Earth Science Informatics (2019) 12:241–252
https://doi.org/10.1007/s12145-018-0371-5

METHODOLOGY ARTICLE

How to prevent maritime border collision for fisheries?-A design of Real-Time Automatic Identification System

Krishnan Saravanan[1] · Selva Aswini[2] · Raghvendra Kumar[3,4] · Le Hoang Son[5,6]

Received: 14 August 2018 / Accepted: 29 October 2018 / Published online: 5 November 2018

Abstract

Maritime Border Collision is one of the vital concerns in coastal states since the maritime boundaries of any two countries cannot be identified easily during fishing. Maritime domain awareness and the border line control are the essential requirement which happens via recognition, and observing of boats inside their country boundary. It is necessary to identify the maritime border and alert the fisherman during the fishing. In this paper, we propose an Automatic Identification System (AIS) which can protect fishermen by notifying the country's border. If they are nearing towards the International Maritime Border Line (IMBL), an alert will be sent to coast guards via VHF set. Using the inbuilt GPS, AIS can find the location and transmits to the embedded systems, which gathers the recent position by comparing autonomy and longitudinal values with the existing assessment. The proposed system is validated under a case study in the maritime border between India and Sri Lanka, which is identified as Gulf of Mannar. It has been revealed that fishermen can aware that they are about to near the nautical border by means of visual and audio alert. Then, protectors in the coast preserve support and afford supplementary assist to those fishermen. This system also provides collision avoidance by using AIS/ ultrasonic sensors. It has better performance than the relevant methods such as RF (Charan et al. 2016), ECDIS (Vanparia and Ghodasara, International Journal of Computer Applications & Information Technology, 1:58–64, 2014), Android (Kumar et al. 2016), GSM and GPS (Sivagnanam et al., International Journal of Innovative Research in Advanced Engineering (IJIRAE), 2:124–132, 2015).

Keywords Automatic Identification System · Embedded system · VHF set · MMSI · Coast guard station · Fisheries GPS

Communicated by: H. A. Babaie

✉ Le Hoang Son
lehoangson@tdtu.edu.vn

Krishnan Saravanan
Saravanan.krishnan@auttvl.ac.in

Selva Aswini
aswiniselvaraj19@gmail.com

Raghvendra Kumar
raghvendraagrawal7@gmail.com

1 Department of Computer Science and Engineering, Anna University Regional Campus, Tirunelveli, Tamilnadu, India

2 Department of Electrical and Electronics Engineering, Anna University Regional Campus, Tirunelveli, Tamilnadu, India

3 Department of Computer Science and Engineering, LNCT College, Jabalpur, MP, India

4 VNU Information Technology Institute, Vietnam National University, Hanoi, Vietnam

5 Division of Data Science, Ton Duc Thang University, Ho Chi Minh City, Vietnam

6 Faculty of Information Technology, Ton Duc Thang University, Ho Chi Minh City, Vietnam

Introduction

Each country in the world has its clear maritime boundaries through International Maritime Border Line (IMBL) laws (Binder 2017). Fisherman should obey these laws and also should aware of the boundary line. Crossing these boundaries will lead to severe problems such as incarceration or casualty penalty. This is the foremost difficulty countenance by the fishermen in daily life since the maritime boundaries of any two countries cannot be identified easily during fishing (Churchill 2018). As an example, the fishing right of Indian and Sri Lankan fishermen is an ongoing issue. Regardless of many agreements and understanding, the fishermen issue has raised in many occasions (Amarasinghe and Bavinck 2017). Even though the IMBL line was clearly defined and marked by international laws, fishermen cross the line unwittingly. Another example can be seen from the dispute between ASEAN countries and China about the China's Nine Dash Line Claim (Beckman 2017). It has been widely known that the East Sea (a.k.a. South China Sea) is not property of

China; however, still there has been disputes regarding this problem which leads to violation in the sea (Nguyen 2017). The main difficulty in the fishing constitutional rights is the disagreement among laws of the sea and conventional fishing rights (Rosello 2017). Hence, it is necessary to identify the maritime border and alert the fisherman during the fishing (Charan et al. 2016).

Another important note of determination of maritime border is for tourism industry, which contributes significant economic impact to the country's growth and wealth (Bunholi et al. 2018). Effective border promotes economic prosperity, national sovereignty, and preventing from terrorist threats and criminal acts. Maritime spatial planning for the Romanian Black Sea coastal zone is a typical example for setting up maritime border to regulate coastal economic activity for tourism (Vintilă et al. 2017). Greek maritime network, another successful example shows the triplet of tourism–transportation network–economy based upon such the formulation of border for marine (Tsiotas 2017). It has been shown that maritime has great influence to the economic and industry of a country (Yin et al. 2017).

Many countries in the world share the Exclusive Economic Zone (e.g., Iran and Egypt for Saudi Arabia) in the maritime boundaries for fishing and customs (De Lessio et al. 2017). A new term - smart border has been given for powerful and cost-effective border surveillance and secure in 24-h persistent (Singh and Kushwaha 2017). EUROSUR (Jeandesboz 2017) is an example for smart border. Regarding the sea, International Maritime Organization (IMO) is the agreed agency network responsible for safety, security and efficiency of international merchant shipping and prevention of marine pollution by ships (Lim 2017). It developed a system for measuring marine causalities, services, maritime traffic and security. However, it is worthy noted that the system is inadequate for automatic notification of fishermen. In 2015, 600 fishermen get affected by crossing the border line and the number is getting increased years by years (Lampert 2017). Hence, it is necessary to avoid such scenarios by alerting them before reaching the line.

In this paper, we propose an Automatic Identification System (AIS) for preventing fisherman from crossing the International Maritime border as well as helping them from collision avoidance. In the system, all fishing vessel contains a boat element including an AIS transceiver, VHF set and an embedded system. The satellite generates indicator to AIS which has inherent GPS recipient. Then, the GPS exchanges traditional signal to preferred data recovered by the embedded system. The autonomy and longitude values of IMBL are characterized as border line assessments and stored as indication values in the embedded system. Real-Time GPS assessments are evaluated with accumulated assessments occasionally. If any contradiction originates, an alarm is set as a warning. In anguish situation, fisherman can employ the tragedy key provided with in the hand-held component of VHF position. The Latitude and Longitude organizes of the present position of the fisherman acquired from AIS transceivers are broadcasted to the security guards using VHF with DSC in the seashore location. Consequently, the seashore position of fisherman can be used for salvage operations when needed. In short, the proposed system is able to do the following things:

a) Finding exact position of the boat through AIS integrated with GPS security;
b) Alert fishermen nearing to the maritime boundary;
c) Collision avoidance scheme to detect boats in 360 degrees surrounding.

This paper is organized as follows: in second section gives a brief introduction for the related works. Third section proposes the system using integrated AIS/GPS along with hardware design. Fourth section visualizes the results with performance discussion, followed by conclusion in fifth section.

