Unmanned Floating Waste Collecting Robot

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***Abstract*—This paper presents the design of a cost-effective remote controlled floating waste removing robot which can be used in canals, ponds, rivers or in oceans. As the usage of plastic is growing in an unregulated way in many countries, toxins from these elements cause an imbalance in the ecosystem and are threatening to human health leading to cancers, birth defects and immune system problems. A prototype of the robot is built in which there are two propellers which are connected with two DC motors to move forward, backward, left and right– mobile application based Bluetooth control system to control the robot from a distance and a robotic hand to make it easy to collect the trashes. A conveyor belt arrangement guiding the trash to the collection box and a sensor arrangement for protection against overloading have been used. Both manufacturing and maintenance cost are kept very affordable. The prototype itself can collect trash weighing upto 10 kg, clean an area of about 3000 square centimeters drawing only 45 watts from the battery. The robot has the capability of working for four hours continuously without the necessity of charging. Floating waste collecting robot can be a savior for the endangered aquatic animals.**

***Index Terms*—floating waste, remote controlled, motor control, aquatic animals, water pollution**

I. Introduction

One of the most severe threats to nature that the ever growing world is facing today is plastic contamination in river, pond, lake or any surface water. Jenna R. Jambeck et al estimated that in 2010, in 192 coastal countries, 27 million metric tons of plastic waste was generated of which 4.8 to 12.7 million metric tons entered the ocean [1]. Global plastic resin production was about 288 million metric tons in 2012 [2]. The solid waste generation has also increased over the past five decades [3]. Human health is threatened tremendously by the plastic toxins that leads to cancers, birth defects and immune system problems. 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. Various attempts have been taken till date to materialize unmanned water bot technology. An autonomous water surface vehicle under the Union Water and Resources Ministry's Ganga Action Plan (GAP) has been under application to clean the chemical effluents and floating waste from rivers in India [4]. N. Ruangpayoongsak and J. Sumroengrit have developed a scheme to detect floating waste for surface cleaning robots by means of laser sensor and have made a working prototype using scooping mechanism for waste collection [5], [6]. Many commercial techs are also in use like aqua drone developed by the WasteShark to address the problem [7]. For testing of navigation and control systems, ocean exploration, military applications various models have been developed [8]. The local government of the District of Columbia in USA also initiated Floating Debris Removal Program [9]. Manual manned water vehicles have also been implemented using peddling mechanism for motion control [10]. All these models are used in larger commercial aspects and the costs of removing the trash are tremendous.

Here we are presenting a cost-effective remote controlled robot with advanced control features that can assist the humans in removing the floating water waste safely and quickly making work easier and more sustainable. A prototype of such a robot is presented in this paper. The design has been inspired from the system implemented by Kader et al [11]. The robot moves by means of two propellers connected to a DC motor. The propellers are controlled by a mobile app that communicates to the robot via Bluetooth. The person operating the robot requires to move the robot via remote close to the waste and the robot will pick it up. There is a mechanical hand that pushes the floating waste towards it to be carried into a collector onboard by a conveyor belt arrangement. As the hand

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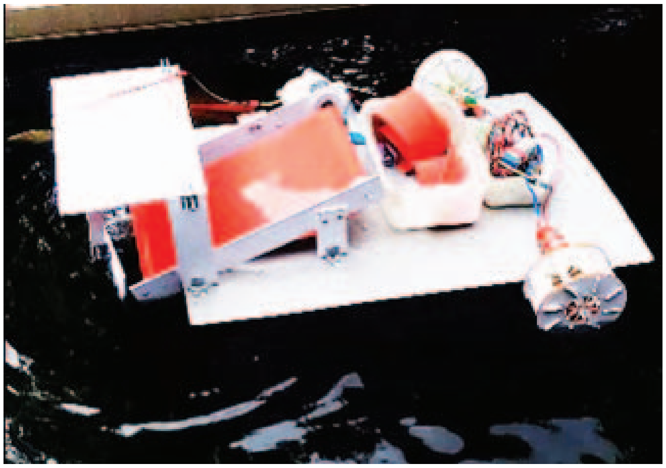

