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Stand-Alone Coastal Cross Border Surveillance System Using Internet of Things and Wireless Networks.

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ABSTRACT

In day-to-day life we hear about many Indian fishermen being arrested by neighbouring countries for border-crossing in sea waters. The sea border between the countries is not easily identifiable which becomes the main reason for the cross border cruelty. Also due to lack of weather information such as wind speed and direction, tidal waves information, and other oceanic conditions many fishermen loss their lives. Automatic and wireless surveillance is emerging as an important research area to overcome these difficulties. This paper proposes a stand-alone surveillance system to alert the fishermen when they reach near a country's border and to update them about the oceanic conditions as well. A working model consisting of an Internet of Things (IoT) based Remote Base Station (RBS) and Electronic Control Unit (ECU) is designed. The ECU would receive the weather conditions from the RBS located on coastal ground and would send back the boat's Global Positioning System(GPS) coordinates back to the RBS which could be used for monitoring purposes. The ECU has predefined three zonal boundaries separating four zones namely, normal, warning, pre-restricted and restricted zone. When the boat reaches the periphery of any of the three zonal boundaries, different forms of alert and control mechanisms will be activated. The ECU also consists of an 'All direction obstacle detection system' for boat protection. An experimental setup established proved the success of the proposed method. The results obtained indicated the usefulness of the proposed system in terms of border detection, monitoring and alerting.

Keywords: RBS, ECU, IoT, ZigBee, Ultrasonic Sensor, Data Scrapping.

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INTRODUCTION

Monitoring of behavioral activities in order to prevent illegal cross border maritime actions and elimination of crime using systematic and comprehensive surveillance and control system is the central idea of this research. One of the major issue faced by Indian Fishermen is trespassing of maritime boundaries because small boats tend to drift by currents and end up having unknown orientation, which is a potential irritant. To stop our fishermen from being the victim of this cross border cruelty a working model has been developed which would alert the fishermen when they reach near the country's maritime border. The existing system are GPS and RADAR based run by coastal guards. But due to its short range coverage, high cost and inefficiency the system has been modified where instead of radar technology, Wireless Sensor Network(WSN) based Received Signal Strength Indication(RSSI) technique were used. But this method also proved to be inefficient due to lack of proper transmission signals at sea level. Further the system was also proposed which used Global System for Mobile Communication(GSM) modem for wireless communication. Wireless Sensor Networks emerging as a flexible and dynamic option in rural, sub-urban and urban area was narrated in [1].An innovative solution for ship intrusion detection is Wireless Sensor Network equipped with three-axis accelerometer sensors on the sea's surface to detect ships from [2]. But GSM did not seemed to be the good idea due to its small range and poor signal strength at sea level. For monitoring and controlling the speed of boat's motor Advanced Risc Machine (ARM) processor is the existing system. ARM processor being expensive and complex is not widely used. Thus to overcome all these problems the proposed system has been designed which consists of Arduino Mega as a processing unit for proper monitor and control of boat's motor system based on zonal location of boat. For wireless communication between ECU and RSB units, Zigbee is preferred. Zigbee provides long way communication at sea level and is by far the best solution for wireless data transmission at sea level where network strength is very poor. An analytical tool suitable for both real life and simulation scenarios to the network designers to forecast and optimize the expected detection performance was discussed in [3]. A border surveillance system able to recognize intruder actions like standing, walking, crawling, and bending, etc. in illuminated as well as in dark conditions was elaborated in [4]. The system is able to detect whether the moving object is a human being or an animal and activates an alarm if it detects human movement. The utility of ultrasonic sensors to distinguish between people and animals walking were explored with the phenomenology associated with human and animal walking in [5].

