Design and Development of Low Cost Navigation and Security System for Indian Fisherman Using Adrino Nano Platform

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ABSTRACT

The fishing industry plays a major role in development of Indian economy. The recent attacks on fishermen taking place in Indo-Srilanka and Indo-Pakistan maritime boundaries have been major concerns. These attacks are primarily caused by the lack of navigation and security features during the voyage. Hence the current situation demands the implementation of precise facilities for reducing man and material loss. This paper involves the design and implementation of a Low cost Navigation and Security System for Indian fishermen on Arduino Nano platform. The system developed solves the above said issues by continously tracking the location of fishing vessel and providing minimal security features. The system ensures that navigation is in safe zone within the nation's maritime boundary and also prevents crossover. This is acheived using GPS receiver which directly links to GPS satellites for current location of the vessel. The required data fields like the latitude and longitude data along with the time stamps are extracted from the GPS samples and used for comparision for determining the exact location of the vessel. This procedure will help in detection of corner cases when the vessel is nearing or about to crossover the maritime boundary, which cannot be marked physically. It is useful for triggering conditions like enabling or disabling fuel injection system, the warning beeps and display notifications to the fishermen. Manual override facility for restarting the engine in case of crossover for limited duration is provided. The security features like authentication for the genuine operator to get access to the engine panel, the support for distress message and the storage of the exact time stamps and GPS locations after encryption in case of initiation of transmitting distress message is provided as a blackbox feature. The passcode based mechanism allows for maximum of three attempts to unlock access to control panel. The GSM modem allows for transmission of distress message to the registered base station/coast guard. The encrypted GPS samples and time stamps are stored in on-chip EEPROM memory for future reference.

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1. INTRODUCTION

The Tamil Nadu factor in India-Sri Lanka relations that had been quiet for long has come to the force in the form of the fishermen issue. Frequent incidents of fishermen from Tamil Nadu getting shot in the Sri Lankan's maritime boundary have enraged all citizen of the state. From Tamil Nadu about 18,000 boats of different kinds conduct fishing along the India-Sri Lanka maritime border. Ever since violence broke out in Sri Lanka two decades ago, fishing activity has not been peaceful. Tamil Nadu fishermen are arrested, or shot, by the Sri Lankan Navy. 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 (**Roy-Chaudhury Rahul**). At the same time however, quite a few Indian fishermen engage in free floating to exploit marine resources in Sri Lankan waters, knowing full well, the risks involved in crossing the International Maritime Boundary Line (IMBL). Growing markets for marine resources has forced Tamil Nadu fishermen to take risks.

1.1. Application of GPS in Fishermen Navigation System

GPS (Global Positioning System) is increasingly being used for a wide range of applications. It provides reliable positioning, navigation, and timing services to worldwide users on a continuous basis in all weather, day and night, anywhere on or near the Earth.

GPS is made up of three segments: Space, Control and User. GPS has become a widely used aid to navigation worldwide, and a useful tool for map-making, land surveying, commerce, scientific uses, tracking and surveillance, and hobbies such as geocaching and way marking. None of the present GPS systems satisfy the requirements for the safety of civilian navigation in the sea as the maritime boundary of a country cannot be marked.

This work adds on the versatility and the usefulness of a GPS device in the sea. The main objective of the system is to help the fishermen not to navigate beyond country's border. If a fisherman navigates beyond the country's border, an alarm is generated indicating that the fisherman has nearing the border. With this alarm, the fisherman can be caution and come back inside the country's border. Additionally, a message transmitter is interfaced with the device to send a message to base station located on the shore indicating that a vessel has crossed the border. Thus coast guards in the shore can assist and provide additional help to those fishermen if needed.

1.2. Challenges in Using the System

There are many challenges associated with the accuracy and usefulness of navigation system in marine environment. For fisherman navigation system there are limitations on the equipment used and the quality of the GPS data. GPS data reception may not be consistent due various reasons like cloudiness.

2. BOUNDARY LOCATION

The practice of apprehending Indian fishermen, along with their boats, has been followed by Sri-Lankan Navy and Maritime Security Agency (MSA) of Pakistan. Indian Coast Guard or the Indian navy does the same to Pakistani and Sri Lankan fishermen, due to which poor fishermen on all sides have suffered (Karthikeyan R). as shown in Figure 1.

2.1. Boundary Locations between Srilanka and India

The maritime boundary between Sri Lanka and India in the Gulf of Mannar in terms of GPS locations has been depicted with the listed positions in Table 1., in the sequence given below, defined by latitude and longitude:

Table 1. GPS locations for Indo-Srilankan maritime boundary

POSITIONS	LATITUDE	LONGITUDE
Position 1	09°06'.0 N	79°32'.0 E
Position 2	09°00'.0 N	79°31'.3 E
Position 3	08°53'.8 N	79°29'.3 E
Position 4	08°40'.0 N	79°18'.2 N
Position 5	08°37'.2 N	79°13'.0 E
Position 6	08°31'.2 N	79°04'.7 E
Position 7	08°22'.2 N	78°55'.4 E
Position 8	08°12'.2 N	78°53'.7 E
Position 9	07°35'.3 N	78°45'.7 E
Position 10	07°21'.0 N	78°38'.8 E
Position 11	06°30'.8 N	78°12'.2 E
Position 12	05°53'.9 N	77°50'.7 E
Position 13	05°00'.0 N	77°10'.6 E

While the maritime boundary between Sri Lanka and India in the Bay of Bengal is shown in Table 2.

