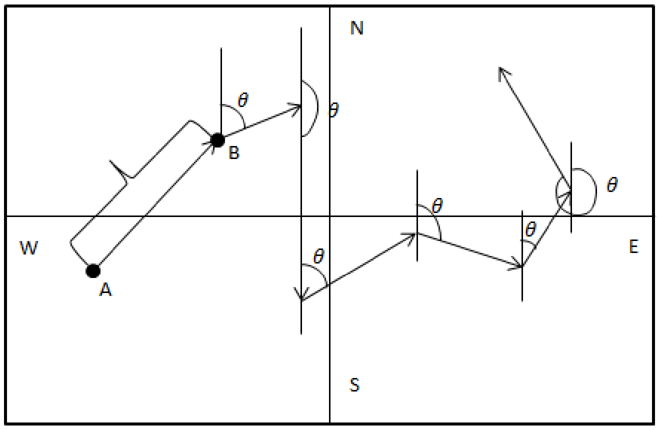

Fig 3: Movement pattern of a person

Fig 3, the proposed strategy takes the GPS location using GPS receiver after this the GPS sensors are turned off and the average foot step length is calculated. From the next foot-step the latitude and longitude values are calculated using the magnetometer value and average footstep length calculated in earlier steps.

Our proposed method also has an added advantage, if the initial GPS location and the average footstep length of the person is known, then there is no use of GPS sensors. GPS coordinates can be calculated only using magnetometer and accelerometer sensor values. We calculate the magnetic angle of the smart phone using the ORIENTATION_SENSOR which is provided by the android API. It uses accelerometer and magnetometer to calculate the magnetic angle of the phone where:

0 degree = North.
90 degree = East.
180 degree = South.
270 degree = West.

In second phase we make use of the average footstep length along with the direction in which the person is moving to calculate GPS coordinates. Then onwards after each footstep the new GPS coordinates of the person is calculated as shown in Fig 4.

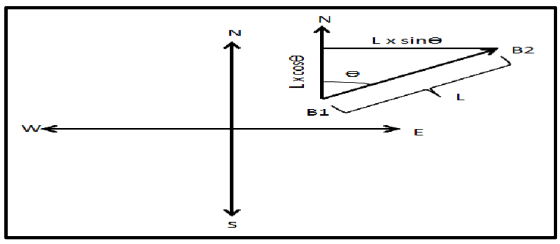

Fig 4: Calculating GPS coordinates using average footstep length.

From B1 to B2 (as in Fig 4) the GPS co-ordinates are derived by simple arithmetic operations. "L" is the average footstep's length, "θ" is direction of movement in degrees and is measured with respect to North direction. By applying the concepts of trigonometry, displacement along East (E) and North (N) axis are derived. For a right angle triangle

sinθ = height / hypotenuse.
cosθ = base / hypotenuse.

As shown in Fig 4:
Hypotenuse = L(the average footstep length).
So, Height (displacement along East as in Fig 4) = L x sinθ.
Base (displacement along North as in Fig 4) = L x cosθ.
As the displacement values are in units of length (meters in our approach), the proposed strategy converts that distance into respective "degree" values (latitude and longitude) using the corresponding formula as has been described in [8]. When the latitude difference is 1 degree, corresponding to π/180 radians, the arc distance, say ΔLAT, is calculated using equation(2).

$$\Delta LAT = \frac{\pi a(1-e^2)}{180(1-e^2\sin^2\emptyset)^{-3/2}} \tag{2}$$

When the longitude difference is 1 degree, corresponding to π/180 radians, the arc distance, say ΔLON, is calculated using (3).

$$\Delta LON = \frac{\pi a\cos\emptyset}{180(1-e^2\sin\emptyset)^{1/2}} \tag{3}$$

Where 'a' is the length of exact equatorial radius i.e. 6,378,137.0 m. 'e^2' is eccentricity squared having value of 0.00669437999014. Now based on "θ" (the direction of movement of the walking person), the degree of displacement values are added or subtracted (depending on the angle cosθ or sinθ may be positive or negetive) from the previous GPS co-ordinate i.e. latitude and longitude and new GPS coordinate is generated. Following is our proposed algorithm (algorithm 3 and 4) for calculating GPS coordinates using average footstep length and direction of movement.

