

Original Article

# Plastic Waste Cleaning Autonomous Robot using Object Classification Technique and Path Planning Algorithm

Abdul Razak K<sup>1</sup>, Mohammed Ismayilk<sup>2</sup>, Mohamed VasimAkram N<sup>3</sup>, Muhammad Umar Fayaaz A<sup>4</sup>, C.Ramuvel K<sup>5</sup>

<sup>1,2,5</sup>Dept. of Electronics and Communication Engineering M.A.M School of Engineering, Tamilnadu, India.

<sup>3,4</sup>Dept. of Computer Science Engineering M.A.M School of Engineering, Tamilnadu, India.

**Abstract:** The escalating contamination of water is a critical issue in the contemporary society. It results in a range of issues, such as a rise in the level of hazardous content in the water. This study presents a novel concept for a robot designed to clean oceans or other bodies of water. The robot uses a camera and a specialized machine learning model to identify different types of debris. It then separates the waste and collects it in a basket attached to the robot. The collected rubbish may later be recycled at a base station. The robot's ability to be deployed on any sea surface makes it more efficient than a large-scale ocean pollution remediation strategy. This device has the capability to remove oil spills resulting from shipwrecks and pipeline leaks. Additionally, it can assess the water quality in a specific area and transmit an emergency signal to the base station if any irregularities are detected. The water quality data and information on pollutant types from the machine learning model may be utilized to develop local legislation aimed at mitigating pollution and raising awareness about the specific materials that wind up in the ocean or water bodies.

**Keywords:** Environmental Instrumentation, GPS, Marine, Mobile Computing, Neural Network, Robotics, Sensors and Transducers, Solar Energy.

## INTRODUCTION

Polluted water, as defined by the World Health Organization (WHO), is water that has undergone changes in its composition to the extent that it is no longer beneficial or usable. The water is toxic and unfit for consumption or use in vital activities such as agriculture. It leads to illnesses like as diarrhea, cholera, dysentery, typhoid, and poliomyelitis, resulting in the death of more than 500,000 individuals annually [1]. The water in the region becomes contaminated due to the contamination of oceans and other bodies of water, rendering it unsuitable for human consumption as well as for marine organisms [2]. It leads to a multitude of problems, including an increase in dangerous levels of substances in the water. This high concentration poses a risk to the food chain, which in turn has adverse consequences on human beings [3]. This article presents an idea for a robot designed to clean oceans or aquatic bodies. The robot's main goal is to identify and segregate different types of garbage while collecting them in a carriage attached to the robot. This allows for proper disposal or recycling of the waste at a designated base station.

Machine learning algorithms [4] and models for image classification [5] were trained and built to accomplish the objective of categorizing contaminants in water. The learned model is then put on a Raspberry Pi device. The machine learning model development of this was done with consideration for the computing resource limitations of the Raspberry Pi. The user's text is "[6][7]." The robot can utilize ultrasonic and lidar sensors for collision avoidance. The user's text is "[8]." The robot is equipped with a path planning algorithm [9][10] that enables it to go to a specific spot by inputting the destination coordinates. This implies that the robot has the capability to autonomously find its way back to the base station when it is necessary to return or when it is required to cease its operations due to unfavorable weather conditions. The robot's construction is designed to imitate that of a catamaran in order to achieve improved stability and excellent operating efficiency. Within the robot, there are mechanical gates that guarantee the entry of categorized material into the appropriate compartment, ensuring effective recycling at the base station. The miniature conveyor belt facilitates the seamless transfer of marine debris into the compartment located in the attachable basket. The robot possesses the capacity to remediate oil spills in the seas resulting from shipwrecks and pipeline damage. The robot navigates across the water utilizing differential drive technology. The presence of on-board solar panels guarantees that the battery remains free from strain for an extended duration. The robot is equipped with water quality monitoring sensors that assess the water quality at its position and promptly



notify the base station in case of any deviations from normal levels. The water quality data and pollutant information obtained from the machine learning model may be utilized to formulate local policies aimed at reducing pollution and increasing awareness regarding the kind of items that end up in the ocean or other bodies of water. This facilitates the cleanup of lakes and ponds, making it simpler to use the water for human use, hence mitigating water shortages.

### **LITERATUREREVIEW**

The examinations discussed in this section focus on the definition related to the water purification process, machine learning, and path planning. Raschka [4] outlines a framework for the development, training, and deployment of machine learning using Python, highlighting its significant capabilities in smart devices and products. Xin and Wang [5] suggest an alternative strategy that is purportedly superior to conventional machine learning models relying on multilayer perceptron models. The M3 CE-CEc was evaluated using MNIST and CIFAR-10, which are two commonly used datasets in deep learning. Matthies [6] is an interactive system that utilizes geometric scene knowledge to react to changes in the dynamic environment. A lightweight machine learning model was trained and constructed by Norris and Donald [7]. The model was implemented on a Raspberry Pi. The model demonstrated its efficacy even on a computationally constrained device such as Raspberry Pi. Luongo and Di Vito [8] created an autonomous collision avoidance system specifically intended for a dynamic environment.

The model was constructed solely based on radar technology. Teleweck [9] provided a concise explanation of the path planning method and the computing it involves. The project aimed to provide a fundamental comprehension of path planning and navigation for the robot in a dynamic environment. The essay by Esmael Khanmirza and Morteza Haghbeigi attempts to examine many well recognized and important path planning algorithms, including D\*, A\*, RRT, and bidirectional RRT. The study aims to provide a concise analysis of the disparities and benefits of the algorithms. Pranayand Agrawal [11] has developed a multi-robot system designed specifically for the purpose of cleaning lakes. Three robotic systems were simulated using MATLAB. The robots are let to travel in a random manner, with the expectation that over time, they will cover most areas. The proposed approach demonstrated high efficiency in the simulation. Khatib and Qalalweh [12] propose a cost-effective photovoltaic-based pumping apparatus to eliminate algae by injecting a chemical component into the water of an artificial pond. This chemical inhibits the formation of algae on the water surface. The health impacts of hazardous chemicals, such as lead, have been detailed by Needleman and Bellinger [13]. The article provided an overview of the recent biological and epidemiological impacts of a little amount of lead. S.M. La Valle [14] has introduced and executed an RRT route planning algorithm. The suggested technique has several benefits, such as taking into account the limitations of unmanned vehicles and being well-suited for a dynamic environment. These advantages enhance the usefulness of the model in a multi-robot environment. Taru, aged 15, have proposed an innovative idea.

Arduino-based approach for water quality monitoring. The system included of pH sensors, a turbidity sensor, and a temperature sensor for the purpose of monitoring the water quality. BertoandNapoletano [16] conducted a concise investigation on wireless mesh networks utilizing LoRa technology. Wireless mesh networks facilitate communication between devices and the server. Lenes and Henrick (17) developed and deployed an autonomous unmanned surface vehicle (USV) utilizing the Robot Operating System (ROS). Raghavi and Varshini, both 18 years old, have created an RF-controlled Robot capable of monitoring water pH. Akash Sinha and Prashant Bhardwaj (19) introduced a system that uses the Kalman Filter to detect pollutants. The system incorporates both the "HSV Color Space" and "SURF" techniques for measurements, resulting in highly reliable pollutant tracking. Shreya Phirke and Abhay Patel, both 20 years old, have created a robot that utilizes a robust mechanical framework, sensor fusion, and computer vision to achieve independent cleaning capabilities. R Praveen and L Prabhu [21] introduced a beach cleaner robotic vehicle that is operated by RF signals. This vehicle is specifically built to clean the coastal area. Additionally, they created a 3D model of the robot. Max Washington and Cameron J. Shearer [22] have developed an economical and environmentally friendly approach to remediate oil spills in the water by utilizing a Polysulphide combination.

### **PROPOSED METHODOLOGY**

The robot's design incorporates a Raspberry Pi as the main computing board, along with Arduino and LoRa modules. The Raspberry Pi is responsible for performing tasks related to image processing, object

categorization, and motion controls. On the other hand, the Arduino is connected to the LoRa module and the water testing unit. The robot can categorize ocean contaminants based on item categorization and store them in a separate section of the basket for more convenient recycling. The robot is capable of cleaning algae-infested ponds or lakes, as well as oil spills in the vast expanse of the ocean. Path planning algorithms are utilized to navigate the robot to a specific area of focus and may also be employed to determine the optimal route back to the base station. The robot undergoes overnight charging at the base station, while solar panels are integrated into its structure to enable energy harvesting from sunshine, so alleviating the burden on the battery. The robot is equipped with a LoRa-based communication system, which enables communication between devices and gateways located at the base station. The robot is equipped with water testing sensors, such as a pH sensor and an electrical conductivity sensor (EC), which may be utilized to check the water quality in the water body. The robot operates autonomously and has an onboard system. The GPS module is utilized to determine the precise location of the robot.

### **COMPONENT DESCRIPTION**

Raspberry Pi is a series of small single-board computers developed by the Raspberry Pi Foundation. The Raspberry Pi is an affordable single-board computer (SBC) that has a system-on-a-chip (SOC) produced by Broadcom, which includes an ARM-compatible central processing unit (CPU). The Raspberry Pi operates on a Linux-derived Operating System. A standard USB camera is utilized to supply a video stream to the Raspberry Pi. The solar panels transform solar energy into electrical energy, which may be utilized to alleviate the reliance on batteries and enhance the robot's operational duration before requiring recharging. The Arduino Nano is utilized to get sensor data from the water quality monitoring equipment and is connected to the LoRa module. The Nano is favored over the Uno due to its diminutive dimensions, which facilitate its integration onto a printed circuit board. The TP4056 is a voltage regulator that adjusts the voltage from a solar panel and directs it to the battery to prevent damage caused by excessive voltage. The HC-SR04 ultrasonic sensor determines the distance of an item in front of it by emitting ultrasonic sound waves and converting the reflected sound wave into an electrical signal. The transmitter and receiver are the fundamental elements of ultrasonic sensors, responsible for detecting the sound after it has traveled to and from the target. The L298N motor driver module is utilized for the purpose of controlling and powering DC motors. This module comprises an L298N motor driver integrated circuit (IC) and a 5V regulator. The L298N Module is capable of controlling both the direction and speed of motors, since it functions as an H-bridge bipolar motor driver. GPS module and antennas

GPS modules get data directly from satellites via dedicated RF frequencies. The signal from each visible satellite, together with additional data, is received. The satellite broadcasts the signals at the same instant they are delivered. The distance between each satellite may be estimated by subtracting the time the signal was broadcast from the time it was received. The pH sensor is capable of determining the alkalinity and acidity levels of water. The main working idea of pH sensors is the ion exchange from the sample solution via the glass membrane to the internal solution of the glass electrode, which is a pH 7 buffer. Prolonged usage will decrease the porosity of the glass membrane, resulting in a decrease in the probe's performance. The conductivity sensor, also known as the EC sensor, is a device used to quantify the conductivity of a solution. This measurement provides information on the presence of ions in water. Electrical conductivity (EC) may be transformed into total dissolved solids (TDS). LoRa is a long-range communication device utilized for transmitting data to either the base station or the peer robot. PWR-SNS is an embedded multi-meter unit that is utilized for monitoring the battery voltage.

