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Review

A Review to do Fishermen Boat Automation with Artificial Intelligence for Sustainable Fishing Experience Ensuring Safety, Security, Navigation and Sharing Information for Omani Fishermen

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Abstract: Fishing wealth is one of the richest resources in the Sultanate of Oman. It is considered as one of the most important economic developments that nation depends on in a larger way. The Sultanate of Oman is characterized by the presence of a large fishing fleet as the number of fishing vessels and boats in it. Good research with the application of modern technology in fishermen boats is required to increase the quality of fishing by providing fishermen with a safe and secure fishing experience. Artificial intelligence (AI) in boat automation technology is new and it is a mandatory demand for Oman's fisheries sector. At the time of fishing, there are a lot of problems fishermen face such as weather changes, border tracking, navigation, illegal fishing, pirate attack, oil spill, technical fault in boats, etc. Therefore, the application of AI and related techniques in boat automation, information sharing, and preparation of documentation resources is very important in this sector. The main requirement for a fisherman is a high-quality fishing boat with proper communication devices to provide all the required information to fishermen and the control room. In this paper, a review has been made on fishermen's boats with artificial intelligence for a sustainable fishing experience ensuring safety, security, navigation, and sharing information for Omani fishermen.

Keywords: boat automation; artificial intelligence; surveillance; machine learning

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1. Introduction

The fishery sector is Oman's second largest natural resource before the discovery of oil resources in the 1960s. The fisheries sector is a major contributor of Oman's economy and is a traditional and dynamic industry for the country. Oman's fishery sector consists of fishing, processing, exporting, and aquaculture. Fish export is forecast to contribute Omani Rials (OMR) 1.3 billion to the country's Gross Domestic Product (GDP) in 2023. Approximately 24,050 fishing ships and boats are owned by Omani fishermen as of 2017 who ride the sea every day, and the fishery sector provided 54,410 direct employment opportunities in 2017 [1]. In an article published in an Oman observer newspaper on July 2022, it is mentioned that twenty-four thousand, three hundred forty-nine artisanal fishing boats, six hundred and eighty-eight artisanal fishing vessels, two hundred and twenty coastal fishing vessels, and nine commercial fishing vessels were available at the end of 2022 in the Sultanate of Oman [2].

This review paper aims to find the opportunities and also to implement modern technologies in the fisheries sector and the development of boat automation and control using artificial intelligence and machine learning to facilitate safety, security, navigation, and information sharing for Omani fishermen. The main requirement for a fisherman is a high-quality fishing boat with proper communication devices to provide mandatory

information to fishermen and the control room. Modern technologies, such as, robotics, artificial intelligence (AI), cloud computing, machine learning, expert systems, etc., are playing a vital role in automobiles, flight technology, manufacturing industries, and process industries and now it is possible in marine technologies as well.

The major approaches of fishing in Oman are traditional fishing, commercial fishing, and coastal fishing [3]. The fisheries sector in Oman is one of the key job-providing sectors that gives opportunities to many young Omani entrepreneurs. Al Kalbaniyeh [4] stated that the fishery sector is one of the promising sectors that produces entrepreneurs in Oman even though there are many challenges. He has discussed the requirements which should be provided by the government to improve the fishery sector. He also mentioned in his research paper that it is possible to provide 29,000 new job opportunities to the young people of the Sultanate of Oman. The fishery sector in Oman can contribute to the country's economic development in a larger way if we provide modern technologies and proper training to the fishermen. Neil J. Rowan's paper titled "The role of digital technologies in supporting and improving fishery and aquaculture across the supply chain–Quo Vadis?" discussed the possible modern technologies which can be used for the development of the fishery sector. He mentioned clearly in his paper that "addressing key challenges by way of the global digital transformation of fishery and aquaculture industry will meet several sustainable development goals of the United Nations catered around the application of disruptive technology". So, it is clear that implementation of modern technologies in Oman's fishery sector will contribute a sustainable growth in the sector and also for the economic development of the nation [5].

The most vital challenges in Oman's fisheries sector are the traditional fishing strategy and the technical gap. Many researchers in the past pointed out in their research articles about the challenges in technology implementation in the fishery sector and overcoming weak technical capabilities. Chaudhry et al. [6] discussed the opportunities and challenges in the fishing industry of the Muscat governorate. He has indicated clearly that the lack of knowledge of Omani fishermen about modern trends in fishery science is affecting the opportunities for fishing and marketing the captured fish. The results of this study supported the fishermen to develop their profession and explained the opportunities provided by the government, such as the provision of modern services and techniques, facility funding, training, and labor. As per an Oman news agency article published in Nov 2022, "The Sultanate of Oman's fish production by the end of July 2022, reached 400,115 tons, comprising a decline by 21.5% compared to the same period in 2021 when it stood at 510,020 tons" which is based on the latest data issued by the National Center for Statistics and Information (NCSI), Sultanate of Oman. We can say that the decline may be due to the ignorance of the latest technologies in fishing boats which might have affected fish production in July 2022. To improve fishing in Oman, Oman Aquaculture Development Company (OADC), which is a government-owned company, is also taking many steps on the other side to develop the fisheries sector by investing a lot with the objectives of diversifying the national economy and reducing the dependency on hydrocarbon [7].

As per a Muscat Daily newspaper article published on May 16, 2019, "Oman Fisheries reported a net loss of OMR 782,554 for the quarter ended 31 March 2019, as against a net profit of OMR 65,246 in the corresponding period of last year (2018), according to the company's quarterly results submitted to the Muscat Securities Market". The main reason stated in this article for the loss is due to illegal fishing. So, it is very important to prevent illegal fishing in the fishery sector as per the article [8].

An Oman Observer article published on 14 May 2019, "Illegal fishing impacts Q1 revenues: Oman fisheries which indicate that there is some illegal fishing that is affecting the growth of the fishing sector" [9]. So, it is very essential to erase these kinds of activities through modern technological developments. As per various pieces of literature, there is a heavy demand for technological advancements in the fishery sector, which this paper addresses to a larger extent. From the above discussions, some of the various issues which are constantly faced by the vessels can be listed as follows:

1. One of the major problems faced is crossing the border area without any intention or due to misguidance;
2. Attack by pirates is unknown leading to life loss and injuries;
3. Unknown environmental conditions;
4. Unknown wind speed which leads to facing unknown storms around the ship;
5. Oil spills lead to fire safety issues;
6. Illegal fishing is affecting the economic growth of the country and the overall growth of the fishing sector.

As per the research article published by Rakesh Belwal [10], the government of Oman allocated a financial support of OMR 128 million for the establishment of modern auction houses, cold storage, refrigerated vehicles, and other supply chain and delivery mechanisms in the eighth five-year plan released in 2011. The results of 2016 five-year plan released by the government of sultanate of Oman shows that the non-oil sector contributed 2.3% in average GDP growth. The Non-oil sectors economic performance in ninth five-year plan is shown in Figure 1. The tenth five-year plan released on 18 November 2020 (2021–2025) is giving importance to fisheries which states that aqua farming, food, and fish processing industries contribute to enhancing food security and attracting more investments within the blue economy. However, there are many issues in fishing which should be addressed at the earliest using modern technologies in the Sultanate of Oman. To solve these problems, there is a requirement of modern boats for fishermen using boat automation concepts with the help of advanced technologies such as artificial intelligence, machine learning, deep learning, embedded system, mobile and web application development, and Internet of Things (IoT).

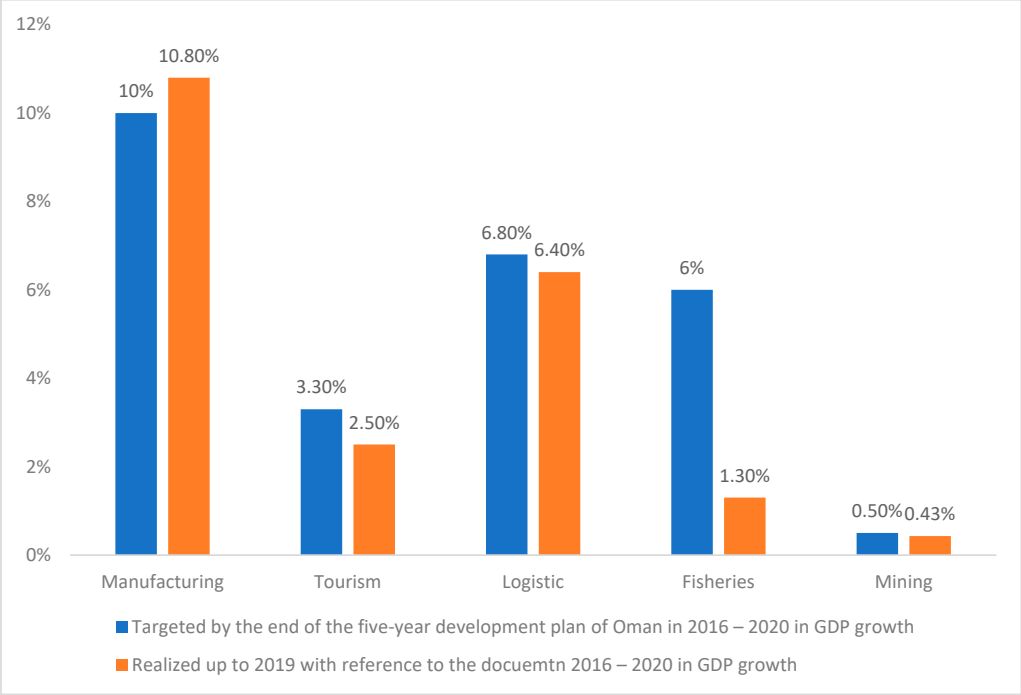

Figure 1. The economic performance of the ninth Five-Year Development Plan of the Sultanate of Oman—Derived from the literature [11].

The researchers of this paper have carefully identified the relevant literature of AI-based systems for boat automation and synthesized all of the papers and concluded as "review" in phase 1. Using this theoretical approach, a possible hi-tech solution is proposed by the researchers as the second phase of this paper. The major contribution by the researchers are the review of boat automation with artificial intelligence in the various pieces of literature and the proposal on design of a reliable AI model for sustainable

fishing experience ensuring safety, security, navigation, and sharing information for Omani fishermen. The overall arrangement of this paper is given in Figure 2.