Fig. 1. Prototype of Unmanned Floating Waste Collecting Robot

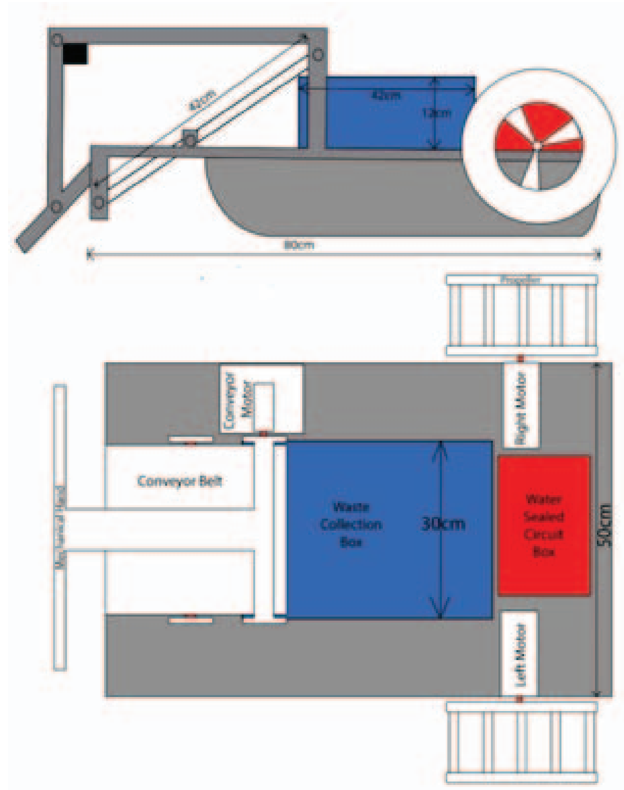

Fig. 2. Mechanical Model of the Unmanned Floating Waste Collecting Robot

pushes the waste towards the conveyor belt, the moving belt picks up the waste and dumps it in the bin attached at the back. The robot has been designed in such a way that it can easily float on the water and have the accessibility to move in all four directions, namely- forward, backward, right, left, with neat precision. The onboard loading feedback system will ensure that it is not damaged. Alongside constant water quantity monitoring will keep the aquatic bodies safe. The prototype presented here is very cheap compared to other floating trash collecting robots which ensures cost effectiveness. Also, easy controlling and monitoring system of the device makes it a feasible solution to the problem. In a very low cost, clean, plastic pollution free water can be ensured for lives both on land and water.

II. Design and Implementation

The system is an unmanned water bot and thus the design needs to be streamlined, water resistant, light weight and durable. The material chosen for the body of the robot is polyvinyl chloride (PVC) board keeping all the aspects in mind. A floating tube has been designed to keep the body afloat and the streamlines structure aids movement through water currents. The surface of the conveyor belt is roughened rubber surface and is chosen for its water repellent nature. The whole body including the conveyor belt are made of water repellent materials that do not add excess weight to the robot.

The trash collector has slots engraved where the excess water that comes from the conveyor arrangement can flow back into the water body and do not add to the weight of the trash in the container. The propeller has been laser cut and the principle of breastshot waterwheel has been put into effect [12]. The only difference being that instead of flowing water, a motor controls the motion of the wheel. The motors used are high-torque so that the water currents cannot force the motor to rotate. The specification of robot are tabulated in table I.

TABLE I
Design Specifications

Dimension of robot	80cmX50cmX25cm
Dimension of waste collector	42cmX30cmX12cm
Body weight (Unloaded)	2.3kg
Maximum body weight (Loaded)	10kg
Battery Life	4 hours
Control System	Manual
Waste Removal per run	300 square cm fully waste filled area
On board sensor	Resistive Overload Sensor

III. Control Mechanism

A. Control Unit

The central processing unit of the floating waste collecting robot is an atmega328p microcontroller based Arduino Uno. The Arduino generates all the control signals including motor control, sensing overload and communicating with the remote station. Bluetooth communication module is used for communication between the remote mobile phone and the unmanned floating robot. A mobile application feeds the Arduino with instructions of speed and directions and the Arduino automatically stops the conveyor belt using the onboard overload sensors feedback.

B. Controller Design

Atmega328p microcontroller acts as the central processing unit and the controller is built surrounding it. The controller is so designed that it takes instructions of propeller and conveyor belt movements based on Bluetooth signals. It has been given the capability to override the external Bluetooth signal in case of overloading. The controller is equipped with hardware filters and the sensor data pass though filters to ensure maximum data accuracy and low noise in measurement. The controller also controls the power flow through to the different parts of the system. The power section is isolated from the controller by means of optocouplers to ensure minimum noise in operation. The controller employs twelve drive signals based on the user input in order to run the three bidirectional motors in H-bridge configuration. It also communicates back to the mobile application that it is connected to in case internal failures or overloading and employs auto shutdown to the conveyor belt in case of overloading to stop further trash collection.

