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A Review of Trash Collecting and Cleaning Robots

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***Abstract*— Trash present at different locations, both outdoor and indoor is a menace. Collection of the garbage so that it can be disposed off properly can be a mundane and time-consuming job requiring human labor. This was avoided by using Robots to automate this task and increase efficiency. Technologies involved in the development of these automated systems using sensors and processing units such as Arduino, Raspberry Pi. Most of them were built more specific to their requirements like which terrain (indoor or outdoor, land or water) they must work on, and different autonomy levels (manual, remote-control or fully autonomous were attained or proposed to attain successfully by using IoT for remote-control and path-planning using image-processing in fully autonomous robots.**

Keywords*— Trash, Garbage, Robot, Arduino, Raspberry pi, sensors, Robotic arm.

I. INTRODUCTION

The problem that was addressed in this paper was the collection and handling of trash with the help of robots. Robots can be used to save the environment and maintain cleanliness and a hygienic neighborhood. Litter present in manifolds at different locations is a major gnawing issue. An eclectic approach was followed to build a robot to perform such a job, the different ideas proposed by them, and the variety of prototypes and final models already built were discussed in depth.

Modern developments in technology like manipulators with higher number of possible configurations, IoT (Internet of Things), and image-processing combined with machine learning were also harnessed to build these Robots. Some of these robots made use of mobile applications through which the user could easily control from a distance. IoT was the network of interconnected devices which could interact and exchange data among each other. It was a data sharing method used where the devices at different locations could communicate to compute the information from various devices and give the appropriate output from the specified device.

In IoT, for this mentioned data sharing distance serves no barrier, given the range of the internet was available at that point where the device was situated. Many of the research papers have used Microcontroller platforms like Arduino and Raspberry Pi to direct their prototypes. Earlier machines were mostly mechanical, i.e., having gears and controlled by pneumatic or hydraulic systems, whereas in recent times it can be observed even in the research papers that are to be discussed in detail that electronic circuits and software too constitute an imperative part of the Robotic Control System. The invention of these microchips has allowed scientists and engineers to construct faster, more compact, and complex machines.

On further reading of this paper, one can understand what role sensors and actuators like motors play in these trash detections and picking Robots. The sensors contributed to the automation and the actuators were responsible for both traversing of the whole robot and motion of any component or tool attached to the robot. With the current technology robots which could seemingly do such jobs of trash collecting for humans were built so that humans could move on to do more intellectual tasks. Researchers used various mechanisms to collect the trash from various planes like sand, grassland, man-built surfaces like roads, flooring of materials like wood or tiles, and water into these bots. The robots on ground like sand were used in collection of the trash from beaches which was left by the tourists and locals, robots designed to operate on the floors were required to sweep dust and other contaminants from the interior of the buildings and the robots designed to operate on water were designed to collect large amounts of floating trash from the respective water bodies. A lucid view of the practical implementations in this area of study was imparted in this literature review.

II. TERRAIN

The Robots that had been built to collect trash floating on water, like in [1]–[3], all were designed to have a floating body and move with the help of propellers. [1] used PVC (polyvinyl chloride) board to build a body which floats on water. In papers[1]–[4], there were conveyor belts used. The trash collector had multiple slots to ensure the drainage of water. Robots built to operate on terrains other than water, like sand, gravel, grass, or floor, were all moving on 4-wheels. The robots that had been built to operate on smooth surfaces of land were observed to have a lower center of gravity of the entire body, in general [5]–[8] as opposed to the ones built to conquer and function on rugged surfaces [4]–[16]. A shovel was attached in front of the robot which when rotated picks the object in front by ploughing through the sand [12].

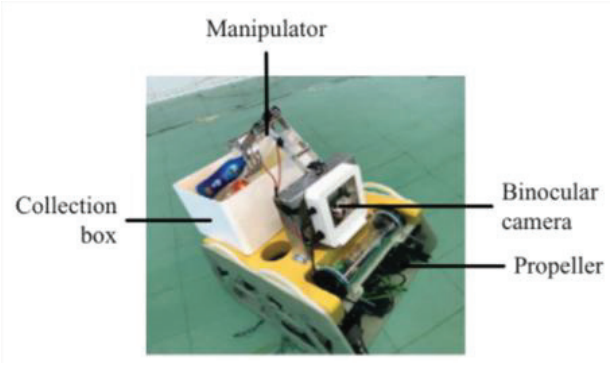

Fig. 1. Swimming pool Water Terrain [17]