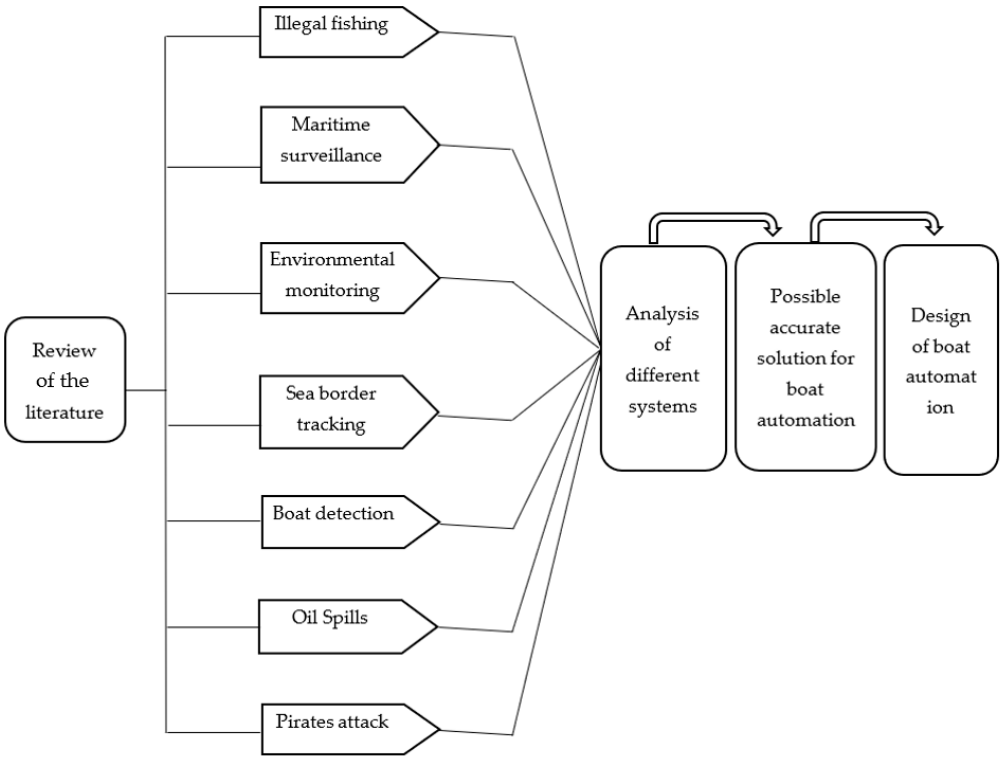

Figure 2. Flow content of the study and research contribution.

2. Review of Illegal Fishing, Maritime Surveillance, and Environmental Monitoring

Manaa Al Habsi and Nik Mustapha [12] have given brief information about the sustainability of the fishery sector in Oman in their research paper. They have explained about overfishing and its consequences in Oman fishing industries. They have pointed that a more effective fisheries management system is required in the Sultanate of Oman to improve this sector. This paper has performed the analysis of data collected from all coastal regions.

The Ministry of Agriculture and Fisheries of the Sultanate of Oman revealed that the annual fish production of the country has increased from 250,338 tons in the year 2017 to 553,000 tons in the year 2018, registering a rise of 59 percent [13]. The Food and Agriculture Organization of the United Nations has also reported that in the year 2017, the average annual per capita consumption of fish in the Sultanate of Oman was about 28.7 kg. This per capita consumption of fish was the highest in the Middle East countries along with the United Arab Emirates (UAE). The increase in fish production in the Sultanate can be threatened by the incidents of illegal, unreported, and unregulated fishing activities in the Oman's exclusive economic zone (EEZ). Illegal fishing activities are detrimental to the fish production sustainability of the country. The illegal, unreported, and unregulated (IUU) fishing activities within its EEZ have to be addressed seriously for the protection and preservation of its marine resources. The Oman observer newspaper had given the news dated 24 October 2018 that more than 500 cases have been arrested every month for violating the Omani Marine Law and for using illegal tools and equipment for fishing, according to the Ministry of Agriculture and Fisheries [14]. There are various forms of illegal fishing such as bottom brawling in which big and heavy fish nets are dragged on the sea floor or sea bed and scoop almost every marine life in the sea. This activity can eventually kill or deplete all marine resources if not stopped and destroy the marine habitat of the country. Furthermore, unregulated fishing is also a big threat to the sustainability of the marine resources. Fish and marine sanctuaries must always be protected and preserved.

Non-fishing months declared by the ministry for a particular location with its EEZ should always be followed and obeyed, otherwise the fish production will reduce tremendously and will affect the future fishing industry of the Sultanate of Oman.

The deployment of technologies is mandatory to use in marine transports to improve fisheries monitoring and navigation. Michelin has proposed a camera-based electronic monitoring (EM) system in industrialized fisheries with gear sensors and sophisticated data analysis that is used to provide full accountability for fishing activities. This offers benefits such as high levels of compliance, documentation of sustainable fishing practices, and access to markets. However, due to various constraints, such as the lack of infrastructure, cost, and lack of capacity to use and analyze EM data, only 1% of the world's fishing vessels are using EM [15].

The Smart Surveillance System using Thing Speak and Raspberry Pi was developed by Chandana to analyze and comprehend the camera and its operation in an IoT-based system. It employs hardware components such as a Raspberry Pi (model B), a Gyro sensor, and a Raspberry Pi camera. When a boat/vessel/ship motion is detected by the Gyro sensor, the Raspberry Pi instructs the camera to take a shot and sends an alert email with the image to the user via a Wi-Fi adapter, as per the software written in Python. At the same time, a sensor is utilized to show real-time data in the form of charts in Thing Speak. This system just detects motion using the Raspberry Pi camera and cannot identify objects. The technology is unable to determine if the moving item is human or not. The system also lacks a camera with night vision capabilities. In extremely low light situations, the camera cannot detect motion. Other risks, such as smoke, are also not detected by the system [16].

Kamalakkannan et al. [17] have developed a system that protects fishermen from shooting and arresting by another country's navy when they cross the sea border without any awareness. This system consists of a Global System for Mobile communication (GSM), ARM microcontroller, and Radio Frequency Identification (RFID), and three levels of boundaries. When the first two boundaries are crossed, the system gives an alert to the fishermen. If the alert system fails to do so, when the third boundary is crossed, the system automatically turns off the motor in the boat and this information is sent to the control room.

Boats aim to perform surveillance of marine borders through the means of the Global Positioning System (GPS). The boatsmen may cross the marine boundaries unknowingly due to the lack of a proper differentiation or visual aid for the boatsmen. The unknown entry into foreign marine boundaries may result in legal action against the boatsmen or absconding. Therefore, Jayapal et al. [18] proposed a two-unit system: one of which is installed within the boat, and the other is situated in the coastal area. The first unit, situated in the boat, continuously tracks the live location using the GPS that is integrated using a microcontroller. As the GPS uses the concepts of latitudes and longitudes, the data are read in the same format by the microcontroller. To ensure that the boat does not cross over the border, initial latitude and longitude values that are indicative of the boundary are set up and configured into the microcontroller. Henceforth, a condition is programmed into the microcontroller such that if the live location of the boat approaches the predefined threshold value of latitude and longitude (the sea border), then, an alert is sent to the coastline authorities, or the server that is set up as the second unit. The technology used to alert and notify the boatmen is an indicator panel, while radio frequency is utilized to alert authorities at the coastline. The very high-frequency radio waves are transmitted, which can cover large distances, and a receiver at the coastal end receives the signal. Moreover, certain environmental parameters, such as rain and wind, are read through sensors and displayed through the Liquid Crystal Display (LCD). The parameter readings can also be stored in the database that is integrated with the microcontroller. The proposed two-unit system is given in Figure 3.

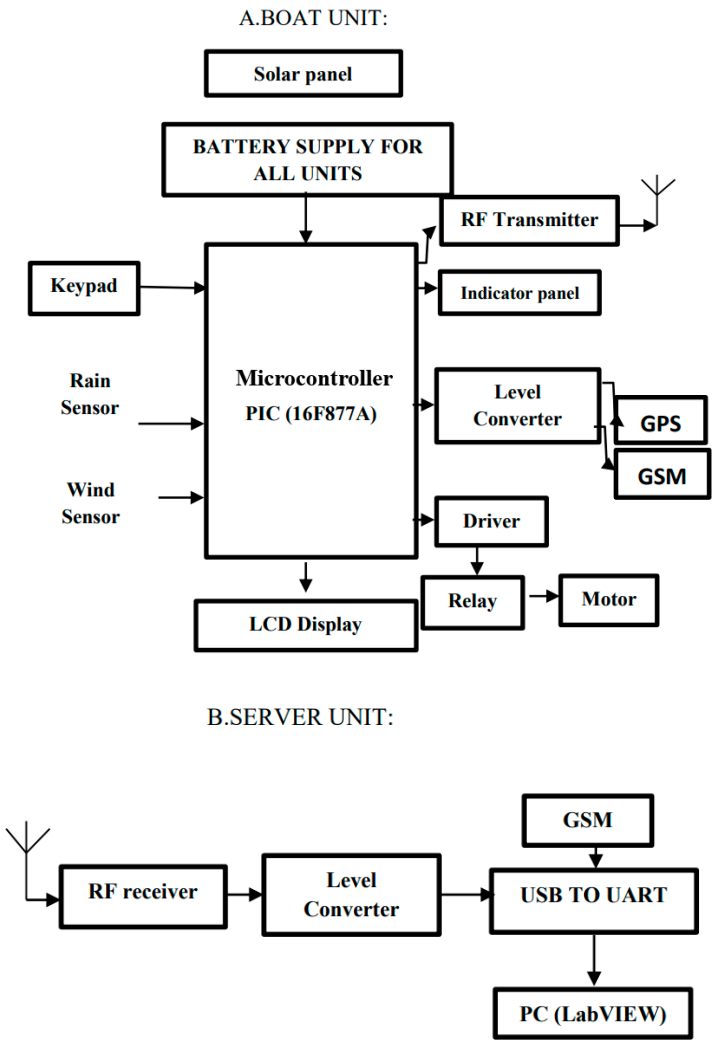

Figure 3. Boat and server unit proposed by Jayapal et al. [17].