SYSTEM DESCRIPTION

The experimental setup consists of ECU and RBS. The occupants of the base station are the coastal guards who receives the GPS coordinates (latitude and longitude) of the boat thereby directing the fishermen to change their direction when they reach near the maritime boundaries. The sea area is divided into four zones-normal zone, warning zone, pre-restricted zone and restricted zone. The continuous monitoring and comparison of current coordinates of the boat obtained from GPS to the pre-defined zonal coordinates is done using an Arduino Mega processor. When the fishermen's present coordinates match the pre-restricted zone's pre-fed coordinates, the corresponding LED will blink and the alarm will start indicating the fishermen his closeness to the maritime boundary. In addition to this the speed of motor in the boat will be reduced by fifty percent. Further, if the fishermen cross the pre-restricted zone and reaches the restricted zone the motor will stop thereby preventing the fishermen to cross the maritime boundary. All this time the alarm will continuously sound as an indication to the fishermen. All these control actions are being continuously monitored by the coastal guards sitting in the base station. The current GPS location of boat is being sent to the base station using wireless sensor network (WSN), Zigbee in our prototype as WSN has emerged as a powerful tool for connecting physical and digital world. In addition to this Zigbee communication is also used to transfer scrapped weather conditions like tidal types and height, wind speed and direction, etc., from a website using the concept of IoT to the LCD display installed in ECU of the boat to keep fishermen updated about the weather conditions. Predicting nearby obstacle is another problem to be dealt with. For this four ultrasonic sensors are placed on four different directions for 360-degree obstacle detection. The designed prototype is made cost effective so that it can be widely used by fishermen to protect themselves from such cruelty and inhumane behavior.

The ECU unit consists of Arduino Mega microprocessor for monitoring and controlling purposes. The interfacings to the Mega are GPS which is used for location tracking of the boat using it's latitudinal and longitudinal values, LEDs to indicate the zonal location of boat i.e. whether the boat is in normal zone or any of

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the restricted zones. In addition to this Ultrasonic sensors and LCD is also interfaced to the Arduino Mega processing unit. Four ultrasonic sensors are placed in four different directions which forms the 'All Direction Obstacle Detection System' to protect the boat from any form of hindrance. To each sensor single LED is interfaced to indicate in which direction obstacle is sensed. LCD is used to display the current GPS coordinates of the boat and the weather conditions (tidal type and height, wind speed and direction, temperature) in hour basis. These weather information has been scrapped from a weather forecast website using IOT technique through RASPBERRY PI which forms the central part of RBS unit.

The RBS unit uses PYTHON codes for scrapping of data and transfers it wirelessly to the display of ECU using XBEE communication. Two transceiver XBEEs are installed in base station for continuous transferring of information (weather condition from RBS to ECU and boat's location information from ECU to RBS) between the two units. Thus XBEE facilitates the mode of interaction and linking of two separate units.

DESIGN OF ECU

ECU is installed in the fishermen boat in sea area. Wireless Zigbee communication forms the only link between ECU and RBS. The ECU unit is designed using the following components:

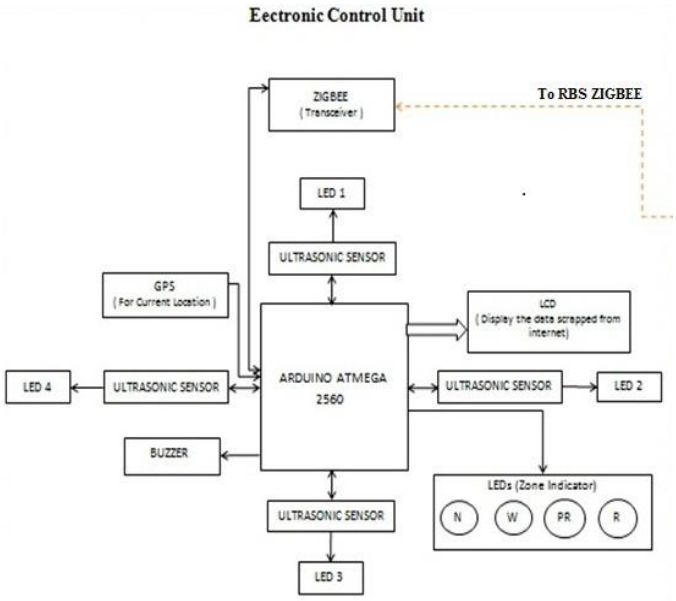

Fig.1 Electronic control Unit(ECU)

Global Positioning System (GPS) Module

Global Positioning System is used world-wide for reliable and precise location detection. The Global Positioning System (GPS) is a satellite-based navigation system made up of a network of 24 satellites placed into orbit by the U.S. Department of Defense. GPS works in any weather conditions, anywhere in the world, 24 hours a day. GPS satellites in a very precise orbit circles round the earth twice a day and transmit signal information to earth. GPS using trilateration method to calculate the exact location. For calculating 2-D position (latitude and longitude) GPS uses atleast three satellites and track location. Due to the multi-channel design GPS tracking has become highly accurate. This prototype uses GY-GPS6MV2 GPS module. Its accuracy is upto 3 m.

The GPS system comprises of three parts: Space segment, User segment and Control segment. The diagram of the structure of GPS is given below.