Related studies

Internet of Things (IoT) interconnects billions of sensors across the world and it is expected to grow 24 billion in the year 2020 (Saravanan and Srinivasan 2018). IoT sensors are implemented in most of the devices today to share data faster and effective. IoT devices become thin client performing their core operations, whereas the computation and storage is offloaded to the cloud environment. It makes the IoT devices for longer run and also smarter, smaller and cheaper. Cloud and IoT are inseparable in the current M2M (Machine to Machine) communication advancement (Saravanan 2017). There are many IoT platforms exist such as Arduino and Rasperry Pi to develop applications. IoT devices are invariably used in smart city/home and industry automation such as SCADA (Supervisory Control and Data Acquisition System). Cloud based IoT applications are implemented in many sectors for its cost effective, reliable and scalable solutions. Here, IoT based border security system is implemented using AIS and GPS.

Sivagnanam et al. (2015) developed a coast guard alert and salvage scheme for IMBL line crossing of fisherman upon sighting an intruder. This GSM enabled device allows fisherman to compute its precise location using the integrated GPS receiver, and radiates the information to nearest coastguard stations. Kumar et al. (2016) proposed an alert structure for fishermen traversing the boundary, which helps fishermen in the boundary to discover the suitable path to accomplish an objective location. This device was implemented so that the request can be simply been exploited by all the people in the environment. Another system of location tracking of the boat was implemented in (Kumar and Ranjith 2014) using DGPS (Differential Global Positioning Satellite) to trigger an alarm. It consists of a Piezo-buzzer, when the border is approached or crossed. Here, when the fisherman penetrates closer distance, route of intrusion is displayed using an interface on the touch screen display. The intruding location is measured by joining this information with the identified location of fishermen using the incorporated GPS recipient. The major disadvantage of GSM is communication failure in the sea boats. If the signal network strength is too low to transmit the data, messages cannot be broadcasted. We cannot anticipate appropriate signal power in the middle of the ocean (Charan et al. 2016).

Vanparia and Ghodasara (2014) made a system in which alert is made when fishermen cross other country's border and warning in terms of voice messages in their regional language. This application also works in GPS enabled mobile devices and in specific GPS instrument. Vivek et al. (2015) proposed an automatic border crossing detection and navigation of boat to alert the fishermen by coast guard using two devices: transmitter at coast guard station and receiver at boat. As of now, there are minimal presented systems which can recognize the nearby location of the vessels using DGPS and RADAR steering scheme. It offers the majority truthful technique to steer and determine velocity of vessel and position. The Ultra High Frequency (UHF) broadcast presents small wavelength with elevated regularity (Reza and Mason 2015).

Viji et al. (2017) discussed this issue with microcontroller and GPS system. With the help of International Mobile Equipment Identity (IMEI) number along with the latitude and longitude coordinates, fishermen position is sent to Mobile Object Database (MOD). It helps the live tracking of fishermen. This system uses Google Map API for finding the coordinates. Asha-Rose (2017) investigated maritime security and safety issues in Tanzania with policies and framework. It has been revealed that Tanzania borderline is shared with many surrounding countries. Many illegal activities (such as terrorism and piracy, smuggling, armed robbery at sea, illegal fishing, drug trafficking and pollution) are big concerns. Hence, technology enabled solutions are very much needed in maritime domain of Tanzania.

Further, solution such as Coastal Surveillance System with sensors was explored (Olivier 2017). The primary sensor known as maritime radar can detect all non-moving or fast-moving boats at long range by using thermal Infra-Red camera. Maritime Picture, which is geographical maps for different zones, is used to track naval areas. Similarly, advanced technologies such as Unmanned Surface Vehicles (USV), Autonomous Underwater Vehicles (AUV) and Remotely Operated Vehicles (ROV) were introduced in (Hassene & Mondher, 2017). The Integrated Coast Surveillance System contains subsystems such as sensors, communication, command and control and intercept. Unmanned aerial vehicles, infrared sensors and Wireless Integrated Network Sensors (WINS), radar and satellite surveillance were used to maritime safety as in (Eman et al. 2017). Automatic Identification System (AIS) transmits a vessel's name, type, position, size, course, destination and speed to the coastal guard at periodical intervals (Page 2017). Small vessel tracking utilizes solar powered transponders for both terrestrial. Satellite AIS was implemented with sea trail using low-cost battery for efficient on-board power (Proud et al. 2017). Other studies regarding AIS and advanced systems can be seen in (Amal et al. 2018; Balakrishnan and Arunkumar 2018; Boulila et al. 2018; Charles et al. 2016; Chatterjee et al. 2018; Chuan et al. 2018; Chen et al. 2018; Giap et al. 2018; Goudossis and Katsikas 2018; Kapoor et al. 2018a, b, c; Kumar et al. 2018; Kowsalya et al. 2017; Louati et al. 2018; Ngan et al. 2018; Praczyk 2018; Saravanan et al. 2018; Singh et al. 2018; Son et al. 2018a, b; Tam et al. 2018).

Though there were many researches done for maritime border security with GSM with GPS, these systems may fail in sea borders due to network unavailability. Therefore, this paper proposes an integrated novel solution using GPS and AIS for the fishermen safety. Herein, AIS system with satellite communication still works in these types of conditions.

Proposed system

Architecture

Figure 1 denotes the architecture of the proposed system. The core components are: AIS, VHF set, micro controller, voice module along with loud speaker and ultrasonic sensor. This device has been shaped to assist fishermen not to shift outside their country's boundary. The AIS device has 2 modes of operation. In the active mode, AIS works as a transceiver and in the passive mode, it acts as a receiver. Coast guards set the AIS in passive mode whereas fishermen trigger the AIS in active mode. Different data formats of AIS are dynamic (course over ground, speed over ground) and static (MMSI, IMO number) and voyage (ship draught, hazardous cargo) of other boats for fishermen to avoid collision in the sea.

AIS transceiver in fishing boat is connected to the embedded system by serial programming which is compiled and can be debugged in MPLAB. Then, AIS is connected to the PIC embedded system via serial cable; thereby information like latitude and longitude positions will be displayed on LCD so that fishermen can know about the navigational status. AIS receiver in the coast guard station is able to know about the position of every ongoing fishing boat that has AIS transceiver within the range up to 70 nautical miles.

