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Effector: Energy Efficient Mobility Classification and State Based Route Creation

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Abstract: **— Mobility analysis of users with or without location determination using accelerometer sensor embedded within the user smart phone is energy efficient and provides real-time contextual information. The accelerometer measurements for mobility analysis of human beings presents its own challenges as users carry their smart phones differently and these measurements are dependent on body placement of the mobile phones. On demand remote data exchange for analysis and processing of measurements plays a key role in mobility state analysis using accelerometer sensor which is less energy efficient has higher network costs and is not real time. This method presents an energy efficient novel framework capable of identifying mobility state of the user and creating route maps based upon a probabilistic algorithm that neutralizes the effect of different smart phone on body placements and orientations to allow human movements to be more accurately and energy efficiently identified. In addition it tracks the location of the user and creates routes based on the mobility states. The use of embedded smart phone accelerometer and GPS without need for referencing historical data and accelerometer noise filtering is capable of identifying human mobility states in real time with a time constraint of 2 seconds based on which user paths can be generated. The method achieves an overall average high classification accuracy and saves energy to a great extent when compared to exsisting GPS only usage for route creations.**

Index Terms**— Energy Efficient Mobility Classification and State Based Route Creation (EFFECTOR), Global Positioning System (GPS), Smartphone Accelerometer, Activity Log, Activity Chart, Route Maps.**

I. INTRODUCTION

Mobile computing is a technology that allows transmission of data, voice and video via a computer or any other wireless enabled device without having to be connected to a fixed physical link. It is human computer interaction by which a computer is expected to be transported during normal usage. One of the applications of mobile computing is mobility based services. Mobility awareness and mobility based services (MBS) focus on mobility in the sense of how someone or something moves in the physical world to a pre-planned destination and covers ad hoc movement away from the current location. The emphasis is on the type of the mobility rather than on the location context, however these two may be combined in a complementary manner. Mobility can be determined using smart phone sensors such as accelerometer and GPS. The first one is a non transceiver based sensor that directly measure physical world phenomena that relate to position and/or orientation changes. The accelerometer is the most valuable non-transceiver sensor used to provide the data for activity monitoring as it gives more information about movement forces. Accelerometer is used to measure the acceleration force a moving object. The second sensor GPS is a transceiver based location signal sensor which require data exchange between multiple transmitters and receivers, determining the degree of physical exercise, the usage patterns for types of public and private transport, the time spent at a location all relate to human mobility profiling which constitutes one of the motivations for mobility based services. Adapting to the mobility information services dynamically based upon the travel mode in case where a pedestrian map is triggered after detecting walking shows safer places to cross roads whereas a motorist map focuses more on the main routes which is another motivational factor for MBS.

II. LITERATURE SURVEY

There are several methods for detecting human activities. Electronic pedometer [1] is a simple portable and electronic device used to assess physical activity. The device is used to determine the step count that a person takes by detecting the motion of the person's hands or hips. The step counts thus obtained can used to determine the distance travelled by user. This work could determine only step counts and no other mobility states could be determined.

User annotated acceleration data [2] uses multiple wire free accelerometers are mounted on hoarder boards and worn simultaneously on different parts of the body to detect mobility states of user. Accelerometers sample acceleration values for various activities of the user during a specific time intervals. However since multiple accelerometers were used it caused practical difficulties for the user and could be used only in laboratory settings.

Befit garden [3] uses on body sensing, activity inference and a novel personal, mobile display to encourage physical activity. It consists of three components fitness device, interactive application, glance able display. This system consists of two separate entities MSP and mobile phones. Hence user has to maintain these two entities and hence maintenance overhead is slightly high and on body placements of MSPS are required for correct inference of activities.

Using every day GSM traces [4] and parsimonious mobility classification using GSM and Wi - Fi traces [5] for mobility detection uses coarse grained GSM data from mobile phones to recognize high level properties of user mobility. These signals preserved the location privacy details of the user as Wi - Fi and GSM signals do not use location details of the user for mobility detection. But these signals could classify only limited activities like dwelling, walking or driving and also resulted in decreased detection accuracy.

Mobility based on GPS data [6] infer peoples motion modes from their GPS logs. Mobility classification is performed by the segmentation, feature extraction, and inference processes. Though detection accuracy is high using GPS data's, it reduces the battery life of to a great extent thereby increasing energy consumption.

Wang [7] in his work identifies an energy efficient mobile sensing for automatic user state recognition (EEMSS) which is a sensor management scheme for mobile devices. The demerit of using this scheme are on body placement of accelerometer is required hence its limited use. Also it was used to identify only if object is moving and trigger other sensors for motion type identification.

The above mentioned related papers had limitations like low detection accuracy and high phone battery power consumption. These drawbacks were overcome by the energy efficient human mobility sensing (EHMS) [8] model. This model is used to classify the real time human mobility state using smart phones. The novel features of this research when compared to previous systems involving activity recognition was that it used extracted features from accelerometer data sensitive enough to classify activities with similar human patterns. This model permits similar activities such as motorized travel by bus and car to be classified at granular levels because the accelerometer data was more aligned to the activity.