A D.O Sensor is utilized for the purpose of quantifying the concentration of dissolved oxygen present in water. Dissolved oxygen permeates from the sample via an oxygen-permeable membrane and enters the sensor in an electrochemical dissolved oxygen sensor. The oxygen undergoes a chemical reduction process within the sensor, leading to the generation of an electrical signal. The sensor is capable of detecting this signal. The MPU6050 is a sensor unit that combines an accelerometer and a gyroscope. It provides information on the orientation of the robot. When two masses make contact as a result of vibration or a change in motion (acceleration), the piezoelectric material generates an electrical charge that is directly proportional to the applied force. A servo motor is employed in the valve gates to direct the debris into the appropriate bin. A servo motor is utilized because of its ability to accurately regulate the angle of rotation. The motor is equipped with a potentiometer that exhibits variable resistance in response to changes in the rotation angle. DC motors are employed to push the robot in the intended direction and are utilized on the conveyor belt.

Lidar is utilized in conjunction with HC-SR04. Lidar offers higher resolution and a greater range compared to ultrasonic sensors. The Lidar device emits a beam of light and determines the distance by measuring the time it takes for the light to reflect back. Lights are used to provide illumination in gloomy areas and to communicate communications using Morse code.

**Discussion of the Workflow**

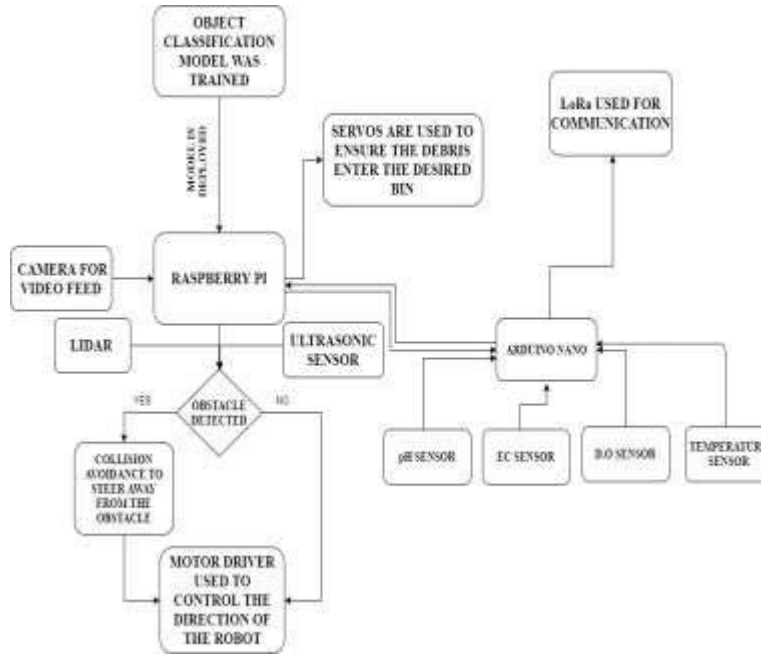


Figure 1: Flow Diagram of the Proposed System

Figure 1 depicts the schematic of the robot's flow diagram. The object categorization model was trained using the Edge Impulse platform and is now operational on a Raspberry Pi device. The Raspberry Pi is linked to a USB camera to receive the video stream. The Raspberry Pi is equipped with both a Lidar and an ultrasonic sensor to enable collision avoidance. The L298N motor driver is connected to a Raspberry Pi, allowing you precise control over the motor's direction and speed. If an impediment obstructs the path of the robot, the collision avoidance system activates and redirects the robot away from the obstruction. The Raspberry Pi is coupled to servo motors, which are utilized to direct the pollutant into its designated compartments. The Arduino is linked to the LoRa module, which is responsible for receiving and transmitting data to the base station, as well as to the peer robots and repeaters. The Arduino Nano is linked to the Raspberry Pi via USB, facilitating communication between the two devices. The Arduino is coupled to pH, EC, and D.O sensors, which are used to check the water's purity. The Arduino Nano is linked to a Lora module for the purpose of communication. Lora technology enables the efficient transmission of little data packets over long distances while consuming minimal power.

**Machine Learning Model for Object Categorization**

A classifier is a method that utilizes a set of distinctive features to determine the category of an item. The dataset including the sample photos and corresponding labels is utilized to train the classifier algorithm. The training set is a compilation of established objects that classification systems utilize to acquire the knowledge necessary for classifying them. The training set comprises example photos representing several kinds of contaminants, such as plastic bags, plastic bottles, Styrofoam, algae, metals, and oil spills. Once the training data is loaded, the learning rate is determined, an appropriate classification model is selected, and the number of neurons is specified. Figure 2 depicts the training data that was submitted for the object classification algorithm to process.

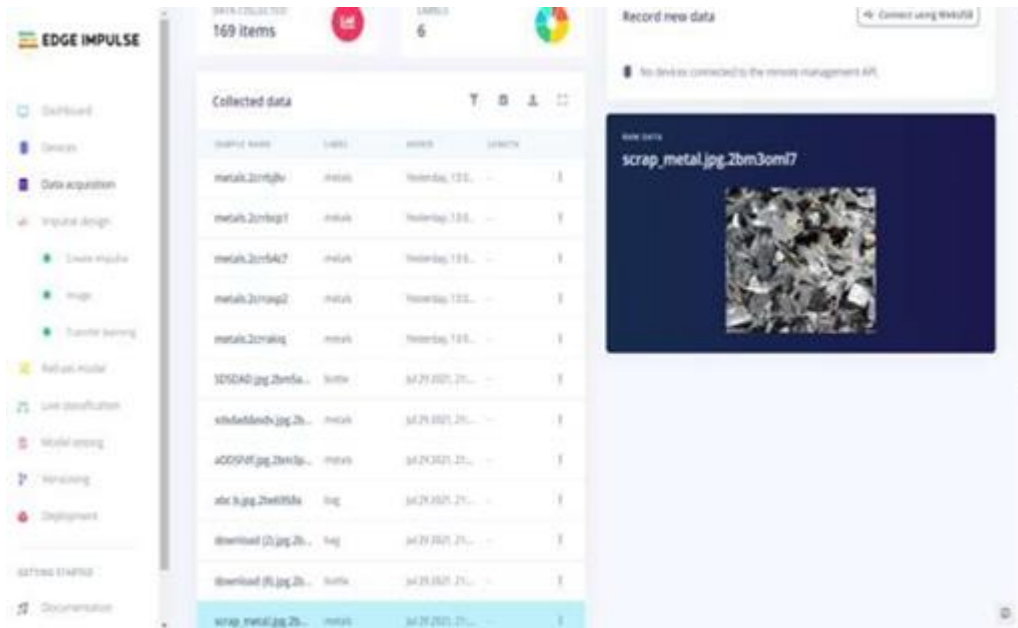


Figure 2: Dataset Uploaded For Training the Model

Following the completion of the training data upload, the procedure of feature extraction is carried out. Feature extraction is a crucial phase in the process of reducing the dimensionality of data. It entails splitting and compressing a substantial quantity of original data into smaller groupings. As a result, the processing and computation will be significantly reduced. Model testing is the subsequent stage in the object categorization process. If the accuracy falls below the specified threshold, the parameters are adjusted and the model is retrained. Figure 3 demonstrates the model accurately recognizing the object in the uploaded image from the test set.

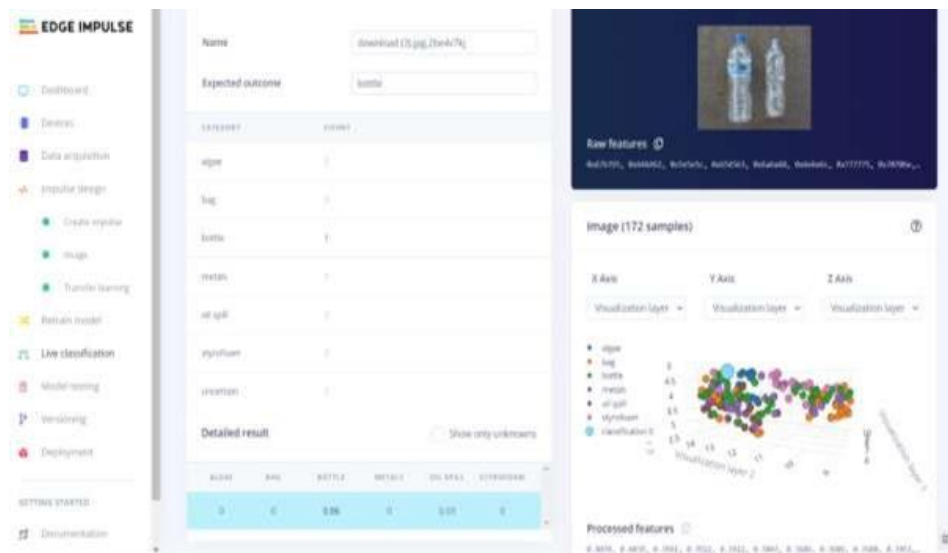


Figure 3: Testing the Model Using Sample Images

Once the model's functionality has been verified, it will be implemented on the Raspberry Pi. Figure 4 illustrates the implementation of the custom object categorization model on an Android phone for the purpose of testing.