Table 2. Maritime boundaries in Bay of Bengal

POSITIONS	LATITUDE	LONGITUDE
Position 1	10°05’.0 N	80°03’.0 E
Position 2	10°05’.8 N	80°05’.0 E
Position 3	10°08’.4 N	80°09’.5 E
Position 4	10°33’.0 N	80°46’.0 E
Position 5	10°41’.7 N	81°02’.5 E
Position 6	11°02’.7 N	81°56’.0 E
Position 7	11°16’.0 N	82°24’.4 E

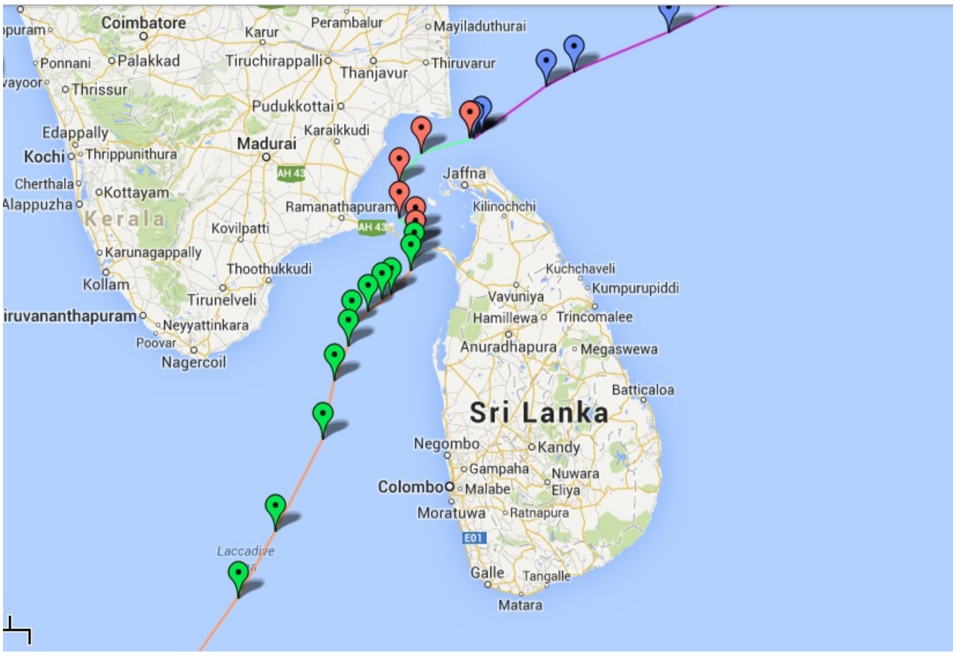


Figure 1. Graphical Representation of India-Srilanka maritime border [6]

2.2. Fishermen Issues between India and Sri-Lanka

In the case of Indian-Srilanka, there is no physical boundary in the sea. In most cases fishing boats can unwillingly and unintentionally cross into the other territories because of tidal currents, engine failure, wind force, cyclones etc. The apprehending force is keenly watching and following them with a view of arresting or attacking them (**Dahanayaka Piumali**). Sri Lankan fishermen, who venture on high seas for ‘multi-day fishing’, are also caught poaching in Indian waters.

2.3. Maritime Boundary between India and Pakistan

India–Pakistan maritime trespassing refers to the frequent trespassing and violation of respective national territorial waters of India and Pakistan in peacetime. Most trespassing is common to Pakistani and Indian fishermen operating along the coastline of the Indian state of Gujarat and the Pakistani province of Sindh. Most violations occur due to the absence of a physical boundary and lack of navigational tools for small fishermen. Hundreds of fishermen are arrested by the Coast Guards of both nations, but obtaining their release is difficult and long-winded owing to the hostile relations between the two nations [].

2.4. Fishermen Issues between India and Pakistan

The long-standing territorial disputes and military conflicts between India and Pakistan have led to vigilant and strict patrolling of territorial waters in the Arabian Sea and the coastline shared along the Indian state of Gujarat and the Pakistani province of Sindh by the Maritime Security Agency of Pakistan and the Indian Coast Guard. The absence of a physical boundary and lack of proper demarcation leaves small fishing boats and trawlers susceptible to illegally crossing territorial waters. The problem is aggravated by the dispute over the Sir Creek in Kutch and the failure to officially determine the maritime boundary between the two nations. Most local fishermen possess no navigational tools and are unable or incapable of determine their location by longitudes or latitudes. Even the terrorists responsible for 2008 Mumbai attacks gained entry through sea route after hijacking a fishing boat as represented in Figure 2.

Indian authorities estimate that more than 100 fishing boats and admit that they often cannot ascertain how many fishermen had strayed (**K R Srinivasan**). During periods of improvement in bilateral relations, the governments of both nations have taken steps to release imprisoned fishermen as a confidence-building measure and gestures of peace and goodwill. In 2006, Pakistan released more than 400 Indian fishermen (including 30 children) and India reciprocated by releasing 130 Pakistani fishermen, but claimed that as many as 350 fishermen were still languishing in Pakistani jails.