Fig. 2. Lake Water Terrain [2]

Fig. 3. Floor Terrain [6]

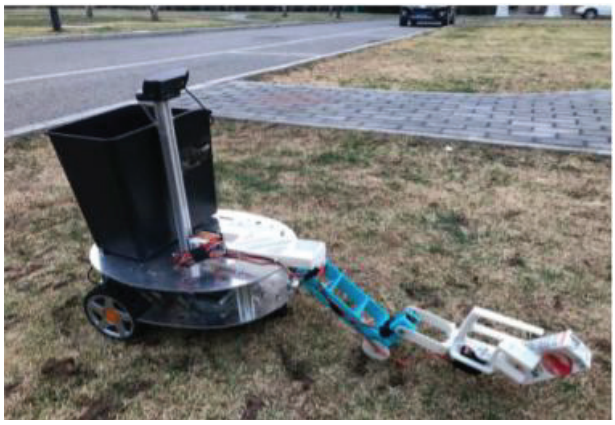

Fig. 4. Grass Terrain [18]

III. AUTONOMY LEVEL

Infrared proximity sensors installed in the robots detected stationary obstacles and then devised a collision-free path [7], [8], [10], [12]. Infrared sensors used in some checked if the garbage collecting bin was filled [7]. While some robots were equipped with ultrasonic sensors calculated the depth of the trash bin and were programmed in such a way to then perform actions further in accordance. The Raspberry Pi was the predominant unit for processing and Arduino-Mega was the sub-system that was utilized to read Analog values from sensors like ultrasonic and infrared sensors and it transferred this data to the chief unit [8].

The operator of the robot (may be skilled) had the ability to control it remotely by simply monitoring the camera feed in real-time, from the camera module fitted on the robot, that was received at the other end. This was accomplished by making use of a WIFI module [10], [11], [16] like ESP8266 or by RPi, Bluetooth module like HC-05 [1], [3], [7]. The robot was remotely controlled through a mobile app via Bluetooth and an IP camera was attached for the visual display [Autonomous Beach Cleaner]. Bluetooth uses Ultra High Frequency (UHF) Radio waves at 2.4GHz to communicate. Such robots may be grouped under semi-autonomous. In [8] LIDAR (Light Detection and Ranging) was used essentially for mapping of the room which was to be cleaned. It was a device which provided the distance between any object within a range and the Robot on top of which it was fitted, with good accuracy. Three servo motors were incorporated to enable movement of the LIDAR sensor in the 360-degree space and these actuators are instructed by the Arduino, after receiving commands from the Raspberry Pi while it simultaneously processes the input it received from LIDAR. One servo motor was used for the charging dock. The GPS (Global Positioning System) guided the Robot to the correct direction.

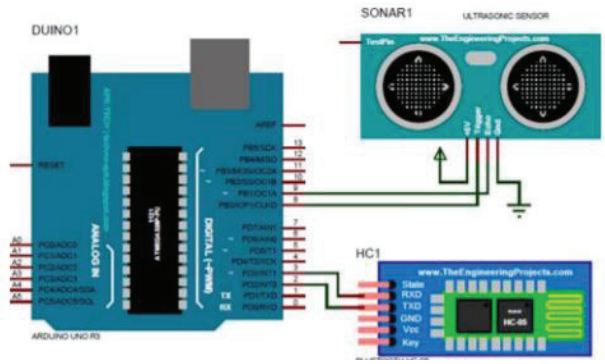

Fig. 5. Integration of Arduino ATMEGA328 with ultrasonic sensor and Bluetooth Module [7]

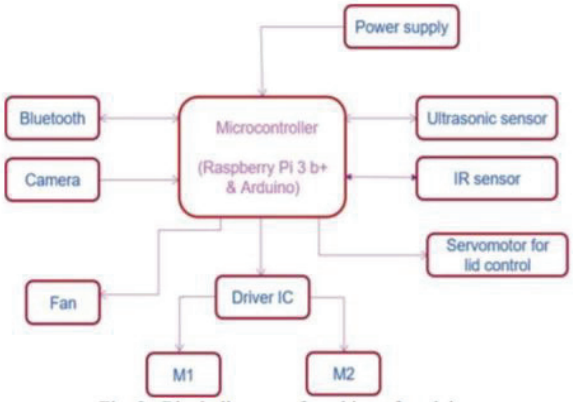

Fig. 6. Block diagram of Trash Bot [7]

The camera installed in the bot that may be integrated with the Raspberry Pi gave the robot the vision it required to operate on its own instead of being operated through remote control. The visuals from this camera were either interpreted on board or be processed on the cloud or another by sharing those visuals with them. When the visuals were processed, the algorithm recognized the items that were in the frame, and this information was given back to the controller to respond accordingly.