Figure4: Machine Learning Model Identifying the Pollutants

### Discussion on Movement of the Robot

The robot utilizes Differential Thrust Technology, which bears a striking resemblance to the Differential Drive Technology often employed by land robots and rovers. The movement of the system is determined by the relative force exerted by the motors. If both motors (left and right) rotate in the same direction, with both rotating clockwise, the robot travels ahead. If both motors rotate counterclockwise, the robot will travel in reverse. To orient the robot in a sideways position, differential thrust technology would be utilized. In order for the robot to turn left, the motors on the right rotate while the motors on the left remain still. This results in an increased application of force on the right side of the robot, leading to the robot drifting towards the left. And conversely, in order to make a right turn. Figure 5 illustrates the trajectory of the robot's motion

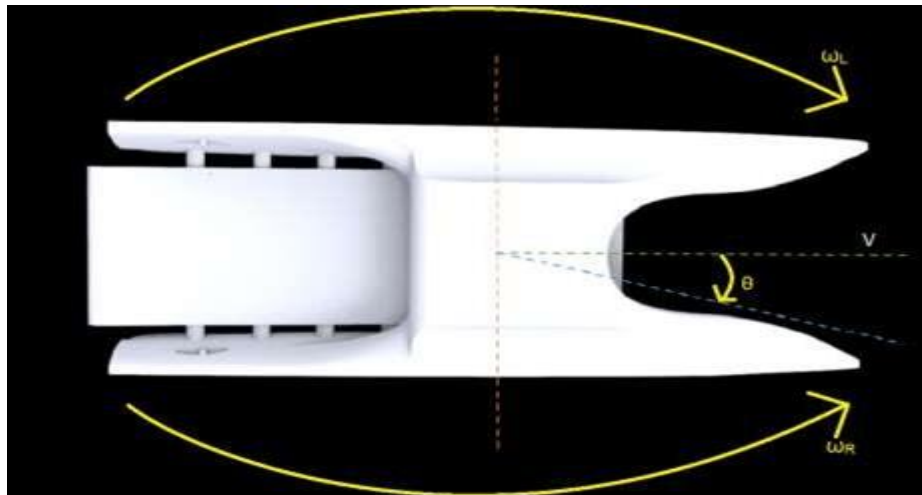


Figure 5: Visualisation of Robot Movement

### CIRCUIT DESIGN OVERVIEW

The circuit design and component selection are meticulously optimized to provide maximum efficiency while minimizing power consumption and weight. The robot is comprised of three primary subsystems: the control subsystem, water quality monitoring subsystem, and communication subsystem. The subsequent lines provide a detailed explanation of the subsystems.

#### Control Subsystem

To prevent water damage, the electronics will be positioned at the highest point of the robot, even in the event of accidents. The object categorization aspect is managed by the Raspberry Pi, which is linked to a standard USB camera to receive the video stream. The Raspberry Pi is equipped with both lidar and

ultrasonic sensors to enable an obstacle avoidance system. The Raspberry Pi is attached to two servo motors, which control the bin where pollutants are directed. The Raspberry Pi sends a command based on the output from the object classification model. The robot is operated with a 12-volt battery, with the motor driver being linked directly to the battery. The motor driver regulates both the orientation and velocity of the motors. The motor driver gets the command for controlling motion from the Raspberry Pi. The motor driver comprises an H-bridge. An H-bridge is an electrical circuit that enables the reversal of voltage polarity given to the motor. This feature allows the robot to utilize differential propulsion technology, enabling it to alter its course. The robot's accelerometer transmits the robot's orientation. If the robot topples, a message can be sent to the base station based on the accelerometer data.

The PWR-SNS gadget is directly attached to the battery and serves as an integrated multi-meter. This is utilized for monitoring the voltage of the battery. If there is any anomaly, an alarm is sent to the Raspberry Pi, which then conveys the message to the base station. The solar power will be captured and employed to alleviate the burden on the battery. The TP4056 regulator would control and stabilize the voltage generated by the solar panel. Figure 6.1 and Figure 6.2 depict the circuit architecture and schematic layout of the control subsystem

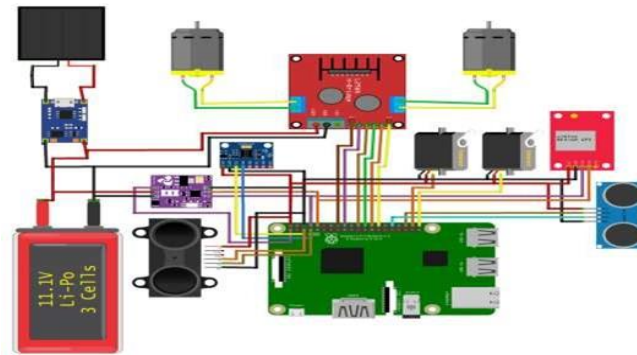


Figure 6: Circuit Design of Control Subsystem

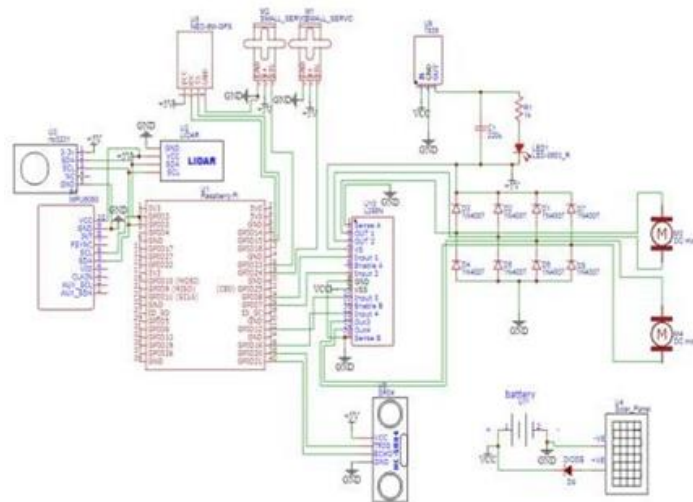


Figure 7: Schematic Layout of the Control Subsystem

### Subsystem for Monitoring Water Quality

The robot is equipped with an integrated dissolved oxygen sensor, electrical conductivity sensor, pH sensor, and waterproof temperature sensor. A dissolved oxygen sensor aids in comprehending the oxygen levels in the water that is accessible to the aquatic species and plants. An electrical conductivity sensor measures the water's conductivity to electric current. This aids in comprehending the level of ions present in the water, hence providing the measurement of salt concentration. To convert EC to TDS, multiply the EC value by 1000 and divide the result by 2. A pH sensor is used to quantify the concentration of hydrogen ions in water. The pH scale, ranging from 0 to 14, is used to measure the acidity or alkalinity of the sample solutions by comparing them to pure water, which is considered neutral. The DS18B20 is a sensor that is

utilized to gauge the temperature of water, providing insights about its warmth and its capacity to sustain aquatic life. Figure 7 depicts the circuit connection of the water quality monitoring equipment.

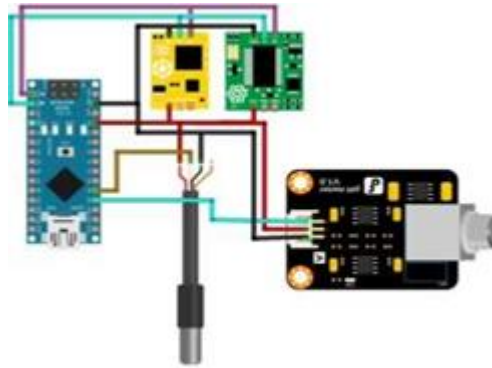


Figure 8: Circuit Design of Water Quality Monitoring Unit

### Communication Subsystem

Effective communication is essential for the robots to interact with one other and the base station in order to operate well. In order to do this, the utilization of LoRa technology has been implemented. The LoRa technology enables the transmission of bidirectional data over long distances with little power consumption [15]. The Radio Head Packet Method facilitates communication between two LoRa devices. The diagram illustrates the flow of the communication system in the shape of the number 8.

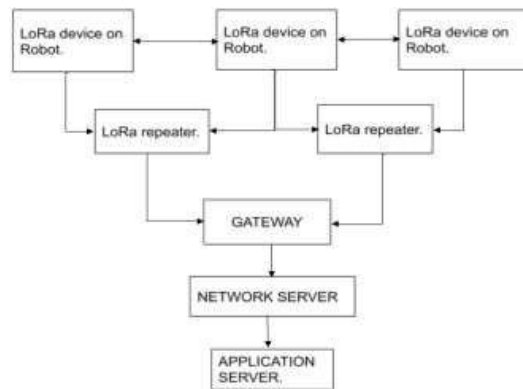


Figure 9: Communication Design of the Robot

A LoRaNode consists of a Radio Module and a Microprocessor. The microprocessor retrieves data from the sensor and transmits it wirelessly over the radio module to a LoRa gateway. The LoRa Gateway includes a Radio Module and a Microprocessor, although it often relies on AC mains for power due to its greater power needs. A LoRa Gateway has the capability to receive data from many LoRa nodes, while a single LoRa node may transmit data to several gateways, maintaining data integrity. The diagram in Figure 9 illustrates the connection between the LoRa module and Arduino Nano within the robot.