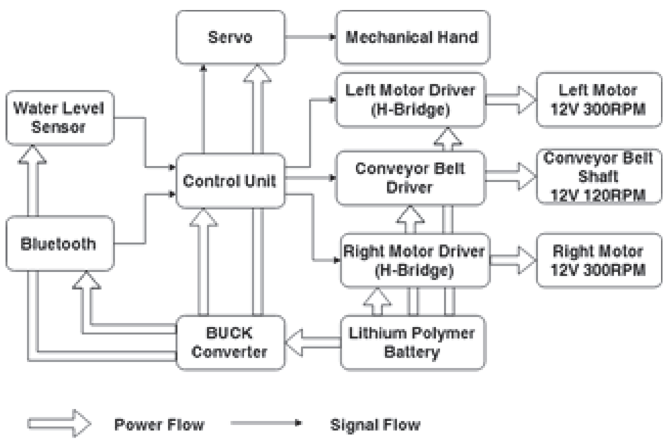

Fig. 3. Functional Flow Diagram of Unmanned Floating Waste Collecting Robot

C. Power Control

A 3-cell lithium polymer battery is used as a power source which directly feeds the h-bridge controlling the motor. A switch-mode buck converter has been designed which provides the power to the 5V devices including bluetooth, control system, sensors and servo motor. For scaling up, the lithium polymer battery has to be replaced by sealed lead acid battery for longer battery life and higher capacity. The prototype can run four hours at a stretch on full charge.

D. Propeller Mechanism

Two propellers are used to provide the driving force for controlling the speed of the robot as well as the direction. Each of the propeller is connected to a 12V 300 RPM geared DC motor.
Dual H-bridge motor controlling technique has been widely used for driving the DC motors and was suitable for our purpose owing to the simple construction and control [13]. Both the high and low side MOSFET gates are driven using opto-couplers in totem-pole arrangement [14]. The problem of high in-rush current starting a high torque DC motor has been solved by gradually increasing the duty cycle [15].
The robot is capable of moving forward, backward, left and right and is controlled remotely.

E. Conveyor Belt Mechanism

Designing the mechanism for collecting the floating rubbish is one of the major issues in the development of the robot. Most of the floating rubbish is small and deformable, and hence it is hard to use a robot manipulator to grasp them. Moreover large volumes of trash needs to be collected at once. For the purpose, a conveyor belt mechanism has been adopted to collect the floating trash. The control mechanism is simplified by a great margin as the conveyor belt can be controlled by a single DC motor with the help of bearings and frame. A 12V 120RPM geared DC motor has been used for controlling the conveyor belt.

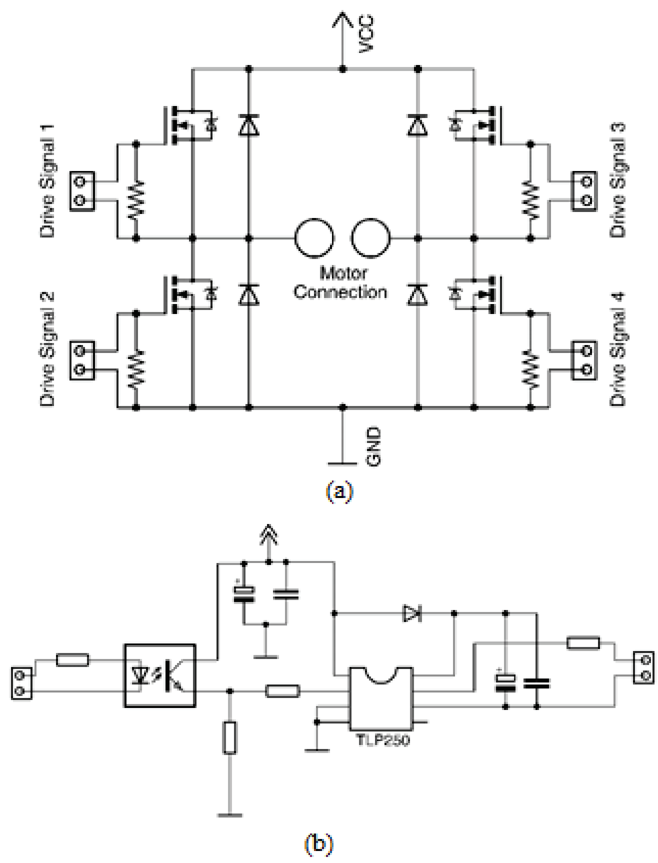

Fig. 4. (a) H-bridge motor controller for conveyor belt and propellers and (b) MOSFET Driver

F. Mechanical Hand Control

The person controlling the robot requires to move the robot close to the floating waste and the robot will pick it up using a mechanical pulling hand towards a conveyor belt to drop the waste into an onboard trash collector. The hand is attached to the body of the robot. A Servo Motor is used to control the hand movement for collecting the trash near the conveyor belt.