C. Algorithm 3:

(First phase - calculation of average foot step length).
Initialization (to calculate average footstep)
Step 1. If initial location and average footstep is known.
Step 2. Enter initial GPS coordinates and average footstep length as an input to the application.
Step 3. 'AFL' = average footstep length.
Step 4. Else
Step 5. Find out the GPS location of the starting point (G1 = Lat1, Lon1).
Step 6. Walk straight along horizontal position for a reasonable footsteps, say 'n' and get the GPS location of the destination point (G2 = Lat2, Lon2).
Step 7. Calculate distance between G1 and G2 using (1) stated in section III.
Step 8. Calculate 'AF' = (distance/n);
Step 9. End.

D. Algorithm 4:

(Second phase - localization without using the Smart-phone's GPS)
Step 1. Initialize the visit from a location (lat1, long1).
Step 2. Recognize a foot step.
Step 3. Update Latitude and Longitude based on the distance of each foot step and the deviation of the angle compared to preceding direction.
Step 4. Record latitude and longitude value to a file.
Step 5. Put the co-ordinate to the map.
Step 6. Repeat steps 3 to 5 until the application is switched off.
Step 5. End

IV. EXPERIMENTS AND RESULTS

A. Experimental Setup:

The proposed strategy has been implemented in the Android platform with support to API level 14 and above. Experiments have been carried out extensively with persons carrying smart phones while walking and running in various paths and patterns as shown in Fig 5. We have used Asus Google Nexus-7andSamsung Galaxy Grand smart phones for carrying out our experiments. The primary challenge for our work was to eliminate rather minimize the inherent error of the mobile GPS sensors. The inbuilt GPS sensors of smart phone itself takes some time to initialize and give approximate location and that too with a certain level of accuracy. Here if the initial location that has been fetched is improper, then our approach would also produce some error. To minimize this error we have incorporated some delay while the app gets started. Meanwhile the GPS sensors can fetch the most approximate location with minimum error. Using this technique we have attained significant good results. We have traveled (by walking) a path of about 2 kilometers in Kalyani (a town in the West Bengal state of India), near Kalyani Government Engineering College campus as marked in Fig 5. Our walk initiated in front