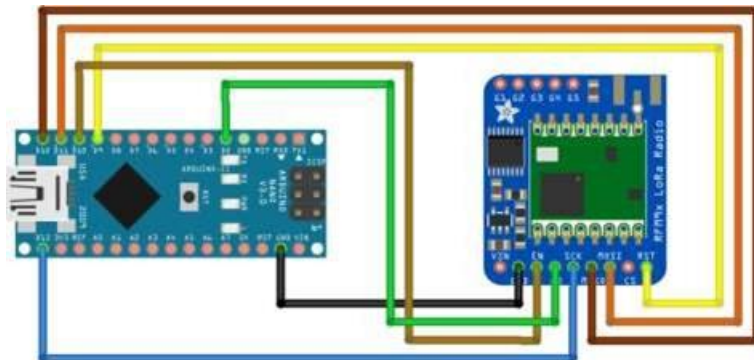


Figure 10: Connection between LoRa and microcontroller

### Solar Panel

A solar panel is utilized to capture solar energy and convert it into electrical energy, which may then be stored in a battery. The solar panel is comprised of solar cells. Typically, a solar cell has a maximum voltage output of 0.6V. Therefore, to enhance the voltage; solar cells are linked in a series configuration. The quantity of solar cells required for connection is determined by the individual application [23], financial considerations, and the available space for fitting a solar panel. The selection of a 40W solar panel for this robot was based on several factors: its lightweight design, cost-effectiveness, compact size requirements, and its impressive electrical specifications, including a maximum power current capability of 2.06 A and an open circuit voltage of 19.5V

Connecting solar cells in series to boost the voltage is suitable under optimal sunny conditions. However, on a cloudy day, when the sunlight is partially obstructed by clouds, only the remaining sunlight reaches the panel. This results in an elevated resistance for the entire system, as the cells are connected in series. To address this issue, bypass diodes are installed in parallel with each junction of the solar panel. The diodes allow the current to flow through them, so resolving issues related to increased resistance when the screen is partially covered. In the event that a single cell in the array of cells fails, this protects the entire solar panel from failing, even if just one cell is not operating.

### Algorithm for Avoiding Obstacles and Planning Paths

The system utilizes data obtained from the ultrasonic sensor and Lidar to compute the distance between the approaching obstacles. The ultrasonic sensor operates based on the idea that when sound waves are emitted and encounter an impediment, they reflect upon striking the obstruction. This reflected wave may be utilized to ascertain the presence of an obstruction, while the duration it takes for the sound to rebound provides the measurement of the distance covered by the sound from the sensor to the obstacle and back to the sensor. The real distance between the sensor and the obstruction may be determined by dividing the obtained distance by 2. The formula for determining the distance is provided below.

$$\text{Distance (in cm)} = \text{time taken for the sound wave to bounce back} * 0.0344 / 2 (1)$$

The simulation of the collision avoidance system using the robotics toolbox in MATLAB is shown in the figure 10

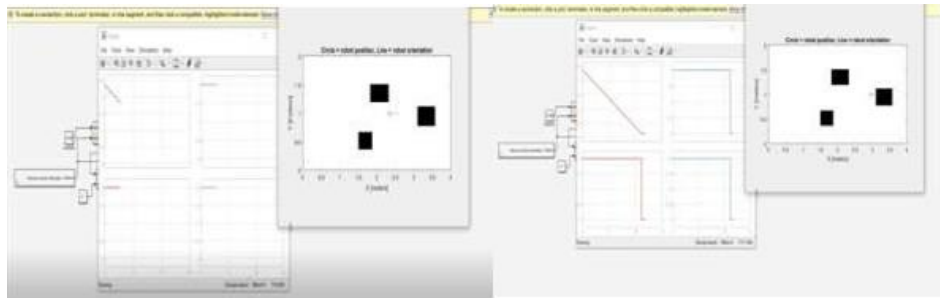


Figure 11: Implementation of collision avoidance system in MATLAB

The robot utilizes a path planning algorithm that is founded on a rapidly explored Random Tree (RRT) [14]. By employing this approach; the robot may navigate to any specified point on the provided map, based on its present coordinates. An RRT produces a tree by using random samples from the search space, with the tree rooted at the initial posture. As each sample is selected, a connection is formed between it and the state that is nearest to it in the tree. If the connection is feasible (i.e., it does not pass through an obstruction), the new state is added to the tree. This procedure repeats until the robot reaches the desired position. The adoption of this approach is favored over the general path planning algorithm and A\* due to its minimal memory and computational demands.

Figure 11 depicts the progressive growth of the tree as it moves from the initial position to the desired stance while successfully navigating around obstacles. The start stance is represented by a smaller green circle, while the target pose is represented by a bigger green circle. This simulation is implemented using the PYTHON programming language and viewed using the PYGAMES environment. The probabilistic pathway has been outlined in pink

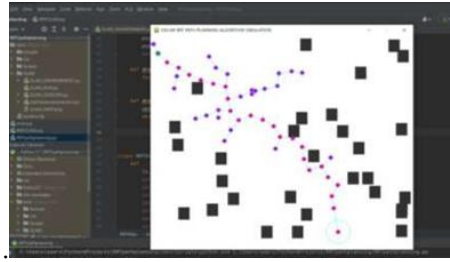


Figure 12: RRT Path Planning Algorithm Simulate During Python

### MECHANICAL DESIGN ERGONOMICS OF THE ROBOT

The robot chassis will be constructed using Polyethylene terephthalate glycol (PETG). PETG is selected because to its exceptional impact resistance, moisture resistance, cost-effectiveness, and ease of recycling. PETG is a suitable option for environmentally friendly items because to this. The stability of an object suspended in a fluid is contingent upon the precise determination of the position of its center of buoyancy. When the robot is submerged in the water, the robot's weight and the buoyant force exerted on the robot are in equilibrium. These forces act through the center of buoyancy and the center of mass. If the two locations are sufficiently proximate, it is more convenient to stabilize the robot. If the two places are too far, the robot will experience more rocking and a higher likelihood of capsizing. The design of the robot underwent meticulous analysis and modification to ensure that both the center of mass and the center of buoyancy are positioned as closely as feasible, hence enhancing stability. Figure 12 illustrates the centroid of buoyancy of the robot.

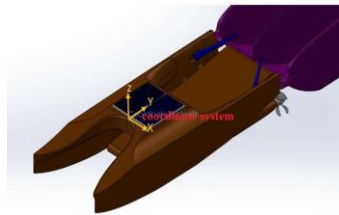


Figure 13: Centre of Buoyancy of the Robot

The software calculated that the mass of the chassis, constructed using PETG as the building material, is 15611.17 grams. Center of mass:

X = -0.48  
Y = 527.50  
Z = -81.28

The camera location is related to the design, which includes a broad input, conveyor belt, separator, and carriage.

### Inlet Design

The primary objective during the construction of the entrance was to provide the optimal angle flow of water, which would effectively capture the majority of pollutants (limited only to the bot's identification) that accumulate in a single-serve. As the rubbish enters the bot from the inlet, it flows in a narrow flow, facilitating the separation of the collected waste and ensuring a sufficient flow of the garbage materials. Dispose of it in the rear bin. Therefore, the inlet has a narrow-pointed entrance. The diagram in Figure 13 illustrates the design of the waste intake.

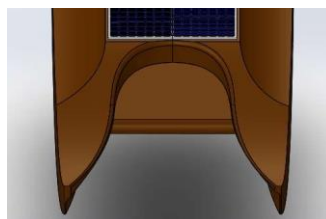


Figure 14: Waste Inlet Design

### Conveyer Belt

The primary function of the conveyer belt is to facilitate the uninterrupted movement of collected waste from the inlet point to the carriage through the separation system. This is necessary because the bot is controlled by a classification algorithm that relies heavily on parameters related to the types of pollutants. By employing a continuous system such as a conveyer belt, the need for additional parameters like collector speed and robot's speed can be eliminated. Opting for a conveyer belt system simultaneously results in lower energy usage compared to the majority of other advanced pollution separation systems now available. The figure 14 depicts the sectional view of the robot.

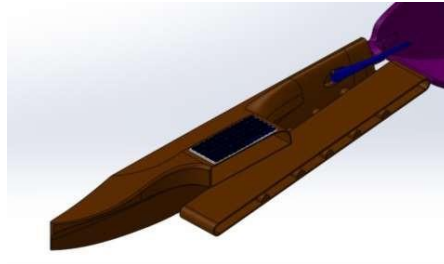


Figure 15: Sectional View of the Robot Depicting the Conveyer Belt

### Separator

The segregation technology under development aims to effectively separate two primary water pollutants: plastics and metals. The separator operates in two distinct modes: when it comes across non-biodegradable garbage such as bottles, bags, and Styrofoam, it diverts it to one compartment; conversely, when it finds metal debris, it sends it to the other compartment. The operation of this system entails the utilization of two elongated levers, which are attached to opposite sides of the robot. These levers are then linked together using a servo motor, whose input is regulated by the Raspberry Pi. This also guarantees that the debris will not become trapped in the middle. Figure 15 depicts the divider used to direct the garbage into the appropriate container.

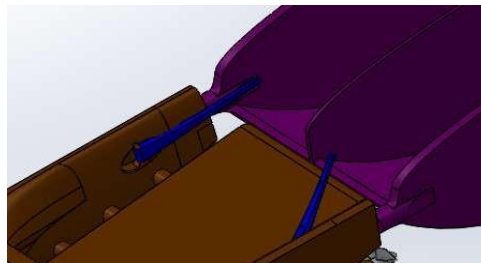


Figure 16: Separator Design to Channel the Waste into Their Corresponding Bin

### Carriage System

The robot categorizes the garbage and directs it into the appropriate container, as previously said. The plastic garbage and metals are sorted into their respective containers. Styrofoam, bottles, and bags are categorized as plastics, whereas scrap metals and metal tins are categorized as metals. Algae and oil spills do not occur in the same region, as oil spills often happen in seas and oceans, whereas algae production takes place in lakes and ponds. The combination of algae and plastics is indistinguishable on the robot itself, necessitating the use of advanced machinery and processes for separation. Figure 16 depicts the carrier responsible for collecting the pollution.