III. PROBLEM DEFINITION

The EHMS model used a standalone accelerometer framework for detecting human activities. One major drawback of this system was that it could not be used for determining the location or position of the user. This standalone framework could be further extended or enhanced to support various mobility based service applications in a better energy efficient manner. As the sensor used was a single accelerometer this model was incapable of identifying the user position or location. These limitations were looked upon and a new method was introduced to identify the position of the user along with their mobility states.

IV. NEW METHODOLOGY

To overcome the above mentioned drawbacks of the existing method which was EHMS a new system has been introduced called effectors which are energy efficient mobility classification and state based route creation. The salient features of the new system that overcomes the limitations of the existing system are that this new system is an energy efficient mobility classification model that integrates the energy efficient human mobility sensing model along with the GPS sensors. This model can be used to identify the mobility states of users using an embedded smart phone accelerometer. It can also be used to identify the user locations with the help of GPS sensors inside the user phone.

4.1 Effector system architecture

effector consists of six following phases. They are

- Activity detection
- Feature extraction
- Activity personalisation
- Mobility classification
- GPS based location tracking
- State based route creation

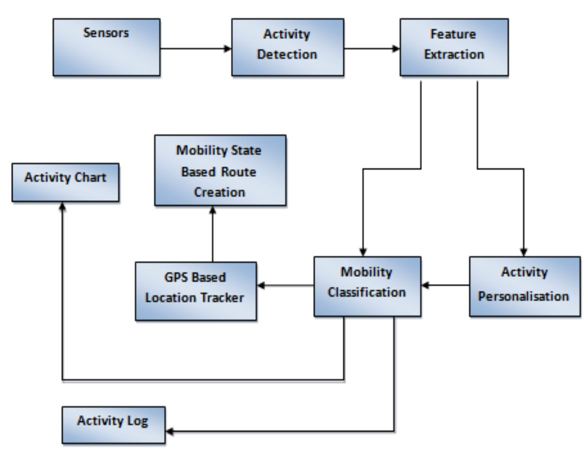

Figure 1: system architecture of effector

4.2 Activity detection

Mobility can be determined using smartphone sensors like GSM, wi-fi, GPS, accelerometer etc. Of the above, the sensor that consumes the least amount of battery power of mobile phone is the accelerometer. Hence the proposed system uses accelerometers for detecting activities of the user. These sensors directly measure the physical world phenomena that relate to position and/or orientation of objects. In this activity detection phase the user activates the accelerometer sensor in his smartphone and performs an activity by holding the smartphone or placing it on any part of his body. The accelerometer senses the activity performed by the user and starts capturing the activity readings in the x,y,z, z directions.

4.3 Activity feature extraction

In this phase of the proposed research, the focus is on using these 3d readings captured by the accelerometer for a user activity and determines a parameter called magnitude of the accelerometer signal vector (MASV). This MASV is used to combine (x, y, and z) readings regardless of the smart phone orientation. Using the magnitude of the accelerometer signal vector six other computation features are extracted as classifiers from the accelerometer readings for a given human mobility state. These extracted features are light to calculate and can be extracted using a comparatively low sampling rate such as 4 HZ and setting the extraction window as 2 seconds. For identifying similar activities features like mm, PMM and TMM are extracted and for different activities peaks and troughs are extracted.

4.4 Activity personalization

This personalization phase is the next step once the above features have been extracted for an activity. For similar activities different human mobility patterns are generated by different users. The personalization algorithms must be able to adapt to the various variations while a user is performing an activity. This personalization process is a onetime process where the user performs the activity continuously for 14 seconds. Activity personalization phase involves deriving the following: tpt range estimation, PMM range, and TMM range. Hence in this phase the user customizes the personalization algorithms for each type of mobility states and stores the values in the phone for further activity classification process. Personalization algorithm is used for determining the threshold ranges for a new activity performed by the user.

The design of the algorithm is as follows:

1. Initialize feature extraction period as 2 sec.
2. Initialize sampling frequency as 4hz.
3. Perform an activity continuously for 14 sec.
4. Extract peaks and troughs at interval of 2 sec.
5. Aggregate tpt values for all seven iterations
6. Check if sum for 2 or 3 consecutive tpt values is greater than or equal to 75 percent.
7. If true, tpt range for an activity is between the corresponding min and max tpt values.

4.5 Mobility classification

in the mobility state classification phase with the help of the extracted features from the accelerometer sensor, the next step is to identify the human mobility state of a user. This is determined with the help of the threshold values that are personalized for each user which are t_{pt} ranges, mm ranges, p_{mm} ranges and t_{mm} ranges. Accelerometers embedded inside the smart phone are used to identify the mobility state of an user once the determined values like mm, t_{pt} , p_{mm} and t_{mm} which are calculated every two seconds fall within the above estimated range values. The classification algorithm is used for identifying the mobility state of the user. The design of algorithm is as shown:

1. Initialize feature extraction period as 2 sec.
2. Initialize sampling frequency as 4hz.
3. Perform an activity.
4. Extract the peaks and troughs at interval of 2 sec.
5. Determine the values for mm, t_{pt}, p_{mm} and t_{mm} for the activity performed.
6. Verify if the value for mm, t_{pt}, p_{mm} and t_{mm} falls within the max and min threshold values.
7. If true, current activity is the mobility state stored in user phone.