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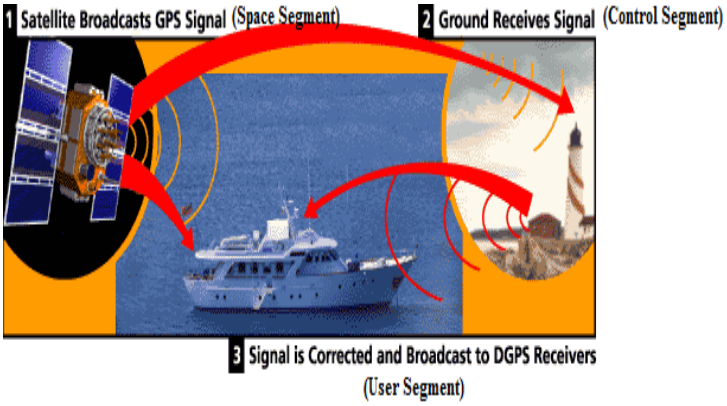

Fig.2. GPS Module

Space Segment : The satellites are the heart of the Global positioning system which helps to locate the position by broadcasting the signal used by the receiver. To calculate the position, the signals of four satellites should be locked.

Remote Segment – This segment includes military and civilian users. It comprises of a sensitive receiver which can detect signals and a computer to convert the data into useful information. GPS receiver helps to locate your own position but disallows you being tracked by someone else

Control segment – This helps the entire system to work efficiently. It is essential that the transmission signals have to be updated and the satellites should be kept in their appropriate orbits.

Arduino is an open-source computing platform based on a simple i/o board and a development environment for implementing the Processing language. Arduino can be used to develop stand-alone interactive systems. The Arduino Mega is a microcontroller board. It has 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. This prototype uses ARDUINO MEGA for comparing and initiating various control actions. The user predefines the location coordinates into four specific zones- Normal, Warning, Pre-Restricted and Restricted. Arduino Mega compares the current location coordinates of the boat which are procured by GPS and compares those coordinates to the predefined coordinates determining the zone boat is in. When the boat is in Pre- Restricted zone an interrupt signal goes high and alarm goes on. Further when this boat reaches the restricted zone the boat's motor automatically stops thus preventing the boat from crossing the maritime boundary.

Ultrasonic Sensors

The principle of ultrasonic sensors is, Piezoelectric materials generate a longitudinal wave which is used to measure the distance of obstacle. In this instance, the sensor is used to alarm the fisherman about any obstacle which is moving towards it or stationary. Four ultrasonic sensors are placed in four directions- East, West, North, South providing almost 360 degree obstacle detection. The corresponding LED flashes indicating the obstacle is in which direction.

Liqiud Crystal Display (LCD)

The display unit is mainly achieved by the 16X2 LCD. A liquid crystal display (LCD) is a flat panel display, electronic visual display, or video display that uses the light modulating properties of liquid crystals (LCs). LCs do not emit light directly. In this project LCD is used to display sensor value. A LCD display is assembled in the ECU for displaying the boat's current location , Weather conditions or any message from Operator sitting in base station.

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Buzzer

A buzzer or beeper is a signaling device, usually electronic, typically used in automobiles, household appliances such as a microwave oven, or game shows. It most commonly consists of a number of switches or sensors connected to a control unit that determines if and which button was pushed or a preset time has lapsed, and usually illuminates a light on the appropriate button or control panel, and sounds a warning in the form of a continuous or intermittent buzzing or beeping sound. The buzzer in the proposed prototype starts as soon as the boat reaches the pre-restricted area and continues till the motor of the boat stops when it reaches the restricted area.

DESIGN OF RBS

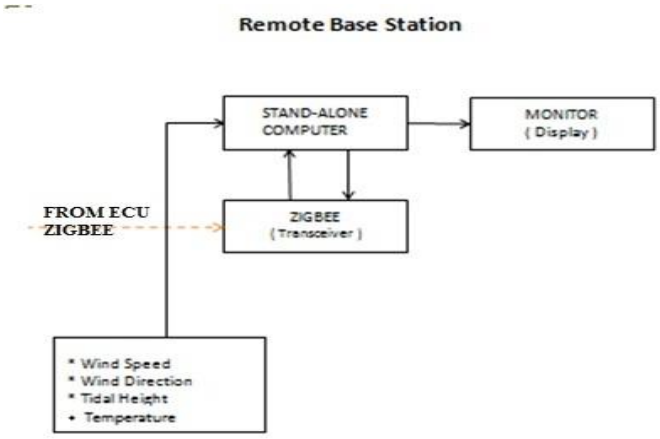

Fig.3. Remote base Station(RBS)