Figure 17: Carriage Design to Collect the Pollutants

### DESCRIPTION OF THE OPERATION

The suggested robot would be deployed in areas with a high concentration of pollutants. The base station is strategically positioned in close proximity to the robot's location to ensure continuous communication between the two. Additionally, the robot has the capability to return to the base station in the evening, during inclement weather, or when the basket is full. Additionally, it simplifies the process of charging the robot. The Raspberry Pi serves as the central processing unit of the robot. The camera is linked to the Raspberry Pi, enabling it to observe the surrounding environment. Object categorization is performed on a Raspberry Pi, and the object is sorted into the appropriate bin based on its kind. The garbage is directed into the bin using servo motors, which function as a separator. The robot has the ability to categorize a wide range of prevalent contaminants, including plastic bags, plastic bottles, Styrofoam, metals, algae, and oil spills.



Figure 18: Deployment of the Model on Raspberry Pi

The diagram in Figure 17 demonstrates the model's high accuracy when executed on a Raspberry Pi, with the resulting output being shown on a terminal window. This data may be utilized to get information on the specific pollutant type and subsequently regulate the servo motors accordingly.

Generally, oil spills and algae are unlikely to occur in the same body of water. Oil spills are incidents that happen in seas and oceans, whereas algae growth is a phenomenon that occurs in lakes and ponds. When cleaning algae, it is extremely difficult to remove plastics from it within the robot itself, since the plastics become stuck within the algae. Consequently, alternative procedures will be used at the base station to separate the plastics. In order to remediate an oil spill resulting from a shipwreck or a pipeline rupture, an aircraft is utilized to disperse low-density polysulphide throughout the affected area. The polysulphide compound adsorbs the oil layer floating on the surface of the water [22], and the robot is capable of retrieving the mixture, thereby eliminating up to 90% of the oil. The oil may be extracted by mechanical compression, and the polysulphide can be reused afterwards.



Figure 19: Clear Water

Figure 19: Oil Spill on Water



Figure 20: Adding as or ben material to collect oil and removing it

Figure 18 depicts the transparent water that serves as the test subject. Figure 19 illustrates an oil spill on water, while figure 20 demonstrates the process of oil cleaning by the application of a sorbent substance. This procedure is highly effective in both cleaning up oil spills and preventing harm to marine life. The robot utilizes differential thrust technology for both propulsion and steering. The robot is equipped with a collision-avoidance system that enables it to change direction and avoid obstacles that come at it. The GPS module on the robot maintains continuous communication with satellites, enabling it to accurately determine its precise location at any given moment. The robot is equipped with a resilient mechanism that effectively separates and clears trash, preventing it from being trapped within the robot's gates and avoiding any potential blockages. By utilizing the path planning algorithm, the robot may be directed to any site with a significant accumulation of pollutants, as long as a map of the surroundings is available and the robot's position is known. The robot continuously analyzes the water quality of the water body and alerts the base station if there are any abnormalities in the findings. Consequently, measures may be implemented against both the company and the individual responsible for the pollution, while simultaneously raising awareness. To notify nearby vessels of its presence in a certain area, the robot utilizes its LEDs to emit intermittent flashes in Morse code spelling out the phrase "ON DUTY". The code can be understood by the boat or ship's pilot to traverse the location. Figure 21 depicts the visual representation of the robot.



*Figure 21: Rendered Image of the Robot on Operation*

#### **DISCUSSION ON WATER QUALITY IN DIFFERENT WATER BODIES**

The natural water quality found in lakes, reservoirs, rivers, and below the surface of the earth is influenced by numerous interrelated factors. Water's natural state is never pure since it may dissolve a wide range of materials and react with minerals found in rocks and the ground. It also flows over and through the surface of the earth. It typically contains a mixture of organic, soluble organic, and soluble inorganic components. Furthermore, large amounts of insoluble substances can be transported by water in suspension. Numerous factors affect the quantity and kind of contaminants found in natural water, which vary depending on the region and season. Among these are biological processes, geography, climate, geology, land use, and biological processes. Pollutants in a body of water determine its characteristics.

The chemical compositions of rainwater, ocean, river, and groundwater are remarkably different, and their total dissolved solids (TDS) vary greatly. The TDS of rainwater is 7 mg l<sup>-1</sup>, river water is 118 mg l<sup>-1</sup>, and saltwater is 34 400 mg l<sup>-1</sup>. Groundwater TDS levels vary too much to be utilised as a general average. TDS is a great indicator of the quality of the water, and maximum TDS levels have been set for drinking water and other uses of water.

#### **WASTE MANAGEMENT**

Approximately 8 million plastic pieces enter the ocean every day, contributing to the 5.25 trillion macro and microplastic particles that are already present in the water. These numbers are already rising at worrisome rates; if they keep going up, the Earth may face a serious hazard. The reason behind the slow pace of plastic recycling can be attributed to various factors such as the cost-effectiveness of producing new plastics vs recycling them, as recycling requires the separation of distinct plastic polymers. Trends, prospects, and policy responses also play a role in this. The government ought to take steps to increase the use of recyclable or reusable materials while decreasing the use of new plastics. For instance, instead of using traditional textiles for their clothing, shoes, and gloves, front-line workers can utilise recycled materials like recycled plastics, which will save costs and increase public awareness of recycled plastic items. The two primary concepts that can be created with recovered plastic waste are,

### Recycled and Eco-Friendly Shoes:

Sadly, the majority of the over 25 billion pairs of shoes produced annually around the world are not produced sustainably because the textile industry is ranked second in terms of pollution behind the oil and gas industries. Through cleaning, grinding, and melting, plastic waste from food packaging and water bottles can be given a second chance at life. This thread can then be woven like traditional cloth to create stylish and comfortable shoe uppers. Depending on the model and style, three to seven recycled plastic bottles can be used to make each pair of shoes. An easier path for the growth of algae is created by the ocean's surplus chemicals and rising temperatures. These toxic algae can be processed (drying, crushing, and adding synthetic elements) to make eco-friendly and bio-sourced materials for shoe insoles and outsoles. This stops the manufacturing of about 20% less synthetic materials and also clears the ocean of algae.

### Bricks Utilised in Building:

The best materials for creating bricks include high-density polyethylene, which is frequently used in milk and shampoo bottles, low-density polyethylene, which is used for cereals and sandwiches, and polypropylene, which is used for ropes, buckets, and other items. Plastic wastes must be sorted and dried to eliminate any moisture content before being used to make bricks. After that, the discarded plastic is ground into tiny particles and made into fine dust. After that, the furnace is used to heat this fine dust till it becomes liquid. After that, molten stonedust and sand particles are combined, placed into brick moulds, and squeezed to take on the desired shape. It has been demonstrated that bricks manufactured from these plastic wastes are both significantly more affordable and stronger than standard concrete bricks. The least amount of water may be absorbed by the plastic bricks, preventing water from seeping through the ceiling. As a result, plastic bricks are cleaner than conventional sand and concrete bricks and are more beneficial to the construction sector to create a more sustainable environment.

## CONCLUSION

In addition to cleaning up the water body, recovering and recycling the pollutants that are put there lowers the carbon footprint associated with creating new materials because the waste may be recycled. The robot's goal is to purify the water body by gathering pollutants and keeping an eye on the water's quality. While there are numerous large-scale techniques for cleaning up pollution in the middle of the ocean, there aren't many for cleaning rocky or coastal water basins. Little bodies of water, such as lakes and ponds, are not the only places this robot can be employed. Lakes make up only 0.013% of Earth's water, and 40% of lakes in the United States are unfit for human consumption due to pollution. While there are several techniques for cleaning lakes, the majority of them rely on organic processes that require a lot of time. When it comes to cleaning certain kinds of water bodies, the robot would be effective because large-scale approaches cannot be used there. Local rules that would benefit society as a whole may be drafted using the robot's information about pollution and water quality.

### Acknowledgment

The administrators of the VIT University Chennai campus are appreciated by the authors for enabling the conduct of this study.

## REFERENCES

- [1] Mahboob, S.; Al-Ghanim, K.A.; Al-Misned, F.; Shahid, T.; Sultana, S.; Sultan, T.; Hussain, B.; Ahmed, Z. Impact of Water Pollution on Trophic Transfer of Fatty Acids in Fish, Microalgae, and Zoobenthos in the Food Web of a Freshwater Ecosystem. *Biomolecules* 2019, 9, 231. <https://doi.org/10.3390/biom9060231>
- [2] Campbell L.M., Norstrom R.J., Hobson K.A., Muir D.C.G., Backus S., Fisk A.T. Mercury, and other trace elements in a pelagic Arctic marine food web (Northwater Polynya, Baffin Bay). *Sci. Total Environ.* Volumes 351-352, 2005, Pages 247-263, ISSN 0048-9697
- [3] Kumar, A.; M.M.S., C.-P.; Chaturvedi, A.K.; Shabnam, A.A.; Subrahmanyam, G.; Mondal, R.; Gupta, D.K.; Malyan, S.K.; Kumar, S.S.; A. Khan, S.; Yadav, K.K. Lead Toxicity: Health Hazards, Influence on Food Chain, and Sustainable Remediation Approaches. *Int. J. Environ. Res. Public Health* 2020, 17, 2179. <https://doi.org/10.3390/ijerph17072179>
- [4] Raschka, Sebastian & Patterson, Joshua & Nolet, Corey. (2020). Machine Learning in Python: Main Developments and Technology Trends in Data Science, Machine Learning, and Artificial Intelligence. *Information*. 11. 193. [10.3390/info11040193](https://doi.org/10.3390/info11040193).
- [5] Xin, M., Wang, Y. Research on image classification model based on deep convolution neural network. *J. Image Video Proc.* 2019, 40(2019). <https://doi.org/10.1186/s13640-019-0417-8>

