Development of an Eco-friendly and Autonomous Beach-cleaning Robot

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***Abstract*—Nowadays, pollution on the beach is a major problem. Due to unsanitary conditions, the number of tourists who visit the beach decreases. As a result, there is an economic slowdown within any local area that houses a beach. Thus, this research suggests an autonomous and eco-friendly beach-cleaning robot (ABCbot). It intends to drive automatically using GPS. The robot also is designed to utilize a LiDAR aimed at avoiding collisions with obstacles as well as a proximity sensor and infrared camera to further aid the detection and movement systems. Most existing beach-cleaning robots are controlled by humans, but ABCbot can control itself. This paper goes in depth on the process of creating a beach-cleaning robot that keeps the beach clean without the need for labor and to save the various costs that come with it.**

***Index Terms*—eco-friendly, autonomous, GPS, computer vision**

I. Introduction

Trash that beach-goers throw away and trash that has been washed up by natural disasters contribute to beach pollution [1]. Beach pollution is harmful to the wildlife that live on the beach, the local residents, tourists, and especially the beach itself. According to the research, implementing all feasible interventions that a human could contribute, approximately 710 million metric tons of plastic waste will occur and affect all ecosystems [2]. In addition, pieces of glass along the beach could directly hurt people and wildlife [3]. Trash also causes the reduction of tourists and it makes around 85% of residents losing up to about 8.5 million dollars because picking up 15 pieces of trash per one square meter is the equivalent to roughly 8.5 million dollars [4].

However, there is a limit that a human can clean up. Therefore, there are multiple different types of beach-cleaning machines that have been developed and implemented. Looking around at robots that are already on the market, many beach-cleaning machines are automatic robots, however those are not completely automatic in the sense that it requires a human operator. Even though several studies have been conducted on fully automatic beach-cleaning robots, existing ones have a range of only twenty square meters or they are remotely controlled or autonomously driven through Bluetooth.

ABCbot, automatically drives using GPS which means that it can minimize human interference and can clear a wider range. Based on the aforementioned autonomous driving, ABCbot uses LiDAR, proximity sensors, infrared cameras to avoid colliding into obstacles as well as remove pollution. During the day, sunlight supplies power through solar panels. If the panels can not supply as much desired power due to low insolation such as cloudy weather, then wind turbines can supply power assuming the wind is utilized without intervention. This would most likely be the case because there is minimal obstruction against the wind on a beach, i.e., lack of buildings.

In this study, trash can be defined as anything from a two liter plastic bottle to a plastic straw. Obstacles will be defined as objects with sizes comparable to those of people. The objects could be people and would include inanimate objects such as parasols, sunbeds, mats, etc. that could be easily observed on the beach.

This research aims to keep the beach clean by clearing any trash with the greater efficiency than any other existing automatic beach-cleaning robot. Due to the robot's nature and its goal to clean up the beach, the research will improve the condition of the beach itself. In addition, the robot using eco-friendly methods of energy consumption would also contribute to keeping the environment clean and minimizing pollution. The idea of using ABCbot instead of humans or other types of robots, would make the cleaning process more efficient while also making sure to spend less money; additionally it would also improve the safety of visiting tourists as well as preserve the safety of marine life.

II. Literature Review

A. The Different Types of Robots and Cleaning Methods

In recent years, multiple different types of beach-cleaning machines have been developed and implemented. They can be categorized into three different types based on how they are controlled. Category one is the tractor-towed machines. Category two is the walk-behind machines. In the last category, category 3 is remote-controlled machines.

The machines can also be grouped into two categories based on how they pick the trash. The two categories are raking and screening. Raking involves picking up trash on the beach using rakes and turning them over continuously until a sufficient amount of trash is disposed of accordingly. Screening involves shoveling the sand initially and then proceeding to disintegrate the sand and the trash. Both methods of cleaning have their benefits. Raking is good for beaches that are concerned with erosion because raking involves digging sand sparsely [5].