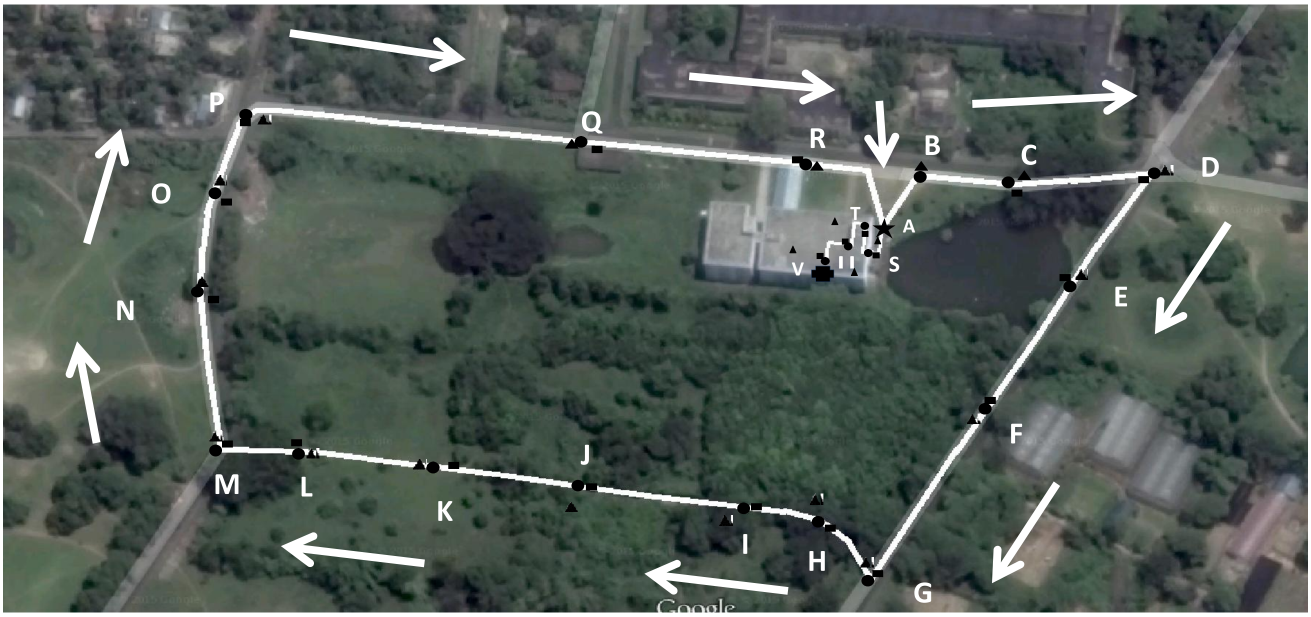

Fig 5: Experimental setup

of the college building marked as point A and denoted by a star symbol(★)in Fig 5. We walked a complete path and returned back to our college building, and the path ended at point V denoted by a plus symbol (✚) in Fig 5, which is inside the college building. We ended our walk inside the college building to check the accuracy of our approach in indoor scenario also. We have collected the locations of specific points at certain interval of distance as denoted by circular symbol (●) in Fig 5, both using our application (TrackMe) as well as inbuilt GPS sensors. Also we have obtained the actual coordinates from Google Maps denoted by triangular symbol (▲) in Fig 5.The coordinates calculated by our application (TrackMe) is denoted using square symbol (■) in Fig 5.

B. Results:

- Comparison of accuracy of using inbuilt GPS and our localization approach*:*

In Fig 5, the circular symbol denote the actual location obtained from Google Maps, the triangular symbol represent location from inbuilt GPS sensors, and the square symbol represents location calculated by our application (TrackMe). The following table shows the comparison between actual location, location from GPS sensors and location calculated by our application (TrackMe):

Table 1: GPS coordinates obtained by inbuilt GPS and our application.

Points	**Original location (Google Map)** ●		**GPS of smart phone** ▲		**Our application (TrackMe)** ■	
	Lat	***Long***	***Lat***	***Long***	***Lat***	***Long***
A	22.990603	88.448867	22.990611	88.448864	-	-
B	22.990756	88.448972	22.990772	88.448963	-	-
C	22.990725	88.449247	22.990731	88.449289	22.990689	88.449286
D	22.990767	88.449757	22.990761	88.449772	22.990764	88.449724
E	22.990380	88.449503	22.990394	88.449521	22.990372	88.449476
F	22.989928	88.449204	22.989892	88.449153	22.989942	88.449210
G	22.989403	88.448861	22.989442	88.448834	22.989417	88.448876
H	22.989506	88.448607	22.989581	88.448592	22.989514	88.448598
I	22.989592	88.448396	22.989586	88.448429	22.989542	88.448323
J	22.989656	88.447858	22.989609	88.447864	22.989642	88.447894
K	22.989723	88.447389	22.989720	88.447364	22.989739	88.447410
L	22.989784	88.446904	22.989781	88.446950	22.989790	88.446938
M	22.989801	88.446649	22.989823	88.446628	22.989803	88.446661
N	22.990354	88.446569	22.990366	88.446587	22,990313	88.446626
O	22.990708	88.446635	22.990739	88.446659	22.990689	88.446674
P	22.990984	88.446747	22.990990	88.446799	22.990962	88.446738
Q	22.990884	88.447849	22.990864	88.447821	22.990909	88.447843
R	22.990803	88.448587	22.990789	88.448608	22.990800	88.448551
S	22.990444	88.448814	22.990497	88.448826	22.990435	88.448820
T	22.990583	88.448787	22.990591	88.448666	22.990586	88.448750
U	22.990522	88.448684	22.990474	88.448554	22.990538	88.448672
V	22.990438	88.448638	22.990360	88.448726	22.990444	88.448611

