PID Controlled Autonomous Water Surface Trash Collector and Water Quality Analyzer

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***Abstract*— This report presents the ins and outs of PID controlled autonomous water surface trash collector and water quality analyzer. One of the most severe threats to nature that the ever- growing world is facing today is plastic contamination in rivers, ponds, lakes, or any surface water. Alongside plastic contamination, presence of water hyacinth in lakes is a cause of major oxygen level depletion in water bodies killing aquatic animals and harming the ecosystem. It is a huge matter of concern to keep the water surface clean from any floating harmful waste. Thus, effective waste removal from water surfaces has been a topic of concern for many years. Various attempts have been taken till date to make a cost-effective water surface garbage cleaner, as in the present world, aquatic waste management and control is of main concern for implementing smart cities and achieving the mission of SDG, reducing plastic pollution. Therefore, we aim at creating an automated water surface cleaner to tackle the problem of water waste removal. In this project we are going to build a prototype using a microprocessor for our proposed bot. It will collect the waste from the surface of water autonomously and dump it into the tub placed behind it. With the use of motors, the bot and collectors will have to & fro movement. Besides garbage collection it can also determine the quality of the water. Again autonomous mode the robot also has manual control in case of emergency.**

I. INTRODUCTION

In an era characterized by fast technological growth, our environmental worries have grown in lockstep with our capabilities. One of the most formidable challenges confronting our ever-expanding globe is the persistent issue of plastic contamination in our waterways—rivers, ponds, lakes, and surface waters—which poses a major threat to wildlife. Simultaneously, the unrestrained spread of water hyacinth in these environments exacerbates the situation, resulting in severe oxygen depletion, aquatic life death, ecosystem disruption, and the rise of the dengue epidemic in Bangladesh. The need to keep water surfaces clean and clear of harmful material has never been more pressing.

Aquatic waste management and control have emerged as critical goals in the larger pursuit of smart city development and the achievement of the Sustainable Development Goals (SDGs), with a particular emphasis on reducing plastic pollution. Countless efforts have been made over the years to develop cost-effective technologies for efficient garbage removal from water surfaces. This difficult problem, however, remains.

This paper proposes a "Autonomous Garbage Collector" bot equipped with real-time item and clog detecting technologies to address the issue of water waste disposal head on. The bot scours the surface of the water autonomously, collecting material and depositing it in a designated receptacle. This incredible achievement is made possible by painstakingly controlled motor mechanisms that allow for exact back-and- forth movements across the water's surface.

This project's technological complexities lay at the confluence of innovation and environmental stewardship. By successfully removing debris from our rivers, we not only help to preserve aquatic ecosystems but also counteract the negative consequences of plastic pollution and invasive species.

The sections that follow go deeply into the technical aspects of the Autonomous Garbage Collector bot project, from its design and construction to its operational modes, which include both autonomous and manual control features.

II. LITERATURE REVIEW

A. *Incorporating Autonomy In Cleaning Bots*

There have been many researches and projects on cleaning bots and the majority of them are centered around making manually controlled ones and they are also bulky in size. The existing autonomous bots use very high-end microprocessors and autopilot systems that consume a lot of power, hence being detrimental to the environment, apart from being very expensive to construct and maintain. We have to build a prototype that will not only be autonomous but cheaper and more environment friendly than existing models.

B. Scaling the Field of Application

Existing models are employed in very extensive fields of use like cleaning entire lakes or large areas of water reservoirs. Our concern is to construct one for use in our community based on cloud sharing. Anyone within the community can be granted access to the bot for cleaning a specific area when necessary based on availability.

III. METHODOLOGIES

A. Mechanical Design

The first step of is building the 3D printed mechanical partof the project which consists of-

1. Propeller: The paddle wheel-type propellers enable the bot to move to and fro with the help of DC motors. A 2D analysis of the blades was taken in Ansys Fluent to see how much they Ansys Fluent to see how much they generate thrust force. The analysis indicates that a thrust force of 200N from each motor will be generated while rotating.