Screening is better for beaches with fine sand and beaches with small-sized trash or pollution covered with oil due to the filtration process of screening.

For example, BARBER [6] and SCAM [7] are two sources that sell beach cleaner machines, which can utilize raking and screening methods. BARBER and SCAM have tractor-towed and walk-behind products; however, they are currently not holding any remote-controlled models. 4Ocean [8] provides BeBot, which is a screening-based remote-controlled model. BeBot uses solar panels as the more eco-friendly method of energy consumption.

B. The Problem with Using Humans to Clean Up Beaches

The prominent limitation of current market beach-cleaning machines is the fact that they require human operators. When the operators are with the machines to control them, safety problems can arise due to the proximity of the trash. In addition, cleaning costs are increased as a result of labor costs. Furthermore, because cleaning is a repetitive task, operators might lose their concentration gradually, leading to a decline in performance and motivation. Therefore, to reduce the reliance on humans and make beach cleaning more effective, several studies have been conducted on self-sufficient beach cleaning robots.

C. Studies on Two Different Robots that Pick Up Trash with a Repetitive Motion

A portion of studies aims to collect the garbage on the beach as an autonomous operation. Dhole et al. [9] proposed the design of a beach-cleaning machine that collect wastes such as bottles, plastic, and cans. The machine utilized rakes attached to the lifter with a conveyor to pick up the trash. Also, it could be used for drainage. Two hoppers were used to separate pieces of trash through density differences. Balasuthagar et al. [10] designed and fabricated a beach waste collector machine operated via human power or electric motors. The design of the machine shared similarities to the design of Dhole et al. [9]. The main difference between the two machines is that Balasuthagar et al.'s method involves human-driven pushing power or a separate electronic motor charged via solar panels which in turn powers the conveyor movement system. In addition, the machine can fit within the rear of a car. However, these two sources handle a simple method that picks up the trash in a repetitive motion, an autonomous working machine would work better than humans manually picking up the trash.

D. Studies of Remote-controlled Robots and How They Pick Up Trash

Multiple studies aim to develop a remote-controlled beach cleaning robot. Watanasophon and Ouitrakul [11] built a remote controllable garbage collector robot that works via Bluetooth. It can collect different types of garbage like glass bottles and plastics, as large as 12.5*49 cm using its sieve-like shovel. The installed IP camera on the robot is there so that the human operator can see through the robot's point of view. It can be controlled remotely as far as 20 meters away, however, there is a delay time. The delay time varies with the distance between the robot and the operator. The robot uses solar panels as a source of power while making sure to stay environmentally safe. Bano et al. [12] developed a radio-controlled beach cleaning robot. The robot aimed to collect small litter-like plastic pieces, glass pieces, cans, cigarette butts, etc. Therefore, it utilized a sieve and oscillatory motion to filter the sand. Its operator exploited radio waves via Bluetooth modules. It would sweep the beach and move following the commands sent through radio signals. Shelke et al. [13] presented a remote-controlled robot operated by an android device via Bluetooth connection. It would gather plastic wrappers and bottles through the arm with rakes. It worked through three photo sensors that can detect the size of obstacles or trash. In the case that one or two photo sensors sense an object, the object is considered trash, causing the robot to pick up the trash accordingly. Otherwise, if all three sensors sense an object, it is considered excessively large, to which the robot would deem the object as an obstacle and proceed to avoid it. Despite there still being a need for a human to be operating the machine, this method can separate the human from the waste, minimizing any potentially dangerous outcomes. However, like many technological advances, there is always room for improvement and growth.

