AN IMPROVED ANDROID-BASED APPLICATION FOR TRAVELER LOCATION MONITORING USING RAY CASTING GEOFENCE AND KALMAN FILTER ALGORITHMS

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ABSTRACT: Geo-fencing is a virtual perimeter in a geographical area that uses location-based services as a boundary for an area. To provide better accuracy and improving tracking of travellers using an optimized virtual fencing (geo-fence) to detect unusual user locations. This work presents a proposed technique for testing the possibilities of merging a geo-fencing technique and Kalman Filter to provide more accurate data to the smartphone users. The location monitoring system is an LBS (Location Based Services) system which utilizes the GPS found on a smartphone. This location is subjected to error variance using Kalman filter and then sent to the server. The server will display the location of the traveller's whereabouts on a map that can be accessed via the website or next of kins smartphone. The use of geo-fencing would limit traveller supervision areas and notification will appear to user in the form of a message or alarm via their smartphone device should in case the traveller leaves the Geo-fence area. The proposed scheme presents a model that allows family members to directly monitor the whereabouts of loved ones using the incorporation of Geofencing technology, Kalman filter, GPS, and SMS (Short Messages Services).
KEYWORDS: Geo-fence, tracking, Location Based Services, Smartphone, coordinates, Kalman Filter

1. INTRODUCTION

GPS is a technology that enables the location of people and goods. It works by using signals from two or more satellites (Kharisma et al., 2019; AlRashed et al., 2013). Kidnapping, insurgency, and other security attacks have been observed on Nigerian highways in the past few years (Chinwokwu & Michael, 2019). Series of attacks on innocent victims in moving vehicles, and abduction of individuals in their vehicles has risen alarmingly in the past few years (Alofe et al., 2019). According to Alofe et al., (2019), mobile tracking application can help with user locations. However, the device should be easily accessible and can be used to unlock a phone instead of trying to lock it. Additionally, the device must be lightweight while proffered solution should include a method for detecting and forecasting the victim's or moving vehicle's location. Furthermore, the application must be able to notify a third party in order to provide the quickest assistance (Alofe et al., 2019). One of the main advantages of GPS is that it can be used to monitor the movements of individuals (Ahmad Fuad & Drieberg, 2013). However, it is very expensive and comes with high subscription fees. This is not an ideal solution for parents who are not able to afford the GPS device (Tayo et al., 2014).

Geo-fencing is a term that refers to a virtual fence that surrounds a conditional location (Yelne & Kapade, 2015). It refers to a method of limiting mobile users to a specified geographic location by using GPS to track their location (Raflesia et al., 2019). Geosecurity is a place-based service that allows users who enter/exit a specified geographical area, called a geosecurity, to receive messages (Eldho John & Joseph Mamutil, 2021; Rahate & Shaikh, 2016). It is now one of the most widely used location-based mobile tracking strategies. However, the process of creating geo-fences is currently manual (Muriach, 2015), requiring a retailer to identify the geo-fence position and radius of region around it. As soon as the traveler steps out of the Geofence area, the next of kin can be warned by SMS, voice alert or mail. Geofence is designed in two ways: The first one is static geofence, the polygon area defined herein are used as geofence (Ozdemir & Tugrul, 2019). while the second one is followed by the dynamic geofence and the map is used as a geofence area without recording the polygon. The advantage of this is to make new drawings at any time and actively use the work (Ozdemir & Tugrul, 2019). There are many causes of errors in the GPS data (Pochampally & Liu, 2018). A few of these are weather conditions, reflections in the atmosphere, and the reflection of the signals hitting buildings. This error rate may vary depending on the device used, the weather conditions at the location and the density of the building. Although the error in the data is caused by many reasons, the error rate can be reduced by making corrections on the data (Ozdemir & Tugrul, 2019).