- [6] Matthies, J. Papon, R. Detry "Task-oriented grasping and geometric scene understanding" International Conference on Intelligent Robots and Systems (IEEE, 2017), pp. 3329-45
- [7] Norris, Donald. (2020). Machine Learning with the Raspberry Pi: Experiments with Data and Computer Vision. 10.1007/978-1-4842-5174-4.
- [8] S. Luongo, V. DiVito, G. Fasano, D. Accardo, L. Forlenza and A. Moccia, "Automatic Collision Avoidance System: Design, development and flight tests," 2011 IEEE/AIAA 30th Digital Avionics Systems Conference, 2011, pp. 1-21, DOI: 10.1109/DASC.2011.6096245.
- [9] Teleweck, P. & Chandrasekaran, B. (2019). Path Planning Algorithms and Their Use in Robotic Navigation Systems. Journal of Physics: Conference Series. 1207.012018. 10.1088/17426596/1207/1/012018.
- [10] E. Khanmirza, M. Haghbeigi, M. Nazarahari and S. Doostie, "A Comparative Study of Deterministic and Probabilistic Mobile Robot Path Planning Algorithms," 2017 5th RSII International Conference on Robotics and Mechatronics (ICRoM), 2017, pp. 534-539, doi:10.1109/ICRoM.2017.8466197.
- [11] Agrawal, Pranay & Bhattacharya, Bishakh. (2013). A aquatic multi-robot system for lake cleaning. 171-8. 10.1142/9789814525534\_0024.
- [12] Khatib, T.; Qalalweh, S.; Ameerah, R.; Warad, I. An Efficient Method for Water Treatment of Artificial Ponds in Jordan Valley Based on Photovoltaic Pumping System. Agriculture 2019, 9, 151. <https://doi.org/10.3390/agriculture9070151>
- [13] Needleman, H.L., & Bellinger, D. (1991). The Health Effects of Low-Level Exposure to Lead. Annual Review of Public Health, 12(1), 111-140. doi:10.1146/annurev.pu.12.050191.000551
- [14] Algorithmic and Computational Robotics. 2001. "Rapidly-Exploring Random Trees: Progress and Prospects," 303-307. doi:10.1201/9781439864135-43.
- [15] Y. K. Taru and A. Karwankar, "Water monitoring system using Arduino with LabVIEW," 2017 International Conference on Computing Methodologies and Communication (ICCMC), 2017, pp. 416-419, DOI:10.1109/ICCMC.2017.8282722.
- [16] Berto, R.; Napoletano, P.; Savi, M. A LoRa-Based Mesh Network for Peer-to-Peer Long Range Communication. Sensors 2021, 21, 4314.
- [17] Lenes, Jan Henrik. "Autonomous online path planning and path-following control for complete coverage maneuvering of a USV." Master's thesis, NTNU, 2019.
- [18] R. Raghavi, K. Varshini, and L. Kemba Devi. Water Surface Cleaning Robot, International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering / volume 8 Issue 3 ISSN: 2278-8875, March 2019.
- [19] Aakash Sinha, Prashant Bhardwaj, Bipul Vaibhav, and Noor Mohommad "Research and development of Roboat: an autonomous river cleaning robot", Proc. SPIE 9025, Intelligent Robots and Computer Vision XXXI: Algorithms and Techniques, 90250Q.
- [20] Phirke, Shreya & Patel, Abhay & Jani, Jash. (2021). Design of an autonomous water cleaning bot. Materials Today: Proceedings. 46. 10.1016/j.matpr.2021.04.044. RPraveen et al 2020 IOP Conf. Ser.: Mater. Sci. Eng. 993012030.
- [21] Worthington, Max & Shearer, Cameron & Esdaile, Louisa & Campbell, Jonathan & Gibson, Christopher & Legg, Stephanie & Yin, Yanting & Lundquist, Nicholas & Gascooke, Jason & Albuquerque, Inês & Shapter, Joseph & Andersson, Gunther & Lewis, David & Bernardes, Gonçalo & Chalker, Justin. (2018).
- [22] Sustainable Polysulfides for Oil Spill Remediation: Repurposing Industrial Waste for Environmental Benefit. Advanced Sustainable Systems. 2.1800024. 10.1002/adsu.201800024.
- [23] Balo, Figen & Şağbanşua, Lütfü. (2016). The Selection of the Best Solar Panel for the Photovoltaic System Design by Using AHP. Energy Procedia. 100.50-53. 10.1016/j.egypro.2016.10.151.
- [24] Divit Gupta, Anushree Srivastava "Investigating the Use of Artificial Intelligence in Talent Acquisition Procedures" IJARCCCE International Journal of Advanced Research in Computer and Communication Engineering, vol. 12, no. 11, pp. 77-87, 2023/ Crossref <https://doi.org/10.17148/IJARCCCE.2023.121111>
- [25] George, J.G.; Marin-Esponda, T.T. & Kumar-Dandpat, P. (2019). Analyzing the impact of excess inventory of California Glam to control the inventories of distributors by integrating product and distributor segmentation concept in the supply chain. Trabajo de obtención de grado, Especialidad en Gestión de la Cadena de Suministro. Tlaquepaque, Jalisco: ITESO.
- [26] A. Ganesh, R. Ramakrishnan, A. K. Sekar and J. Logeshwaran, "A Load Balancing Architecture to Improve the Security of Cloud Computing in the Disease Management Centers," 2023 Second International Conference On Smart Technologies For Smart Nation (SmartTechCon), Singapore, Singapore, 2023, pp. 1299-1305, doi: 10.1109/SmartTechCon57526.2023.10391528. | Google Scholar
- [27] Kushal Walia, 2024. "Scalable AI Models through Cloud Infrastructure" ESP International Journal of Advancements in Computational Technology (ESP-IJACT) Volume 2, Issue 2: 1-7. | Link
- [28] Muthukumar Vaithianathan, Mahesh Patil, Shunye Frank Ng, Shiv Udgar, 2024. "Low-Power FPGA Design Techniques for Next-Generation Mobile Devices" ESP International Journal of Advancements in Computational Technology (ESP-IJACT) Volume 2, Issue 2: 82-93. [PDF]
- [29] Sridhar Selvaraj, 2024. "SAP Supply Chain with Industry 4.0" ESP International Journal of Advancements in Computational Technology (ESP-IJACT) Volume 2, Issue 1: 44-48. | Google Scholar

- [30] Bhattacharya, S. (2024). Decentralized Identity Verification via Smart Contract Validation: Enhancing PKI Systems for Future Digital Trust. *International Journal of Global Innovations and Solutions (IJGIS)*. <https://doi.org/10.21428/e90189c8.93f690d2>
- [31] Chanthati, Sasibhushan Rao. (2021). How the Power of Machine – Machine Learning, Data Science and NLP Can Be Used to Prevent Spoofing and Reduce Financial Risks. 10.13140/RG.2.2.18761.76640.
- [32] VenkataSathya Kumar Koppiseti, 2024. "Machine Learning at Scale: Powering Insights and Innovations" *ESP International Journal of Advancements in Computational Technology (ESP-IJACT)* Volume 2, Issue 2: 56-61. [Link]
- [33] SumanthTatineni, AnirudhMustyala, 2024. "Leveraging AI for Predictive Upkeep: Optimizing Operational Efficiency" *ESP International Journal of Advancements in Computational Technology (ESP-IJACT)* Volume 2, Issue 1: 66-79.
- [34] Arnab Dey, "Innovative Approach to Mitigate Man-in-the-Middle Attacks i Secure Communication Channels", *International Journal of Science and Research (IJSR)*, Volume 11 Issue 8, August 2022, pp. 1497-1500. <https://www.ijsr.net/getabstract.php?paperid=SR24320191712>
- [35] DhamocharanSeenivasan, "ETL (Extract, Transform, Load) Best Practices," *International Journal of Computer Trends and Technology*, vol. 71, no. 1, pp. 40-44, 2023. Crossref, <https://doi.org/10.14445/22312803/IJCTT-V71I1P106>
- [36] Shreyaskumar Patel "Performance Analysis of Acoustic Echo Cancellation using Adaptive Filter Algorithms with Rician Fading Channel" Published in *International Journal of Trend in Scientific Research and Development (ijtsrd)*, ISSN: 2456-6470, Volume-6 | Issue-2, February 2022, pp.1541-1547, URL: <https://www.ijtsrd.com/papers/ijtsrd49144.pdf>
- [37] Panwar, V. (2024). Optimizing Big Data Processing in SQL Server through Advanced Utilization of Stored Procedures. *Journal Homepage: http://www.ijmra.us*, 14(02).
- [38] Dixit, A., Sabnis, A. and Shetty, A., 2022. Antimicrobial edible films and coatings based on N, O-carboxymethyl chitosan incorporated with ferula asafoetida (Hing) and adhatodavasica (Adulsa) extract. *Advances in Materials and Processing Technologies*, 8(3), pp.2699-2715.
- [39] Amit Mangal, 2024. *Role of Enterprise Resource Planning Software (ERP) In Driving Circular Economy Practices in the United States*, *ESP Journal of Engineering & Technology Advancements* 4(3): 1-8. [Link]
- [40] Chanthati, Sasibhushan Rao. (2021). Second Version on A Centralized Approach to Reducing Burnouts in the IT industry Using Work Pattern Monitoring Using Artificial Intelligence using MongoDB Atlas and Python. 10.13140/RG.2.2.12232.74249.
- [41] Dileep Kumar Pandiya, NileshCharankar, 2024, Testing Strategies with Ai for Microservices and Apis, *INTERNATIONAL JOURNAL OF ENGINEERING RESEARCH & TECHNOLOGY (IJERT)* Volume 13, Issue 04 (April 2024)
- [42] Chanthati, S. R. (2024). Product Colour Variation Management with Artificial Intelligence. *Sasibhushan Rao Chanthati. American Journal of Education and Technology*, 3(3), 46–52. <https://doi.org/10.54536/ajet.v3i3.3213>
- [43] VenkataSathya Kumar Koppiseti, 2024. "Deep Learning: Advancements and Applications in Artificial Intelligence" *ESP International Journal of Advancements in Computational Technology (ESP-IJACT)* Volume 2, Issue 2: 106-113. [Link]
- [44] Ramesh, S. S., Anish Jose, Samraysh, P. R., Mulabagala, H., Minu, M. S., &Nomula, V. K. (2024). Domain Generalization and Multidimensional Approach for Brain MRI Segmentation Using Contrastive Representation Transfer Learning Algorithm. In P. Paramasivan, S. Rajest, K. Chinnusamy, R. Regin, & F. John Joseph (Eds.), *Advancements in Clinical Medicine* (pp. 17-33). IGI Global. <https://doi.org/10.4018/979-8-3693-5946-4.ch002>
- [45] Naga Ramesh Palakurti, Bridging the Gap: Frameworks and Methods for Collaborative Business Rules Management Solutions , *International Scientific Journal for Research: Vol. 6 No. 6 (2024): ISJR*
- [46] Kalla, Dinesh and Smith, Nathan and Samaah, Fnu and Polimetla, Kiran, Facial Emotion and Sentiment Detection Using Convolutional Neural Network (January 2021). *Indian Journal of Artificial Intelligence Research (INDJAIR)*, Volume 1, Issue 1, January-December 2021, pp. 1–13, Article ID: INDJAIR\_01\_01\_001, Available at SSRN: <https://ssrn.com/abstract=4690960>
- [47] Pratiksha Agarwal, Arun Gupta, "Harnessing the Power of Enterprise Resource Planning (ERP) and Customer Relationship Management (CRM) Systems for Sustainable Business Practices," *International Journal of Computer Trends and Technology*, vol. 72, no. 4, pp. 102-110, 2024. Crossref, <https://doi.org/10.14445/22312803/IJCTT-V72I4P113>
- [48] Shreyaskumar Patel "Performance Analysis of Acoustic Echo Cancellation using Adaptive Filter Algorithms with Rician Fading Channel" Published in *International Journal of Trend in Scientific Research and Development (ijtsrd)*, ISSN: 2456-6470, Volume-6 | Issue-2, February 2022, pp.1541-1547, URL: <https://www.ijtsrd.com/papers/ijtsrd49144.pdf>
- [49] Kalla, Dinesh, Nathan Smith, FnuSamaah, and Kiran Polimetla. "Enhancing Early Diagnosis: Machine Learning Applications in Diabetes Prediction." *Journal of Artificial Intelligence & Cloud Computing*. SRC/JAICC-205. DOI: [doi.org/10.47363/JAICC/2022\(1\)191\(2022\):2-7](https://doi.org/10.47363/JAICC/2022(1)191(2022):2-7).
- [50] Borra, Praveen; Exploring Microsoft Azure's Cloud Computing: A Comprehensive Assessment *International Journal of Advanced Research in Science, Communication and Technology* 2 8, 897-906, 2022 IJAR SCT.
- [51] Palakurti, N. R. (2024). Intelligent Security Solutions for Business Rules Management Systems: An Agent-Based Perspective. *International Scientific Journal for Research*, 6(6), 1-20.

