Design of Refuse Collection Mechanisms for an Intelligent Beach Cleaning Robot

Yathunanthanasarma B.
Department of Electrical Engineering
University of Moratuwa
Colombo, Sri Lanka.
yathunanthanasarmab.19@uom.lk

Barathraj M.
Department of Electrical Engineering
University of Moratuwa
Colombo, Sri Lanka.
barathrajm.19@uom.lk

Mahiliny J.
Department of Electrical Engineering
University of Moratuwa
Colombo, Sri Lanka.
mahilinyj.19@uom.lk

A. G. B. P. Jayasekara
Department of Electrical Engineering
University of Moratuwa
Colombo, Sri Lanka.
buddhikaj@uom.lk

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I. INTRODUCTION

Ensuring the protection of natural habitats from growing coastal pollution includes the important task of cleaning plastics from beaches. The buildup of plastics and debris not only endangers marine life but also amplifies the problems, underscoring the need for effective intervention measures.

While manual beach cleaning efforts are admirable, they are time-consuming and can lead to health issues for workers, including musculoskeletal diseases. Moreover, relying solely on manual labor proves inadequate given the large scale of the problem. Thus, there is an urgent need for advanced technological solutions capable of assisting and enhancing human efforts. This paper advocates for the deployment of intelligent beach cleaning robots as a promising approach towards a more sustainable and efficient strategy for mitigating coastal pollution.

II. LITERATURE REVIEW

The development of design and implementation of refuse collection mechanisms has garnered significant attention in recent years as they have emerged as a critical area of research. These robotic systems are tasked with the formidable challenge of efficiently managing refuse in coastal areas, necessitating robust and adaptive collection mechanisms.

The robot "Binman" introduces a filtration component comprised of a conveyor equipped with rows of steel tines [1] which exhibit spring-like characteristics with a degree of torsion, enabling the capture of waste with a sand director guide. But utilization of continuously rotating conveyor belt makes it to have ineffective energy usage and unavoidable battery consumption. The robot "Hirottaro" discusses a system utilizing a brush mechanism which emulates the functionality of a floor cleaning human with a broom and dustpan [2] by a linkage mechanism. However, this robot exhibits substantial size and entails significant expenses. In later contributions, a modular robot uses an anterior claw appendage [3] which was conceived and affixed to the robot, facilitating the retrieval of cans from ground level. Nonetheless, this gripper design configuration demands a significant power supply. Moreover, a radio-controlled bot is designed with a filtration segment of sieve [4] which contains a wire mesh to transfer all the ploughed sand on it, and another one incorporated a picking up mechanism [5] which makes it focused for can collection but ineffective for other wastes.

But what we emphasize is the need for a robust collection system that can adapt to varying types and sizes of debris commonly found on beaches. This paper demonstrates the efficacy of dual modes of refuse collection mechanisms (in which only one mode can be selected at a time): raking mechanism and sieving shaker mechanism. Building upon previous work, this research introduces a cost-effective approach that leverages intelligent systems to enhance refuse collection capabilities.

III. MATERIALS AND METHODS

The proposed prototype combines two modes of refuse collection mechanisms to be affixed onto a tracked mobile robot platform. It includes a raking mechanism tailored for the retrieval of larger-sized debris and a sieving shaker mechanism designed for sand filtration. The aforementioned mechanisms were designed using SolidWorks software.

A. Raking Mechanism

This configuration, as shown in Fig. 1, incorporates a rake-like implement with a revolute joint arm with 1 DOF, facilitating the elevation of debris into a designated storage bin. The rake itself measures 32 cm by 25 cm, with a height of 20.4 cm from ground level. Each branch of the rake features a 30:31 dual curve bending and maintains a 1.6 cm spacing within the array. For producing the components for this mechanism, 3D printing is employed. This mode of refuse collection is complemented by object detection, ensuring swift and efficient servicing of the robot, thereby minimizing operational downtime during cleaning procedures.

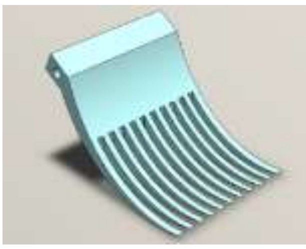

Fig. 1. Raking Mechanism

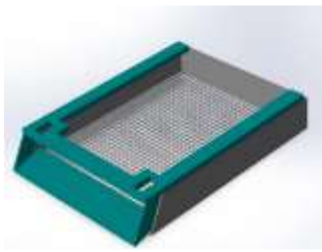

Fig. 2. Sieving Mechanism

B. Sieving Shaker Mechanism

As shown in Fig. 2, this mechanism includes a sand director measuring 32 cm by 4 cm, responsible for elevating debris to the sieve area. A vibrating mesh is deployed for the purpose of sifting through sand, while effectively retaining solid waste. The mesh possesses dimensions of 32 cm by 40 cm and maintains a height of 6 cm. Given the necessity for robustness in the components, the fabrication of parts for this mechanism was accomplished using sheet metal. This mode primarily targets the capture of larger debris categories, including plastics, glass, wrappers, and driftwood, while allowing smaller sand particles to pass through. The collected refuse is subsequently transported to a designated storage compartment for subsequent disposal.