Fig. 7. BLYNK App [16]

In some of the ideas implemented, the live data was instantaneously uploaded on cloud and that data was retrieved and visible to the operator on a mobile application built by a developer. An app known as BLYNK which worked on iOS, android smartphones and tablets and it could be used for IoT communications as well. BLYNK provided a platform for the developer to easily implement IoT into their systems. The platform had three major units: - the application, the server, and the libraries. The app provided a user-friendly interface. The libraries allow interaction with the server and compute the input and output commands [16]. IoT modules like ZigBee also could be used in semi-autonomous/remote-control and fully autonomous systems.

IV. Technologies Used

In articles [4], [5], [7], [8] pi model 3 b+ was used as the prime brain of the robot, whereas in others Arduino Uno was used or considered as a possible choice for the building of trash collecting robot [1], [3], [5], [7], [8], [15], [16]. Choosing a brain for the robot was by far the most imperative decision in building one, based on what application it was used for and what level of intelligent tasks were expected from it. The raspberry pi model 3 is a 64-bit microcontroller, has a RAM of 1 gigabyte and a quad-core 1.2GHz processor while Arduino Uno is an 8-bit microcontroller with a 16MHz processor. Trash detection performed with the help of elementary methods like using ultrasonic or infrared sensors [2], [4], [7], [8], [10] remotely kept an eye on the camera feed and gave appropriate commands to move towards trash, also avoided obstacles and accumulated the trash in the vicinity [13], [16]. It relied on the Deep Learning, Extended Kalman Filter and PID (Proportional Integral Derivative) control for the robot to smoothly operate on its own. Localization of the Robot was achieved with the help of an IMU (Inertial Measurement Unit) which was an inertial sensor consisting of a triaxial gyroscope, a triaxial accelerometer and a triaxial magnetometer. This IMU consolidated with odometer and GPS provided instantaneous location information and was a more viable option as in places like parks, the GPS signals received might be weak due to hindrance from thick foliage and woods. Strong GPS signals improve localization and reduce the estimate error in dead-reckoning navigation where the current position of a non-stationary object, in this case the Robot, is computed. The pose of the robot was decided by the combined functioning of the mentioned sensors with the Extended Kalman Filter (EKF) algorithm. Pose of the robot consisted of the planar coordinates in 2-D (dimensional) as well as the angular orientation. The motor driver with the implementation of PID controlled the forward, backward and rotatory motion of the Robot [18].

V. Trash Collecting Technique

The ultimate motive of the trash collecting robot, as its name suggests, was to gather garbage. To execute this activity, a manipulator, also known as a robotic arm, was utilized. The degree of freedom of the manipulator was decided as per the task at hand. The manipulator picked up the trash and its degree of freedom may vary; a 3 d.o.f. (degree of freedom) manipulator with 3 servo motors was used in [17], [19] and a 4 d.o.f. arm in [18], [20] and a 7 d.o.f. manipulator was used like in the paper [6]. A gripper was attached as the end effector to grasp the object desired.

Some of the Trash collecting Robots followed other techniques to collect trash like using vacuum where dirt was sucked in like in a vacuum cleaner, the difference being that the Robot was automated and additionally had greater accuracy. [5]–[8]

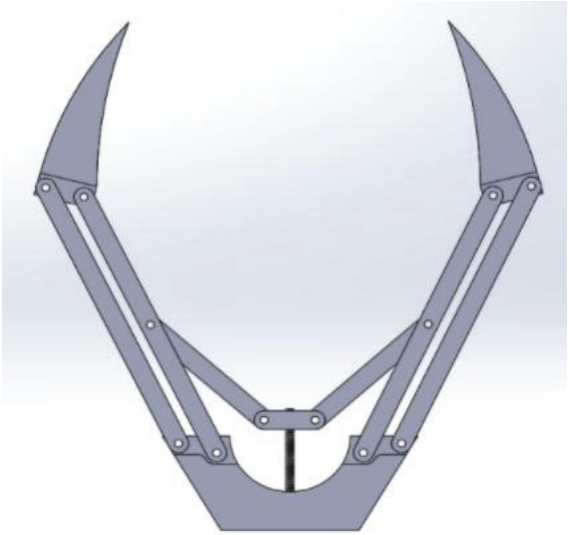

Fig. 8. Gripper [20]