- [52] "Secure and Ethical Innovations: Patenting Ai Models for Precision Medicine, Personalized Treatment, and Drug Discovery in Healthcare". (2023). International Journal of Business Management and Visuals, ISSN: 3006-2705, 6(2), 1-8. <https://ijbmv.com/index.php/home/article/view/60>
- [53] Bodapati, J.D., Veeranjanyulu, N. &Yenduri, L.K. A Comprehensive Multi-modal Approach for Enhanced Product Recommendations Based on Customer Habits. J. Inst. Eng. India Ser. B (2024). <https://doi.org/10.1007/s40031-024-01064-5>
- [54] ArchanaBalkrishna, Yadav (2024) An Analysis on the Use of Image Design with Generative AI Technologies. International Journal of Trend in Scientific Research and Development, 8 (1). pp. 596-599. ISSN 2456-6470
- [55] S. E. VadakkethilSomanathanPillai and K. Polimetla, "Integrating Network Security into Software Defined Networking (SDN) Architectures," 2024 International Conference on Integrated Circuits and Communication Systems (ICICACS), Raichur, India, 2024, pp. 1-6, doi: 10.1109/ICICACS60521.2024.10498703.
- [56] Vamsi Katragadda "Ethical AI in Customer Interactions: Implementing Safeguards and Governance Frameworks" Iconic Research And Engineering Journals Volume 7 Issue 12 2024 Page 394-397.
- [57] Sure, T. A. R. (2023).The Internet of Things: Securing Smart Technologies for the Mobile Age, Journal of IOT Security and Smart Technologies, 2(3), 21-25.
- [58] Sure, T. A. R. (2022). Ambient Computing: The Integration of Technology into Our Daily Lives. Journal of Artificial Intelligence & Cloud Computing.SRC/JAICC-147. DOI: doi.org/10.47363/JAICC/2022(1)135.
- [59] Chanthathi, S. R. (2024). Artificial Intelligence-Based Cloud Planning and Migration to Cut the Cost of Cloud Sasibhushan Rao Chanthathi. American Journal of Smart Technology and Solutions, 3(2), 13-24. <https://doi.org/10.54536/ajsts.v3i2.3210>.
- [60] Artificial Intelligence-Based Cloud Planning and Migration to Cut the Cost of Cloud SR Chanthathi - Authorea Preprints, 2024 <http://dx.doi.org/10.22541/au.172115306.64736660/v1> Sasi-Rao: SR Chanthathi will pick up the Google scholar and Chanthathi, S. R. (2024).
- [61] A. Dave, N. Banerjee, and C. Patel, "CARE: Lightweight attack resilient secure boot architecture with onboard recovery for RISC-V based SOC," in Proc. 22nd Int. Symp. Quality Electron. Design (ISQED), Apr. 2021, pp. 516-521.
- [62] Bhattacharya, S., & Kewalramani, C. (2024). Securing Virtual Reality: A Multimodal Biometric Authentication Framework for VRaaS. International Journal of Global Innovations and Solutions (IJGIS). <https://doi.org/10.21428/e90189c8.25802e82>
- [63] Chanthathi, S. R. (2024). How the power of machine - machine learning, data science and NLP can be used to prevent spoofing and reduce financial risks. Sasibhushan Rao Chanthathi. <https://doi.org/10.30574/gjeta.2024.20.2.0149>
- [64] Kumar Shukla, Shashikant Tank, 2024. "CYBERSECURITY MEASURES FOR SAFEGUARDING INFRASTRUCTURE FROM RANSOMWARE AND EMERGING THREATS", International Journal of Emerging Technologies and Innovative Research (www.jetir.org), ISSN: 2349-5162, Vol.11, Issue 5, page no.i229-i235, May-2024, Available: <http://www.jetir.org/papers/JETIR2405830.pdf>
- [65] Sukhdev S. Kapur, Ashok Ganesan, Jacopo Pianigiani, Michal Styszynski, Atul S Moghe, Joseph Williams, Sahana Sekhar Palagrahara Chandrashekar, Tong Jiang, Rishabh Ramakant Tulsian, Manish Krishnan, Soumil Ramesh Kulkarni, Vinod NairJeba Paulaiyan, 2021. *Automation of Maintenance Mode Operations for Network Devices*, US10938660B1. [Link]
- [66] Shashikant Tank, Kumar Shukla, 2024."A COMPARATIVE ANALYSIS OF NVMe SSD CLASSIFICATION TECHNIQUES", International Journal of Emerging Technologies and Innovative Research (www.jetir.org), ISSN: 2349-5162, Vol.11, Issue 5, page no.c261-c266, May-2024, Available : <http://www.jetir.org/papers/JETIR2405231.pdf>
- [67] Chandrakanth Lekkala 2023. "Implementing Efficient Data Versioning and Lineage Tracking in Data Lakes", Journal of Scientific and Engineering Research, Volume 10, Issue 8, pp. 117-123. [Link]
- [68] Patel, N. (2024, March). SECURE ACCESS SERVICE EDGE(SASE): "EVALUATING THE IMPACT OF CONVERGED NETWORK SECURITYARCHITECTURES IN CLOUD COMPUTING." Journal of Emerging Technologies and Innovative Research. <https://www.jetir.org/papers/JETIR2403481.pdf>
- [69] Ayyalasoamayajula, Madan Mohan Tito, Sathishkumar Chintala, and Sandeep Reddy Narani. "Optimizing Textile Manufacturing With Neural Network Decision Support: An Ornstein-Uhlenbeck Reinforcement Learning Approach." Journal of Namibian Studies: History Politics Culture 35 (2023): 335-358.
- [70] Vishwanath Gojanur , Aparna Bhat, "Wireless Personal Health Monitoring System", IJETCAS:International Journal of Emerging Technologies in Computational and Applied Sciences,eISSN: 2279-0055,pISSN: 2279-0047, 2014. [Link]
- [71] Ayyalasoamayajula, Madan Mohan Tito, et al. "Proactive Scaling Strategies for Cost-Efficient Hyperparameter Optimization in Cloud-Based Machine Learning Models: A Comprehensive Review." ESP Journal of Engineering & Technology Advancements (ESP JETA) 1.2 (2021): 42-56.
- [72] Mistry, H., Shukla, K., & Patel, N. (2024). Transforming Incident Responses, Automating Security Measures, and Revolutionizing Defence Strategies throughAI-Powered Cybersecurity. Journal of Emerging Technologies and Innovative Research, 11(3), 25. <https://www.jetir.org/>
- [73] Ayyalasoamayajula, M., & Chintala, S. (2020). Fast Parallelizable Cassava Plant Disease Detection using Ensemble Learning with Fine Tuned AmoebaNet and ResNeXt-101. Turkish Journal of Computer and Mathematics Education (TURCOMAT), 11(3), 3013-3023.