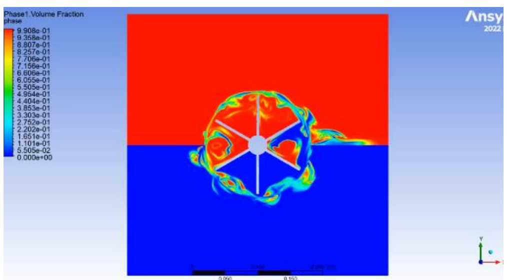


Figure 1: 2D numerical analysis of propeller

2. Trash Collector: A net will be used to collect trash from the water surface which will be supported by a stand. A servo motor, connected with the stand will rotate 90 degree forward and backward to ensure the successful collection ofwaste.

3. Trash Collector Door: A door system is implemented before the trash collector. This door ensures that trash does not come out of the trash collector net. A belt pulley folding door mechanism is implemented for the opening and closing of the door. A stepper motor will be attached to the belt for precise control of the folding door.

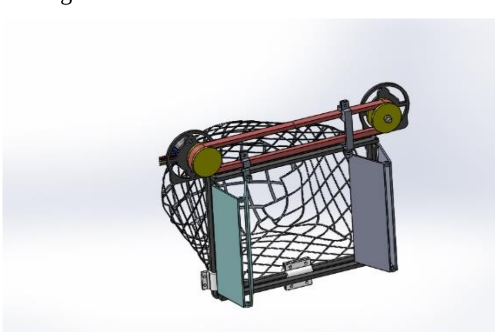


Figure 2: Folding trash collector door

4. Main Body: A 3D printed buoyancy tube-type structure has been used as the main body.

5. Camera and Sensor Stand: There are two stands in which the camera, sensors and some other things will be mounted which will help us with navigation, water quality analyzing and trash detection.

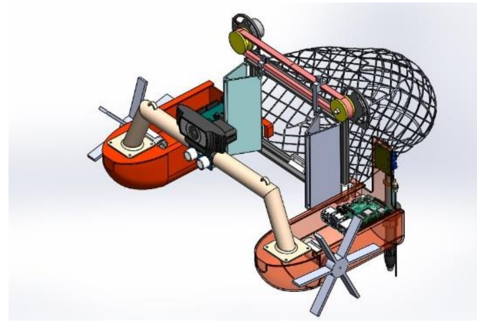


Figure 3: 3D Render of the Mechanical Model

B. Control Mechanism

The detailed trash collecting mechanism can be described with the following flowchart:

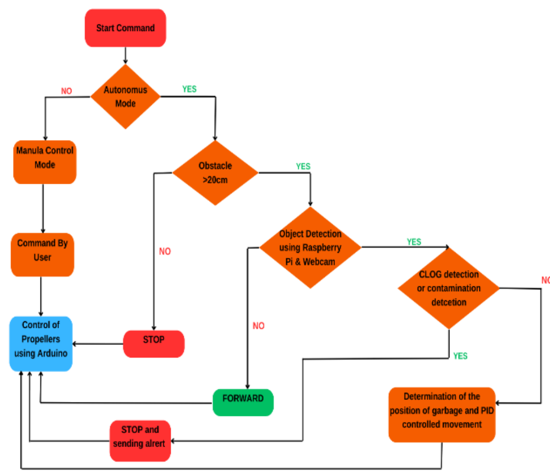


Figure 4: Flowchart of the Trash Collecting Mechanism

Based on whether the bot is operating in autonomous or manual mode, the methodology is slightly different. In autonomous mode, if the distance form obstacle detected by the SONAR sensor is less than 20 cm, it will not move. If not, then the objects are detected by the Raspberry Pi as the real time video is captured by the webcam and the bot moves determining the position the nearby trash by PID algorithm. Upon the number of objects detected exceeds a certain threshold, the bot identifies that as a clog. If no object is detected it will move forward in search of trash. In manual mode, the movements are controlled by the user. In all cases, the movements of the propellers by the DC motors are activated by the Arduino microcontroller.