ZigBee Transceiver

For establishing the communication between the two networks we needed WPAN (Wireless personal area network). Zigbee configurations are most suitable for our prototype. Out of the pair, one Zigbee is configured as COORDINATOR and another one is configured as ROUTER. The Coordinator Zigbee is used for transmission of coordinates of boat and reception of weather forecast which would be displayed on lcd installed in fisherman's boat. The Router Zigbee is used for transmission of weather forecast and reception of coordinates of boat which would help the coastal guards to track the current location of the boat. It is also used when Marine Coastal guards wants to communicate any message to individual boat.

RasberryPi

Raspberry Pi is used to procure data from the internet using Data Scrapping techniques and the concept of IoT. Temperature, Wind Speed, Wind Direction and Type of Tides are the data which is extracted from Internet. This data is shared with Zigbee Transreceiver of the CU. The OS on which these operations are performed is Raspbian. Raspberry Pi is connected to a Display Monitor.

SOFTWARE DESCRIPTION

XBEE wireless communication is established using XCTU software and Ardiuno Mega. XCTU is a free multi-platform application designed for Zigbee point to point communication. It includes new tools that makes Zigbee set-up,configuration and testing quiet easy. Unique features like graphical network view, which graphically represents the Zigbee network along with the signal strength of each connection, and the Zigbee AT frame builder, which intuitively helps to build and interpret AT frames for XBees being used in AT mode, combine to make development on the XBee platform easier than ever. XCTU can be used to manage and configure multiple RF devices. The FIRMWARE UPDATE process is used to restore module setting, automatic

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handling of mode and baud rate changes. API and AT modes are used to facilitate wireless communication. XCTU contains complete and comprehensive documentation which can be accessed any time.

This surveillance system uses python software to scrap weather forecast data from website and transfer it wirelessly to the ECU unit. C programming is used to pre-feed the zonal latitude and longitudinal values and to compare it with current GPS coordinates of the boat to initiate various control actions which would help the fisherman from crossing the maritime boundary.

GPS POSITION CALCULATION

The GPS calculation in the receiver uses the four equations for the four unknowns x, y, z, tc where x, y, z are receiver co-ordinates and tc is time correction for GPS receiver's clock. The four equations are:

$$d_1 = c(t_{t,1} - t_{r,1} + t_c) = \sqrt{(x_1 - x)^2 + (y_1 - y)^2 + \sqrt{(z_1 - z)^2}}$$
$$d_2 = c(t_{t,2} - t_{r,2} + t_c) = \sqrt{(x_2 - x)^2 + (y_2 - y)^2 + \sqrt{(z_2 - z)^2}}$$
$$d_3 = c(t_{t,3} - t_{r,3} + t_c) = \sqrt{(x_3 - x)^2 + (y_3 - y)^2 + \sqrt{(z_3 - z)^2}}$$
$$d_4 = c(t_{t,4} - t_{r,4} + t_c) = \sqrt{(x_4 - x)^2 + (y_4 - y)^2 + \sqrt{(z_4 - z)^2}}$$

Where,

- c = speed of light (3×10^8 *m/s*)
- $t_{t,1}$, $t_{t,2}$, $t_{t,3}$, $t_{t,4}$ = times that GPS satellites 1, 2, 3, and 4, respectively, transmitted their signals (these times are provided to the receiver as part of the information that is transmitted).
- $t_{r,1}$, $t_{r,2}$, $t_{r,3}$, $t_{r,4}$ = times that the signals from GPS satellites 1, 2, 3, and 4, respectively, are received (according to the inaccurate GPS receiver's clock)
- x_1, y_1, z_1 = coordinates of GPS satellite 1 (these coordinates are provided to the receiver as part of the information that is transmitted); similar meaning for x_2, y_2, z_2, *etc.*

The receiver solves these equations simultaneously to determine *x, y, z,* and t_c.