The Fishing Boat Safety Monitoring System proposed by Budiman and Suryana assists the authorized officials who work with the government to oversee, monitor, and enforce maritime law which helps the government at the port to maintain marine order. This device uses a panic button and a GPS module to follow the ship and to report emergencies. The suggested system makes use of cameras, sensors, and artificial intelligence to warn both the people on the boat and the authorities of any intruders, surrounding individuals, such as pirates, oil leaks, and other risks. The suggested approach makes use of a web application as well [19].

The Low-Cost Smart Security Camera with Night Vision Capability Using Raspberry Pi and OpenCV project was proposed by Wilson Fiepeng Abaya, Nif et al. The system is a CCTV (Closed Circuit Television) surveillance system, and it focuses on a low-cost smart security camera that has night vision capabilities. The system can be used to detect humans as well as smoke during the daytime or during the night with night vision. With the aid of infrared (IR) LED, it is possible to utilize the object-detection software along with the night vision capability of the camera to perform object detection in the dark. The system uses a background subtraction algorithm to detect motion; then, the algorithm checks if the motion is caused by a human or smoke; if either of those is detected, the user is alerted by an email that there is danger. The algorithm was optimized by separating it into three different parts including motion detection, human detection, and smoke detection. If the motion is detected, the flow of the algorithm is to check for humans first; if there is a human

detected, the user is alerted that there is an invader, otherwise, it will go further in the algorithm to check for smoke [20].

Multiple specialized sensor nodes with processing and sensing capabilities make up a wireless sensor network (WSN). These nodes can sense and keep track of physical parameters, and they can use wireless communication technologies to transfer the information they gather to a central location. A WSN's inherent characteristics include an uncontrollable environment, topological limitations, and constrained node resources for energy and computation capacity. Wireless sensor networks have been widely used in terrestrial contexts so far, and some of these installations have demonstrated serviceable performance.

Though the bulk of WSN-based systems are still experimental, the use of WSNs for monitoring the maritime environment is still in its early phases. A few of the challenges addressed by wireless sensor networks for monitoring marine environments include oceanographic sensor protection, improved buoy design, energy-harvesting system design, system stability and reliability, and other problems. The experiment's findings show that wireless sensor networks (WSNs) can be used for real-time monitoring at a low cost, helping to monitor the environment and ensure the safety of anyone using the technology [21].

In recent years, there has been an increased interest in autonomous ships in marine transport such as Maritime Autonomous Surface Ships (MASS), unmanned surface ships, autonomous underwater vehicles, and underwater gliders. There are many challenges in autonomous vehicles such as automatic control, collision avoidance, ship target identification, motion planning, track control, etc. In all of the areas, the artificial neural network (ANN) is playing a vital role, which means AI-based systems are used in autonomous technology [22].

Lois vanhee et al. have proposed autonomous fish capturing and autonomous fishing operation system in their research paper. As per their conclusion, autonomous fishing vessels will give more deployment in fishing operations in the near future [23].

Ramat MB et al. developed an autopilot unmanned smart board vehicle (AUSV) based on fishing zone prediction. In this paper, researchers have developed an AUSV prototype which can run an average distance of 15.5 m [24]. Even though this kind of research is in the infant stage, it may acquire more importance in the near future in the area of fishing.

Underwater monitoring sensors are normally used to perform collaborative monitoring and data collection of the sea and the changing weather conditions that come with it. However, these types of monitoring systems can face many limitations and challenges throughout their life span such as limited bandwidth in the wireless sensor networks, noise, resource utilization, high propagation delay, and huge power constraints [25].

According to researchers from the University of Florida, the technology of the anemometer can be used to identify the early signs of a hurricane. "Each radar scan and the anemometer were subjected to a fast fourier-transform (FFT) analysis, yielding approximately 300 FFTs per hour of analysis", says Dr. Forest. Furthermore, the results of the mapping and wind analysis led to the majority of hurricanes showing early signs that may predict the direction and estimated speed to reach a specific location. The findings of this study will enable engineers to detect wind speed and direction more accurately using radar and anemometers rather than the nanometer alone, which can result in inaccurate results.

Andrey A kurikin et al. [26] applied various image-processing algorithms to identify vessels to support illegal fishing. They have applied a Constant False Alarm Rate (CFAR) detector and multi-channel detection technique to identify the vessels. In this paper, CFAR detector is used for the initial algorithm which was defined as follows:

Vessel is detected,

If $S_d > T(L)$, $S_d = \frac{I_t}{I_b}$, I_t = *target intensity and* I_b = *background intensity*, T = *constant threshold that defines false alarm rate of the CFAR detector*, L = *equivalent number of looks*; S_d = *detection signature*.

In the second algorithm, which is the multi-channel detection technique, the CFAR S_d equation was calculated by separating vertical receive polarization data and horizontal receive polarization data. Based on this, V_v (Vertical transmit and vertical receive polar-

ization date) and V_H (vertical transmit and horizontal receive polarization data) and two independent detection signatures $S_d{}^{VV}$ and $S_d{}^{VH}$ were produced. Then, both were merged as follows:

$$S_{gm} = (S_d{}^{VV} \times S_d{}^{VH})^{\frac{1}{2}} \quad (1)$$

This paper has given more information to estimate vessel location, dimensions, and heading, which is based on one offset center of gratuity method by applying in the collected image. Vessel length and width were estimated in this paper as follows:

$$Length = \left(\sum_{x=0}^{Nx} S_x\right)^2 / \sum_{x=0}^{Nx} (S_x)^2,\ Width = \left(\sum_{y=0}^{Ny} S_y\right)^2 / \sum_{y=0}^{Ny} (S_y)^2 \quad (2)$$

where $S_x = \sum_{y=1}^{Ny} S_{x,y}/N_y,\ S_y = \sum_{x=1}^{Nx} S_{x,y}/N_x$, and $S_{x,y}$ is the output of morphological filter at pixel position (x,y), N_x and N_y are the dimensions of the vessel analysis windows. Vessel horizontal and vertical coordinates were estimated as:

$$X_p = \left(\sum_{x=0}^{Nx} S_x \cdot x\right)^2 / \sum_{x=0}^{Nx} S_x,\ Y_p = \left(\sum_{y=0}^{Ny} S_y \cdot y\right)^2 / \sum_{y=0}^{Ny} S_y \quad (3)$$

A refined estimate of vessel orientation was obtained in three steps. Firstly, the vessel analysis window of size $N_x x N_y$ was split equally into left and right halves. Then, using the offset center of gravity (OCOG) method, Equation (3), was applied to each half to estimate the center coordinates (X_L, Y_L) and (X_R, Y_R). An orientation angle was then estimated as:

$$\text{Angle} = \tan^{-1}[(Y_R - Y_L)/(X_R - X_L)] \quad (4)$$

Equation (4) gives an estimate of vessel orientation with an ambiguity of 180 degrees.

Domenico D Bloisi et al. [27] discussed the quality-enhancement procedure for maritime surveillance systems which is used for vessel-tracking system functions. This paper has given the problem of tracking multiple objects using multiple sensors. In this paper, n number of moving objects and n number of sensors are taken for the tracking algorithm.

The approach described in this paper aims at enhancing the current vessel-tracking system (VTS) functions, generating a unique view where the information coming from the camera and the VTS tracks are merged. The proposal here is a distributed tracking approach, able to fuse data from multiple heterogeneous and not synchronized sources. The input observations are provided by the visual detection module.

The problem of tracking multiple objects using multiple sensors can be formulated as follows. Let set of all moving objects considered as $O = \{O_1, \ldots O_n\}$, and each one having a different identity, and considered set of all sensors $S = \{S_1, \ldots S_S\}$. The goal of this methodology is to determine an estimation of the position of ships.

Each ship has an associated field-of-view (FOV), typically covering only a limited area of the scene inside the sea. The total number n of objects that will be observed is unknown, and the number l of the current objects in the scene, with $0 \leq l \leq n$, can change over time. The set of observations about the objects in the FOV of a sensor $s \in S$ at a time t is denoted by $z_{s,t} = \{\overset{(1)}{z_{s,t}}, \ldots \overset{(l)}{z_{s,t}}\}$ where a measurement (observations) $\overset{(i)}{z_{s,t}}$ can be either an actual object or a false positive.

The set of all the observations gathered by all the sensors at time t is denoted by $z_{S,t} = \{z_{s,t} \mid s \in S\}$.

The history in time of all the observations coming from the sensors is defined as:

$$z_{S,1:t} = \left\{z_{s,j} : 1 \leq j \leq t\right\} \quad (5)$$

Since the sensors can have different refresh rates, researchers do not assume that the observations generated by the sensors are synchronized.

The goal is to determine an estimation of the positions $x_{s,t}$.

Moving objects are represented as $x_{s,t} = \{{}^{(1)}_{x_{s,t}}, \ldots {}^{(l)}_{x_{s,t}}\}$, for all the objects in the scene at time t in a distributed fashion, i.e., exploiting all the available sensors. To achieve the position of the ships, the Bayesian recursion approach is used, defined as follows:

$$p(x_{s,t}|\, z_{S,1:t}) = \frac{p(z_{S,t}|x_{s,t})p(x_{s,t}|\, z_{S,1:t-1})}{\int p(z_{S,t}|x_{s,t})p(x_{s,t}|\, z_{S,1:t-1})dx_{s,t}} \tag{6}$$

$$p(x_{s,t}|\, z_{S,1:t-1}) = \int p(x_{s,t}|x_{s,t-1})p(x_{s,t-1}|\, z_{S,1:t-1})dx_{s,t-1} \tag{7}$$

In the next step, the author has given that the information coming from the vessel-trafficking system is fused to generate an enhanced and reliable believe state of tracked boats. In the data fusion, ${v_i}^C$ is taken as velocity vector of the boat and i in the camera reference frame C and v^R be the set of velocity vectors of boats in the *VTS* reference frame R.