Kalman filter is a method that can estimate the values of systems in many different fields. In mathematical terms, the Kalman filter predicts the states of a linear system (Ozdemir & Tugrul, 2019). Generally used in GPS systems. It was also used in this study and tested how much it reduces the error. The real purpose of the Kalman filter is to reduce errors in the covariance matrix (Zahaby et al., 2009). The basic Kalman filter accepts measurement results as a linear system, but not many systems in the real world. For this reason, the Kalman filter has been developed and diversified. In this study, a linear Kalman filter was used.

This paper focuses on geographic coordinate and how the application can be opened without delay, in real time, and using geographic location-conscious pushing notification/message to end users. This would enable the recognition of the location in the background, which can cause relevant geo-push messages and optimize battery use, making them as sensitive to end-user privacy as possible. Furthermore, most efforts to optimize the deployment of geo-fences for the tracking of mobile applications lost some precision when trying to optimize batteries.

The focus is on the improvement of GPS data and geo fencing algorithm using an improved Kalman filter and the implementation on an android application. If users are in dangerous situations, the app may send some information on where an individual is disturbed by geo-fence (Gupta & Harit, 2016). Over the years, researchers have tried to figure out how to make best use of that awareness of location for smartphone users, and new modes of activating mobile operating systems (OS) for users based on current location have also been enhanced.

Kalman filter is a method that can estimate the values of systems in many different fields (Güzel & Meral, 2018; Patel & Thakore, 2014). In mathematical terms, the Kalman filter predicts the states of a linear system (Zahaby et al., 2009), generally used in GPS systems. Kalman Filter was first discovered by Rudoff Kalman. It is a filter that is dynamic and can predict the location of the next system in a system with known state space using previous data. If there is scholastic or random noise in the system, the Kalman filter works very well (Patel & Thakore, 2014). The real purpose of the Kalman filter is to reduce errors in the covariance matrix. The basic Kalman filter accepts measurement results as a linear system, but not many systems in the real world (B et al., 2019). The research work focuses on improving location tracking for traveler's using geo-fence and improving the accuracy of the latitude and longitude of the GPS using the Kalman filter algorithm.

2. LITERATURE

This section presents works that has been presented in this area of research. Eldho & Joseph, (2021) proposed the use of neural networks in the geofencing field. The authors explained how neural networks are used to detect a geophysical point. A Client/Server architecture is developed, the server receives the coordinates of the geofence and the dataset of coordinates is then given to the neural network for training. After training the parameters are put in to a file and sent to client. A program was also set up to automatically adjust the neural network to optimize the respective parameters. It is proved in this study that neural networks perform better over commonly used techniques such as the Ray casting method. Arief et al., (2020) proposed a dynamic applies dynamic geofencing technology in monitoring salesperson performance where in some cases many workers enter the area of other workers. By utilizing GPS technology, the signals of employees' cellular devices can be tracked or monitored, if one day employees cross the geofencing area, the supervisor will receive a notification from the system. The method uses G PS technology to monitor the performance of salespeople when they enter an area of other workers. This system can also be used to provide supervisors with information about the whereabouts of their workers.

Hazan & Shabtai (2019) introduced a method that dynamically updates the probabilities of the grid-based location predictions made by the algorithms after processing the user's feedback. This method achieves its goal by taking into account the user's speed and direction in the post-processing step. The method was able to improve the accuracy of the predictions by up to 90%. Raflesia et al., (2019) developed an IT-based protection for children that can help parents and government monitor the place of their wards. The system has developed a sensor module that activates the system to send parents and servers notifications. Furthermore, the geographical fence technology has been used to enable parents to monitor their children using the virtual fence feature. Ozdemir & Tugrul (2019) On the application screen, an audible warning is given when leaving the Geofence area. GPS does not always show the exact correct position; it has a certain margin of error. Many factors affect this margin of error. This causes the application to give false alarms and operate with the wrong location. In order to reduce this error, the error rate was tried to be reduced by using Kalman filter, logistic regression analysis and moving average filter. Normally the error margin of up to 15 meters is considerably reduced by these filters.