Sats	HDOP	Latitude (deg)	Longitude (deg)	Fix Age	Date	Time	Date Age	Alt (m)	Course ---	from GPS	Speed ----	Card ----	Distance to London	Course ----	Card ----	Chars RX	Sentences RX	Checksum Fail
****	****	*********	*********	****	*********	********	****	******	******		*****	***	*******	******	***	0	0	0
10	83	12.824831	80.044883	382	04/23/2016	10:49:30	400	104.90	0.00		0.09	N	8219	320.33	NW	490	2	0
10	83	12.824831	80.044883	392	04/23/2016	10:49:31	409	104.90	0.00		0.06	N	8219	320.33	NW	978	4	0
10	83	12.824832	80.044883	400	04/23/2016	10:49:32	420	104.90	0.00		0.04	N	8219	320.33	NW	1466	6	0
10	83	12.824833	80.044883	413	04/23/2016	10:49:33	432	104.80	0.00		0.22	N	8219	320.33	NW	1954	8	0
10	83	12.824833	80.044883	420	04/23/2016	10:49:34	438	104.80	0.00		0.11	N	8219	320.33	NW	2442	10	0
10	83	12.824833	80.044883	432	04/23/2016	10:49:35	449	105.00	0.00		0.11	N	8219	320.33	NW	2930	12	0
10	83	12.824834	80.044883	426	04/23/2016	10:49:36	443	104.90	0.00		0.02	N	8219	320.33	NW	3418	14	0
10	83	12.824834	80.044883	447	04/23/2016	10:49:37	464	104.90	0.00		0.06	N	8219	320.33	NW	3908	16	0
10	83	12.824834	80.044883	459	04/23/2016	10:49:38	476	104.90	0.00		0.02	N	8219	320.33	NW	4396	18	0

Fig.4.GPS location results

Fig.4. shows the GPS location by calculating the values *x, y, z,* and t_c.

EXPERIMENTAL RESULTS

On performing various tests on the border surveillance system, following results were found:

After the pair of Zigbee were properly configured as coordinator and router the two-way wireless communication was successfully established where weather forecast data were scrapped and transmitted

from RBS and displayed on ECU and GPS coordinates of boat's current location were transmitted to the control room.

Weather forecast data which gives information about the wind speed, wind direction, wave height, wave type (high or low), temperature, etc. is taken from the website using the method of 'Data Scrapping'. This data scrapping is done using PYTHON programming and stand-alone monitor made using RASPBERRY PI. The whole process is achieved using the concept of IoT. This technique helps to keep the fisherman updated about the weather conditions of nearly the whole day analyzing which he could plan his work.

Fig.5 Display unit

Tracking the position of fisherman and controlling his movement by sending the boat's GPS coordinates to the RBS unit, thus avoiding him to cross the maritime boundaries is the other important result of the proposed model. Fisherman will be alerted by the beeping of the buzzer and blinking of the LED when he reaches the pre-restricted zone.

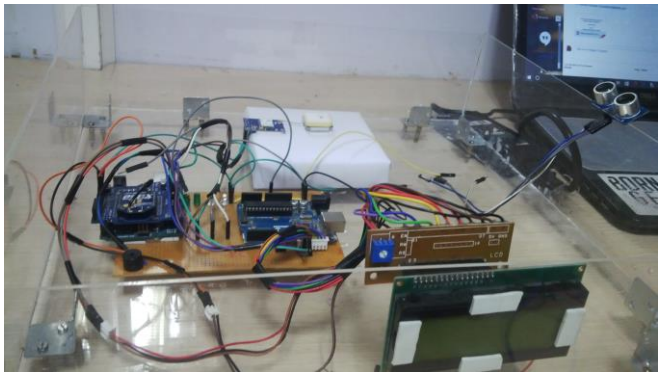

Fig.5 Hardware setup

A '360-degree obstacle detection' is another added feature of the model. To establish this four ultrasonic sensors are placed in four directions i.e east, west, north and south and a LED is interfaced with each of the sensors. When an obstacle is detected in any of the direction the corresponding led blinks thus alerting the fisherman to take necessary actions.

CONCLUSION

Using Arduino programming and python for data encryption, the prototype was designed and tested. The results showed that the prototype coastal border survillence system can be successfully implemented for real time working. The proposed stand -alone system can successfully ameliorate the current problems faced by both the maritime surveillance crew as well as the fishermen from accidental trespassing overseas. The Arduino based microcontroller controls the overall action of ECU and the raspberry pi being the central processing unit for data storage and encryption. The main hardware design goes hand in hand with the programming which forms the soul of the overall system working. The prototype has a clear execution. The programming is total logic oriented, user friendly and moreover debugging is easy. End users can easily access the result. Hence the stand alone alone coastal cross border survilence system is an overall combination of ECU,RBS, Zigbee module along with its smart programming. So it is quiet handy to both surveillance crew and

fishermen .The user friendliness and accurate data packaging gives it an overall advantage over other existing systems and also makes it sustainable.

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