The best matching candidate in v^R to be fused with the boat i in the camera reference frame is selected by computing for each $VjR\ \varepsilon\ v^R$

$$\begin{bmatrix} v^R_{xj} \\ v^R_{yj} \end{bmatrix}^T \cdot \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \approx \begin{bmatrix} v^C_{xj} \\ v^C_{yj} \end{bmatrix}^T \tag{8}$$

where the rotation parameter θ between the camera and the VTS reference frames is calculated using a policy gradient algorithm. More specifically, the optimization process finds the best value for θ starting from a predefined initial value. (Authors used $\theta = 15°$ in their experiments). In the next step, tracking and data fusion are performed by assigning θ value to obtain quantitative results. Then, researchers perform two computations in parallel that use a low and high value of θ, respectively. After computations, researchers compute the quantitative results, checking for which direction the performance improves. They set this as the new value and considered it as the "initial value" and the algorithm is executed until there is a significant variation in the quality metrics used for the performance evaluation of the system. This approach calibrates the θ rotation parameter between the camera and the VTS data. In the case of multiple matches for ${v_i}^C$, the data fusion algorithm continues to calculate the evolution for all the current matches until a unique match is found eventually [27].

3. Review of Sea Border Tracking and Automatic Boat Detection Using AI

Fishermen are being caught by maritime forces of the neighboring country for crossing the border of the fishing region of their own country's limit due to the lack of awareness about the sea border tracking. Sometimes, the navy forces of the neighboring country give severe punishment to the fishermen for crossing the border. So, the automatic boat detection and position of the boat information is mandatory to fishermen to avoid issues between neighboring countries.

The development of terrestrial networks and satellite constellations of automatic identification system (AIS) has created a new era in maritime traffic surveillance. Periodically, AIS provides millions of data such as ship identifier, their global positioning system coordinated, and other details. This huge amount of data, if properly mined, will be used for maritime surveillance effectively.

Duong N. et al. [28] have designed an automatic system using a recurrent neural network to mine information from AIS data streams for maritime surveillance. This system learns from noisy and partial AIS data streams. Mathematical models have been developed for reconstruction and forecasting, maritime route estimation, vessel type identification, detection of abnormal vessel behaviors, etc. This system is demonstrated with real datasets of the Brittany coast and Gulf of Mexico.

Jeong et al. [29] have proposed an automatic ship detection method using an artificial neural network and support vector machine from synthetic aperture radar (SAR) satellite

images. The median filter and multi-look operations were used to reduce the background noise. The median filter was also used to remove ships in an image to maximize the difference between the pixel values of ships and the sea. An intensity difference map and a texture difference map were extracted from the SAR images, and the maps are given as input neurons for artificial neural network (ANN) and support vector machine (SVM) learning techniques. Shaileshnhai and Brahmbhatt [30] have reviewed several algorithms for AIS signal detection transmitted by ships and methods of decoding for detected AIS signals which will help to improve detection probability.

IoT-Based Border Alert and Secured System for Fisherman project was proposed by Uthayakumar Jothilingam and Liston Deva Glindis to protect fishermen themselves when they are close to the country border by sending a notification on a mobile device and with the help of GPS. The longitude and latitude values are sent to the microcontroller, and then the controller compares the current values with the predefined values to find the current location. After obtaining the result of the comparison, the fishermen are notified if they are close to the border [31]. The system protects from the hijacking of fishermen's boats by pirates; it is also possible to identify shipwrecks that are caused by natural calamities. This system also helps with the management of boat traffic on the sea by providing the locations of boats, and in case of accidents occurring in the area, the location of the accident can be sent to the rescue teams to help the fishermen.

Devi, Kumar, and Clement Sunder [32] have developed a system that uses an ATmega328p chip and a GPS receiver module to determine the location and positioning of a boat. Using an ESP8266 Wi-Fi module, the GPS location data are uploaded to the IoT cloud. Thus, the navy can monitor the data. The boat's motor speed is decreased to 50% if the GPS location is in the warning zone, and an alert message will be identified with the help of a buzzer. As per the paper, the boat's speed can be changed by controlling the fuel rate to the fuel injector using a microcontroller based Engine Control Unit (ECU). The purpose of using the NEO-6M GPS receiver module and Arduino Uno microcontroller in this research is to give information to the fishermen while at sea.

An IoT-based solution for tracking and monitoring small boats in the Zanzibar coastal region highlights that while IoT has already been utilized in larger ships through the automatic identification system, smaller boats usually miss out on such features and therefore result in frequent accidents and mishaps. It is understood that real-time information is presented on a mobile application and additionally alerts are sent to the application if water leakage or collision is detected. The system is installed within the boat. The project is centered on alerting the boatsmen in various uncertain conditions such as receiving a message if leakage is detected, getting an alert if the boat has close proximity with any other vessel, and constantly monitoring the location of the boat. To achieve such objectives, a variety of technologies are integrated and used, for instance, GPS, water detector sensor, ultrasonic sensor, buzzer, Arduino UNO, Bluetooth, and GSM Module. The data are measured continuously and are transferred to the cloud along with the location tracking. The primary focus of the project is to limit the accidents caused in smaller boats due to the absence of technology by delivering critical information through the mobile application. A cloud server is also maintained to store the data. As data need to be sent to a mobile application, Firebase is used as a storage option as it provides cloud messaging features [33].

4. Review Oil Spill Issues and Its Impact on Fishing Inside the Sea

Oil spill is one of the worst environmental disasters that can happen to any country's exclusive economic zone that will destroy marine resources. Incidents of oil spills will take years of cleaning and rehabilitation to revive marine life back to its normal condition. The high risk of oil spills coming from fishing vessels, cargo ships, and cruise liners traversing the EEZ of the country must be strictly monitored. The Sultanate of Oman is one of the world producers of oil and gas, and the risk of oil spills in its territorial waters is imminent. Chang et al. [34] presented a review of the impact analysis and consequences of oil spills. He presented a framework to clarify and clearly understand the complexity of oil spill

impacts on the society and ecology. The framework talks about ecosystem injury—effects on the species—and mobility habitat, short-term and long-term economic impact, health and social impact, fisheries and marine sectors tourism, etc.

Apart from pollution in the water, oil spill affects the fishing inside the sea. Early information about an oil spill is a mandatory requirement to save the aquatic life. Since there are many fishing vessels in the sea compared to inspection ships or cargo ships, it is possible to obtain early information if a fishing vessel contains oil spill identification devices. So, early information will save a lot of the wild life in the sea which will serve a future of healthy fishing. Similarly, the absorption of small amounts of oil into the cooling system of the fishing/merchant vessel's engine will cause damage to the engine or many of the boat's subsystems. So, oil spill identification is very important for fishermen and for fishing.

There are several emerging technologies to detect and even prevent the potential risk of oil spills from ships or vessels. Fingas and Brown [35] presented a review of oil spill remote sensing. Technologies like using infrared cameras as oil spill sensors to detect the presence of a significant amount of oil on the seawater surface, and radar technology, i.e., satellite-carried radars, provides an option for wide surveillance for 24 h even during rainy and cloudy weather conditions. Strategic oil spill mapping is also carried out by this radar technology.

Gabriele pieri et al. [36] described a Marine Information System (MIS), namely AGRO-MIS, which is used to monitor oil spills. The main goal of the proposed MIS is the continuous environment monitoring of an area of interest. The architectural design of the machine information system with modular structure is given in Figure 4. This paper has given an idea about the Marine Information System and its important features. In this MIS, the researchers have included facilities to share the data which can be used by the marine authorities who are involved in the monitoring and management of sea and coastal oil pollutions.

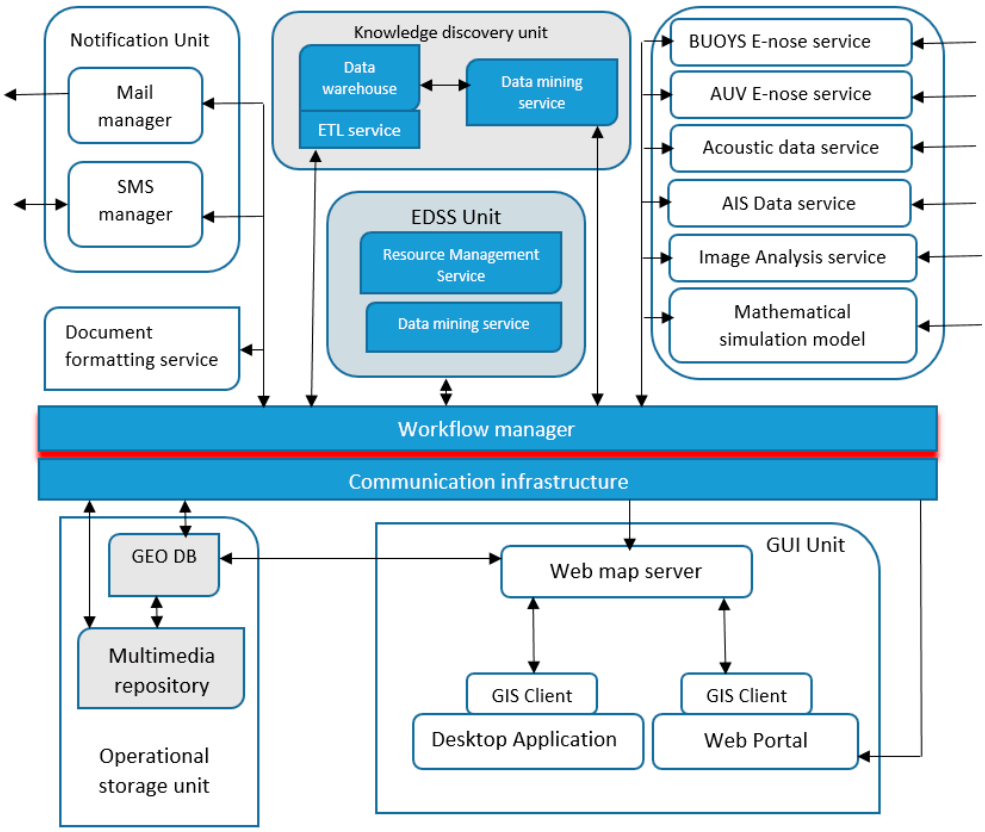

Figure 4. The architectural design of the Marine Information System drawn from the literature [33].