- [74] Aparna Bhat, "Comparison of Clustering Algorithms and Clustering Protocols in Heterogeneous Wireless Sensor Networks: A Survey," 2014 INTERNATIONAL JOURNAL OF SCIENTIFIC PROGRESS AND RESEARCH (IJSPR)-ISSN : 2349-4689 Volume 04- NO.1, 2014. [Link]
- [75] Ayyalasomayajula, Madan Mohan Tito, et al. "Implementing Convolutional Neural Networks for Automated Disease Diagnosis in Telemedicine." 2024 Third International Conference on Distributed Computing and Electrical Circuits and Electronics (ICDCECE). IEEE, 2024.
- [76] Shashikant Tank Kumar Mahendrabhai Shukla, Nimeshkumar Patel, Veeral Patel, 2024." AI BASED CYBER SECURITY DATA ANALYTIC DEVICE", 414425-001, [Link]
- [77] Ayyalasomayajula, Madan Mohan Tito, Akshay Agarwal, and Shah Nawaz Khan. "Reddit social media text analysis for depression prediction: using logistic regression with enhanced term frequency-inverse document frequency features." International Journal of Electrical and Computer Engineering (IJECE) 14.5 (2024): 5998-6005.
- [78] Aparna Bhat, Rajeshwari Hegde, "Comprehensive Study of Renewable Energy Resources and Present Scenario in India," 2015 IEEE International Conference on Engineering and Technology (ICETECH), Coimbatore, TN, India, 2015. [Link]
- [79] Ayyalasomayajula, Madan Mohan Tito. "Innovative Water Quality Prediction For Efficient Management Using Ensemble Learning." Educational Administration: Theory and Practice 29.4 (2023): 2374-2381.
- [80] Sarangkumar Radadia Kumar Mahendrabhai Shukla, Nimeshkumar Patel, Hirenkumar Mistry, Keyur Dodiya 2024." CYBER SECURITY DETECTING AND ALERTING DEVICE", 412409-001, [Link]
- [81] Ayyalasomayajula, Madan Mohan Tito, Srikrishna Ayyalasomayajula, and Sailaja Ayyalasomayajula. "Efficient Dental X-Ray Bone Loss Classification: Ensemble Learning With Fine-Tuned VIT-G/14 And Coatnet-7 For Detecting Localized Vs. Generalized Depleted Alveolar Bone." Educational Administration: Theory and Practice 28.02 (2022).
- [82] Aparna K Bhat, Rajeshwari Hegde, 2014. "Comprehensive Analysis Of Acoustic Echo Cancellation Algorithms On DSP Processor", International Journal of Advance Computational Engineering and Networking (IJACEN), volume 2, Issue 9, pp.6-11. [Link]
- [83] Ayyalasomayajula, M. M. T., Chintala, S., & Sailaja, A. (2019). A Cost-Effective Analysis of Machine Learning Workloads in Public Clouds: Is AutoML Always Worth Using? International Journal of Computer Science Trends and Technology (IJCTST), 7(5), 107-115.
- [84] Nimeshkumar Patel, 2022." QUANTUM CRYPTOGRAPHY IN HEALTHCARE INFORMATION SYSTEMS: ENHANCING SECURITY IN MEDICAL DATA STORAGE AND COMMUNICATION", Journal of Emerging Technologies and Innovative Research, volume 9, issue 8, pp.g193-g202. [Link]
- [85] Bhat, A., & Gojanur, V. (2015). Evolution Of 4g: A Study. International Journal of Innovative Research in Computer Science & Engineering (IJIRCS). Booth, K. (2020, December 4). How 5G is breaking new ground in the construction industry. BDC Magazine. <https://bdcmagazine.com/2020/12/how-5g-is-breaking-new-ground-in-the-constructionindustry/>. [Link]
- [86] Nimeshkumar Patel, 2021." SUSTAINABLE SMART CITIES: LEVERAGING IOT AND DATA ANALYTICS FOR ENERGY EFFICIENCY AND URBAN DEVELOPMENT", Journal of Emerging Technologies and Innovative Research, volume 8, Issue 3, pp.313-319. [Link]
- [87] Bhat, A., Gojanur, V., & Hegde, R. (2014). 5G evolution and need: A study. In International conference on electrical, electronics, signals, communication and optimization (EESCO) – 2015.[Link]
- [88] Chintala, S. , & Ayyalasomayajula, M. M. T. . (2019). OPTIMIZING PREDICTIVE ACCURACY WITH GRADIENT BOOSTED TREES IN FINANCIAL FORECASTING. Turkish Journal of Computer and Mathematics Education (TURCOMAT), 10(3), 1710-1721. <https://doi.org/10.61841/turcomat.v10i3.14707>
- [89] A. Bhat, V. Gojanur, and R. Hegde. 2015. 4G protocol and architecture for BYOD over Cloud Computing. In Communications and Signal Processing (ICCSPP), 2015 International Conference on. 0308-0313. Google Scholar. [Link]
- [90] M. Hindka, "Securing the Digital Backbone: An In-depth Insights into API Security Patterns and Practices", Computer Science and Engineering, Vol. 14, No. 2, pp. 35-41, 2024.
- [91] M. Hindka, "Design and Analysis of Cyber Security Capability Maturity Model", International Research Journal of Modernization in Engineering Technology and Science, Vol. 6, No. 3, pp. 1706-1710, 2024.
- [92] Hindka, M. (2024, June). Optimization Accuracy of Secured Cloud Systems Using Deep Learning Model. In 2023 4th International Conference on Intelligent Technologies (CONIT) (pp. 1-5). IEEE.
- [93] M. Siva Kumar et al, "Efficient and low latency turbo encoder design using Verilog-Hdl," Int. J. Eng. Technol., vol. 7, no. 1.5, pp. 37-41, Dec. 2018,[Link]
- [94] Kartheek Pamarthi, 2024." Analysis On Opportunities And Challenges Of Ai In The Banking Industry", International Journal of Artificial Intelligence and Data Science, Volume 1, Issue 2:10-23[Link]
- [95] Ankitkumar Tejani, Jyoti Yadav, Vinay Toshniwal, Rashi Kandelwal, 2021. "Detailed Cost-Benefit Analysis of Geothermal HVAC Systems for Residential Applications: Assessing Economic and Performance Factors", ESP Journal of Engineering & Technology Advancements, 1(2): 101-115. [Link]
- [96] Ankitkumar Tejani, Jyoti Yadav, Vinay Toshniwal, Harsha Gajjar, 2022. "Achieving Net-Zero Energy Buildings: The Strategic Role of HVAC Systems in Design and Implementation", ESP Journal of Engineering & Technology Advancements, 2(1): 39-55. [Link]

- [97] Mihir Mehta, 2024." *Evaluating the Trade-offs Between Fully Managed LLM Solutions and Customized LLM Architectures: A Comparative Study of Performance, Flexibility, and Response Quality*", International Journal of Management, IT & Engineering, volume 14, Issue 10, [Link]
- [98] Dhameliya, N., Mullangi, K., Shajahan, M. A., Sandu, A. K., & Khair, M. A. (2020). BlockchainIntegrated HR Analytics for Improved Employee Management. ABC Journal of Advanced Research, 9(2), 127-140. [Link]
- [99] Vikramraj Kumar Thiyagarajan, 2024. " *Predictive Modeling for Revenue Forecasting in Oracle EPBCS: A Machine Learning Perspective*", International Journal of Innovative Research of science, Engineering and technology (IJIRSET), Volume 13, Issue 4, [Link]
- [100] T Jashwanth Reddy, Voddi Vijay Kumar Reddy, T Akshay Kumar, 2018. "Population Diagnosis System", International Journal of Advanced Research in Computer and Communication Engineering, Volume 7, Issue 2, pp. 207-210. Doi: 10.17148/IJARCEE.2018.7238 [Link]
- [101] Radhika Kanubaddhi, Ramakanth Damodaram, Prasad Gandham, Ramu Pedada, "Perspectives On Solving Cybersecurity Using AI Techniques," International Journal of Computer Trends and Technology, vol. 72, no. 9, pp. 131-136, 2024. Crossref, <https://doi.org/10.14445/22312803/IJCTT-V72I9P120>
- [102] Radhika Kanubaddhi, 2022. "Designing an Enterprise-Grade, Cloud-Native Chatbot Solution for the Hospitality Industry Using Azure QnA Maker and Azure LUIS", ESP Journal of Engineering & Technology Advancements, 2(1): 56-62. <https://espjeta.org/jeta-v2i1p108>
- [103] Radhika Kanubaddhi, "Real-Time Recommendation Engine: A Hybrid Approach Using Oracle RTD, Polynomial Regression, and Naive Bayes," SSRG International Journal of Computer Science and Engineering , vol. 8, no. 3, pp. 11-16, 2021. Crossref, <https://doi.org/10.14445/23488387/IJCSE-V8I3P103>
- [104] Suman Chintala, Vikramraj Kumar Thiyagarajan, 2023." *AI-Driven Business Intelligence: Unlocking the Future of Decision-Making*", ESP International Journal of Advancements in Computational Technology (ESP-IJACT), Volume 1, Issue 2, PP 73-84. [Link]
- [105] Suman Chintala, "Next - Gen BI: Leveraging AI for Competitive Advantage", International Journal of Science and Research (IJSR), Volume 13 Issue 7, July 2024, pp. 972-977, <https://www.ijsr.net/getabstract.php?paperid=SR24720093619>
- [106] Chintala, Suman. (2024). Emotion AI in Business Intelligence: Understanding Customer Sentiments and Behaviors. INTERNATIONAL JOURNAL OF COMPUTER SCIENCE AND MATHEMATICAL THEORY E-ISSN. 06. 8.
- [107] Gokul Ramadoss, 2023. "Cloud Migration Strategies for EDI Transactions in Healthcare Payor Ecosystems", N. American. J. of Engg. Research, vol. 4, no. 3, Aug. 2023, Accessed: Oct. 18, 2024. [Online]. Available: <https://najer.org/najer/article/view/42>
- [108] Gokul Ramadoss, 2023. "Adoption of Care Management Applications in Healthcare", Journal of Health Statistics Reports, Volume 2, Issue 3, PP 1-5, [Link]
- [109] Ali, A., Ahmad, M., Nawaz, S., Raza, T., & Sunil Kumar Suvvari (2022). An effective structure for data management in the cloud-based tools and techniques. *Journal of Engineering Science*, 15(4), 215-228. <https://journal.esrgroups.org/jes/article/view/5519/3943>
- [110] Roman, B., & Sunil Kumar Suvvari (2021). *Social Media Control Version 1.2*. Roman Publications. <https://romanpub.com/resources/smc-v1-2-2021-7.pdf>