G. Trash Management

The conveyor belt moves the trash upward. The on-board trash collector is placed in such a way as to ensure that the waste drop into the collector. The trash collection box has a hinged door which can be used to take out the trash when it is filled. The floor of trash collector contain small slits that allow excess water coming from the conveyor belt or water present in the waste itself to flow out and not increase the load on the robot. A depth of the robot inside water is accurately measured using a precise resistive water level sensor which works as overload sensor which sends water level data to the control system. The Arduino stops the conveyor arrangement when the water level has risen above a pre-programmed limit which ensures security of the robot itself and decreases the probability of drowning.

H. Mobile Application

A mobile application has been developed dedicated for the robot which communicates with the control system of the robot and controls both the direction and speed of the propellers and direction and speed of the conveyor belt.

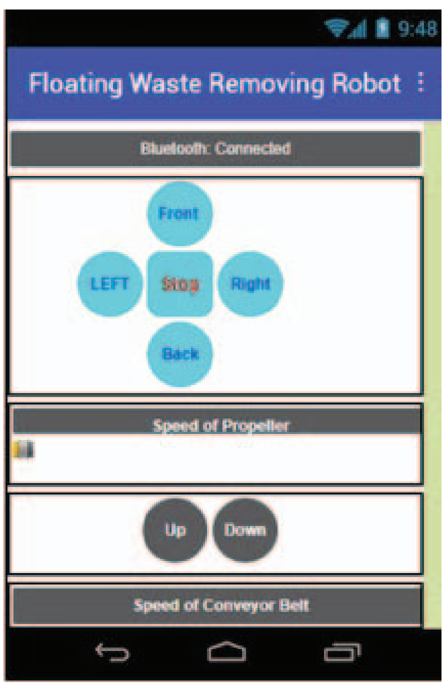

Fig. 5. Mobile Application Developed for the Robot

IV. Cost Analysis

The prototype is a small scale representation that can clean waste filled area of 3000 square centimeters with maximum weight of 10kg at once. But the system can be easily scaled for larger water bodies like lakes or rivers. The cost of building the prototype is tabulated below and the cost of scaling up to clean 100 square meters area is approximated in table II.

TABLE II
Cost approximation of unmanned floating waste collecting robot

Component Name	Cost for prototype (USD)	Approximated cost after scaling (USD)
Material for body	10	300
Motor	40	150
Propeller	12	80
Motor Driver	10	80
Wiring, circuitry and insulation	30	100
Floating tube	10	100
Hardware components (Screws, bearings etc.)	15	50
Battery	18	150
Miscellaneous	15	100
Total	160	1110

Thus estimated amount of 1110 USD can be used for cleaning 100 square meters of plastic filled area. If we consider 5 per cent of total water surface is covered in plastic, a single robot would be able to clean approximately 2 square kilometers area of water body at each run.
Another unique advantage of using the robot is savings on human-hours. Only one to two operators are sufficient per robot and thus it reduces the need of plenty of human resources appointment in water-body cleaning projects.

V. Result and Analysis

The system has been tested to analyze its functionality. The analyses have been documented below:

A. Loading Capacity of the System and the Conveyor Belt

The system weighs 2.3kg and is able to withstand a total load of 10kg. The conveyor belt itself has the capability to pick up 500 grams of trash at a time. The dimension of the trash container is 42cm X 30cm X 12cm

B. Servo Motor Accuracy with Respect to Change in Input Signal

The output angular displacement with respect to the input command is presented in the table III.

TABLE III
Servo motor input-output relation

Change in Input Signal (in Degrees)	Change in output (in Degrees)
90	95
70	73
50	54
30	33
10	9

C. Power Consumption

The propelling motors and motors of the conveyor belt being the largest power consuming units, the prototype consumes only 45 watts in stagnant water. The power is controlled into the motors via pulse width modulation technique and the consumption can be reduced while moving downstream with the aid of the mobile application. Though the robot is intended to use in stagnant water where the floating wastes accumulate, it can be made to move upstream if and when needed. There is a provision to increase the power flow to the propeller by controlling the duty cycle of the drive signals. With greater duty cycle, the power consumption increases while moving upstream. The prototype can handle 100 watts of power in case of moving against the stream for two hours continuously which can again be scaled if needed. In stagnant water in optimum conditions, the battery life of the prototype is 4 hours.