In this MIS, six important units are proposed which are as follows:

1. Service unit;
2. Operational storage unit;
3. Knowledge discovery unit;
4. Notification unit;
5. Graphical user interface;
6. Environmental decision support system unit.

Since the main aim of this work is related to the monitoring of oil spills, oil spills monitoring includes:

- Space borne SAR imaging and analysis;
- Ground-based monitoring technology;
- Hyper spectral image and analysis;
- Electronic nodes for hydrocarbon and oil spill detection;
- Underwater monitoring technologies.

One of the main goals of the system is continuous environmental monitoring. The main issues in this monitoring are:

1. Proactive management of the available resources;
2. The provision of services for notification and alerting.

The services, as well as the notification unit (see Figure 4), are built based on intelligent software that works autonomously and independently, but are integrated into the MIS using an inner logic representing a workflow composed of committed specific tasks. So, overall, the literature is encouraging to the application of AI techniques in the identification of boats, tracking of sea border, and navigation.

5. Review of Pirates Attack and Its Impact on Fishing Inside the Sea

The maritime sector is a major global industry. An article published by the World Bank reports that shipping accounts for 80% of all world trades in total volume. However, like other lucrative industries, it does not only deal with accommodating a high demand for services, but also constantly faces numerous environmental issues. Shipping companies have shown significant concern with promoting the ocean's cleanliness and safety by reducing their impacts on water pollution. For instance, they use chemical-resistant bunds and shipping containers to control the spillage of harmful liquids. Oils and alkali fluids can largely jeopardize the ocean's animal and plant life. Therefore, storing them in specialized containers is somewhat helpful in case the cargo goes overboard. However, while such practices are indeed essential, there are also concerns with gas emissions, and resolving these is just as crucial as taking care of the ocean. This is because as climate change continues to worsen every year, the volume of carbon monoxide emitted by ships also increases at an alarming rate. This being said, it is high time for maritime transport agencies to be responsive to resolving climate change issues and design and implement measures to lessen repercussions. Apart from this, a big threat to sea transportation is maritime piracy. Maritime piracy is defined as any illegal act of violence or detention, or any act of depredation, committed for private ends by the crew or the passengers of a private ship based on Article 101 of the 1982 United Nation Convention on the Law of the Sea (UNCLOS).

There is much evidence for pirate attacks including a pirate attack on two fishing boats in 2019 at the coast area of Somalia. Pirates not only attack the merchant vessel, but also attack the fishing vessels. So, it is an essential need to find a technology-based solution to provide protection to the fishermen to guard themselves and also to save the vessels from pirates.

Tseng, P.H., ChaoHer, Z., and Pilcherc, N have conducted a mixed analysis model by combining Fuzzy Analytic Hierarchy Process (FAHP) and in-depth expert interviews to explore effective defense strategies against piracy attacks; specifically, for shipping companies and ships themselves to prioritize and adopt through a FAHP analysis and

in-depth interviews. Even though this kind of device is not yet commercialized, it is needed to avoid maritime piracy. In this modern world, machine learning- or deep learning-based devices are possible which may give better efficiency than fuzzy-based devices [37].

Santiago Iglesias Daniela and Juan Vinagre Ríos discussed piracy in the topic of Piracy in Somalia: A Challenge to The International Community. The boom that piracy has undergone in Somalia since about the middle of the last decade has threatened one of the world's main maritime trade routes and called for an international community response. Researchers conclude in this paper that the main goal is to find a solution to the problem of what to do about pirates in maritime policy in the future [38].

As per the article published in 2020 by Goh Wai Pheng in safety for seas "Artificial Intelligence (AI) has made advancement to improve maritime safety, optimize maritime operations and processes, and aid in travel planning and vessel maintenance. AI allows new sense-making possibilities by generating insights through deep analysis of data and relaying critical information to the control room/right authorities promptly, so that, decisions can be made for the best outcomes to save travel people inside the ship/vessel". This article added that "The use of AI-based systems to create fully automated piracy alerts can allow seafarers a few moments to react, potentially saving lives" [39].

Cuong Manh Nguyen and Tien Quoc Le discussed in their research paper about the impact of piracy on maritime transport and technical solutions for prevention in which the researchers have given four methods to arrest the pirate attacks. The first one is to "secure the ship method" which means placing a fence with 9000 volts near the outer wall of the ship. The second method is "cruise tracking and recording system" which offers a satellite-based tracking system by recording the positioning of the vessel. The third one is an anti-pirate water hose system against pirates which represents high-speed water jets. Fourth is a non-lethal slippery chemical foam in which a foaming machine is used to arrest climbing pirates [40]. Even though the researchers in this paper have discussed four different methods to arrest piracy, there is no discussion about the modern technological trends such as AI, machine learning, deep learning, etc.

Dozens of piracy attacks every year on merchant and fishing vessels cause significant economic losses and put trade routes at risk. This is detrimental for maritime transport that evolves with the times and results in it taking measures to ensure safety. According to the Geneva Convention, piracy is an "illegal act of violence, detention or depreciation through the use of a ship". An act of piracy requires four conditions:

1. To be committed on the high seas.
2. To involve violence.
3. For the pirate ship to be civil.
4. For the attack to be committed for private ends.

Pirates always operate in strategic areas, some out of tradition, such as the Strait of Malacca in Southeast Asia or the Caribbean. Modern-day piracy is posing a genuine threat to the shipping industry and all maritime transport. There are particular hotspots such as the Gulf of Aden, the Gulf of Guinea, and the South China Sea. In 2019 alone, there were 162 gun-armed pirate attack incidents all over the world on ships, with boarding from the water being the most common pirate tactic.

Various organizations, such as the International Maritime Organization (IMO), are collaborating with global governments and liner operators to establish best practice guidance and procedures for when such incidents happen and how to prevent them.

For example, the guidance calls on vessels to communicate their intentions to transit the piracy high-risk area to naval forces in the region and to employ vessel self-protection measures based on a vessel-specific risk assessment.

From the shipping companies' perspective, they are starting to deploy numerous other tactics to prevent pirate attacks. These include: hiring guard ships to protect the liner vessel through the riskiest waters, hiring security guards on board, operating the citadel affect—total lockdown to protect crew—and even fitting a Long Range Acoustic Device (a device which emits a loud noise to ward off attackers). Some of these tactics do appear to be

beginning to be having an effect on the fight against piracy. However, the wider challenge remains in the high-risk areas around Somalia. Whilst the current ongoing armed conflict, insecurity, and lack of state governance in the country remain, so will the risk of pirate attacks.

All of the above threats are not only applicable to trade vessels, but for fishing vessels as well. Even though the incidents are less compared to the trade vessels, it is mandatory to give safety to the fisherman using modern technologies.

6. Possible Solution to Obtain a Better Fishing Experience for Omani Fishermen

After addressing many issues in boat automation and also conducting a vast literature review and its comparison in the fishery sector as shown in Table 1, there is a necessity to provide a solution for the fishermen to overcome these problems, and this section will address a solution for all of these problems. A well-defined technological system should consist of a master module with all the sensors and cameras connected, and firmware is required to monitor all the features and predict the abnormalities and alert the people in the ship/boat/vessel. The features can be seen as follows:

- 360 Degree Monitoring;
- Live Location Tracking;
- Radius Monitoring;
- Environmental Monitoring;
- Wind Speed Monitoring;
- Data Monitoring;
- Control Device for Wireless Control and Monitoring;
- Web Application;
- Mobile Application;
- Notification.

The following are the main objectives to perform boat automation which is very important for fishing in the Sultanate of Oman:

1. To provide safety, security, and documentation resources to Omani fishermen.
2. To avoid sea border crossing by Omani fishermen and also to identify the entry in the Oman Sea zone by neighboring countries' fishermen.
3. To navigate the boat, the navigation information will be shared with the control room, and two-way communication between fishermen and the control room.
4. To identify the pirate boats, pirate attacks, and disturbances by external sources.
5. To avoid illegal fishing.
6. To monitor and prepare documentation resources of the parameters such as temperature, humidity, and pressure with specific time periods.
7. To identify fires using smoke sensors and oil spills using chemical sensors and to give alarm warnings to the fishermen immediately.
8. To identify the distance of other boats or external objects from the fishermen's boat in the sea using image-processing techniques, artificial intelligence, and machine learning.
9. To develop a battery monitoring which is mandatory to work all of the above systems and information storage.
10. To implement modern technologies, such as artificial intelligence, machine learning, cloud storage, networking, etc., in the fishery sector.
11. To give effective information sharing between the control room, fishermen, and fishermen's family members.
12. The Section 7 will discuss the materials and methods involved in boat automation.

The Section 7 will give an idea about the system design and control to have a better experience in fishing for fishermen.

Table 1. Review of existing work on fishing boat automation.