VI. CONCLUSION

The robot was remotely controlled through a mobile app via Bluetooth. It used a 4-bar mechanism for the turning, and water wheels for propellers. The trash was collected by a conveyor belt [3].

The user was needed to input the area that was to be cleaned in NI LabVIEW and ThinkSpeak. Encoder and gyroscope sensors were used to measure and guide the movement of the robot. The robot used broom bristles to collect the garbage in a tray which could move to dispose off the trash into the bin attached with the robot [11].

The robot had two modes, autonomous and manual. In the autonomous mode, the robot moved avoiding the obstacles until a yellow color was detected through the camera. It then moved towards the yellow color and opened the lid for a few seconds. While in manual mode it was controlled through a mobile app via Bluetooth. There was

also a suction fan below the robot's body to work as a vacuum [7].

In the autonomous mode, the robot picked any sufficiently small object and treated bigger objects as obstacles. In the manual mode the robot was controlled through a mobile app via Wi-Fi. The robot had a robotic arm through which it picked up the objects, and it also segregated them in metallic and non-metallic waste [16].

The robot moved in a S-pattern sweeping and vacuuming the floor. The robot used ultrasonic sensors and a magnetometer to move around accurately. The robot could be controlled through emails which were decoded by the RPi and sent to the Arduino through a RF module [5].

The robot was autonomous and picked the object if the specifications matched with that of the trash bin. The robot moved on a predetermined path and kept collecting trash from the bins until it was full. When the robot got filled, the data was sent over Wi-Fi and the robot moved to a predesignated place to dispose of the garbage [10].

In the manual mode the robot was radio controlled, whereas in the automatic mode the robot moved on its own avoiding the obstacles and maintaining a distance from the banks with the help of the sensors. The robot used a conveyor belt to pick any floating trash from the water body continuously [2].

The robot worked autonomously as it used an adjustable roller brush mechanism to clean and disinfect the tracks as it moved. The GPS module alarmed the bot of any incoming train, and the robot retracted the wheels so that the train could pass over it and then it may resume the work [9].

The robot was radio controlled with a range of up to 1km. It had a mechanism which continuously ploughed and sieved the sand to remove the solid particles and stored them in a bin [15].

A mechanical hand was attached which redirected the trash towards the conveyor belt which led to the collector bin. This 2.3kg prototype could collect trash weighing up to 10kg [1].

The IWSCR consisted of a binocular camera, a 3 d.o.f. Robotic arm to pick the trash and 4 propellers to move. The visuals from the binocular camera were sent to a PC for Image Processing and the results were sent back to the IWSCR. YOLOv3 was used for the detection of the trash and SMC for steering [19].

The manipulator could pick up objects, from the grass covered ground, limited to a 10cm diameter and a maximum of 1kg weight [18].

TABLE I. COMPUTATIONAL TIME FOR THE KEY ALGORITHM [18]

Processing Step	Average Time
Ground segmentation*	10.3 ms
Garbage recognition*	8.1 ms
Obstacle avoidance	16.5 ms
Pickup	1.4 s

a. *: Run on GPU

Pre-existing Care-O-Bot platform was used for this robot as it contained the required features like a 7 d.o.f. Robotic arm, RGB-D sensor, and the computational power. The robotic arm could change the tool based on the task that was needed to be performed. It explored the area, detected dirt, cleared trash cans and vacuum [6].

TABLE II. EXPERIMENTAL RESULTS (R: RECALL & P: PRECISION) [6]

task	success rate	time consumption
map segmentation	100%	1 s
room visiting	100%	1 min per room change
room exploration	100%	2 min per room (20 m^2)
dirt detection	r=95%, p=62%	included in exploration
vacuum cleaning	90%	2 min per spot
trash bin detection	100%	included in exploration
trash bin clearing	90%	3-4 min per trash bin
tool change	90%	3 min

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