Alofe et al. (2019) suggested an effective strategy for saving victims by forecast the future vehicle locations to enable the rescue mission to be operated as soon as possible. The authors provided an overview of state-of-the-art personal safety and location forecasting solutions and offers an Internet of Things (IoT) based model of personal safety to anticipate future vehicle locations by utilizing complex analyzes of the existing and previous data variables, including the speed, direction and geo-location of the vehicles. Experiments based on real-world data sets show the feasibility of our proposed framework in predicting future car locations accurately. Jyothi & Harish, (2016) proposed a GPS tracking system consisting of a portable device, an asset or a vehicle, and a tracking center for which the location of this portable device was monitored. The GPS transfers the co-ordinates to the mobile tracking device, which can easily be sent to the tracking center using the free version of Google Maps APIs, by means of the GSM modem to a personal computer with multiple interface programmes (application programming interfaces). The tests show that the system is low cost, precise, real time and adaptive for a variety of applications. Gupta & Harit (2016) proposed a model for child safety through smart phones that provides the option to track the location of their children as well as in case of emergency children is able to send a quick message and its current location via Short Message services. This proposed system is validated by testing on the Android platform.

Lai et al., (2013) proposed a method known as a location-based delivery (LBD) combining the SMS and GPS and develop a realistic system for tracking target movement. LBD reduces the number and exactness of the location tracking in an acceptable range of short message transmissions. The LBD approach consists of three main characteristics: Short message format, position forecast, and dynamic threshold. The short message format defined is exclusive. The prediction of location is carried out using the current location, the moving speed and the target to predict its next location. The goal was to transmit a short message to the tracker when the distance between the predicted location and the current location exceeds some threshold. The results from the experiment show that LBD actually surpasses other methods because the accuracy of location tracking with relatively few messages is maintained satisfactorily. Zhuang et al. (2010) developed a framework and tested on an Android prototype which follows a principle to increase the efficiency of GPS access when certain locations use GPS asynchronously to make the system more energy efficient. Its four principles are substitution for alternative positioning methods, removal to use fewer high-power sensors such as an accelerometer to determine when a user is moving and does not update the location where it is not moving instead of updating GPS within a fixed time interval. Their prototype reduced the number of GPS calls by up to 98% and improved battery life by up to 75%. Zahaby et al. (2009) presented a novel technique to send GPS coordinates to other mobiles through Short Message Service (SMS) based on Global Positioning System (GPS) technology. Two algorithms, Kalman Filter and Velocity Renovation, which can be used in conjunction with GPS are used as a basis for location tracking. This technique can be used to help people, using their mobile with or without GPS, to find the location of a friend.

3. PROPOSED SCHEME

Inroduction:

The number of devices with integrated support for the Global Positioning System (GPS) are growing at a rapid rate. Today the technology is applied in a varied range of industries. For example: aviation, agriculture, traffic systems, emergency systems, surveying, environmental protection, recreation and many others all successfully employ GPS. A large segment of the current growth of GPS devices is coupled to the growth of the smartphone market. Location-based Services (LBS) became proactive by supporting smart notifications in case the user enters or leaves a specific geographical area, well-known as Geofencing. Therefore, we introduce a novel method to formalize sophisticated Geofencing scenarios as state and transition-based geofence models to track the location of a traveller as he/she embarks on a journey. There are two highly important aspects in order to cover sophisticated scenarios in which a notification should be triggered only in case the user crosses multiple geofences in a defined temporal order or leaves a geofence after a certain amount of time. The positioning accuracy of a GPS, has also become critical for assuring the efficiency and safety of both people and cargo transportation. There are several known cases of positioning error, leading to serious consequences, sometimes deadly ones. Therefore, obtaining precise positioning information

by means of GPS receivers is paramount. where users eventually will venture into areas unsuitable for GPS positioning and the necessary level of accuracy cannot be achieved.
Kalman filter is reliable and efficient way of noise removal process for especially signal and image processing fields. The position data obtained by the proposed device consists of the latitude and longitude data. Accordingly, faults occurring in the location data are the result of faults occurring in the values of latitude and longitude data. Hence, the Kalman filter is applied separately on the latitude and longitude values. The new latitude and longitude values, enhanced by the help of the filtering process(es) are reassembled to determine the new location, which is believed will be far more accurate than the previous measurements as it is expected.