No.	Authors	Year	Title	Journal	Theme
1.	Manaa Al Habsi and Nik Mustapha [12]	2011	Fisheries sustainability in Oman	Journal of economic and sustainable development	Sustainability of fishery sector in Oman
2.	Al Abri, M [13]	2019	Fish production jumps by 59pc in 2018	Online article	Statistical data related to fisheries
3.	Samuel, K. [14]	2018	500 cases of fishing law every month Violations	Oman Observer	Statistical data
4.	Michelin, M. et al. [15]	2018	Catalysing growth of electronic monitoring in fisheries	The Nature Conservancy and California Environmental Associates	Technology-based monitoring in fisheries
5.	Chandana, R.; Hussain, S.; S.A.K. [16]	2015	Smart Surveillance System using Thing Speak and Raspberry Pi.	International Journal of Advanced Research in Computer and Communication Engineering	Technology for surveillance
6.	Kamalakannan, Naresh, and Sakthivel [17]	2016	Protecting fishermen's by detecting and warning them while crossing sea borders using GSM and RFID technologies	International Conference on Green Engineering and Technologies	RFID technology for tracking border
7.	Jayapal, N. et al. [18]	2018	GPS & Labview Based System for Detection And Control of Maritime Boundary Intruding Boats	International Journal of Engineering Research & Technology, Trichy	Sea Border tracking
8.	Budiman, A. and Suryana, T. [19]	2019	Fishing Boat Safety Monitoring System Based Internet of Things.	Online source	Monitoring system
9.	Abaya, W.F. et al. [20]	2014	Low Cost Smart Security Camera with Night Vision Capability Using Raspberry Pi and OpenCV	7th IEEE International Conference Humanoid, Nanotechnology, Information Technology Communication and Control, Environment and Management (HNICEM), Phillipines	Surveillance system
10.	Xu, G.; Shen, W.; Wang, X. [21]	2014	Applications of wireless sensor networks in marine environment monitoring: A survey	Sensors, MDPI, Vol 14, Issue 9	Environment monitoring
11.	Xu, H.; Moreira, L.; Guedes Soares, C. [22]	2023	Maritime Autonomous Vessels.	Journal of marine science Engineering	Autonomous vessels
12.	Loïs Vanhée, Melania Borit, and Jorge Santos [23]	2018	Autonomous Fishing Vessels Roving the Seas: What Multiagent Systems Have Got to Do with It	In Proc. of the 17th International Conference on Autonomous Agents and Multiagent Systems (AAMAS 2018), Stockholm, Sweden	Autonomous vessels
13.	Rahmat, M. B., Arfianto A. Z., Santoso T. B., Santoso1, T., and N. Gunantara [24]	2020	Development of Autopilot Unmanned Smartboat Vehicle (AUSV) Based on Fishing Zone Prediction Map	Journal of Physics Conference Series: 1595 012036	Unmanned smart vehicle

Table 1. *Cont.*

No.	Authors	Year	Title	Journal	Theme
14.	Khalid Mahmood Awan; Peer Azmat Shah; Khalid Iqbal; Saira Gillani; Waqas Ahmad; Yunyoung Nam [25]	2019	Underwater wireless sensor networks: A review of recent Issues and challenges	Wireless communication and Mobile computing, Hindawi publishers	Wireless sensor networks
15.	Andrey A. Kurekin; Benjamin R. Loveday; Oliver Clements; Graham D. Quartly; Peter I. Miller; George Wiafe; Kwame Adu Agyekum [26]	2019	Operational Monitoring of Illegal Fishing in Ghana through Exploitation of Satellite Earth Observation and AIS Data Remote Sensing	Remote sensing MDPI	Illegal fishing
16.	Domenico D. Bloisi; Fabio Previtali; Andrea Pennisi; Daniele Nardi; Michele Fiorini [27]	2016	Enhancing Automatic Maritime Surveillance Systems with Visual Information	IEEE transactions on intelligent transportation systems,	Surveillance system
17.	Duong, D.; Valadaine, R.; Hajduch, G.; Garello, R; Fablet, R. [28]	2018	A Multi-Task Deep Learning Architecture for Maritime Surveillance Using AIS Data Streams	Proceedings of IEEE 5th International Conference on Data Science and Advanced Analytics, (DSAA), 1–3 October 2018, Turin, Italy	Surveillance system
18.	Jeong-In Hwang; Jung; Hyung-Sup [29]	2018	Automatic Ship Detection Using the Artificial Neural Network and Support Vector Machine from X-Band Sar Satellite Images	Remote sensing, MDPI publishers, 2018, Volume 10, Isuue 11	Artificial intelligence application
19.	Shaileshbha andBrahmbhatt [30]	2016	A Technical review–implementation of ship detection algorithm for on board satellite based automatic identification system (SB-AIS) Receiver	International Journal of Science Technology & Engineering, Volume 2, Issue 10, April. Available from: https://fr.scribd.com/document/318178162/A-Technical-Review-Implementation-of-ShipDetection-Algorithm-for-on-Board-Satellite-Based-Automatic-Identification-System-SB-AISReceiver	Ship detection
20.	Uthayakumar Jothilingam; A.T. Ravi; Siva Kumar; G. Saran Raj [31]	2019	Pic Microcontroller based Border Alert and Secured System for Fisherman	International Journal of Engineering Research & Technology	Border tracking
21.	Devi, D.; Kumar, S.; Clement Sunder [32]	2021	Fishermen Border Security Alert System Using Iot	International Research Journal of Modernization in Engineering Technology and Science	Border tracking

Table 1. *Cont.*

No.	Authors	Year	Title	Journal	Theme
22.	ASYA and Mgeni, S. [33]	2021	Development of IoT based solution for small sailing boat monitoring and tracking: A case of Zanzibar	Masters Dissertation Univrsity of Rwanda	Boat monitoring
23.	Chang, S.; Stone, J.; Demes, K.; Piscitelli, M. [34]	2014	Consequences of oil spills: a review and framework for informing planning	Ecology and Society	Oil spills
24.	Fingas, M. and Brown, C.E. [35]	2017	A Review of Oil Spill Remote Sensin	Sensors. e-journal	Oil spills
25.	Gabriele Pieri; Michele cocco; Ovidio Salvetti [36]	2018	A Marine Information System for EnvironmentalMonitoring: ARGO-MIS	Journal of marine science and Engineering	Environmental monitoring
26.	Tseng, P.H., ChaoHer, Z., and Pilcherc, N. [37]	2021	Piracy defense strategies for shipping companies and ships: A mixed empirical approach	Maritime Transport Research	Piracy
27.	Santiago Iglesias Baniela and Juan Vinagre Ríos [38]	2012	Piracy in Somalia: A Challenge to The International Community	The Journal of Navigation	Piracy
28.	Goh Wai Pheng [39]	2020	Steering with artificial intelligence to combat maritime piracy	safety4sea	Piracy
29.	Cuong Manh Nguyen and Tien Quoc Le [40]	2019	Impact Of Piracy on Maritime Transport and Technical Solutions for Prevention	International Journal of Civil Engineering and Technology	Piracy

7. Materials, Methods, System Design, and Control

The boat automation system can be designed as per Figure 5. The system design is indicating the integration of the various systems majorly involved in boat automation. The environmental monitoring system mentioned in the Figure 5 can be extended further with subsystems which are given in the Figure 6.

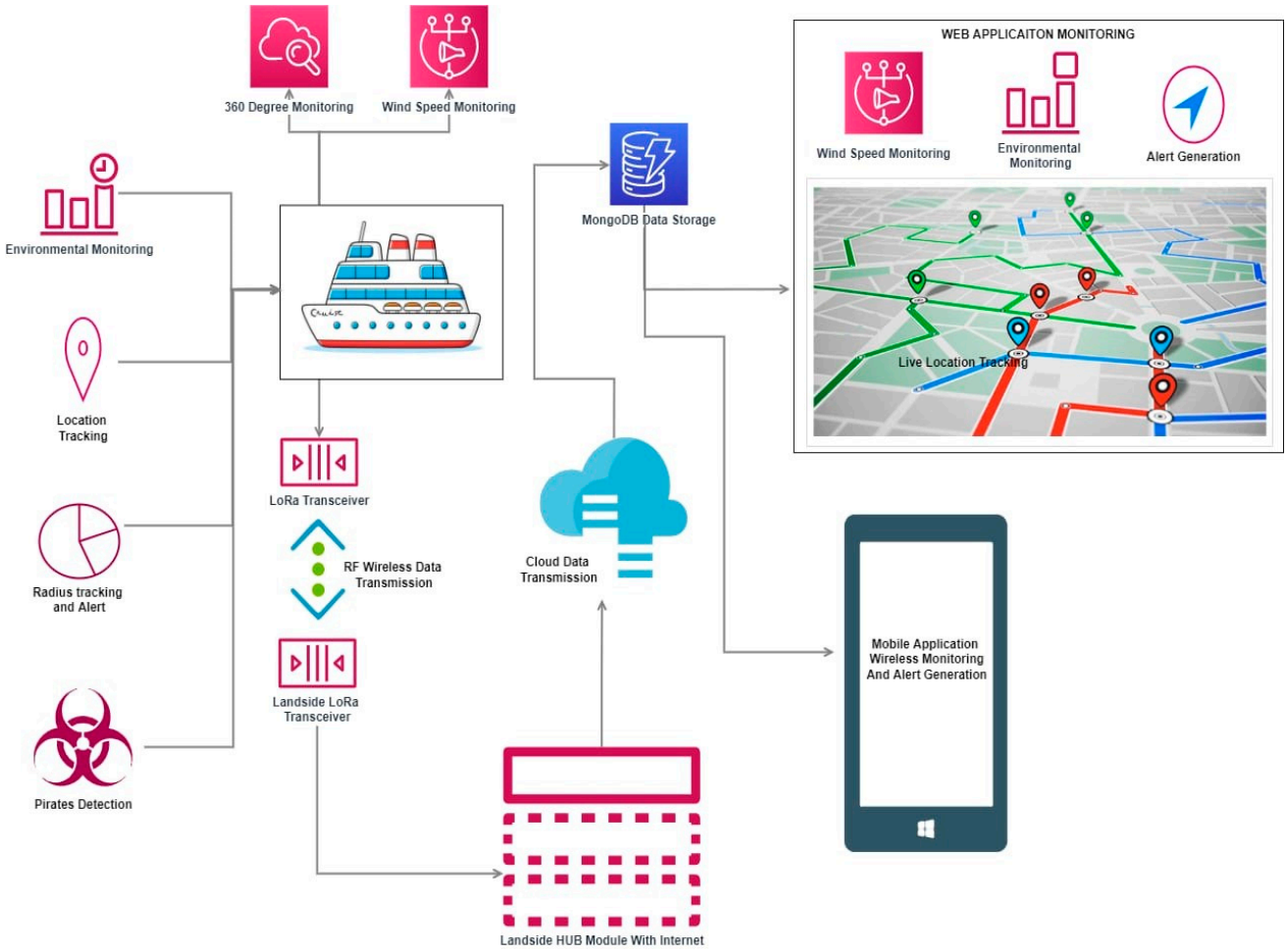

Figure 5. Proposed System design for boat automation.

7.1. 360 Degree Monitoring

- One of the major problems faced by the ships is unknown objects and ships found around the ships.
- Certain situations are unrecognized by the people due to the lack of human ability to have continuous monitoring around the ship and misconceptions about the ships found around it.
- To solve this problem, a 360-degree camera module can be interfaced with the master module with which the surrounding area of the ship is continuously monitored for any objects, ships, etc.
- It differentiates between the known and the unknown ships accurately along with the distance of the ship from them.
- Objects, such as weapons carried by pirates for example knifes/guns, can be successfully predicted and alerted.
- Whenever a ship is recognized to be unknown, an alert will be generated to warn the people so that immediate steps can be taken to fight against the pirates and save their lives.
- For implementing this, an efficient high-resolution camera module with a 360-degree rotating motor can be utilized.