4.6 GPS based location tracking

The mobility state classification phase determined with the help of the features extracted from the accelerometer helps to identify the mobility state of the user. These results can be further used by the user to create routes based on the activity states with the help of GPS location based sensors embedded within the user's mobile phone. Once the mobility state of the user is identified the GPS sensor in the user phone is automatically switched on. Once the GPS is switched on the location of the user is identified at that particular point. The location details of that particular user position are stored and the GPS is switched off. The user keeps on moving and after a particular interval of time the GPS is switched on again and the user location at that point is determined and stored. The GPS is switched off again. The same process is repeated for a sufficient interval of time. Thus as the user moves the location of the user is tracked at different points in an on and off manner using the GPS. The locations thus determined are collected and a path is generated connecting the start and end points along the intermediate locations determined. The pedestrian path thus determined is plotted on a google map.

4.7 State based route creation

once the mobility states of users have been identified route maps can be created for users. The route maps may be pedestrian paths or jogging paths depending on the identified mobility state. These route maps are created using embedded GPS sensors inside the user phone. The advantage of such route maps are they can be used by the users for their customized uses or can be monitored by an admin persons like trainers or government bodies planning for urban development. The route creation algorithm is used to create route maps for users based on their identified mobility states. This is done with the help of GPS sensor inside the user phone. The below steps describe the design of the algorithm.

1. Determine the mobility state of user
2. Automatically turn on GPS sensor in the user phone.
3. Identify and store location details of the user at that point.
4. Turn off the GPS in the user phone.
6. Repeat step 3 through step 5 at time interval of 2 minute until user reaches his destination.
7. Collect the stored location details from the start point to the destination point.
8. Create route map for a pedestrian path with the connected locations using google map api's
9. For states other than walking, running and jogging user location is determined.

V. RESULT ANALYSIS

This integration model specified in the proposed system determines both the mobility state and location of the user. It is an energy efficient scheme which consumes lesser battery power of phone when compared to standalone GPS sensor used

For creating user routes. In the given figure the x axis denotes the exsisting and the effector system and the y axis denotes the resource utilization over time for these two systems. It has been analyzed that for a time interval of 2 minutes, the exsisting system consumes about 192 volts of battery power whereas the effector system consumes only around 16 volts there by saving energy consumption of mobile phones. The proposed system also motivates user to perform physical activities as the user is able to get his activity details in logs and charts. The activity detection accuracy is comparatively higher as accelerometer is used for activity detection before user routes are created.

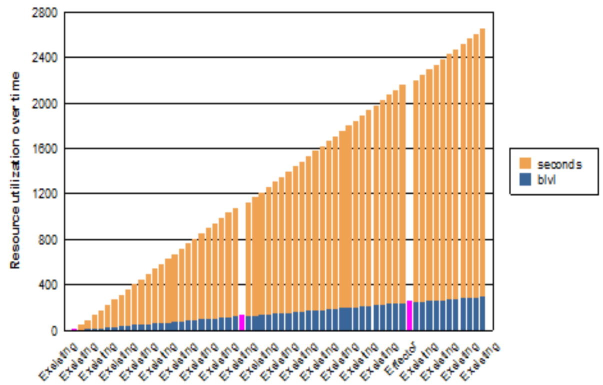

Figure 2: comparison of energy consumption of GPS only system and effector system

VI. CONCLUSION

Effectors present novel frameworks that can energy efficiently identify human movements and location in real time. It neutralizes the effect of different smart phone on body placements and orientations for mobility classification as this model is able to identify the human mobility states irrespective of phone positions. It also creates routes like pedestrian paths or jogging paths for users based on mobility states saving battery consumption of the user phone to a great extent. Hence the proposed system can in addition use the inferred mobility states and create routes like pedestrian paths or jogging paths using GPS based location tracking system in an energy efficient manner. Position determination alone cannot differentiate between some human transport modalities or activities. Additional types of mobility context, other than location need to be sensed to classify these states. Hence our scheme combines acceleration values with location determination. Thus the new proposed system provides a real time human mobility state classification algorithm without need for referencing historical data. It also provides classification of the human mobility state regardless of the smart phone alignment and on body placement. Light weight accelerometer data feature extraction is another added advantage of this proposed scheme. Also there is no need for a remote server connection for computational purposes as all processing is performed within the smart phone. The proposed model is also relatively insensitive to noisy data. This scheme classifies human mobility states using probabilistic algorithms and feature extraction process on the smart phone accelerometer data. Location details are determined along with activity details which is another advantage of this proposed scheme. Thus the new classification and route creation scheme is energy efficient as it uses a switch on switch o mechanisms for route creation.

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