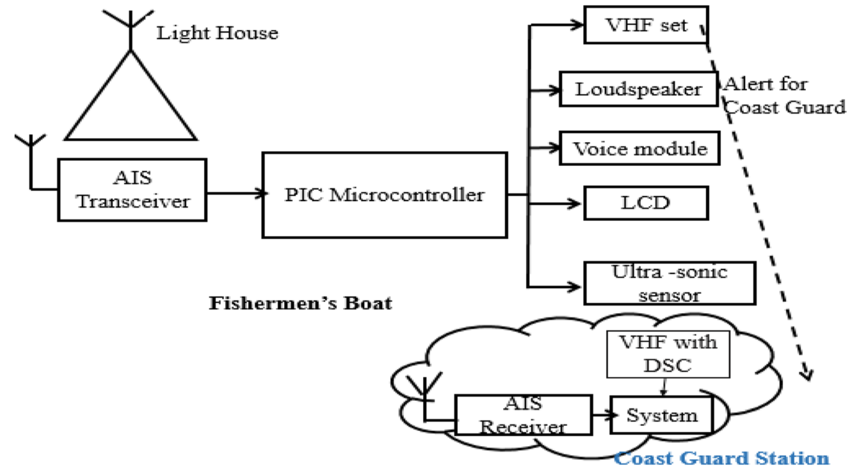


Fig. 1 Block diagram for border security system using AIS

VHF set

In this system, portable VHF set is used along with embedded system in fishing vessel. Once the value of the IMBL reaches in the programming, the organizer sends demand to VHF. Then the MMSI quantity will be sent to VHF with DSC in the coast guard position. The message between the coast guard station and the fishermen will be accomplished by this VHF set.

Embedded system

The embedded system compares the present position values with the predefined stored value of IMBL. Codes are transferred to the embedded system kit via tiny boot loader and validated using the Proteus simulator tool MPLAB. Here, Ports A, B, D are configured as output ports. The remaining ports are configured as an input port.