From this comparison we found that in outdoor scenario both GPS as well as our application (TrackMe) has certain level of accuracy. GPS itself has an accuracy of 5 to 8 meter, due to which some inaccuracy get incorporated in our application since we are initially getting the location from inbuilt GPS. By carrying out various experiments we have found that if initially GPS location is correctly fetched from satellite then our application (TrackMe) performs with accuracy 2 to 8 meter. Further this accuracy depends on the accuracy of footstep detection and also how accurate the magnetic angle is detected.

- Accuracy of footstep count:

We have, in our application, used the change in acceleration due to gravity sensed by the sensors of smart phones to count the number of footsteps taken by the user. Since various smart phones come with various types of sensors, they have different accuracy level. Our application also depends on the accuracy of these smart phone sensors. We have tested the footstep count using various smart phones and the results are described in Fig 6.

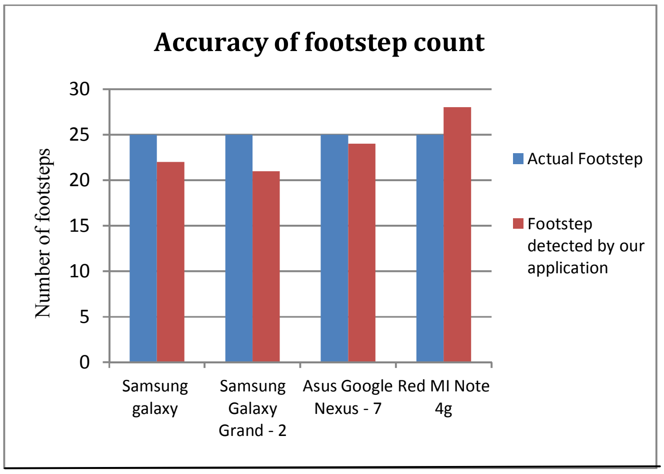

Fig 6: Footstep count accuracy in different android smart phone devices.

Based on our experiments we found that the error in footstep count is 10% to 15% depending on the smart phone sensors. Now average footstep length of a person generally lies between 0.5 to 0.8 meter. Based on this our localization algorithm provides accuracy between 2 meter to 8 meter which is considerable for tracking in indoor or outdoor situation.

- Comparison of battery power consumption of the smart phones:

We have monitored the battery power consumption of smart phones while using our application (TrackMe) and also the inbuilt GPS application, Fig 4 and Fig 5 shows the comparison between them. We have used Asus Google Nexus-7 smart phone, which comes with android operating system and a 4325 mAh Li-Ion battery, for monitoring the battery power consumption. We assumed a constant time frame of about 3 hours(180 minutes) and constantly monitored the battery power consumption using both approaches, and as we can see in Fig 7 and Fig 8, our proposed approach performs better is terms of power consumption which can be very useful in post disaster scenario.

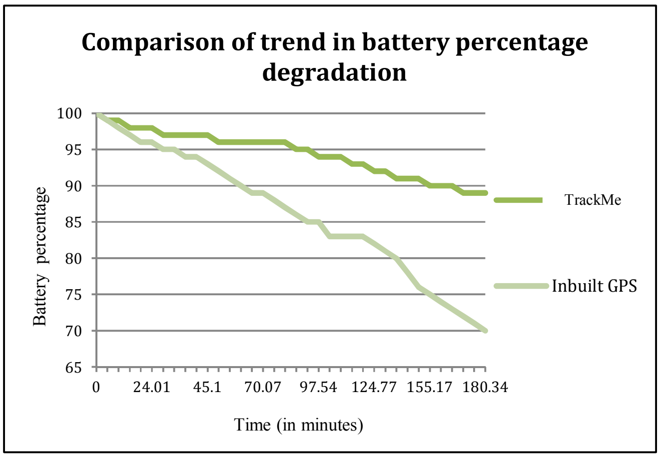

Fig 7:Degradation of battery percentage of smart phones using our approach and inbuilt GPS.