D. Propeller Speed at Loaded Condition with Respect to Duty Cycle

The propeller speed increases with increase in duty cycle. The relation is not linear but it increases at lower duty cycle and shows a saturating trend at higher duty cycle.

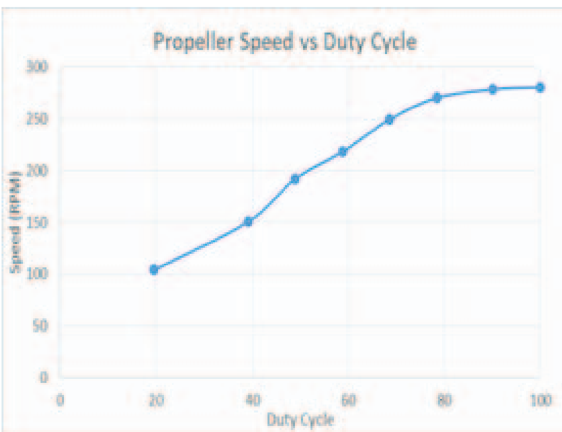

Fig. 6. Propeller Speed vs Duty Cycle

VI. Humanitarian Impact

For the last half-century, plastic materials have become integral part of our life. Each year, the worldwide production of plastic is 300 million metric tons and 8 million metric tons of plastic end up in the oceans [16]. Of the total solid wastes, plastics made up almost 10 per cent by mass in 61 countries out of 105 [17]. This increase in solid waste generation is because the use of plastic products in our daily lives, from bottles, cups and packaging, to plastics found in cigarette filters and straws. Main problem is that plastic garbage are not biodegradable means they are not decomposed naturally in environment and we need to recycle the garbage. But only 9.1 percent of plastic garbage has been recycled since 1950. The rest of plastic produced garbage is not handled properly. We dumped the plastic garbage in the landfill, from there it eventually clutters around drains and enters sea. Rain water and wind wash away plastic garbage as they are lightweight and end up in the lake, river and sea causing damage to the wildlife and ecosystem of the environment. The plastic garbage releases toxic chemical elements that affects very badly the marine food chain and the life of sea creatures. This toxicity also affects human health very badly when they intake the sea creature as food. Many sea birds and sea creatures die every year as a result of plastic debris obstructing their digestive tracts and other organs. Hence, it is of dire necessity to build an effective system for removing floating waste, which will improve the quality of life of ocean creature and lessen the natural pollution. A large percentage of total plastic garbage is floating in the lake, river and sea. In 2014, a study estimated that there are 5.25 trillion particles (or 244,000 metric tons) of plastic floating in the ocean [18]. In 2017, another study found that 79,000 metric tons of plastic are floating in the Great Pacific Garbage Patch [19]. Plastic wastes affect 267 species globally, which include 86 per cent of sea turtle species, 44 per cent of seabird species, and 43 per cent of all marine mammal species [20]. By using this unmanned floating waste collecting robot, the huge amount of floating plastic waste can be collected and can be recycled or reused. This robot is controlled remotely so it gives very effective output. This can play a role in cleaning local aquatic bodies at a small scale and can be scaled to be used in larger water bodies.

VII. Conclusion

Plastic pollution in water bodies is a very alarming issue in both local and global arena. Presented prototype offers an extremely low cost, safe and effective means of floating trash removal with low maintenance cost, easy controlling and monitoring system giving feasible solution to the problem of plastic pollution in water bodies. There are several prototypes for cleaning floating waste from waterbodies. Some of them have been employed commercially as well. Most of the available devices are manned and require a greater man power and involve a risk element for the operator. Again most of the proposed designs use oil based fuels which have the risk of leakage into water and polluting it further. The battery operated devices in use so far lack scalability. Unique feature of the prototype is its scalability and adaptability. With minor adaptions, it can be scaled for use in large water bodies, solar panels can be set up to make it self-sustainable, long distance control can be set up using Wi-Fi communication and sensors for monitoring water condition can be mounted onboard. A huge issue in aquatic robots is safe use of fuels. Use of oil as fuel may cause oil spills in case of accidents which may contaminate the water bodies and be a threat to the lives of aquatic animals. The use of battery makes our proposed design advantageous and safe, and also opens a scope for using renewable solar energy. The circuitry is well sealed and isolated to ensure that the electronic components are safe from water and at the same time do not contaminate the water. Thus the system provides a unique, scalable and sustainable solution to the burning issue of aquatic plastic pollution.

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