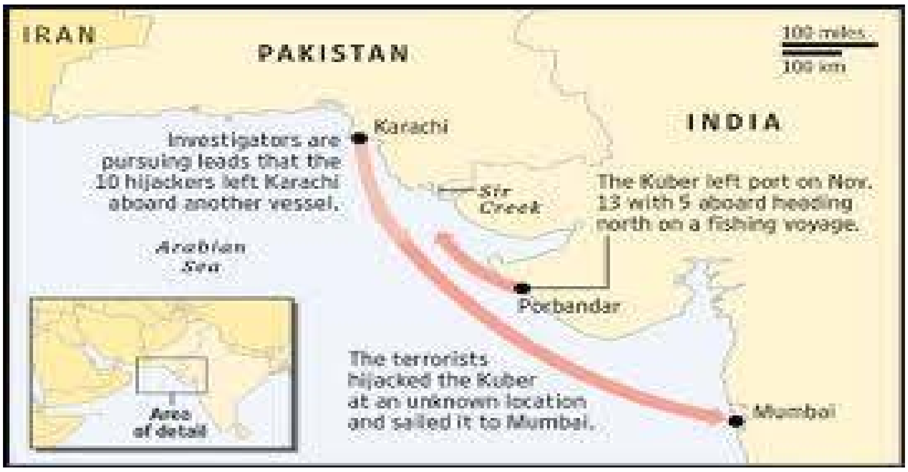


Figure 2. Sea Route Taken by the Terrorist for Mumbai Attack [6]

3. DESIGN AND DEVELOPMENT

The functional block diagram for the proposed system with adequate peripheral interfaces is shown in Figure 3.

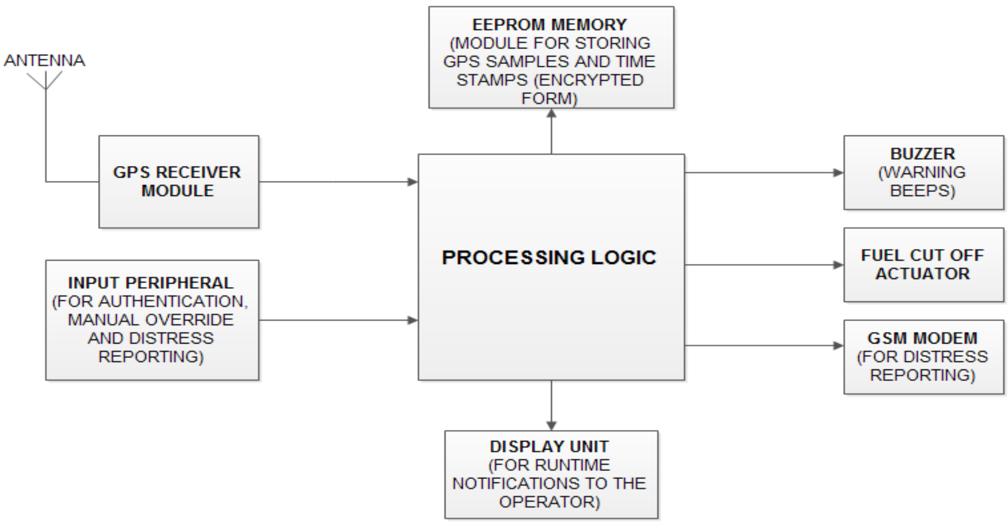


Figure 3. Functional Block diagram for the proposed system

As shown in Figure 3 the system is primarily driven by current GPS locations of fishing vessel hence on the input side GPS receiver module is interfaced. The data from GPS receiver is received in standard NMEA format in the form of packet digital data. An input keypad module is used to facilitate the entering of passcode for authetication of operator. The output peripherals will consist of a display unit to display various message notifications to operator in runtime conditions. The EEPROM memory is used to support storage of GPS data along with time stamps in case of distress signalling emulating black box support. The actuators for fuel injection cut-off during boundary crossover conditions and a buzzer for warning beeps while nearing international maritime boundary is also provided. The GSM modem is also interfaced for supporting delivery of distress message to base station or coast guard. The processing logic for the system is split up across two computing platforms of similar specifications. The reasons for using two platforms include the lack of adequate amount of GPIO pins for interfacing certain peripherals and the need for multiple UART protocol compatible transmitter and receiver pins.

3.1. System Flow Diagram

The Figure 4 shows the proposed flowchart processing logic on platform board-1 for the given system.