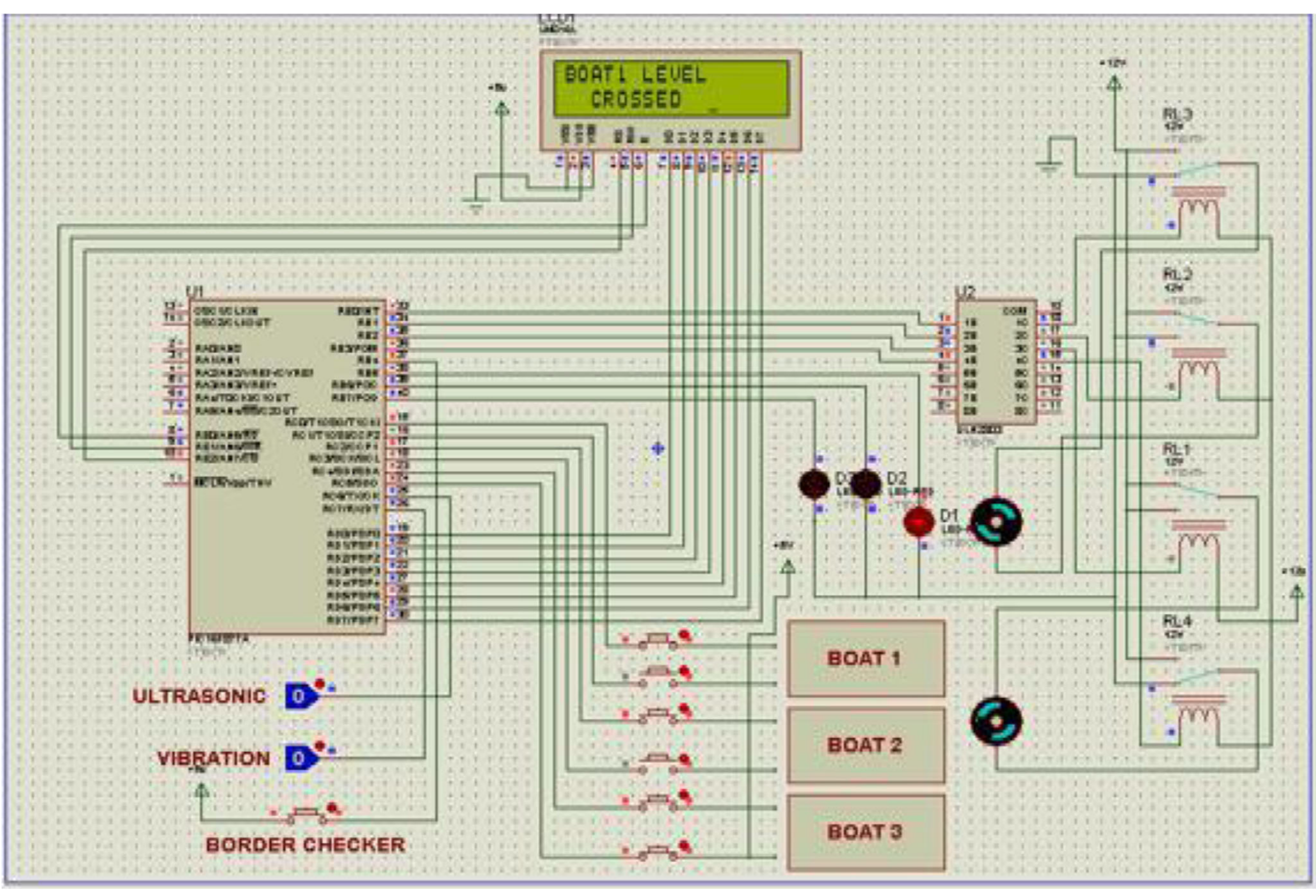


Fig. 2 Output screenshot for boat movement

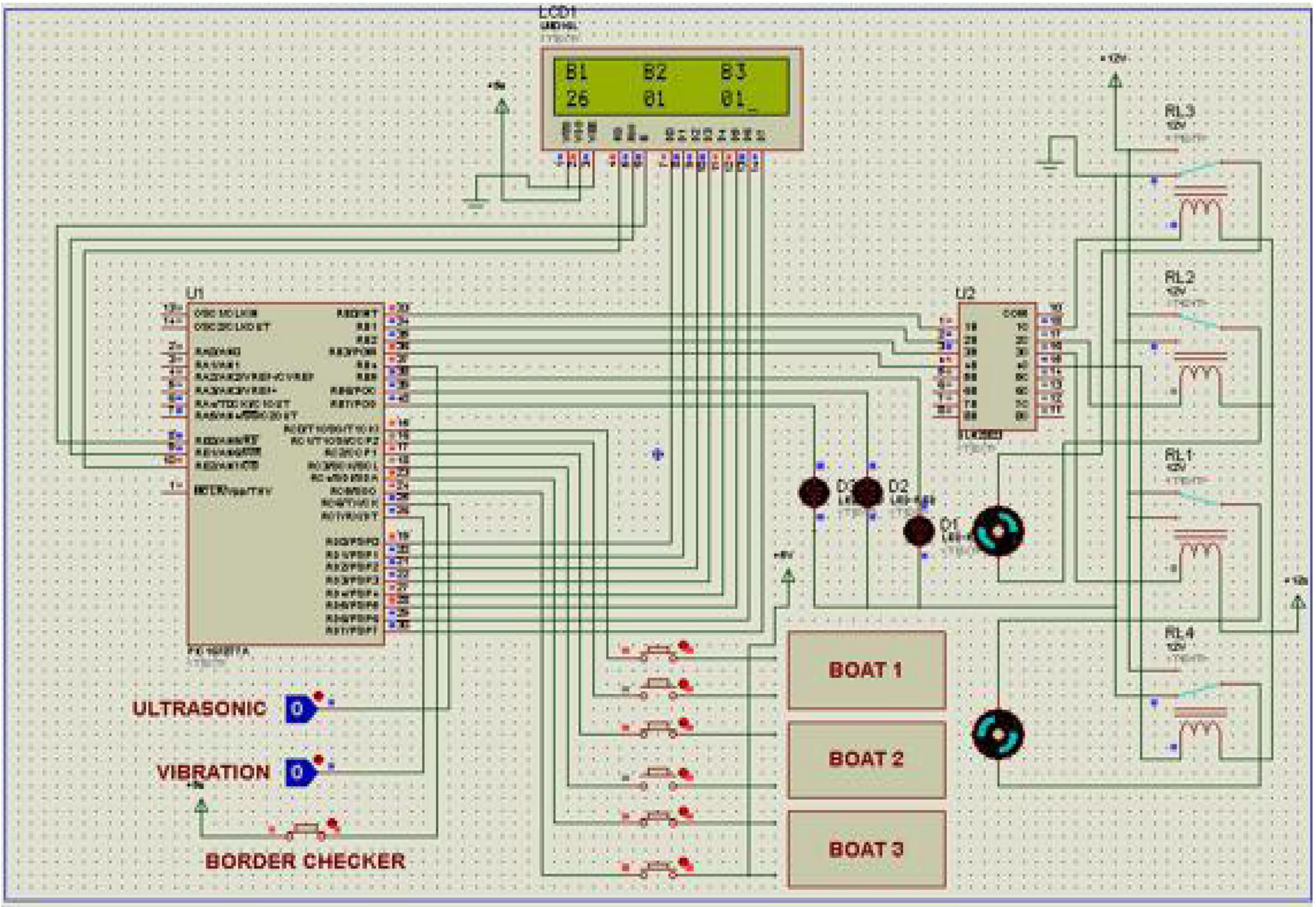


Fig. 3 Output screenshot for border crossing prevention

Voice module

This voice module can able to record four different voices with duration of 40 s for per voice. Voice module can be interfaced directly to the embedded system and can be up to 4 channels. Audio can be recorded with on board MIC. This voice module can be connected to the port B register of PIC embedded system. The port B can be taken as logic 0, configured as output. This module has non-volatile flash memory technology, no battery backup required.

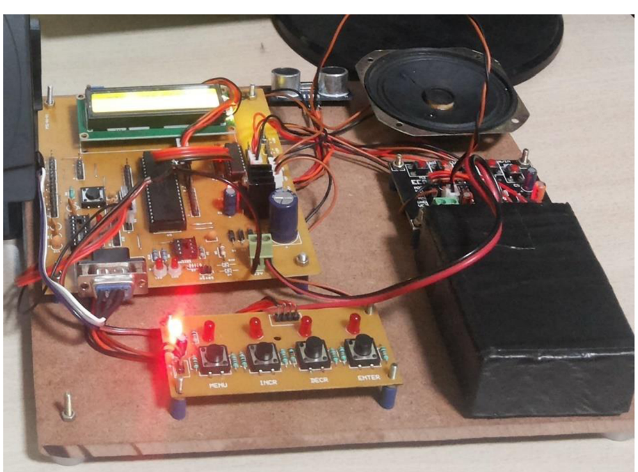


Fig. 4 Hardware setup of proposed system

Ultrasonic sensor

PIC16F877A is the heart of this proposed system circuit design. Transmitter sends out high frequency sound pulse and the time how long it takes for the echo of the sound to reflect back, that distance is displayed in the LCD. The purpose of using ultrasonic sensor is to avoid collision.

Hardware design

The hardware design and implementation of the proposed system consists of PIC16F877A, voice module, loudspeaker, battery, ultrasonic sensor and RS232 serial cable, driver circuit, LCD. The program is written in the MPLAB IDE, compiled and then loaded to the PIC 16F877A embedded system using PICKIT 2 burner. Simulation of the proposed device is done using PROTEUS 8.0 software. The device design is drawn using Proteus and the hex file (which is generated from the MPLAB IDE) is loaded into the PIC embedded system. Finally, simulation with different numbers of boats is done. In this system, results of the boat movement is verified (Fig. 2) and the border crossing of the boat is prevented by indicating alarm as a led display is also verified (Fig. 3).

The hardware setup is shown in the Fig. 4. External port of AIS transceiver in fishing boat is connected to the port A of PIC embedded system. AIS has inbuilt GPS and external connection facility for GPS device is also available. Portable VHF set is used in fishing boat and VHF with DSC is used in the coast guard station. All the external peripherals are connected to the port pins of the embedded system. Port B of RB1 and RB2 pins are connected to the voice module to record the voices. Voice module and the speaker are integrated to obtain the sound signal. For collision avoidance, the ultrasonic sensor is connected to the RB0 and RB4 pin of the controller. Programs are compiled and verified in MPLAB and PROTEUS.

With the help of charged battery, this system connects AIS and VHF using serial cable, then serial data is transferred and dumped into the controller using MPLAB software. AIS and VHF instruments are mandatory for the fishermen along with this hardware setup to prevent them in crossing the sea border. Embedded system receives the input latitude and longitude positions from AIS, and then the current location is compared with the stored assessment of IMBL value. When the value is too closer to the predefined value, voice and visual alert is generated to the fishermen. If no action is taken by the fishermen, the embedded system triggers the VHF to send the MMSI number to the coast guard station. In this way, we can protect the fishermen and auto-monitor the boat movement. This system provides continuous monitoring signals to the coast guards with the help of AIS receiver along with position of the fishing boat also maintained.

Results

Case study

In this section, we validate the proposed system under a case study in the maritime border between India and Sri Lanka, which is identified as Gulf of Mannar. These boundaries are assigned by latitude and longitude values (Fig. 5). The maritime border between Sri Lanka and India in the Gulf of Mannar shall be arcs of huge circles among locations in the progression given in Table 1, defined by latitude and longitude. Similarly, the

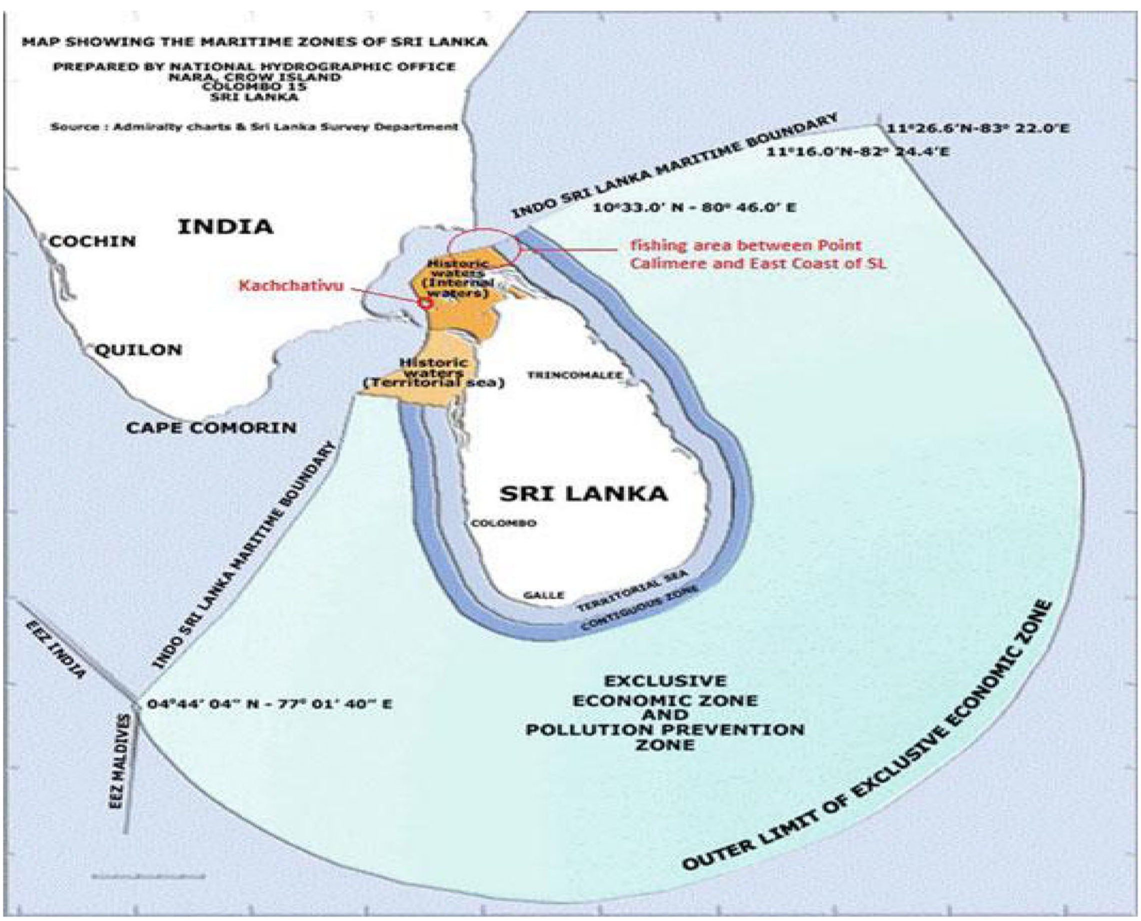


Fig. 5 Case study

Table 1 Maritime boundary in Gulf of Mannar

Location	Latitude	Longitude
Location 1	09° 06′.0 N	79° 32′.0 E
Location 2	09° 00′.0 N	79° 31′.3 E
Location 3	08° 53′.8 N	79° 29′.3E
Location 4	08° 40′.2 N	79° 18′.2 N
Location 5	08° 37′.0 N	79° 13′.0 N
Location 6	08° 31'.2 N	79° 04′.0 N
Location 7	08° 22′.2 N	78° 02 ‘.4 N
Location 8	08° 12′.2 N	78° 59′.4 N
Location 9	07° 35′.3 N	78° 53′.7 N
Location 10	07° 22′.0 N	78° 45′.7 N
Location 11	06° 30′.8 N	78° 38′.8 N
Location 12	05° 22′.2 N	77° 50′.1 N
Location 13	05° 00′.0 N	77° 12′.4 N

maritime border among Sri Lanka and India in the Bay of Bengal shall be arcs of huge circles among locations in Table 2.

We validated the first set of 10 boats then increased the boat quantity to 20, 30, 40 and so on. The following parameters are used for running the experiments (Table 3).

The proposed border security system device is designed using PIC 16F877A embedded system for this experimental case study. The program is written in the MPLAB IDE, compiled and then loaded to the PIC 16F877A embedded system using PICKIT 2 burner. Simulation of the proposed device is done using PROTEUS 8.0 software. The device design is drawn using Proteus and the hex file (which is generated from the MPLAB IDE) is loaded into the PIC embedded system. The proposed hardware setup was placed in the fishing boat with AIS and the VHF set. AIS and the VHF set are readily available instruments in the Indian Coast Guard Stations to help the fishermen.

Figure 6 shows the proposed hardware system with AIS and VHF set. AIS system along with the hardware setup is turned on with the help of battery. Embedded system verifies whether the AIS are connected or not. AIS display the current navigational position as latitude and longitude values when the inbuilt GPS antenna in AIS started to receive the signals.

Table 2 Maritime boundary in Bay of Bengal

Location	Latitude	Longitude
Location 1	10° 05′.0 N	80° 03′.0 N
Location 2	10° 05′.8 N	80° 05′.0 N
Location 3	10° 08′.4 N	80° 09′.5 N
Location 4	10° 33′.0 N	80° 46′.0 N
Location 5	10° 41′.7 N	81° 02′.5 N
Location 6	11° 02′.7 N	81° 56′.0 N
Location 7	11° 16′.0 N	82° 24′.4 N

Table 3 Parameters

No.	Simulation environment	Values
1	Number of boats	100
2	Software	PROTEUS 8.0
3	Programming IDE	MPLAB
4	Programming Language	Embedded C
5	Ultrasonic Sensor	PIC16F877A
6	Transceiver	AIS/GPS

PIC embedded system compares the present values with the original value of IMBL. If the present value reaches near to the stored value, the warning alert will be given to the fishermen. If no action taken about the alert, automatically the position and MMSI of the corresponding boat are sent to the coast guard station via VHF set.

Figure 7 shows the MMSI of the corresponding boat in the VHF with DSC in the Coast Guard Station. Coast Guards can monitor fishermen whenever using the AIS receiver. Figure 6 shows AIS track details monitored by the Coast Guards. Figure 7 shows the results when fishermen are very close to the IMBL by MMSI indication and position tracking information. These information are accurately given to the Coast Guards. The proposed system also helpful in collision avoidance using AIS and ultrasonic sensor.