C. Electrical Design

We have designed a customized PCB where Arduino as microcontroller, L298n as motor driver, logic level converter, relay, 7805 IC, receiver and other components can be mounted. Here two high rpm dc motors move the propeller. The Arduino can make bi-directional communication with Pi using USB port but I2C method can also be used using the GPIO pins of Pi which eventually increases the flexibility. A Li-po battery supplies 12V and 7805 IC converts it 5V which is drives the sensors and Arduino. A buck converter with USB output is used to power up Raspberry Pi as a result only one source that is Li-po battery powers up all the devices resulting a compact system.

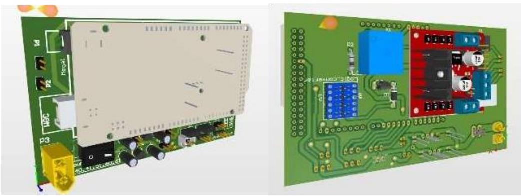


Figure 5: Top and Bottom 3D view of PCB

D. Electrical Power Consumption and operational time:

The raspberry pi consumes 3A, ARDUINO 1A and the two motors consume 500mA at their peak state. Assuming all other sensors consume 500mA at their peak. So if we use a battery of 2200mAh 3S, we can easily operate our bot for 2220/(3000+1000+500+500)*60 or30 minutes which is enough time for small scale purposes.

E. Communication

We can divide our overall communication process in two segments. They are:

Manual Mode:

Data transmitter & receiver: Here we are using a 4 channel "Digital Proportional Radio Control System" to transmit data to Arduino. 3 analog equivalent valued data and one boolean value to control the speed, direction and mode of operation. Our transmitter works in 2.40-2.45GHz range with RF power 20dBm. The receiver connected with the Arduino receives the modulated signal and decodes it with some C coding. The transmitter and receiver are bounded in a way that their communication will be not interfered by anyother RC transmitter. If the channel 4(Boolean value) is 0, our bot is working in manual mode otherwise it is in autonomous mode. The range is more than 100m without line of sight which is ideal for such operation.

Autonomous mode: It is done by bidirectional serial communicationoccurs between Arduino and raspberry pi through USB port. Though we have an option in our customized PCB to communicate through I2C pins, we choose serial communication for easier wiring. For live video streaming purposes, we use Wi-Fi to connect raspberry pi to our laptop so we can start the autonomous mode and also to get the view from the camera. For such purpose a stable Wi-Fi connection is must, but autonomous operation is independent of it.

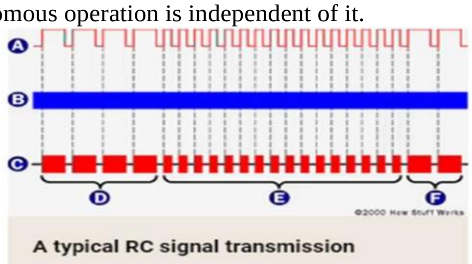


Figure 6: RC signal Transmission

F. Autonomous Operation

Object Detection:

a) Dataset:

For high accuracy and better performance, we require a context based annotated database. To meet this end, we need images of trash in our particular context. We build a custom dataset by combining chosen images from TACO and FLOW dataset with our custom annotated one. This help us to trained our model with more specific data of water surface trash and provide us with better output. Specially FLOW dataset provides us with real life images of water surface trash identical to our target application. Details of dataset are given below:

Dataset Name: DroBOT
No. of Classes: 4
Classes: Bottle, Cup, Plastic Bag, Metal Can
No. of Total Images: 761
Link of Dataset:
https://app.roboflow.com/ds/4JzeUqJXev?key=onjhw8N02

b)Trained Model:

We trained our dataset with "EfficientDet Lite 2" model. It's a object detection model based on tensorflow lite. EfficientDet Lite 2 model provide us with better accuracy then EfficientDet 0 and 1 with a very negligible increase in model parameters thus size. Also, EfficientDet model doesn't have the problem of gradient convergence. We further do 8-bit quantization to make the model lighter and faster so that we can get higher fps while detecting object and raspberry pi can handle them easily.

