MARITIME BOUNDARY GEO-FENCING WITH ENHANCED ACCURACY

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INTRODUCTION

With the influence of the North Equatorial ocean currents flowing around more than half of the Sri Lankan coast, the seas around the island are rich with fish. From ancient times, fishermen have been harvesting this valuable resource. Even today, the Sri Lankan economy is considerably dependent on the fishing industry. At the same time, fishing is a global industry where advanced technologies have been invented to boost the harvest. Satellite aided fish locating and multi-day trawler fishing boats equipped with navigational facilities have given an added advantage over traditional fishing techniques. Amidst all these technological advances, there are a considerable majority of fishermen who still rely on traditional fishing methods due to financial constraints.

Without the help of navigational facilities, fishermen's reach is limited and they are unable to explore distant international seas. However, in their eagerness to search for richer fishing grounds, some cross the maritime boundary between Sri Lanka and India (Figure 1). On the other hand, the absence of physical boundaries in the middle of the sea too paves way to traditional fishing boats running into foreign territories unknowingly. Both Sri Lankan and South Indian fishermen frequently cross the Indo-Lanka maritime boundary which has led to severe consequences.

Figure 1: Indo-Sri Lanka maritime boundary

Source: http://www.lankanewspapers.com

To overcome this burning problem, several steps have been taken to develop low-cost, yet powerful, maritime geo-fencing systems. Some of them are based on smart phones equipped with global positioning system (GPS) (Kaplan, 2006) receivers and relevant maps in which the boats' movements are monitored and displayed on maps. Usually the GPS receivers in these smart phones possess poor accuracy which has led to erroneous readings.

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Dedicated systems like GPS72H (Garmin, 2009) in which a more accurate GPS receiver is included, provide better accuracy in boat movement monitoring. However, the low battery life and the need for manual reading have made these systems less successful in maritime geo-fencing. In particular, the requirement for manual checking for a boundary crossing is not feasible for busy fishermen. An alternative system has been proposed in (Suresh Kumar & Sarath Kumar, 2010) and improved upon later in (Karthikeyan *et al*., 2012 & Samuel *et al*., 2014 & Girja *et al*., 2014), where a fully automatic GPS positioning and geo-fencing is carried out by a microcontroller-based control circuit. The key concept in the automated geo-fencing algorithm employed here is that the boundary is modeled as a collection of straight line segments. Here the discrete points' boundary data are stored in a database. When the current GPS coordinates are detected, the two nearest points (on either side) are used to determine the equation of a line with respect to which the current relative position is determined. There are two clear drawbacks of this approach. First, the calculations involved add a considerable delay in addition to the delay added by the database search. Secondly, the alarm is generated only after the boundary is crossed, whereas the requirement is to alert the fishermen before they cross the boundary.

As a solution to these problems, this paper presents the design of a maritime boundary geo-fencing system which monitors the movement of a vessel, identifies a possible boundary crossing and alerts the fishermen before the boundary is crossed, with an enhanced accuracy.

METHODOLOGY AND DESIGN

The proposed system consists of two main sub units, respectively dealing with position detection and boundary checking. The position detection system is equipped with a GPS receiver circuit which obtains the GPS coordinates from satellites (Figure 2). Note that, in the middle of the sea without barriers like foliage or buildings, it is always guaranteed to have the minimum required number of four satellites for accurate position detection provided that good weather conditions exist. In the presence of a cloudy sky, the receiver produces GPS coordinates with a deteriorated accuracy. The GPS signals are captured every 120 seconds and the coordinate information is extracted from the GPS signal. The selection of the GPS capturing time of 120 seconds is due to a battery power saving mechanism, where the control, alarm and GPS receiver units enter a sleep mode periodically.