Results

We have compared the implemented system with four existing methods (RF, ECDIS, Android & GSM/GPS) for which five metrics identified. Table 4 shows the performance metrics of proposed border security system for fishermen against the existing systems with respect to five performance characteristics. *Reduction in rate of collision*

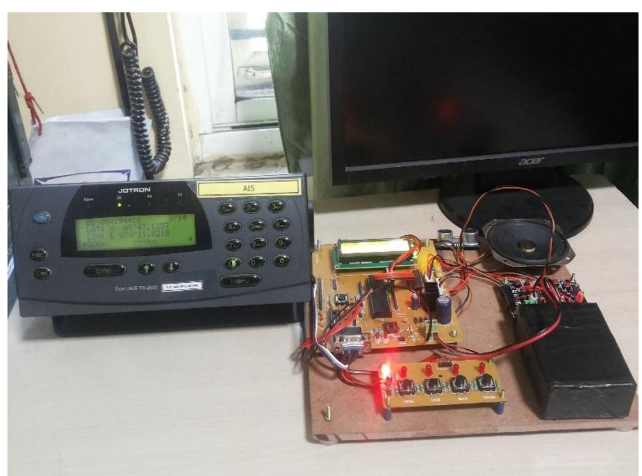


Fig. 6 Hardware design for border security of the case study

Fig. 7 MMSI in VHF with DSC

indicates that fishing boats are known to others in a particular area so that the collision rate will be reduced. It is the rate of number of boat collision reduction over a time. *Distress alert* is the characteristics of the system, in which fishermen can get help during any emergency conditions. It is the accuracy of the alert mechanism for border and collision. *Reliable communication* can be attained among the Coast security station and fishermen with the help of the instruments like VHF having high frequencies. It is calculated from the network signal strength and data rate of the network transfer. *Prevention from border crossing* is the core measurement which does not allow fishermen either known or unknown to cross the other country's border. The formulae for the performance metrics are given in Eqs. (1–4).

Reduction Rate of Collision

$$= \frac{\text{Number of boats with null collision frequency}}{\text{Total number of boats}} * 100 \tag{1}$$

Here, collision frequency is the rate at which boats nearing to each other peripheral distance. Null collision frequency indicates the zero collision among the boats.

Distress Alert

$$= \frac{\text{Total number of True distress alerts sent}}{\text{Total number of alerts generated by the distress alert transmitter}} * 100 \tag{2}$$

Here, True distress alert contains the boat ID, boat location, type of emergency, Time.

Communication Realibility

$$= \frac{\textit{Synchronous signal strenght\%} + \textit{Data rate\%beteween station and boats}}{2} * 100 \tag{3}$$

Prevention rate of Border Crossing

$$= \frac{\text{Number of boats received border alert and avoided crossing}}{\text{Total number of boats}} * 100 \tag{4}$$

Table 4 Performance characteristics of proposed system from existing systems

Performance metrics	RF (Charan et al. 2016)	ECDIS (Vanparia and Ghodasara 2014)	Android (Kumar et al. 2016)	GSM and GPS (Sivagnanam et al. 2015)	Proposed system
Reduction rate of collision	46%	53%	56%	62%	73%
Distress alert	40%	57%	69%	51%	78%
Communication reliability	45%	74%	56%	67%	79%
Prevention rate from border crossing	62%	71%	69%	79%	83%

Here are the details of comparison between various methods.

RF technology (Charan et al. 2016) is used for communication purpose. Reliable communication can be achieved in the sea. Consider 100 boats for the simulation; these nodes are simulated in the software tool using RF. In the mid of the sea, the communication is missing so that 40 fishing boats get communication, the remaining fishing boats are mid of the sea. Thereby, the reliable communication is achieved for 45 boats. 60 fishing boats are prevented from crossing the IMBL.

ECDIS (Vanparia and Ghodasara 2014) is presently used by the Indian Coast Guard Station. The Coast Guards are viewed through ECDIS and this information is getting in real time. Out of 100 boats, nearly half of the fishing boats are good in distress alert and the reliable communication between them are good in most of the boats. Due to reliable communication, the percentage of prevention from crossing is increased.

Android application (Kumar et al. 2016) helps fishermen to discover suitable path to accomplish target in the boundary. Assuming 100 Android application mobiles using fishermen in 4 times, among that 69 people can get proper destination and they adhere to the system commands. Thus, the border crossing issue is decreased. The communication is half of the percentage so that the smuggling rates are also half enough.

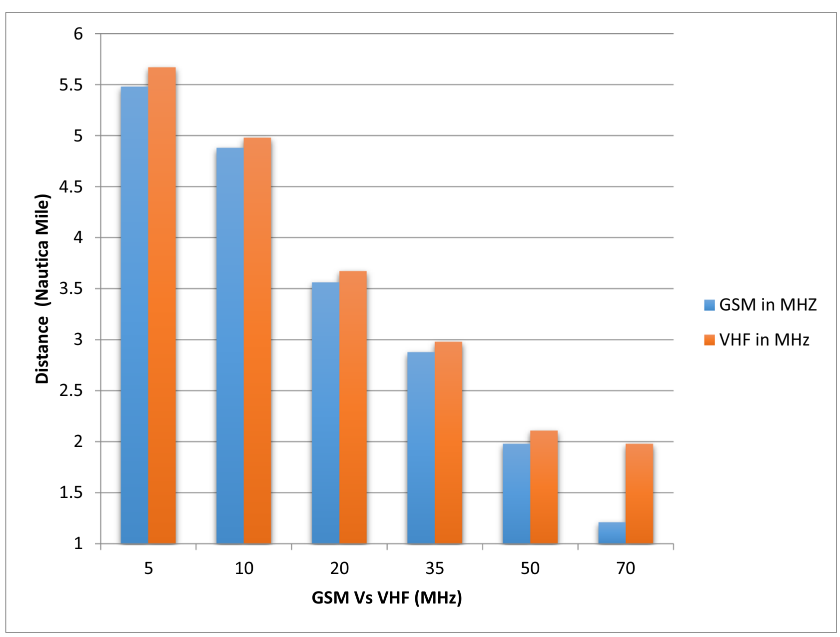
GPS and GSM (Sivagnanam et al. 2015) are the mostly used technology by border security for fishermen. The device allows fisherman to compute its exact position using incorporated GPS receiver, and radiates data to the adjacent coastguard station via GSM communication. Using this GPS receiver, the distress alert can be reduced to 50%. Reliable communication and the percentage of prevention is also nearly 60%.

The proposed system uses AIS within the embedded system. Due to main features of AIS, collision rate is reduced up to 73 out of 100 boats on shore. The distress alert can be made by VHF set. The voyage related details are provided by AIS, which increases the rate of smuggling detection.

From these results, it is evident that the proposed system performs well in all the aspects such as collision detection, alert mechanism and network communication. The novelty of this scheme lies in the integration of AIS with GPS. The border crossing issue can be decreased by the proposed system (nearly 80 percentages) because of reliable communication made by VHF set.

Figure 8 shows the range of communication between the fishermen and the coast guard station using GSM versus VHF set. Most of the existing system uses GSM network for communicating the boats. The drawback of the GSM is that network may not be available at the middle of the sea. Also, frequency range for GSM is shortfall with VHF frequency. On the other hand, VHF communication is highly reliable since it has signal strength up to 70 nautical miles (129.64 Kms). It supports both low and high band signal transmission. From the results, it is evident that when the nautical mile increased from sea shore, VHF can support with high frequencies. Boat simulation range from 5 to 70 is depicted in Fig. 8. The proposed system uses VHF set for communication purpose, the range of VHF up to 70 nautical miles.

