

# Autonomous Trash Collector Robot with Wireless Charging System in a Campus Environment

Analene Montesines Nagayo<sup>1</sup>, Bindu Puthentharayil Vikraman<sup>2</sup>, