GPS BASED MARITIME BOUNDARY IDENTIFICATION APPLICATION FOR MOBILE PHONES

B.M. Safras[#1], A.A. Ajmal[*2], D.U.J. Sonnadara[#3]
[#]Department of Physics, University of Colombo, Colombo, Sri Lanka
**Department Electrical and Information Engineering, University of Ruhuna, Galle, Sri Lanka*
[1]mohamed@shafraz.net
[2]ajmalazees1@gmail.com
[3]upul@phys.cmb.ac.lk

ABSTRACT: *Fishing is one of the main income sources for those who live in the coastal areas of Sri Lanka. Since most fishing boats do not carry navigational or radio equipment, they face the danger of going beyond the Sri Lankan territory and entering into Indian waters without their knowledge. There is also a risk of locating the boats in the deep sea since there is no information communicated back to the shore about their physical locations.*

In this project an application for smart phones was developed. It has a map of Sri Lanka with the maritime boundaries, number of important locations such as coastal belt, maritime border, fishing harbors etc., has been included in the application. It uses the mobile phone's GPS sensor to identify the current location. Application was developed to display fishing harbors, current position of the boat, distance and direction from the nearest harbor. When the boat is in motion, the path of boat will be indicated on the map. Also, the application software monitors the position of the boat with respect to the maritime boundary. If the boat sails beyond the border, a warning message will display on the screen to indicate. In addition, if the Internet access is available, the current position of the boat will be notified to a ground-based station.

Keywords: Longitude, Latitude, Haversine formula, Distance between two points, Global positioning system.

1. INTRODUCTION

Frequent incidents have been reported of fishermen from Sri Lanka getting into Indian waters and vice versa while fishing along the Sri Lanka-India maritime border. At recent times, fishing activities has not being peaceful; the Indian Navy has arrested many Sri Lankan fishermen and vice versa for Indian fishermen.

Most fishing boats carry no navigational or radio equipment, due to their high cost. Therefore, when they are lost at the sea or face a technical problem that they cannot handle, they have no choice other than waiting for external help. "From the fishermen's point of view, straying takes place inadvertently, due to sheer ignorance about maritime boundaries. At times, the drift is because of engine failure or strong currents" [1].

There are a few research studies available in public domain focused on this issue. One of the studies, "Automatic Border Alert System for Fishermen using GPS and GSM Techniques" [2], in addition to generating an alert through a buzzer, the distance from border is displayed in an LCD. Another study, "Intelligent Navigation system for fishing boats using GPS" [3], the study area has been divided into four zones; normal zone, warning zone, near to restricted zone, and restricted zone. In addition to alerting fishermen through a buzzer, it will show current zone in LCD display. These systems have been developed using dedicated hardware and software to address the problems faced by Indian fishermen. This paper address problem faced by Sri Lankan fishermen when they leave a pre-defined closed area. Since the developed system use existing smart phones, rather than dedicated hardware fishermen can download software into their own Smartphone and use, rather than buying separate expensive hardware.

The objective of this project was to design and develop GPS based low cost, user-friendly navigation system to help the fishermen to navigate within the borders of Sri Lankan maritime border. If a fisherman navigates beyond the border, an alarm is generated indicating that the fisherman is nearing the border. With this warning, the fishermen can navigate and within the boarder. In addition, it will aid fishermen by indicating the current position, displaying the nearest fishing harbor and its direction and distance. In addition, it is capable of locating the current location and indicate the travel path of a boat, showing fishing harbors in a map.

2. GEOGRAPHICAL COORDINATE SYSTEM

A. Geographic latitude and longitude

In geography, the latitude of a location on the Earth is the angular distance of that location; south or north of the equator. Longitude is a geographic coordinate that specifies the east-west position of a point on the Earth's surface. It is an angular measurement, usually expressed in degrees, minutes and seconds, and denoted by the Greek letter lambda (λ).

B. Distance between two points

Haversine formula [4] can be used to find distance between two points. The haversine formula is an equation important in navigation, giving great-circle distances between two points on a sphere from their longitudes and latitudes. It is a special case of a more general formula in spherical trigonometry, the law of haversines, relating the sides and angles of spherical "triangles".

$$haversin\left(\frac{d}{R}\right) = haversin(\varphi_2 - \varphi_1) + cos(\varphi_1).cos(\varphi_2).haversin(\Delta\lambda)$$

R = earth's radius (mean radius = 6,371km)

$$\Delta lat = lat_2 - lat_1$$

$$\Delta long = long_2 - long_1$$

$$a = sin^2\left(\frac{\Delta lat}{2}\right) + cos(lat_1).cos(lat_2).sin^2\left(\frac{\Delta long}{2}\right)$$

$$c = 2.atan2\left(\sqrt{a}, \sqrt{1-a}\right)$$

$$Distance = R.c$$

A. Bearing: Angle between 2 GPS Coordinates

$$\theta = atan2\begin{pmatrix} sin(\Delta long).cos(lat_2)\,, \\ cos(lat_1).sin(lat_2) - \\ sin(lat_1).cos(lat_2).cos(\Delta long) \end{pmatrix}$$

Since atan2 returns values in the range –π … +π (that is, -180° … +180°), to normalize the result to a compass bearing (in the range 0° … 360°, with –ve values transformed into the range 180° … 360°), convert to degrees and then use (θ+360) % 360, where "%"is modulo.

For final bearing, simply take the initial bearing from the end point to the start point and reverse it (using θ = (θ+180) % 360).

C. Global Positioning System

A GPS receiver calculates its position by precisely timing the signals sent by GPS satellites high above the Earth. Each satellite continually transmits messages that include

- The time the message was transmitted
- Precise orbital information (the ephemeris)
- The general system health and rough orbits of all GPS satellites (the almanac).

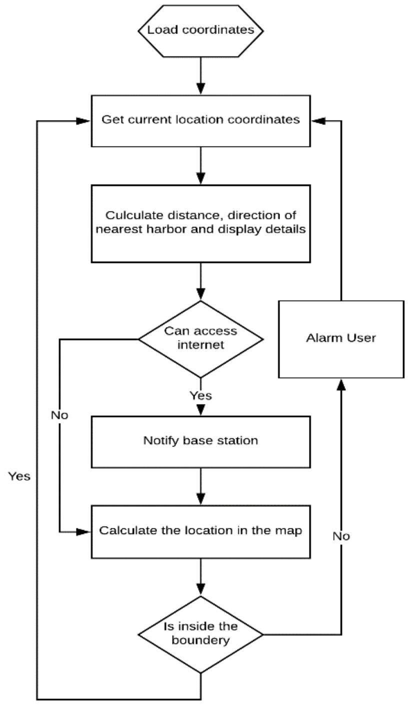
The receiver uses the messages it receives to determine the transit time of each message and computes the distance to each satellite. These distances along with the satellites' locations are used with the possible aid of trilateration, depending on which algorithm is used, to compute the position of the receiver.

Although four satellites are required for normal operation, fewer apply in special cases. If one variable is already known, a receiver can determine its position using only three satellites. For example, a ship or aircraft may have known elevation. Some GPS receivers may use additional clues or assumptions (such as reusing the last known altitude, dead reckoning, inertial navigation, or including information from the vehicle computer) to give a less accurate (degraded) position when fewer than four satellites are visible.

3. METHODOLOGY

The Software was developed will use GPS readings of inbuilt sensor and continuously monitor the current location of the vessel. And will show the current location and traveling path in a Map. Based on GPS readings it will calculate distance from nearest harbor and direction to that. All the calculated information also will be displayed on the screen. If system detected vessel reaching the Sri Lankan boarder it will alert fishermen in message in red color and alarm. If Internet access is available current location of the vessel will be sent to the server.

A. Flow chart of the application



4. RESULTS AND DISCUSSION

A. Location of Sri Lanka

The Island of Sri Lanka lies in the Indian Ocean, to the southwest of the Bay of Bengal. As shown in Figure 4.1, it lies between latitudes 5° and 10°N, and longitudes 79° and 82°E .The country has maximum Length of 432 km (Devundara to Point Pedro) and maximum width of 224 km (Colombo - Sangamankanda)

Table 1: Some important latitude and longitudes

	Longitud e	**Latitude**
Point Pedro [7]	80.23	9.82
Devundara [8]	80.61	5.93
Colombo [9]	80.02	6.87
Sangamankanda [10]	81.83	7.02

Figure 1: Sri Lanka map with marine borders [11]

B. Techniques used in implementation of the project

A Sri Lankan map with width 450 pixels height460 pixels was used to show Sri Lankan territory. It covers longitude +76.86 to +85.36 and latitude +2.38 to +11.57.

Pixels of the image has mapped to latitude and longitude as shown below.

First known points of Sri Lanka were identified in the map and their pixels point were extracted. Then difference of latitude and difference of pixels between two points used to calculate latitudes that represented by a single pixel. Same method was used to calculate longitudes per pixel.

Table 2: Longitude points in map, pixel value and difference of them

	Sangaman-kanda	Colombo	Difference
Longitude	81.83	80.02	1.81
Pixel in map	263	167	96

From above data longitudes per pixel can be derived.

$$Longitudes\ per\ pixel = \frac{81.83 - 80.02}{263 - 167}$$

$$= \frac{1.81}{96}$$

$$= 0.0189$$

Its mean one pixel represents 0. 0189 degree of longitude

Converting pixel to Longitude

$Longitude\ of\ Colombo\ (\lambda_c) = 80.02$

$Number\ of\ pixels\ from\ left\ to\ Colombo\ in\ Map(Pix_c) = 167$

$Longitude\ of\ 0^{th}\ pixel\ in\ map\ (\lambda_0) = \lambda_c - (0.0189 \times Pix_c)$

$= 80.02 - (0.0189 \times 167) = 76.85$

$$Longitude\ of\ n^{th}\ pixel\ (Pix_n) = \lambda_0 + (0.0189 \times Pix_n)$$

Table 3: Latitude points in map, pixel values

	Devundara	Point Pedro	Difference
Latitude	5.93	9.82	-3.88
Pixel in map	282	88	194

From above data latitude per pixel can be derived.

$$Latitudes\ per\ pixel = \frac{5.93 - 9.82}{282 - 88}$$

$$= \frac{-3.88}{194}$$

$$= -0.0200$$

It means one pixel represents 0.0200 degree of Latitude

Converting pixel to Latitude

$$Latitude\ of\ Point\ Pedro\ (\varphi_p) = 9.82$$

$$Number\ of\ pixel\ from\ top\ to\ Point\ Pedro\ in\ Map\ (Pix_p) = 88$$

$$Latitude\ of\ 0^{th}\ pixel\ in\ map\ (\varphi_0) = \varphi_p - \left(-0.0200 \times Pix_p\right)$$

$$= 9.82 - (-0.0200 \times 88) = 11.58$$

$$Latitude\ of\ n^{th}\ pixel\ (Pix_n) = \varphi_0 + (-0.0200 \times Pix_n)$$

C. Deriving GPS points of Sri Lankan maritime border from the map

Using the formulas given above, we can convert pixel point in map to GPS point and vice versa. From above map, pixels of borders have abstracted using image processing software and have converted to Longitudes and Latitudes

D. Determining whether boat inside the border

The point-in-polygon algorithm allows you to programmatically check if a particular point is inside a polygon or outside of it. A common way to tackle the problem is to count how many times a line drawn from the point (in any direction) intersects with the polygon boundary. If they intersect an even number of times, then the point is outside.

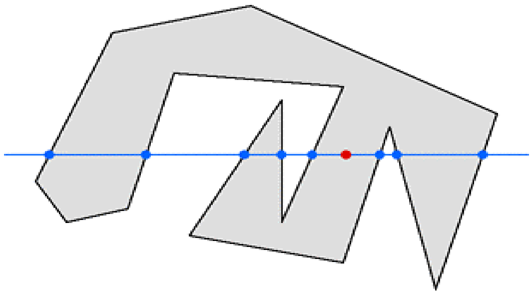


Figure 2: illustration of determining whether boat inside the border [6]

D. Simulation outputs

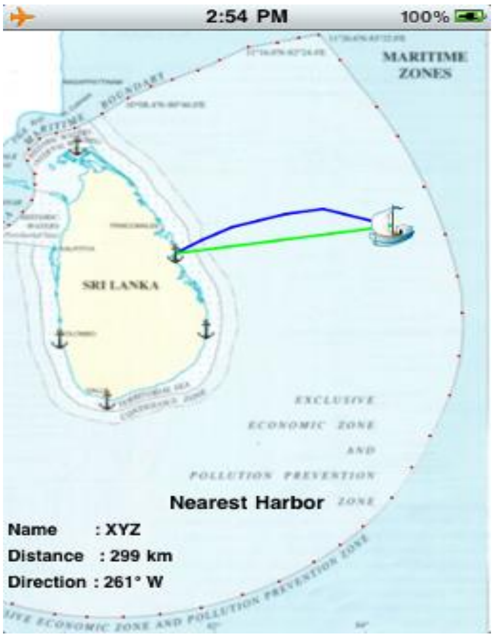


Figure 3: Boat on motion and within border. Blue line indicates the path of the boat and green line indicates direction of nearest harbor

Figure 4: Boat is outside of the border and application alarms in red text.

Figure 5: Boat near Sangamankanda

Figure 6: Simulation output of some random points

Figures 6 show the output of the simulation with some random points. In this simulation, output of the application has been tested with randomly generated GPS coordinates. Coordinates inside the borders shown in blue color and others in red color

5. CONCLUSIONS

GPS based smart hand-held device such as smart phones and smart tabs are cheap, sophisticated and portable devices. Compared to high-end marine navigation systems, those devices can be used in small fishing boats with proper software. There are some online navigation systems which are very popular such as Google Map. The drawback of such systems is that they cannot be used in the Sea because of lack of Internet access. Implementing system with locally available geographical information is the best solution for use in Sea. Currently available smart devices are powerful enough to run such systems locally and have GPS accuracy of about 4.9m [12], which is sufficient to use for to detect borders.

In this project, an application for iPhone/iPod was developed. It has a map of Sri Lanka with the maritime borders. Number of important locations such as important places in coastal belt, maritime border, fishing harbors etc., has been included in the application. Also, the application can be modified to add those data dynamically from a server. It uses the mobile phones GPS sensor to identify the current location.

When the boat is in motion, the path of boat will be indicated in the map. Software monitors whether the boat is within the maritime boundaries or not. If the boat sails beyond the border, it will indicate by showing a warning message on the display. The system is capable of notifying the current position of the boat to a ground base station whenever Internet access is available.

This system gives more useful information to the fishermen compared to some of the work available in literature. Developing custom application for particular regions will be more user-friendly and it can be used by ordinary user too; does not require advanced navigation skills. The developed system can be improved by including information of suitable areas for fishing, and other information fishermen needs.

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