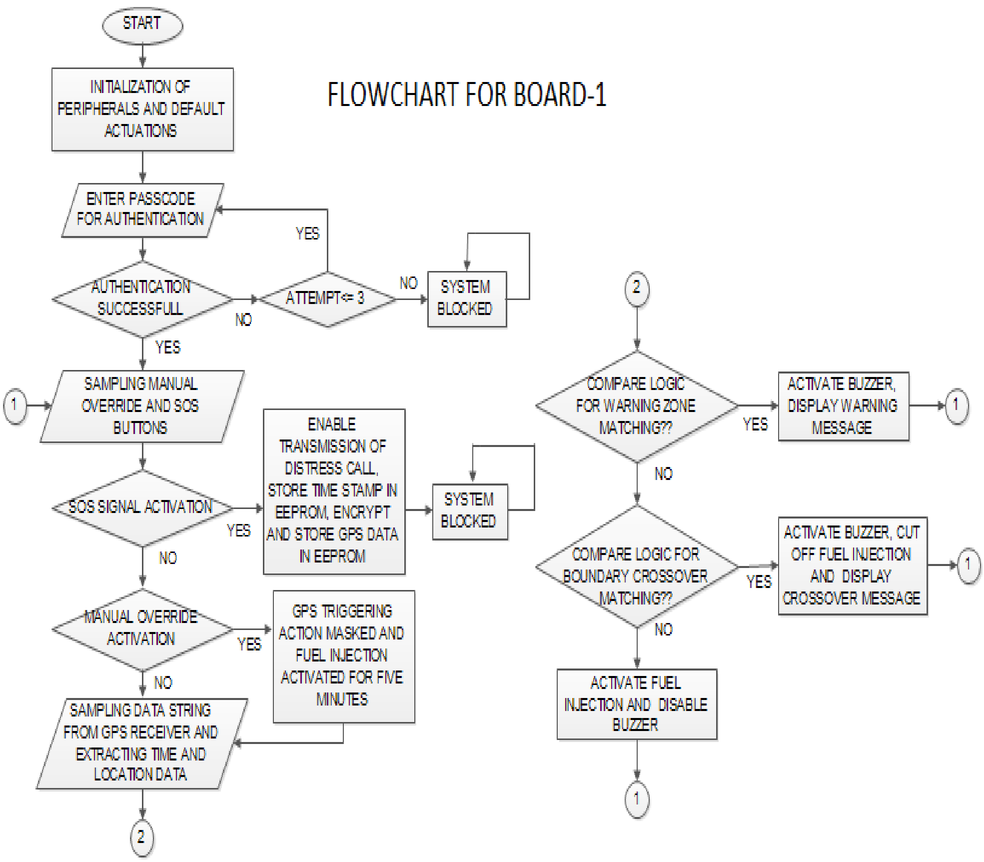


Figure 4. Flowchart for processing logic platform board-1

The board-1 will be interfaced to keypad module, GPS receiver module and actuators for triggering actions of fuel injection cut-off in case of boundary crossover and warning beeps while nearing the international maritime boundary. The logic on platform board-1 interacts with logic on platform board-2 signalling exact indicators for the message strings to be displayed under various scenarios and also request signal for enabling transmission of distress message in case of '**SOS**' button initiation, since platform board-2 will be interfaced to LCD and GSM modem (**AT & T**).

The data flow for logic on board-1 is given as follows:

Step 1: The output ports for LCD display indicators, distress message indicator, fuel injection status and warning beep are initialized and reference GPS boundary locations and passcode are set. The passcode functionality is initiated.

Step 2: The passcode function samples the user passcode and compares against the reference passcode while updating LCD display data indicators for every case (i.e. Authentication successful or unsuccessful).

Maximum of three reattempts are allowed in case of wrong passcode entry, on crossing which the system is blocked. On successful authentication control is switched to servicekey function.

Step 3: In servicekey function input from the custom keypad is sampled, if the input is 'E' (i.e by pressing button E) then SOS functionality is performed by enabling request signal for distress message transmission to platform board-2. Then the time stamp from GPS samples is stored in on-chip EEPROM memory ranging from 20th location to 23rd locations (i.e. 'hh-mm' format).

Step 4: The GPS locations are encrypted by passing the values to ciper algorithm ('encrypt' function). The individual numbers from the passed value are separated and checked within the case logic. In every case the character to replace each number is read from a global character array (i.e. named as 'Elements') using the number itself as the index pointer. The replaced character for each number is stored in another global character array (i.e. named 'Results').

Step 5: the encrypted GPS locations are read from global character array (i.e. named 'Results') and then stored in EEPROM memory ranging from 24th location to 27th location, while also updating SOS notification through LCD display indicators.

Step 6: If the input sampled is 'F' then manual override functionality is enabled and the fuel injection is enabled and the buzzer is disabled for the next five minutes irrespective of previous triggering conditions while updating the LCD display indicators. Upon the return from five minutes delay, the control flow is tranfered to GPS sample function. If both SOS and Manual override conditions are not detected, control flow is directly swicthed to GPS sample function.

Step 7: In GPS sample function the availability of GPS data is checked by reading status of serial buffer. Once data is available the samples are captured in a character array. The sampled data in character array is scanned for finding '$GPRMC' string.

Step: Upon a successful match the data from various positions in GPRMC packet is retrieved and bifurcated with the help of index to the locations of particular data. The time stamp in terms of hours and minutes data is extracted, and GPS locations in terms of latitude and longitude degree and latitude and longitude minutes are also extracted, with position reference from NMEA format.

Step 8: Rest of the data from other fields of GPRMC string is ignored. The selected data retreived which is character form is typecasted and converted to integer format through some small computational operations, with a view of comparing them against the prespecified reference GPS boundary locations.

Step 9: The control flow is then passed to GPS compare function where the condition check for the appropriate Latitude and Longitude degree is done by comparing sampled GPS values and prespecified reference boundary locations. Upon failed condition the fuel injection is cut off, buzzer is enabled and notification of cut off is updated on LCD display indicators. Upon pass condition the condition check for warning zone for enabling the buzzer is done, in case the vessel is nearing maritime boundary (i.e. 2 nautical miles before maritme boundary). Upon pass condition the buzzer is enabled and warning messages is updated on LCD via display indicators.

Step 10: In case the warning zone condition fails, condition check for boundary crossover is done, in case the vessel is approaching maritime boundary (i.e. 1 nautical mile before maritme boundary). Upon pass condition the fuel injection is cut off and buzzer is enabled also updating the crossover notification through LCD display indicators. Upon failed condition the fuel injection is enabled and buzzer is disabled indicating vessel is safe zone. The control flow returns to Step 3 and the process iterates infinitely.