Fig. 8 GSM versus VHF



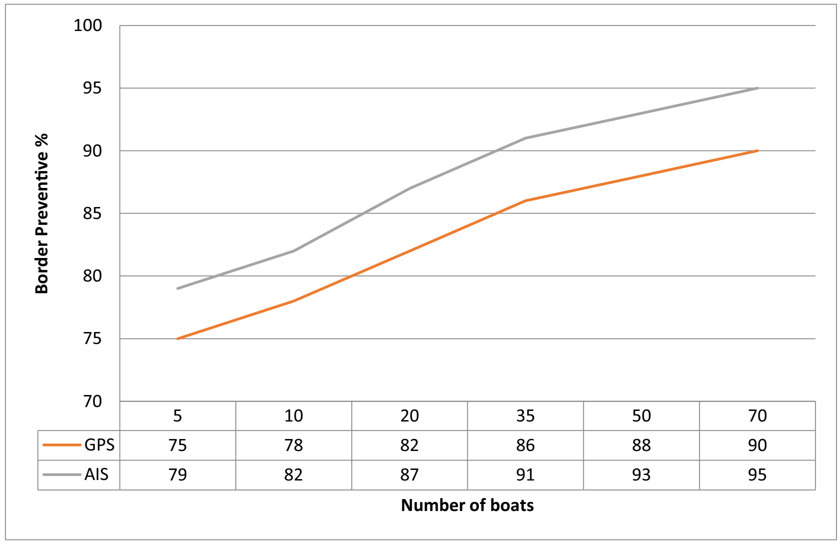


Fig. 9 GPS versus AIS

Figure 9 shows the performance of GPS with AIS in border prevention. AIS can reduce border crossing by accurately predicting the boat location and sending the alert messages in real time without any communication delay. Assume that number of boats in the simulation ranges from 5 to 70, AIS system always performs well when compared to GPS based system. Further, AIS provides more information besides boat location such as boat length, type, speed and so on. AIS is an active system (boat transmits its location), whereas GPS is passive (boat calculate the location from the satellite information). AIS is an improved active version of GPS, as it uses the location data from GPS. AIS has the self reporting capability that streams the data to the receiving stations. There are three cases found in these result: i) boats are never gone near to the IMBL, ii) boats crossed the IMBL, iii) boats prevented from crossing. AIS based system not only traces the exact location of the boat, also decreases the smuggling across the borders.

Conclusion

It is evident that border security for fishermen is a matter in concern as they may get forceful attack for purposely crossing the IMBL in order to get more fishes. In this paper, we proposed an Automatic Identification System (AIS) for preventing fisherman from crossing the International Maritime border as well as helping them from prevention of collision avoidance. The electronic components are low cost and reliable to fishermen. This device is built using PIC16F877A embedded system, AIS, VHF set, voice module and Proteus software. The benefit of using AIS with embedded system enhances safety of fishermen and perfect messages between coast guards and fishermen. The existing systems like Android, ECDIS were used to monitor the fishermen, but not suited for controlling fishermen who are in purpose. The developed border security for fishermen device shows perfect result during fishing. In addition, this system helps fishermen to avoid collision and also smuggling. Each fisherman can be traced involuntarily by coastal guards which guarantee safeness. The proposed system has better performance than the relevant ones such as RF (Charan et al. 2016), ECDIS (Vanparia and Ghodasara 2014), Android (Kumar et al. 2016), GSM and GPS (Sivagnanam et al. 2015). In the future, we will consider the extension of the AIS system by advanced machine learning methods such as Deep Learning for enhancing the accuracy.

Compliance with ethical standards

Conflict of interests The authors declare that they do not have any conflict of interests.

References

Amal L, Son LH, Chabchoub H (2018) SGA: spatial GIS-based genetic algorithm for route optimization of municipal solid waste collection. Environ Sci Pollut Res 25(27):27569–27582

Amarasinghe O, Bavinck M (2017) Furthering the implementation of the small-scale fisheries guidelines: strengthening fisheries cooperatives in Sri Lanka. In: The small-scale fisheries guidelines. Springer, Cham, pp 379–399

Asha-Rose M (2017) Maritime safety and security in Tanzania: challenges and opportunities. 1st International Symposium on Land and Maritime Border Security and Safety, Saudi Arabia, pp 72–79

Balakrishnan NRS, Arunkumar R (2018) Smart real time rescue system for fishermen. Pak J Biotechnol 15(1):73–75

Beckman RC (2017) The China-Philippines dispute in the South China Sea: does Beijing have a legitimate claim? In: The South China sea disputes: flashpoints, turning points and trajectories, pp 23–26

Binder C (2017) Border disputes through ill-defined borders: maritime territorial conflicts and their impact on security. In: Border politics. Springer, Cham, pp 33–50

Boulila W, Farah IR, Hussain A (2018) A novel decision support system for the interpretation of remote sensing big data. Earth Sci Inf 11(1): 31–45

Bunholi IV, da Silva Ferrette BL, De Biasi JB, de Oliveira Magalhães C, Rotundo MM, Oliveira C et al (2018) The fishing and illegal trade of the angelshark: DNA barcoding against misleading identifications. Fish Res 206:193–197

Charan AS, Srinivasaverma VSM, Mahammad N (2016) Lifeline system for Fisherman. Springer India. Microelectronics, Electromagnetics and Telecommunications. https://doi.org/10.1007/978-81-322-2728-1_55

Charles J, et al (2016) Alert system for fishermen crossing border using android. International Conference on Electrical, Electronics and optimization Techniques (ICEEOT)-2016, pp 245–256

Chatterjee JM, Son LH, Ghatak S, Kumar R, Khari M (2018) BitCoin exclusively informational money: a valuable review from 2010 to 2017. Qual Quant 52(5):2037–2054

Chen Z, Xue J, Wu C, Qin L, Liu L, Cheng X (2018) Classification of vessel motion pattern in inland waterways based on Automatic Identification System. Ocean Eng 161:69–76

Chuan PM, Son LH, Ali M, Khang TD, Dey N (2018) Link prediction in co-authorship networks based on hybrid content similarity metric. Appl Intell 48(8):2470–2486

Churchill RR (2018) Maritime boundary problems in the Barents Sea. In: Routledge revivals: maritime boundaries and ocean resources (1987). Routledge, Abingdon, pp 147–161

De Lessio MP, Wynn DC, Clarkson PJ (2017) Modelling the planning system in design and development. Res Eng Des:1–23

Eman HM, Alkhammash, Tahani MS (2017) A survey on the use of technologies in the context of border safety and security. 1st International Symposium on Land and Maritime Border Security and Safety, Saudi Arabia, pp 89–96