Geofencing and Kalman Filter:
There are four main supporting components in Location Based Service technology which can be seen in the following figure. Geo-fence is a digital barrier that can be applied to monitor the movement of objects in a certain area, so that when the GPS detects an object being monitored past that limit, the system will notify the observer. The geo-fencing system is a system that can analyze and track the position of objects automatically and provide reports whenever and wherever when the object exits or enters geo-fence areas that have been previously determined by the observer. The geo-fence area is an area in the form of virtual geometry that limits certain locations. This geo-fence system can send notifications to the registered numbers if the vehicle leaves or enters a certain geo-fence area. An illustration of a point against a geo-fence can be seen in figure 1.

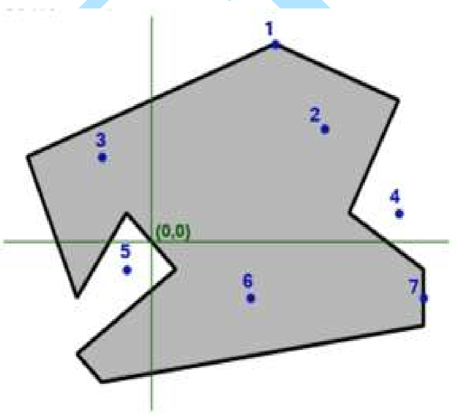

Figure 1: Illustration of a point against a geo-fence

From figure 1, four possibilities that occur are: a. a point is inside the polygon, b. a point is outside the polygon, c. a point is on a vertex (the intersection of two lines that form an angle), and a point is on the edge of the line.

The main purpose of introducing the Kalman filter is to reduce errors in the covariance matrix. The basic Kalman filter accepts measurement results as a linear system, but not for many systems in the real world. For this reason, the Kalman filter has been developed and diversified. In this study, a linear Kalman filter will be used. From figure 2, the input are the coordinates of the traveller as he travels and the latitude and longitude of the geo-fence. The state can be the position, velocity, acceleration, altitude or some other aspect of interest. The method alternates between two steps, the time update step and the measurement update step. In the time step, the state of the system is predicted forward in time using a model-based prediction given the current system state as input.

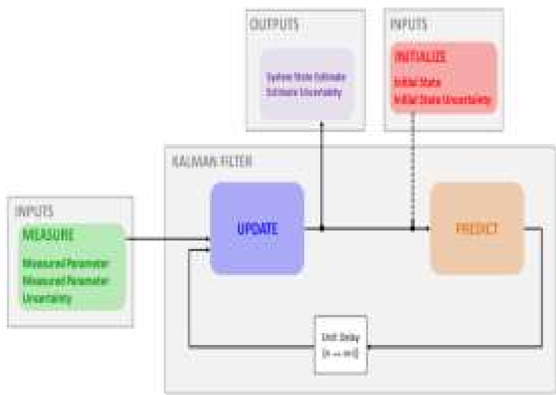

Figure 2: Illustration of the Kalman Filter

The main aim of this research is to develop an improved Android-based application for traveler location monitoring using Geo Fencing and Kalman Filter Algorithm. To achieve this set aim, the researchers intend to adopt the Ray casting algorithm for setting geo-fence, adapt the Ray casting algorithm with Kalman filter algorithm, then implement the algorithm for android based applications and a server to test to test it on. This is followed with the development and implementation of an algorithm to identify and classify points of interest that would be used to set a geo-fence. The application will then be subjected to tests and evaluations on the initial (adopted and implemented Ray casting Geo-fence algorithm) and the improved system (the combnation of Ray casting and Kalman filter algorithms) based on location estimation error.

The problem-solving method that will be used in developing this application is in building two web-based platforms as information data centers and smartphone-based for client data. Reading GPS coordinates from mobile devices which will be analyzed on the server side for object processing with the geo-fencing method follows. The research work focuses on a LBS (Location Based Services) system by utilizing the Global Position System found on the smartphone using Geo-fence and Kalman filter to improve GPS data for traveler location monitoring. The coordinates captured by GPS are sent to the server, then the server will display the location of the traveler whereabouts on a map that can be accessed via the website or the parent's smartphone device. Geofencing, which is a virtual perimeter in a geographical area that uses location-based services, is used to detect traveler leaving predetermined coordinates as it related to his destination. The Ray casting algorithm will be used to implement the point in a geo-fence. The Ray Casting algorithm determines whether or not the position of interest, Gi, is inside a given polygon p, by projecting an infinite ray from Gi. If the infinite ray intersects an odd number of polygon edges, then r is contained in p, otherwise, r is outside of p.

Tracking using GPS requires an active signal to be sent from the GPS receiver to a database or monitoring station via the cellular phone network. In order to track a person, item, or vehicle from a moving location, the person or organization wishing to perform the tracking must have access to parts of the application specifically designed for tracking.

Ray Casting Algorithm

Algorithm:

Input: p is a simple polygon
G_i is the position of interest
buf is a buffer distance.

Output: true if p contains G_i, otherwise false

1: count = 0
2: s is an infinite ray in the +y direction, originating at G_i
3: for all edges e in p do
4: if G_{i_x} is within buf of ex then
5: $e_{x,buf}$ = ex -2 * buf
6: else
7: $e_{buf} = e$
8: end if
9: if G_i is within buf of e or e_{buf} then
10: return false

If the traveler goes past the geofencing limit, a notification will appear to registered phone numbers in the form of a message or alarm via their smartphone device. This research work intends to implement a monitoring system for traveler's location using a smartphone that can send coordinate data from the smartphone's GPS to a web server and provide location information from the traveler based on the coordinates sent to the server and present it into a digital map that can be accessed by parents via website or smartphone. The accuracy of the coordinates is intended to be improved on the go using the Kalman filter algorithms.

Kalman filter is a method that can estimate the values of systems in many different fields. In mathematical terms, the Kalman filter predicts the states of a linear system. Generally used in GPS systems (Ozdemir & Tugrul, 2019). A web-based platforms would be built as server and smartphone-based for client data, by reading GPS coordinates from mobile devices which will be analyzed on the server side for object processing with the geofencing method and Kalman filter algorithm to improve GPS data. The Kalman filter algorithm is used at the beginning to provide accurate data before the Ray casting algorithm is been used to set a geo fence.

The proposed dataflow diagram, algorithm and flowchart for the improved Android-Based Application for Traveller Location Monitoring using Ray Casting Geo-fencing and Kalman filter algorithms are presented below:

The Dataflow diagram of the Geofencing algorithm which Kalman filter will be used to enhance is shown in figure 3.

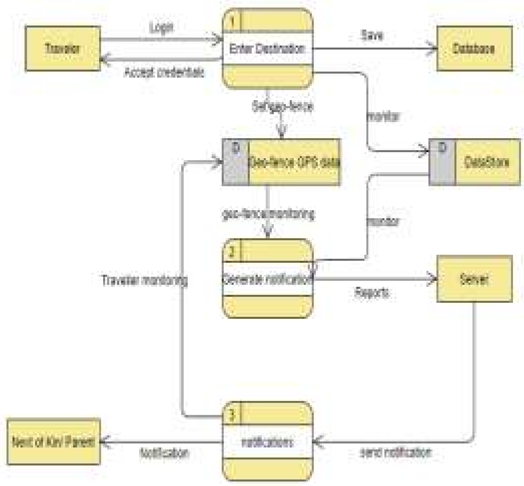

Figure 3: Dataflow Diagram of Proposed System

Input: index of set of geo-fence

Traveller route

Output: position with respect to geo-fence
Step 1: I = getIntersection(index, route)
Steo 2: Computer Prediction State
Step 3: Project the prediction State
Step 4: Compute Error Variance
Step 5: Compute Kalman gain
Step 6: Project the measurement state