Obstacle Detection:

To identify the presence of any obstacle which is not a trash or trained object, we used a sonar sensor. It presence of a large obstacle within 20cm range sonar will command the motor to stop and protect the bot from collision.

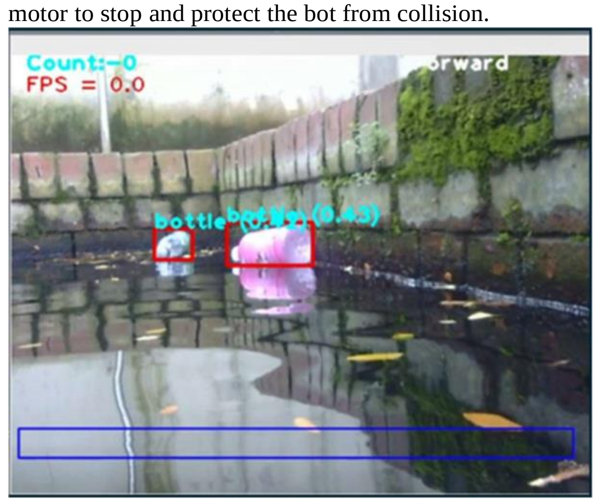


Figure 7: Real-time object detection

G. Measurement of pH level of water

Here we have used a pH meter to determine the quality of water. The sensor is connected to an Arduino. The real time pH value is updated on a serial monitor. The pH sensor takes an analog reading between its electrodes submerged in water and sends it to the Arduino. Then the analog reading is converted into voltage with respect to a reference voltage of 3.3V. Several consecutive pH values are used to generate a moving average pH value. The real time data is uploaded to an IoT server (ThingSpeak) and a dedicated application has also been developed so that users with access can remotely observe the real time pH value in order to comprehend water safety levels of local reservoirs. Here the Raspberry Pi does the work of Wi-Fi module.

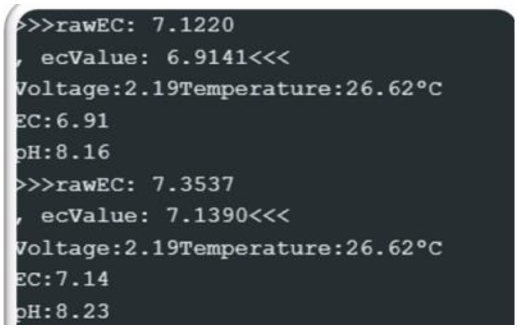


Figure 8: Serial monitor being updated with real time temperature, electrical conductivity and pH values of water

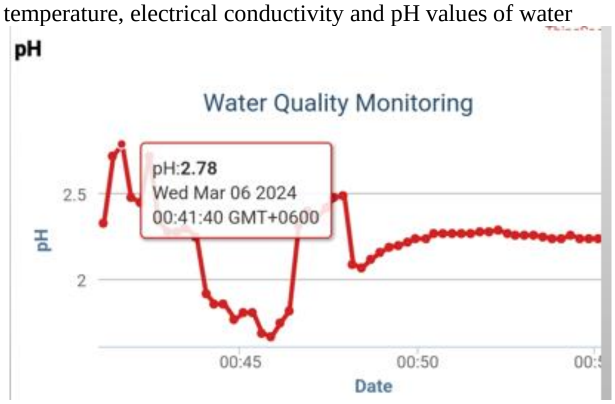
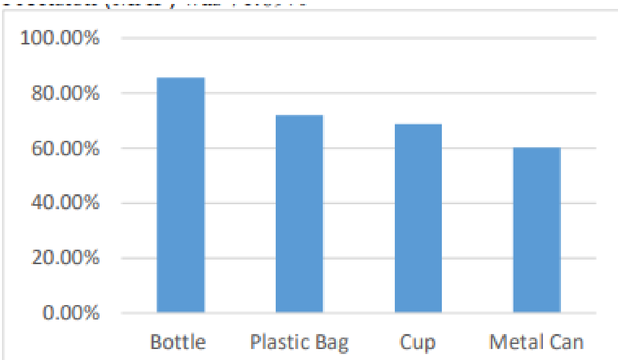