Giap CN, Son LH, Chiclana F (2018) Dynamic structural neural network. J Intell Fuzzy Syst 34:2479–2490

Goudossis A, Katsikas SK (2018) Towards a secure automatic identification system (AIS). J Mar Sci Technol. https://doi.org/10.1007/s00773-018-0561-3

Jeandesboz J (2017) European border policing: EUROSUR, knowledge, calculation. Global Crime 18(3):256–285

Kapoor R, Gupta R, Kumar R, Son LH, Jha S (2018a) New scheme for underwater acoustically wireless transmission using direct sequence code division multiple access in MIMO systems. Wirel Netw:1–13. https://doi.org/10.1007/s11276-018-1750-z

Kapoor R, Gupta R, Son LH, Jha S, Kumar R (2018b) Boosting performance of power quality event identification with KL divergence measure and standard deviation. Measurement 126:134–142

Kapoor R, Gupta R, Son LH, Jha S, Kumar R (2018c) Detection of power quality event using histogram of oriented gradients and support vector machine. Measurement 120:52–75

Kowsalya G, Palani U, Hemalatha P (2017) An innovative android application for maritime border alert system. Adv Nat Appl Sci 11(7): 384–391

Kumar N, Ranjith R (2014) Border alert and smart tracking system with alarm using DGPS and GSM. International Journal of Emerging Technology in Computer Science & Electronics (IJETCSE) 8(1): 78–84

Kumar RD, Aldo MS, Joseph JCF (2016) Alert system for fishermen crossing border using Android. In Electrical, Electronics, and Optimization Techniques (ICEEOT), International Conference on, pp 4791–4795. IEEE

Kumar R, Son LH, Jha S, Mittal M, Goyal LM (2018) Spatial data analysis using association rule mining in distributed environments: a privacy prospect. Spatial Information Research:1–10. https://doi.org/10.1007/s41324-018-0207-x

Lampert T (2017) Stopping illegal fishing and seafood fraudsters: the presidential task force's plan on tackling IUU fishing and seafood fraud. BCL Rev 58:1629

Lim K (2017) The role of the international maritime organization in preventing the pollution of the world's oceans from ships and shipping. UN Chron 54(2):52–54

Louati A, Son LH, Chabchoub H (2018) Smart routing for municipal solid waste collection: a heuristic approach. J Ambient Intell Humaniz Comput:1–20. https://doi.org/10.1007/s12652-018-0778-3

Ngan RT, Son LH, Cuong BC, Ali M (2018) H-max distance measure of intuitionistic fuzzy sets in decision making. Appl Soft Comput 69: 393–425

Nguyen HT (2017) China's "historical evidence": Vietnam's position on South China Sea. In: The South China sea disputes: flashpoints, turning points and trajectories, pp 243–246

Olivier Y (2017) Blue border Security. 1st International Symposium on Land and Maritime Border Security and Safety, Saudi Arabia, pp 64–71

Page CE (2017) Maximizing maritime safety and environmental protection with AIS: (Automatic identification system). OCEANS–Anchorage, 2017, pp78–85, IEEE

Praczyk T (2018) A quick algorithm for horizon line detection in marine images. J Mar Sci Technol 23(1):164–177

Proud R, et al (2017) Small vessel tracking using AIS for enhanced maritime domain awareness. OCEANS–Anchorage, 2017, pp. 147–155, IEEE

Reza Y, Mason R (2015) An energy-efficient transceiver architecture for short range wireless sensor applications. In IEEE Radio and Wireless Symposium, pp 458–461, IEEE

Rosello M (2017) Cooperation and unregulated fishing: interactions between customary international law, and the European Union IUU fishing regulation. Mar Policy 84:306–312

Saravanan K (2017) Cloud robotics: robot rides on the cloud – architecture, applications, and challenges. In: Kumar R, Pattnaik P, Pandey P (eds) Detecting and mitigating robotic cyber security risks. IGI Global, Hershey, pp 261–274. https://doi.org/10.4018/978-1-5225-2154-9.ch017

Saravanan K, Srinivasan P (2018) Examining IoT's applications using cloud services. In: Tomar P, Kaur G (eds) Examining cloud computing technologies through the internet of things. IGI Global, Hershey, pp 147–163. https://doi.org/10.4018/978-1-5225-3445-7.ch008

Saravanan K, Anusuya E, Kumar R, Son LH (2018) Real-time water quality monitoring using internet of things in SCADA. Environ Monit Assess 190(9):556

Singh DK, Kushwaha DS (2017) Automatic intruder combat system: a way to smart border surveillance. Def Sci J 67(1):50

Singh K, Singh K, Son LH, Aziz A (2018) Congestion control in wireless sensor networks by hybrid multi-objective optimization algorithm. Comput Netw 138:90–107

Sivagnanam G et al (2015) Coast guard alert and rescue system for international maritime line crossing of fisherman. International Journal of Innovative Research in Advanced Engineering (IJIRAE) 2(2):124–132

Son LH, Jha S, Kumar R, Chatterjee JM, Khari M (2018a) Collaborative handshaking approaches between internet of computing and internet of things towards a smart world: a review from 2009–2017. Telecommun Syst:1–18. https://doi.org/10.1007/s11235-018-0481-x

Son LH, Chiclana F, Kumar R, Mittal M, Khari M, Chatterjee JM, Baik SW (2018b) ARM–AMO: an efficient association rule mining algorithm based on animal migration optimization. Knowl-Based Syst 154:68–80

Tam NT, Hai DT, Son LH, Vinh LT (2018) Improving lifetime and network connections of 3D wireless sensor networks based on fuzzy clustering and particle swarm optimization. Wirel Netw 24(5):1477–1490

Tsiotas D (2017) The imprint of tourism on the topology of maritime networks: evidence from Greece. Anatolia 28(1):52–68

Vanparia P, Ghodasara YR (2014) Review paper on to study and enhance coastal security system using GIS/GPS tool. International Journal of Computer Applications & Information Technology 1:58–64

Viji C et al (2017) Literature review on alert system for fishermen border crossing. Asian Journal of Applied Science and Technology (AJAST) 1(1):34–37

Vintilă DF, Filip C, Stan MI, Țenea DD (2017). Considerations regarding a sustainable economicdevelopment in the romanian black sea coastal area in the context of maritime spatial planning (MSP). In International Conference on Management and Industrial Engineering (8, pp. 667–675). Niculescu Publishing House, București

Vivek S, Venkatraman A, Aravinth L, Raagul G (2015) Automatic border crossing detection and navigation of boat. International Journal of Science Technology & Engineering 1(8):21–29

Yin Y, Lam JSL, Tran NK (2017) Review of Emission Accounting Models in the Maritime Industry. In Meeting the Energy Demands of Emerging Economies, 40th IAEE International Conference, June 18–21, 2017. International Association for Energy Economics