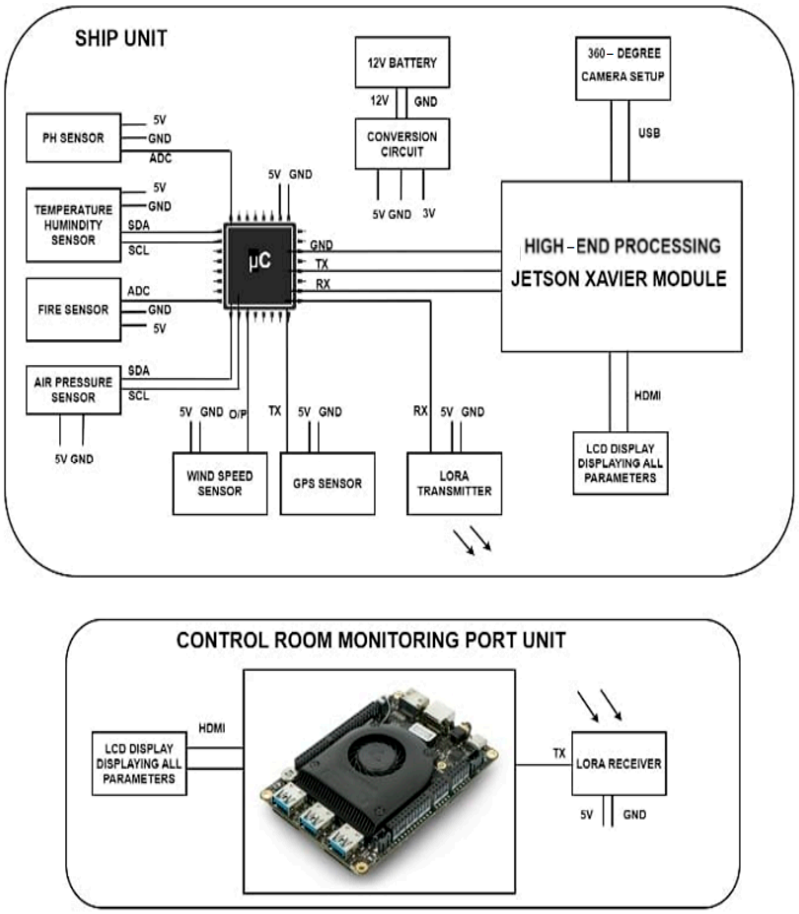

Figure 6. Block diagram of the Environmental monitoring system.

Based on the literature review, the following features can also be included in the design and implementation of boat automation.

7.2. Live Location Tracking

- The live location of the ship can be tracked successfully using GPS modules and update in the master unit, a controller device handled by the coastal area department to track the ship.
- This can help the sailor to travel towards the needed destination without any difficulty.
- The live location can be updated in Google maps.
- To achieve this, hi-tech GPS modules can be used which will fetch the live location accurately.

7.3. Radius Monitoring

- Crossing the radius without knowing "where they are" is one of the major issues faced.
- To solve this, we can integrate navigation assistance with which they can track the ship location and set the radius for their border areas.
- With the help of live tracking, whenever a ship is found to cross a certain border an alert is generated to warn the people so that they can immediately head towards their border area.
- By this, the other border countries will not take unnecessary actions against the ships by conquering them and jailing them for fake reasons.
- This will help the government protect their fishermen and avoid unnecessary chaos with the neighboring countries.
- With the help of a GPS module, this is possible to a certain extent.

7.4. Environmental Monitoring

- Environmental conditions, such as temperature, humidity, and pH of the liquid, can be measured and displayed with which fishermen can become aware of the surrounding conditions, and based on this, they can predict the weather in the upcoming time and make necessary arrangements accordingly to stay protected against the unusual weather change.
- The temperature and humidity are determined using effective digital sensors.
- The pH of the water is derived using the industrial pH sensor from Atlas Scientific, which is recommended for industrial sensor measurement modules worldwide.
- Air pressure sensor and fire sensor can be used for monitoring the pressure and fire presence.

Figure 6 shows the block diagram of the environmental monitoring system.

7.5. Wind Speed Monitoring

- The wind speed of the environment can be monitored continuously and displayed so that fishermen can be aware of it, normal wind speed and abnormal wind speed conditions can be predicted, and ships can be sailed accordingly with safety.
- For determining the wind speed, anemometer sensors can be utilized by integrating with the microcontroller for speed calculation.

Figure 7 shows the circuit design of wind velocity monitoring.

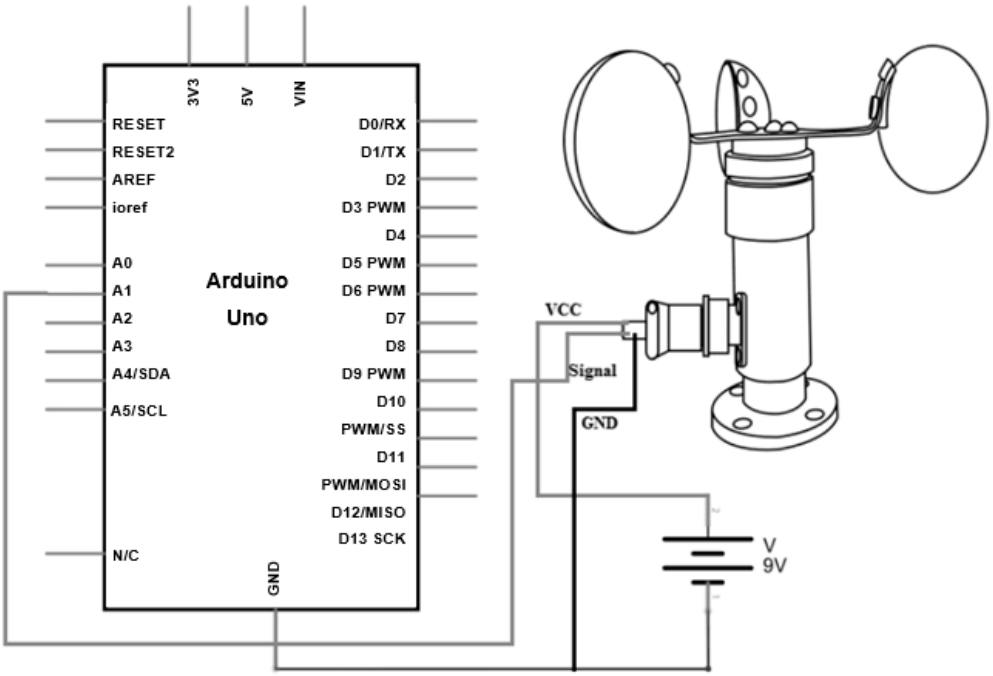

Figure 7. Circuit Design of wind velocity monitoring.

7.6. Data Monitoring

- All the data measured and predicted can be displayed in the monitor interfaced with the master unit which will have a higher-end processing module such as Jetson Xavier.
- From this, they can be aware of the ships surrounding areas and the conditions around the ship, and so on.
- All these data are transmitted using two communications such as Wi-Fi and radio frequency (RF).
- Using RF communication, the data will be transmitted to the coastal area without any internet to monitor it continuously.

- In the coastal unit, using Wi-Fi, the data will be pushed to the cloud for wireless monitoring and stored in the cloud, making it available for the web and mobile application developed for this.
- For achieving this wireless transmission, Seed Studio's LoRa modules can be used.

7.7. Control Device for Wireless Control and Monitoring

- A control device is required to develop separately for controlling the ship from coastal areas.
- All parameters measured will be displayed and controlling the ship on/off can be provided with which they can start and stop the ship wirelessly from the port.
- They can also set the radius for the ship to sail so that whenever the ship crosses the limit an automatic alert will be generated and the same is transmitted to the control room.
- For this, high processing Latte Panda boards can be used with which the LCD will be interfaced for monitoring.

7.8. Web Application

- All these data analyzed and predicted can be viewed using web applications developed independently for this.
- The web application is developed for the control room in the coastal area to have continuous monitoring, and whenever any abnormality is being predicted, such as unknown ships and other such things, an alarm will be generated to alert the people.

7.9. Mobile Application

- An independent mobile app can be developed for this with which all the parameters can be monitored and the ship on–off control can also be integrated into this. The device on–off can also be given in this to switch the device on and off whenever required.

7.10. Notification

- Whenever any abnormal situation is predicted, to alert the necessary authorities, a notification will be pushed to the mobile app.
- This will help to alert the persons when they are not monitoring the ship's condition.

For integrating all the sensors and fetching the real-time reading, an efficient real-time AVR microcontroller is required to use which will process all the information from the sensors and communicate with the Jetson Xavier for any abnormality in the camera live streaming. After collecting all the data, they are transmitted wirelessly to the coastal module with the help of a LoRa transmitter and receiver. According to the design requirements of the integrated automation system, a flowchart is developed and given in Figure 8.

The flowchart demonstrates the various processes involved in the system after the hardware connections are completed. The first step is to interface all the necessary ports using the required programming language, in this case, python. Then, the GPS module is connected and configured to the microcontroller. To ensure boats do not cross the border, the sea border coordinates are set using the software. A logic is formulated such that, if the boat approaches or crosses the predefined border coordinates, an alert is notified through the system LCD.

Secondly, the sensors are connected, and a program is developed to read the values. These values are sent to the cloud to be accessed by the developed website. The camera assists in monitoring the surroundings of objects and other humans. Regarding this, a software model can be developed to detect humans and objects to inform the boatsmen if any object or human is detected. The system continuously monitors the given conditions. The camera images which come continuously are analyzed using AI software to predict the position or movement of the ship/vessel/boat.