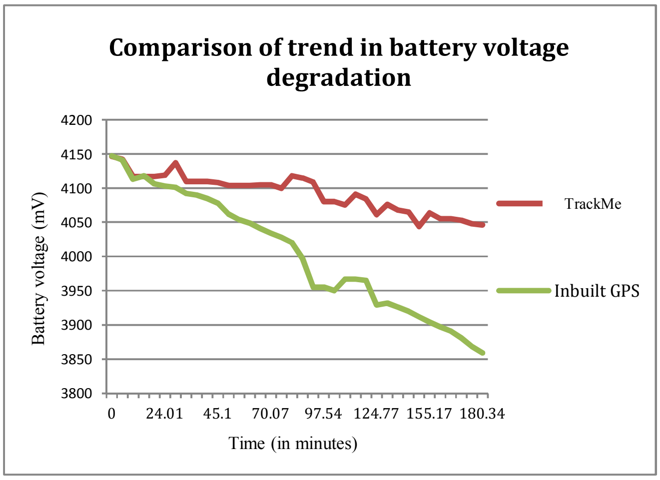

Fig 8: Degradation of battery voltage of smart phones using our approach and inbuilt GPS.

Fig 7 gives the comparison of trend in battery percentage of smart phone while using our developed application and inbuilt GPS. Fig 8 gives the comparison of trend in battery voltage of smart phone using our developed application and inbuilt GPS. We can see that using our application for about 3 hours battery percentage degrades from 100% to 89%and using GPS for about 3 hours the battery degrades from 100% to 70%. By analyzing the rate of battery degradation we found that using our application full battery drains in 13.63 hours whereas using GPS full battery drains in 9.09 hours. Thus we can see that we can extend the use of smart phone up to 4 hours approximately using our application. In terms of efficiency we can say we are getting 30.76% of extra battery life if we use our application.

This technique is also very useful in post-disaster scenario. As indoor localization is a challenging task. Many approaches are there for indoor localization but all of them are depend on signal interference, signal to noise ratio and obstacles. But in our approach localization only depend on internal sensors, so there is no probability of measurement's error with respect to other approaches.

V. CONCLUSION AND FUTURE WORK

Localization and navigation techniques are continuously researched for improvement in their performances owing to their increased practical use and applications. In the current work, a highly efficient technique for localization and navigation has been proposed. The considered scenario consists of situations where human beings walk or run while carrying a smart phone device. An example is the post-disaster relief and resource management. Initially, the walking and running patterns of persons carrying smart phones are identified using local sensors of the smart phone namely the accelerometer, magnetometer and the gyroscope. The identified patterns along with user foot-counts are used in combination to predict the user's foot step length. This is used to continuously locate and track the user's locations while navigating. We have implemented our strategy in the Android platform and have carried out tests using variety of smart phone devices. We have found location accuracy of around 2-5 meters. The system has been tested on both indoor as well as outdoor locations without any observable difference in performance measures. Huge savings, as compared to the existing GPS system, in terms of battery power consumption, as high as 20 percent for a run of 3 hours, have been found, with savings increasing rapidly with the increase in time of run of our system. Our results strongly suggest use of our proposed system as a good alternative for the costly GPS system for location tracking and navigation.

In our future work we would like to calculate the distance using linear acceleration so that persons sitting in car or bus can also track their location. Also, multiple orientation of the devices would be checked in future for their performance.

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