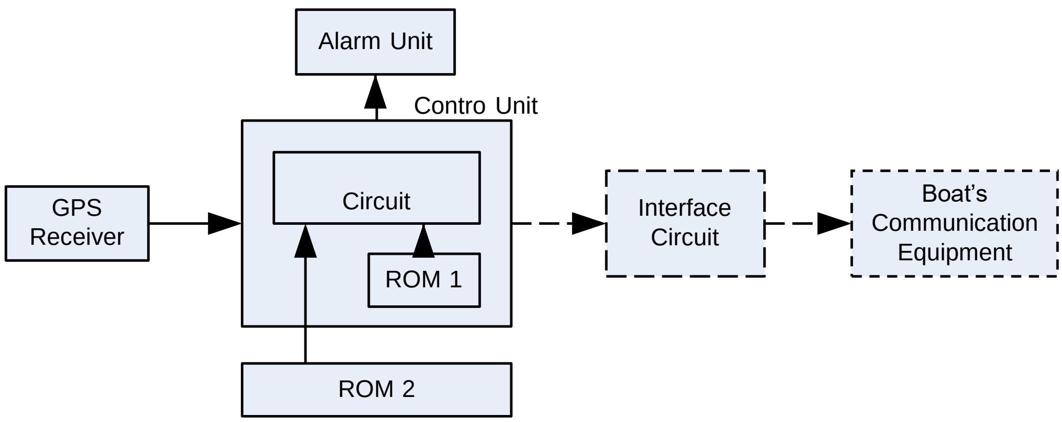

Figure 2: Block diagram of the proposed system

The boundary checking system consists of a database (Figure 3) stored in a read-only-memory (ROM), (ROM2 in Figure 2) which contains the data corresponding to the boundary. These data points are generated by dividing the map into equal-sized rectangles and recording the center coordinates of the rectangles which are along the boundary. It is obvious that smaller the rectangles, the accuracy of the checking would increase. However, this would also increase the database size. Therefore, a tradeoff between database size and the accuracy is to be met by selecting the size of these rectangles. One of the major contributions in this paper is the introduction of the concept of the virtual boundary where a boundary within 2km inside the actual boundary is considered and stored in the database. Thus, the fishermen get the alert before the boundary is crossed, and also, this concept allows to eliminate the mathematical calculations used in (Suresh Kumar, 2010) and to rely only on a database search. The received coordinate's latitude valueب □= ب0□ is used for searching the corresponding longitude value, ب0 of the boundary. A very important thing to note here is that, in order to make the search efficient and fast, a binary search algorithm is followed. Then this boundary valueب0 is compared to the longitude value of the current position, ب to detect a boundary crossing as shown in Figure 4. In the case of a boundary crossing, an alarm is generated to alert the fishermen.

Latitude (y_0)	Longitude (x_0)
09.082 N	79.320 E
09.132 N	79.317 E
09.182 N	79.313 E
09.232 N	79.302 E
09.280 N	79.280 E
09.325 N	79.260 E

Figure 3: Boundary database

The control unit, which consists of a microcontroller based circuit, is responsible for scheduling the capturing of the GPS signals, interpreting these signals and also checking for the boundary crossing. Furthermore, the control unit hardware contains a ROM (ROM1) which hosts the control program.

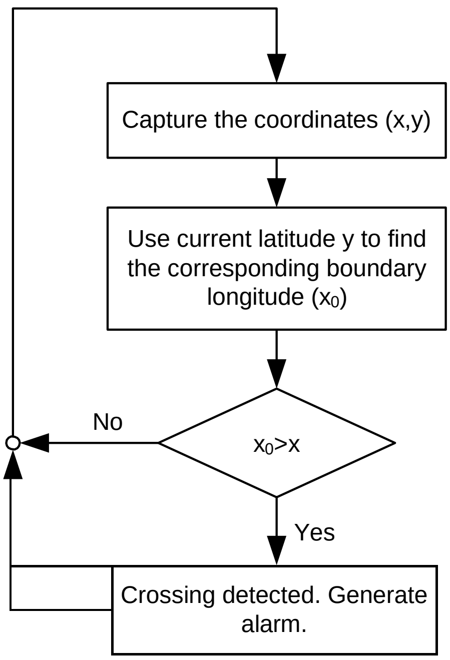

Figure 4: Geo-fencing algorithm

TEST RESULTS AND DISCUSSION

In order to test the accuracy and delay in the proposed system, a model system was implemented and was tested on land. Although blocking due to foliage was not completely absent at the selected test scenario, it closely resembled an unobstructed sea like environment.

A GPS receiver, SkyNav SKM53 with 30m accuracy was employed and a PIC16F877 microprocessor was selected for control. Further, a M2732 programmable ROM (PROM) was selected for storing the boundary data. First, a linear boundary was set and the data was burned to the ROM. Four tests were carried out. In the first, starting from the “within boundary” side, the system was very slowly taken to “outside the boundary”, perpendicular to the boundary and the alarm trigger point was observed. This reading was compared to the actual boundary to calculate the difference between the boundary and the point. We denote this difference as the distance error. It was seen that even at very low speeds, a 47m distance error was present on average. During real actual deployment, this error is acceptable in the scale of the maritime boundary. Second, the device was moved at different speeds from one side to the other, and the distance error was measured and the observations are listed in Table 1. A 64.35m error is also negligible in the maritime boundary scale.

Table 1: Average error vs. travelling speed

Speed (km/h)	Average distance error (m)
10	47.72
20	49.96
30	53.25
40	58.25
50	64.35

Furthermore, another test was carried out to check and compare the position of the system when the alarm indication appears for the existing and proposed systems. It was observed that with the proposed algorithm, 99.2% of the time the boat is notified before an actual boundary crossing, whereas only 58% of the time alarm is notified before a boundary crossing in the existing system.

On the other hand, the direction of the boat’s movement with respect to the boundary affects the accuracy. A fourth test was carried out selecting the angle between the boat’s movement and the boundary, randomly from □$\mathbf{0^0}, \mathbf{90^0}$] and observing the number of times notification occurred before an actual boundary crossing. It was observed that 99.6% of the time, notification occurred before a boundary crossing. Due to the use of the concept of the virtual boundary, in 44% of the cases, an actual boundary crossing happened after more than 300seconds from the notification. However, this is acceptable as the boat is still within 2km from the boundary and accompanies a risk of crossing the boundary.

CONCLUSIONS AND FUTURE WORK

This paper proposes a maritime boundary geo-fencing system where the key contribution is the use of a virtual boundary which improves the accuracy of timely notification. With its special design, it also consumes less battery power and maintains the distance error at an acceptable level.

This system can be further improved by adding a graphical display to the system or by providing an interface to link the system to a smart phone. Moreover, a feature can be included which conveys information of a crossing to the shore using the boat’s common communication equipments so that the necessary action can be taken.

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