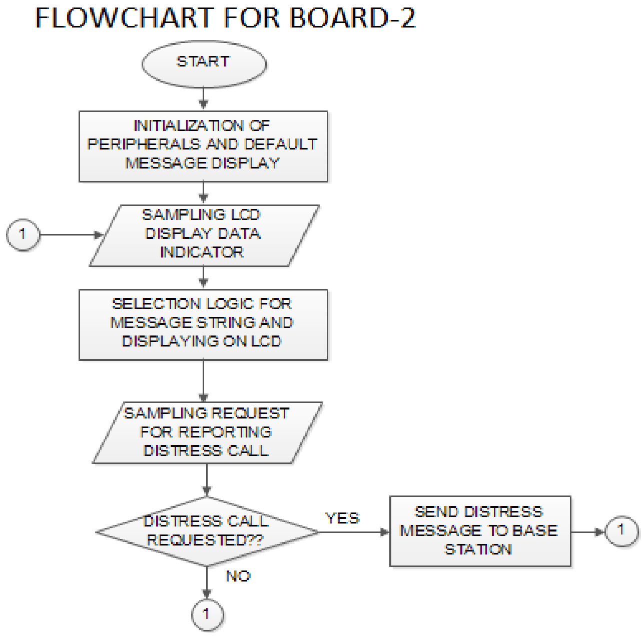


Figure 5. Flowchart for processing logic platform board-2

The platform board-2 is interfaced to LCD and GSM modem. The algorithm on board-2 is developed to sample indicators for particular message strings on LCD under various scenarios (i.e. Authentication messages, Warning beep messages, SOS status messages, Manual Override messages and Fuel cut off messages). The algorithm also samples request for enabling transmission of distress message to base station by sharing the registration number of vessel as shown in Figure 5. The data flow is depicted by algorithm given as follows:

Step 1: Initialising the input pins for LCD display data indicators and for distress message request signal.
Step 2: Initialising the LCD, defining its display format and setting the cursor.
Step 3: GSM is initialised, setting its workable baud rate. Then conditional logic is checked for GSM initialisation status.
Step 4: The function lcd_decoder() is called, where the lcd display data indicators from board-1 are sampled and based on the data received the appropriate value is passed to lcd_disp function.
Step 5: Based on the value received from lcd_decoder function the lcd_disp() function executes the particular case and also displays the message string within the case on LCD message will displayed on the LCD.
Step 6: Now in function lcddisp(), a switch-case condition is verified and depending on that, different messages will be displayed on LCD (i.e. Enter Passcode, Authentication Successfull, Wrong Passcode Please reattempt, Maximum attempts reached system is blocked, Warning zone reached, Crossed Boundary fuel is cut off, Manual Override activated and SOS detected distress call made).
Step 7: The gsm_send() function reads the status of request for transmission of distress message (i.e. gsm_en signal) which is an active low signal.
Step 8: If gsm_en signal is enabled, send the distress message with stored registration number of the vessel to the pre-specified base station number followed by acknowledgement for the sent message and returns to Step 4 and iterates infinitely. If gsm_en signal is disabled the flow directly returns to Step 4 and iterates infinitely.

3.1. System Implementation

The algorithm implementation was carried out in Arduino 1.0.3 IDE using C language and some Arduino specific constructs for deployment on Arduino Nano platform. Arduino Nano is a very small and portable board as shown in Figure 6, built around ATmega328, which is an 8-bit RISC architecture based microcontroller. The GPS receiver used in the navigation system is shown in Figure 7.

Board Specifications:

Operating Voltage	:	5 V
Input Voltage	:	7-12 V
Digital I/O Pins	:	14

Analog Input Pins	:	8
Flash Memory	:	32 KB (ATmega328) of which 2KB is used by bootloader
On EEPROM	:	1KB (ATmega328)
Clock Speed	:	16 MHz

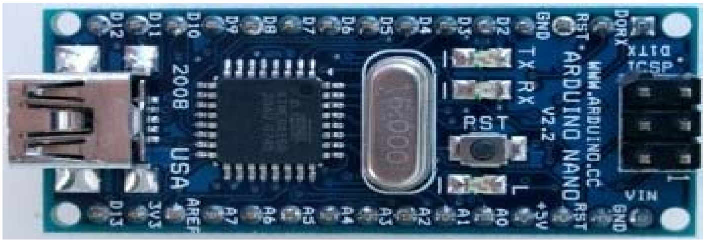


Figure 6. Arduino Nano board

Figure 7. GPS receiver

The GPS receiver shown in Figure 7 it consists of GPS-634R integrated smart GPS module with a ceraminc patch antenna. The antenna is connected via a LNA connector. The GPS receiver is capable of receiving signals from almost 65 GPS satellites and the GPS data is presented in standard NMEA format in terms of digital packet data via the UART port/RS232 serial port. The default baud rates supported by the receiver are 4800 and 9600 (Default Value: 9600)

The GPS receiver features include:

- Industry leading TTFF speed
- Tracking sensitivity reaches -161 dBm
- Cold start approximately 29 sec under clear sky
- Hot start approximately 1 sec under clear sky
- Accuracy 5m CEP