E. Studies of the Different Ways Robots can Detect Trash

Several studies are written to create a robot that can automatically detect trash and track it. Cieza et al. [14] assembled a beach cleaner robot named "Esperanza Negra". It can detect, navigate, and collect wastes via stereoscopic vision and object detection using a 3D camera and a bucket with holes. The scope of the study is quite small, as the robot can only deal with cans. Apaza et al. [15] developed a beach cleaner robot named "HS-GreenFist". The design of the robot is similar to the model of Cieza et al. [14], it only collects cans. It detects cans by calculating depth using cameras, segmenting objects through HSV ,and detecting cans through SVM. In the case it detects a can, it proceeds to scoop up the can with its arm. The arm itself is a single-body entity with a claw at the end. It is worth indicating that the robot practices machine learning techniques instead of hard explicit rule-based classification. Additionally, the robot is equipped with a ramp that brings waste downhill when dumping. Roza et al. [16] created an autonomous beach cleaner that collects cans using its arm which is made up of an upper and lower claw that can be likened to teeth. The machine detects cans and obstacles by processing RGB and HSV image channels obtained by a single camera. The robot uses RGB and HSV range presets to segment the area of an object. Through this method, the robot can detect cans that are partially buried. In addition, it can calculate the position of objects via an optical flow algorithm. However, it can only detect moving obstacles because of its single camera. Though the robot uses rule-based recognition when it scans for cans, the vision system worked since that can recognition is a relatively simple task. There was an attempt that centered around focusing on object detection using several labels conducted by Priya et al. [17]. The robot would utilize a conveyor belt with sharp spikes along the edges to pick up the trash scattered on the beach. Also, the robot had a camera that could detect and classify objects. When it found the trash, it would scoop it up, otherwise, it would move forward. The object detection algorithm of the robot was Faster RCNN-trained with a database of debris images which assisted the collection system of the project. Object detection that uses a deep learning model is a more advanced technique in comparison to explicit rule-based algorithms and SVM, as it classifies different types of images. Furthermore, since data on the types of trash being picked up is sent to a database for analysis, this would enable people to recognize that the beach looks significantly cleaner. It was an excellent decision in the research to adopt object detection into the beach cleaning robot.

F. Study on a Specific Robot that is Completely Autonomous

All the robots suggested by Cieza et al. [14], Apaza et al. [15], Roza et al. [16], and Priya et al. [17] achieved detecting, following, and picking up the trash oxn the beach within the limited range. However, it cannot localize itself on the beach and develop its systematic path plan for the whole beach. Therefore, they are just semi-autonomous robots. Ichimura and Nakajima [18] [19] built a beach cleaning robot named “Hirottaro”. The robot had been developed and redeveloped 3 times in the aspect of its trash collecting method. 1) forklift-bucket; 2) chain-conveyor system; and 3) broom, dustpan. A broom and a dustpan were the final choices by the developers as this method was seen as being the most reliable on uneven terrain. The robot intermittently cleans the surface of the beach by repeatedly going forward and brooming alternately. It executed self-localization by scanning a range finder and using two poles to define and mark landmarks and work areas. The robot could calculate its location within a 20m*20m rectangle. The robot was tested at the sandy beach and could pick up cans and plastic bottles proficiently. In addition, the robot successfully used a systematic traveling strategy by defining subgoals in the work area to reduce errors and clean all ranges of the work area. However, its coverage was insufficient when dealing with a large area, since it requires more than poles per 20m*20m. The paper mentioned that GPS is largely utilized as a self-location system for several robots, but they selected the scanning range finder because of its simplicity. Therefore, a robot that has a GPS can demonstrate better performance in terms of coverage and effectiveness.

In conclusion, there have been copious amounts of research concerning the development of diverse beach cleaning robots that differ in cleaning methods, i.g., raking and screening method. However, most of them could just pick up trash with simple repetitive motions or be remote-controlled by human operators or detect, follow, and pick up the trash without a sound a strategy that would consider the whole beach. There was one study that defined strategy of how to move and clean in the work area, but its coverage only worked within a 20m*20m area. Moreover, few of them considered clean energy like solar power. Furthermore, none of them considered any sea animals or organic debris. Multiple studies have discussed the capabilities of beach cleaning robots, however, there is still plenty of room for improvement.

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