Figure 9: Real time pH level of water on ThinSpeak server

IV. Result Analysis

In real time scenario, our model was quite accurate and fast.On an average we get 6 FPS streaming while running our model for object detection. The overall Mean Average Precision (MAP) was 71.69%.



The model was therefore performing nicely without any lag.

V. Novelty

Our device is simple and has less complex system so it can be built within a reasonable price range. As our model donot require a conveyer belt, it requires less maintenance. The device collects trashes automatically, can give us real-time feedback and provides information about the type and number of trashes being collected. It also has cloud contribution. Besides the water quality analyzing capability makes our bot capable for research purposes also. Water surface cleaner is existed but those are large and very costly in terms of transportation where as our small and light bot can be transported easily and very simple to use.

VI. Cost Analysis

Serial No.	Components	Price (BDT)
01	Raspberry Pi 4 as Processing unit	15000
02	Arduino Mega as microcontroller	1500
03	Camera	1000
04	RC Transmitter	3000
05	Electrical Components (motor, motor driver ph meter, etc.)	3200
06	PCB	800
07	3D Printing	3500
08	Net	500
09	Memory Card	1500
	Total	30,000

VII. Area of Use

Our device can be used in swimming pool, pond, small lake and water reservoir that are open and has the similar size. If the model is scaled up then it can be used in bigger area. It can determine the quality of water body where sample collection maybe hazardous for us. So for both industrial and research purposes it can be used.

VIII. Future Scope

With little modification and installation of appropriate sensors the boatcan be used for different purposes. By installing anti- mosquito sprayer on the device, it will be possible to prevent mosquito reproduction on the water surface. If the model is scaled up then we can install solar panel as a source of energy that will reduce electricity consumption. Besides can also be used for surveillance purposes.

IX. Eco-Friendliness

Our 3D printed model is made of PLA (Poly Lactic Acid) which is an industry certified biodegradable and reusable material. Moreover, the micro-controller used in this project (Arduino MEGA and Raspberry Pi) consume less power while having satisfactory efficiency figures. Needless to say, the main goal of this project is to remove trashes from the water bodies which itself is an environment-friendly action. As it is powered by electricity not by fossil fuels, it emits zero carbon compared to the traditional large devices.

X. SDG Goals

Our device implements SDG goal 14 and SDG goal 15. They are:
Life below Water: By removing garbage from water bodies and keeping them clean our model helps to ensure a healthy environment for the aquatic animals
Life above Land: By cleaning the water bodies our device ensures a better life on land. Water logging and dengue widespread are caused by clogging of drainage system and water bodies. Our device helps to mitigate the problem and solving the problem ensures better livelihood in urban area.

XI. ACKNOWLEDGMENT

We want to express our gratitude to everyone who provided support to us as we wrote this paper. We first want to thank Professor Dr. Celia Shahnaz for her continual advice on object detection technologies. This paper would not have been possible without the literary direction. We also want to thank Md. Jawad Ul Islam for his important contributions to the writing of this study. Besides Professor Sheikh Anwarul Fattah sir also suggested us some modification which we have implemented later. Finally, we wouldlike to express our gratitude to Uboat for helping us with their dataset.

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Object detection | TensorFlow Lite

Floating garbage removal - river cleaning - trash collector | DESMI - Proven technology

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