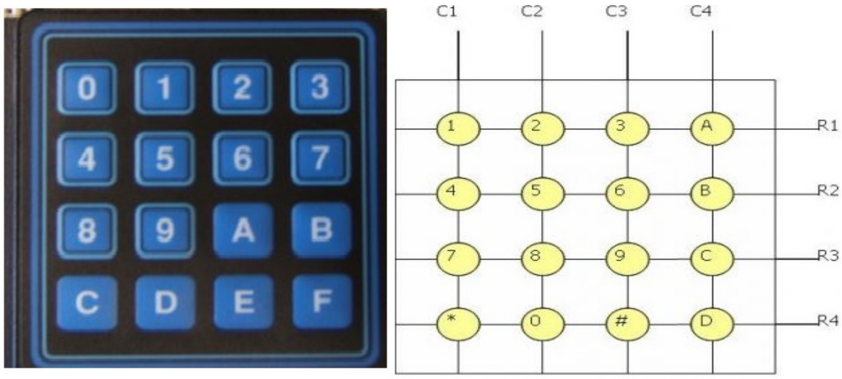


Figure 8. 4x4 Matrix Keypad

The keypad used in the current system is a 4x4 Matrix Keypad as shown in Figure 8. The keypad's pinouts include four row pins (i.e. R1-R4) and four column pins (i.e. C1-C4) allowing for the standard keypad scanning mechanism to be used for detecting any particular button press. The keys with numbers ranging from 0 to 9 are used for passcode functionality. While the keys 'E' and 'F' are used for distress message and manual override facility respectively.
The GSM modem (SIM900) used in the system was primarily chosen because of the library and API support from Arduino.The features and specifications of the modem include:

- Quad-Band GSM/GPRS 850/ 900/ 1800/ 1900 MHz
- Built in RS232 level convertor (MAX232) with configurable baud rate
- Built in Network Status LED and Built in SIM Card holder
- Normal operation temperature range : -20 ^{o}C to +55 ^{o}C
- Input Voltage: 5V-12V DC (**Open Electronics**)
- AT commands compatibility (GSM 07.07 and SIMCOM enhanced AT Commands)

Low power consumption: 1mA (sleep mode)

Figure 9. 16x4 LCD used for display notifications

The Figure 9 shows the LCD used for displaying notifications to fishermen. The LCD is used in only write transaction via 4-bit interface from the microcontroller board; hence the LSB data pins (D0, D1, D2 and D3) are grounded. The features of LCD include:

- 5x8 dots with cursor
- 16 characters *4 lines display
- 4-bit or 8-bit MPU interfaces
- Built-in controller (ST7066 or equivalent)

Display Mode and Backlight Variations

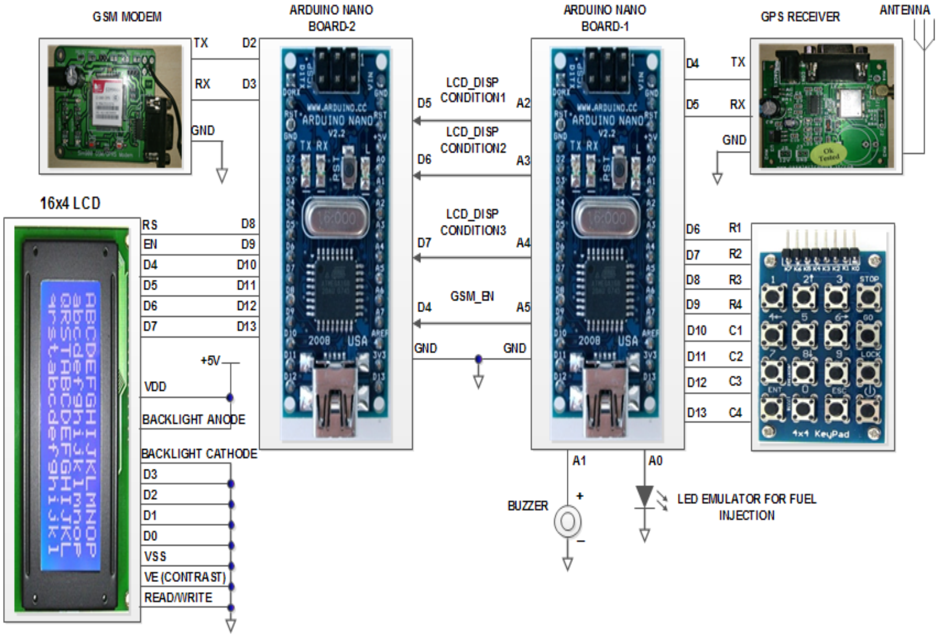


Figure 10. Implementation of the system using Adrino Nano

The Pin Interface diagram for the current system is shown in Figure 10, depicting the exact connection details between the peripherals (i.e. 4x4 Matrix keypad, GPS receiver, GSM modem and 16x4 LCD) with their respective Arduino Nano boards. The interface/control signals flow between the two Arduino Nano boards is also represented.

4. RESULTS AND ANALYSIS

The Figure 11 shows the experimental geo points used for testing the system.