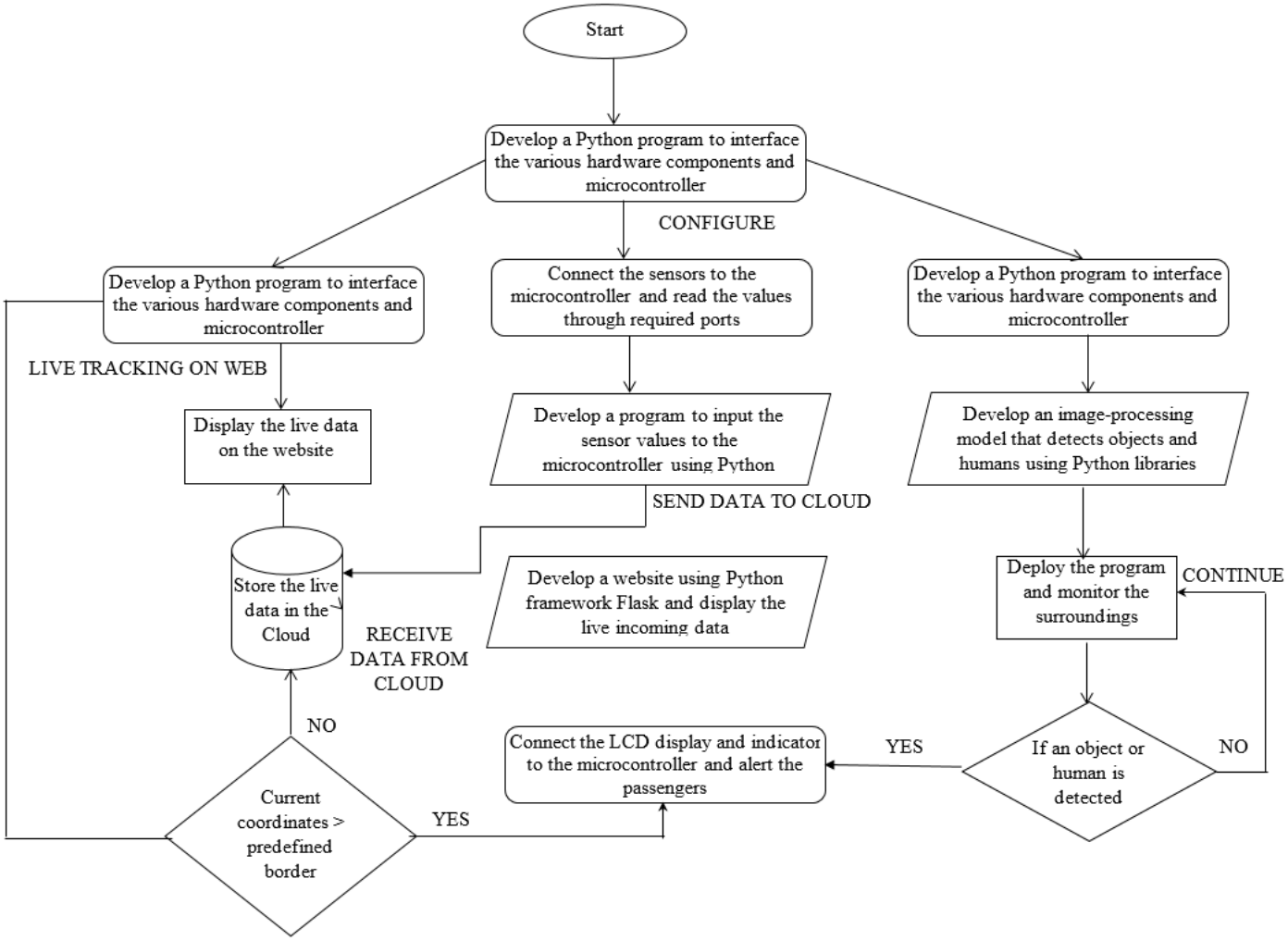

Figure 8. The proposed system's Flowchart to develop an AI-based boat automation system.

8. Reliability Requirement for Boat Automation Systems

The quality outcome of a software-based automation system depends on its software and hardware components' reliability. Reliability functioning of these components is a paramount concern to the millions of users who depend on the software system every day. Unfortunately, many systems still fall short of users' expectations of reliability.

Amuthakkannan et al. have applied the Bayesian model to analyze the reliability of the software-based electro pneumatic system in a systematic way. This attempt helps to take a decision about the reliability of the system and also provides a sufficient confidence in the systems [41]. So, it is clearly understood that for a marine automation system, a good reliability model to confirm the efficiency of the system is needed. As per Amuthakkannan et al. [42], "The increasing demand on quality and productivity of products and services change the industrial dynamics on several fronts including economics, research, technical knowledge, software, communication technologies and so on. To match the demands of increased quality at lower cost, more and more industries are moving towards automation". Overall, we can say a hi-tech reliability model is needed to analyze the marine automation systems before it is integrated with a boat.

All of the systems in marine automation are software-based automation systems which comprise logical and physical components with the integration of networking technologies. The introduction of software, digital technology, and communication engineering in real-time systems has many advantages both concerning flexibility and reliability [43]. However, the reliability analysis of software-based automation system is an important aspect in the industrial and domestic applications. Amuthakkannan et al. discussed the importance of

reliability and performance improvement of software-based automation systems in their paper titled "Performance improvement of software-based system using an integrated approach–A case study". They have applied neural network methodology to predict the response of the software-based automation system for various process parameter values. Then, the genetic algorithm was used to predict the quantitative value of the process parameter to improve the performance of the system [44].

Software quality measurement and improvement is also a big concern in software-based automation systems, which is a mandatory requirement in the development of reliable software for marine automation. Amuthakkannan et al. [45] discussed the methodologies for quality improvement of real-time systems in their paper titled "Software quality measurement and improvement for real-time systems using quality tools and techniques: a case study". The authors applied various quality tools to improve the quality of the software. In the development of software for software-based marine automation systems, the software component assembly is one of the important concerns which needed more attention. Vijayalakshmi et al. [46] developed a systematic procedure to assemble software components to build high-quality software. The proposed algorithm in this paper is based on a dependency chart in which the interaction between the software components is considered as the major criteria. So, in the development of marine software, a good algorithm is needed to obtain fast and reliable software output to interact with the hardware components involved in the system is needed.

9. Discussion and Conclusions

The overall study of the existing literature demonstrates that only a few of the mentioned features are currently available in the automation of boats using modern technologies, such as AI, machine learning, and cloud computing, for the welfare of fishermen. Ebrahim et al. published a review paper for smart fishery which concludes that "AI strategies and AI developments optimize the efficient use of resources, but at present these are not equipped by the policy". So, it is clear that there is no clear policy for AI-based applications in fishing vessels [47]. This paper investigated dimensions of AI for sustainable fishery and future research. So, overall we can understand that there is a standard policy requirement for AI based automation system in fishing vessels in the area of marine engineering. Similarly, no research combines the monitoring and control of different parameters and the systems, such as temperature, pressure, humidity, battery charge, fire, motion control, human detection, external object monitoring, distance detection, sea border tracking, automatic start and stop of motor, navigation, detection of illegal- and overfishing, and weather report, with the application of artificial intelligence, machine learning, and cloud technology. Apart from this, all of the above monitoring and control information should be shared with the control room (coastal guard room) and with the fishermen using a transmitter and receiver where the network is not available. The information from the control room and the transmitter information should reach to fishermen and their family members in both Arabic and English to understand easily. This kind of information sharing in the Arabic language is not yet implemented in any of the technologies or earlier research work. Overall, various kinds of evidence from the literature that the requirement of new technology in Oman's fishery areas are analyzed theoretically and statistically, but concluded that no one has given a promising report about the successful implementation of modern technology in fishermen's boats. The research or development of devices can be an eye-opener for understanding the importance of new technologies in the safety and security of Omani fishermen. Information about fishermen boat location and navigation, which will be shared with the fishermen family members, will be a novel idea to give peace of mind to fishermen's dependents.

So, there are lot of benefits directly and indirectly from the implementation of modern technologies in the automation of Omani fishermen boats. Some of the key benefits are listed below.

1. Improved safety and security for the Omani fishermen and peace of mind for fishermen and their family members;
2. The automation system in the boat will respond more quickly and intelligently to the inclement weather conditions or emergency situations to prevent human losses and serious damage in Oman's fishery sector;
3. Simpler type of navigation which can be easily understood by Omani fishermen;
4. Information sharing about the boat and boat location to Omani fishermen and fishermen families;
5. It is possible to attract younger Omani entrepreneurs to the fishery sector;
6. Boat automation sector will improve in the Sultanate of Oman;
7. Improvement of productivity and export through fishing;
8. Arrest of illegal- and overfishing inside the Oman sea region;
9. Modern technology implementation in Oman fishermen's boats leading to a luxurious boating experience;
10. Economy growth in the Sultanate of Oman through the fishery sector.

Table 2 will provide more information about the key development direction of different strategies in the implementation of modern technologies and the benefits in the fishery sector.

Table 2. Key development direction of different strategies and the benefits in fishery sector.

Technology	Direct Benefit	Indirect Benefits
360-degree monitoring	Pirate attacks detection and detection of nearby vessels	Avoidance of illegal fishing and economic growth
Live location detection	Identification of position of boat	Information sharing to fishermen's family members and also to the control room
Radius monitoring	Avoidance of border crossing	Following of ethical procedure by fishermen; avoidance of problems with neighboring countries
Environmental monitoring and wind speed monitoring	Identification of weather conditions inside the sea	Saving the fishermen's lives
Data monitoring	Maintenance of statistical data at control room and providing data to ministry	Application of AI tools on collected data to predict future
Web application/mobile application	Immediate information collection and sharing	Knowledge improvement among fishermen
Notification	Information sharing and security	Saving the fishermen's lives

With the help of proposed boat automation, we can provide an effective solution for the overall monitoring and surveillance of vessels. A successful prototype is required to develop and integrate in real-time and also important need is to test it successfully which should be further enhanced for commercialization. If this is the case, the fisherman will benefit from increased safety, security, and perhaps even a healthy fishing experience. If this happens, the fishing sector in Oman will obtain remarkable growth which will help to improve the economy of the country. By this review, we aim to achieve the boat automation proposal for the further enhancement and development as an industrial product after all checks such that in the future this can be applied to all fishing boats/vessels.

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