C. Other related functionalities

Fig. 3 illustrates the combined robot utilizing the above two mechanisms. During the operation of the raking mechanism, informed by object identification via YOLO (You Only Look Once) model and guided by the VFH (Vector Field Histogram) algorithm which generates a grid-based map with plastics and obstacles, the robot autonomously determines an optimal path to approach and collect plastics. And upon activation of the sieving shaker mode, the robot utilizes sensor inputs to navigate along a predetermined path, considering obstacles en route and adeptly maneuvering around them. This mode allows for effective filtration of sand while ensuring the efficient movement of the robot. These operations will be implemented with an RGB camera and a Laser Range Finder.

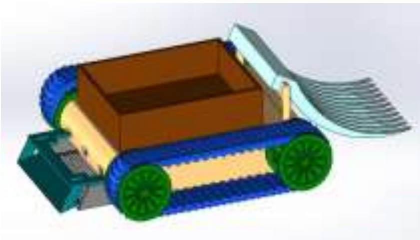

Fig. 3. Combined Design of Robot Prototype

IV. RESULTS AND DISCUSSION

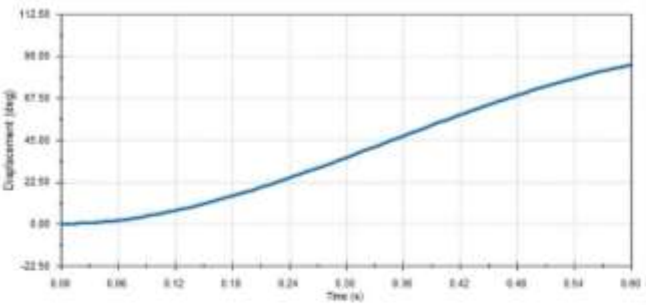

Fig. 4. Displacement(degrees) vs Time(s) graph for Raking Mechanism

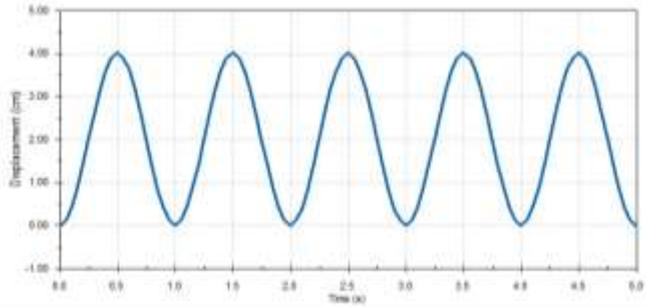

Fig. 5. Displacement(cm) vs Time(s) graph for Sieving Mechanism

The motion study analysis of the dual modes of garbage collections was performed using SolidWorks software.

Upon detecting the presence of garbage, the robot will initiate movement towards it. Subsequently, the raking arm will acquire debris from the ground by rotating the revolute joint through an angle ranging from 90 to 150 degrees, facilitated by servo motors. Fig. 4 depicts the angular displacement of the rake with time at a speed of 10 rpm for a rotation through 90 degrees.

The vibration mechanism of sieve mesh operates at a predefined frequency of 1Hz (60 rpm) and maintains a vibration range of 4 cm. The oscillation of vibration of the sieve is shown in Fig. 5 above. The sand director frame is securely affixed to the sieve mesh frame via an interconnector comprising two joints - one rigid and one free.

V. CONCLUSION

The 3D model of the mechanisms was designed according to the predetermined plan and subsequently subjected to simulation using specific parameters. Our singular prototype selection driven by identified research gaps, is grounded in a thorough literature review. Filling the void of models with integrated essential mechanisms, the prototype prioritizes cost-effectiveness, positioning it as an innovative force. Further improvements will be implemented through a detailed analysis of their optimal values.

Furthermore, we aim at creating a solution for effectively identifying and/or separating seashells from beach debris. Seashells, being primarily composed of substances like $CaCO_3$ and Chitin, based on their unique functional groups, chemical bonds, and molecular arrangements, we can analyze and prepare the FTIR (Fourier Transform Infrared) and Raman spectra of seashells. Following the use of a suitable algorithm, we can compare the real-time spectrum data with the created database to discern seashells from other wastes.

Moreover, thus far our robot relies on human intervention to select its operational mode. So, we intend to develop a proactive behavior with an algorithm that empowers the robot to autonomously initiate and execute tasks without explicit human guidance.

VI. REFERENCES

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