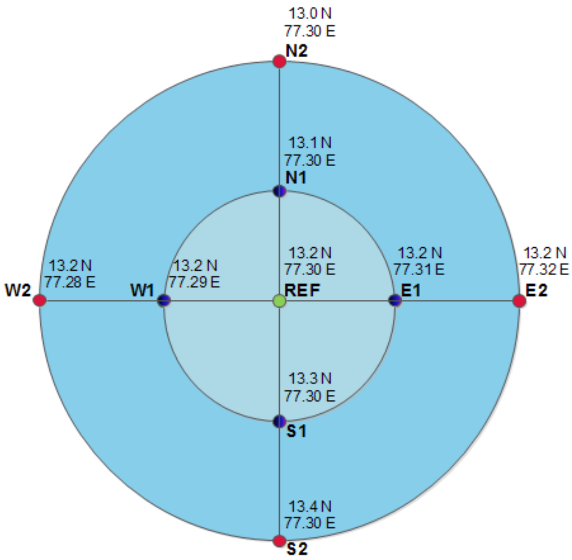


Figure 11. Geo-points used for system testing

The locations around 'REF' tag point represents the safe zone, within which the vessel is allowed to navigate and fuel injection is enabled. The area around the inner sphere marked by N1, S1, E1 and W1 tag points represents the warning zone where the warning beep from buzzer is to be enabled. The area around outer sphere marked by marked by N2, S2, E2 and W2 tag points represents the cut off zone where the fuel injection is to be disabled and warning beep is to be enabled. The Table 3 captures the condition for entry of wrong passcode and the corresponding notifications on serial terminal and LCD. The Table 4 captures the conditions for maximum attempts for passcode and the corresponding notifications on serial terminal and LCD. The Table 5 captures the conditions for successful authentication on correct passcode and the corresponding notifications on serial terminal and LCD.

Table 3. Testcase1 and results of Authentication logic wrong passcode

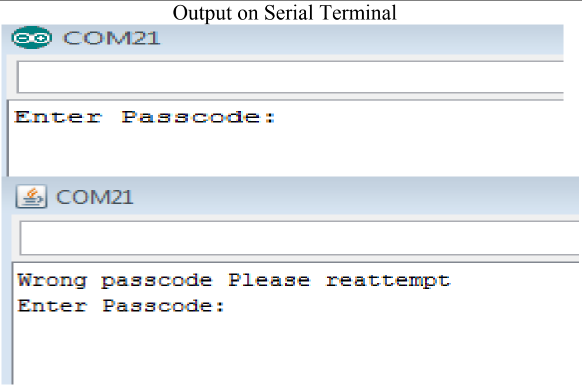
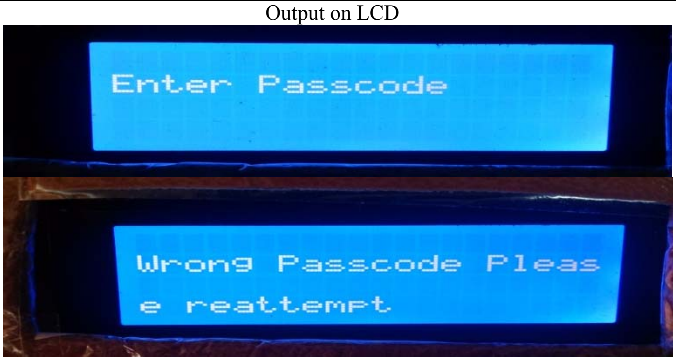
Test Case 1	Authentication logic wrong passcode
Output on Serial Terminal	Output on LCD
	

Table 4. Testcase2 and results of Authentication logic maximum reattempts

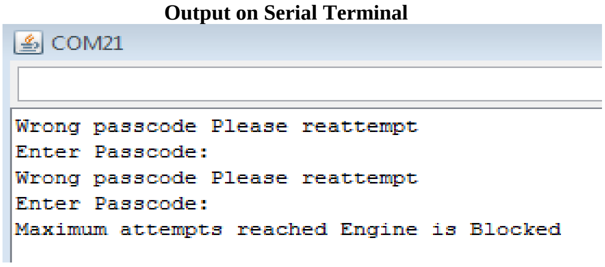
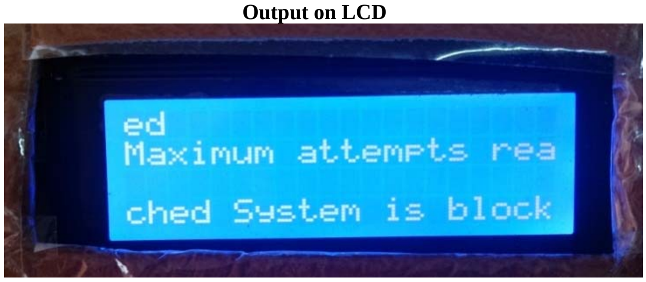
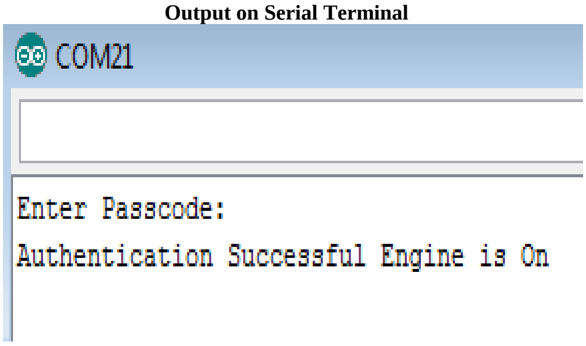
Test Case 2	Authentication logic maximum reattempts
Output on Serial Terminal	**Output on LCD**
	

Table 5. Testcase3 and results of authentication logic successful entry of passcode

Test Case 3	Authentication logic successful entry of passcode
Output on Serial Terminal	**Output on LCD**
	

The Table 6 captures the condition for vessel in warning zone and the corresponding notifications on serial terminal and LCD. The Table 7 captures the condition for vessel in cut off zone and the corresponding notifications on serial terminal and LCD. The Table 8 captures the condition for Manual

Override initiation in case of fuel injection cut off and the corresponding notifications on serial terminal and LCD.