Step 7: foreach pos ∈ I do
Step 8: prev pos = getP revP osition(route);
Step 9: Intersections
= getIntersections(pos, route)
Step 10: if getIntersection(pos, prev pos) is not null then
Step 11: if Intersections number is odd then
Step 12: the object left the fence
Step 13:else
Step 14:the object is still inside
Step 15:end
Step 16:else
Step 17:if Intersections is empty then
Step 18:the object is still outside
Step 19:else
Step 20:if Intersections number is odd then
Step 21:the object entered the fence
Step 22:else
Step 23:the object crossed the fence and it is outside
Step 24:end
Step 25:end
Step 26: end

The algorithm is however presented as a flowchart in Figure 4:

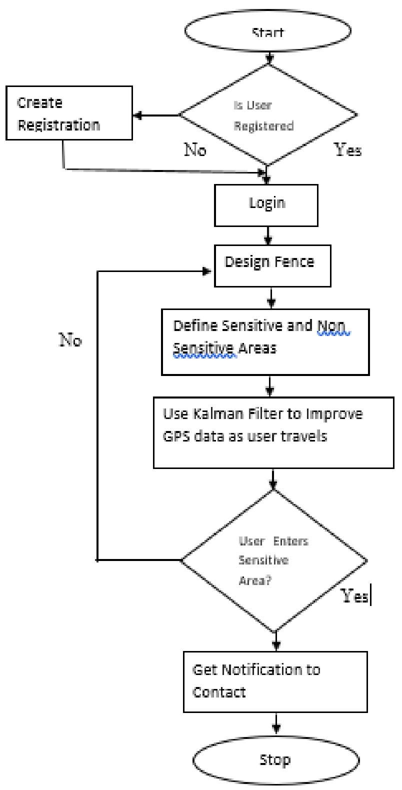

Figure 4: Flowchart for Geofence with Kalman Filter Algorithm

From the improved Android based algorithm, it is envisaged that the application of Kalman filter algorithm will significantly improve the accuracy of distance estimation for GPS in areas of bad signal reception when compared to the unfiltered raw data from the adopted Ray casting Geo-fencing algorithm.

4. DISCUSSION

This traveler location monitoring system would be implemented using GPS coordinates and Geo-fence from a user's Android based device. Retrieved information from the device is then sent to the server. Loved ones can monitor the traveller in real time through the website or registered Android device. This location monitoring system would be implemented to detect the traveler position, in and out of the geofence area, in and out of out of Points of Interest (POI) and Kalman Filter would be used to improve the coordinates by filtering to reduce errors in the covariance. This proposed location monitoring system would be able to send notifications to next of kin Android devices when certain conditions occur. Additionally, the location monitoring system would store track logs or traces of a user and present them in the form of routes on digital maps or in tabular form.

5. CONCLUSIONS

The work presents a model that allows family members to directly monitor the whereabouts of loved ones using the incorporation of Geofencing technology, Kalman Filter, GPS, and SMS (Short Messages Services). The main contribution of this scientific work is the supervision of travelers in real-time once they embark on a journey using Geofencing technology assisted by GPS so that traveler can be monitored. When traveler goes out of the specified area boundaries, a notification will appear to traveler and a SMS alert will be sent to three registered users that have been registered on the application. For the challenges for the future, the researchers will implement this proposed work (methodology) alongside the Ray casting algorithm, test and evaluate both systems in relation to location estimation error. The expectation here is that the proposed approach will successfully and efficiently detect cases of users leaving their predetermined locations in cases of kidnap and accidents.

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