Table 6. Testcase4 and results of vessel location in warning zone

Test Case 4	Vessel location in warning zone
Output on Serial Terminal	**Output on LCD**
GPRMC recd Time= 173915 Date= 051213 Latitude Deg= 13 Latitude Min= 2 Longitude Deg= 77 Longitude Min= 30 Warning zone reached	

Table 7. Testcase5 and results of vessel location in cut off zone

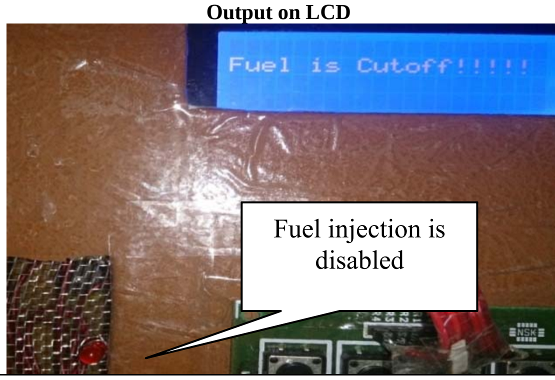
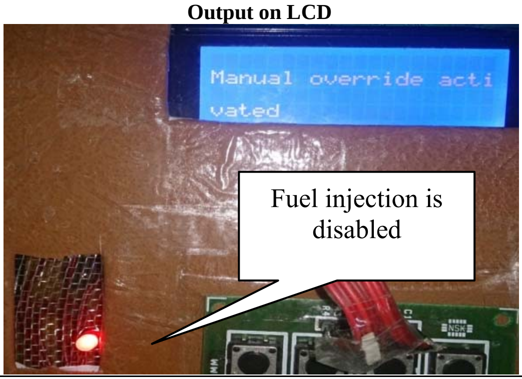
Test Case 5	Vessel location in cut off zone
Output on Serial Terminal	**Output on LCD**
GPRMC recd Time= 180927 Date= 051213 Latitude Deg= 24 Latitude Min= 0 Longitude Deg= 121 Longitude Min= 0 Degree Crossed Boundary Crossed, Fuel is Cutoff	

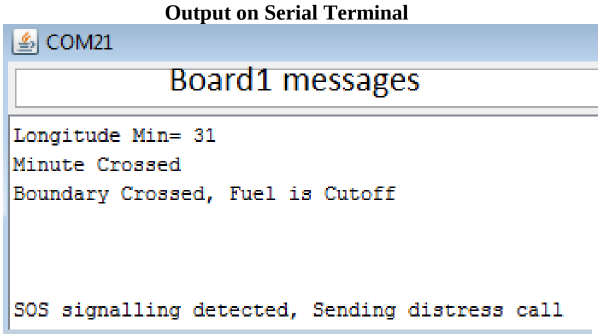
Table 8. Testcase6 and results of manual override initiation

Test Case 6	Manual Override initiation
Output on Serial Terminal	**Output on LCD**
GPRMC recd Time= 173743 Date= 051213 Latitude Deg= 13 Latitude Min= 2 Longitude Deg= 77 Longitude Min= 30 Warning zone reached Manual Override initiated	

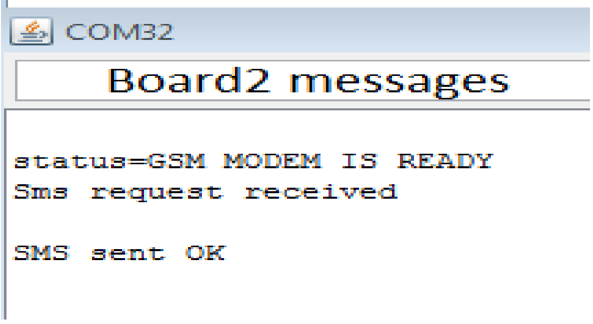
The Table 9 captures the condition for initiation of distress reporting and the corresponding notifications on serial terminal from board-1 and board-2, LCD notifications and the received message on cellphone.

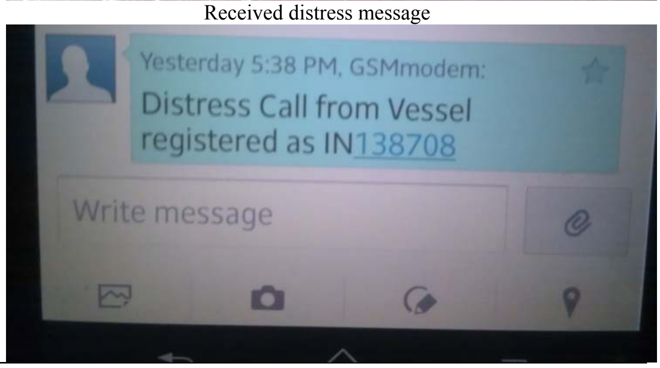
Table 9. Testcase7 and results of initiation of distress reporting

Test Case 7	Initiaton of distress reporting
Output on Serial Terminal	**Output on LCD**



Received distress message





5. CONCLUSION

This work is focused on the critical evaluation on the role and reliability of navigation and security system for Indian fishermen. Primary and secondary resources were used in the project execution. For the primary data, a survey has been conducted among the fisherman community. Secondary resources derived from various publications including books and journals were integrated to support the findings. This system deals on the versatility and the usefulness of a GPS device in the sea. Based on the results of the various test cases, system functionalities were validated. The test results agree that this solution is capable of identifying maritime boundary between countries and provide navigation by enabling various triggering actions under varied conditions. The security features included in the system will have a big role in ensuring the safety of the fishermen.

In addition, system has some other advantages. One of which is its user friendliness through the resolution of common fishermans lack of knowledge of maritime boundary. The integration of Arduino technology in administering this project also made this system a cost-effective product for common fisherman.

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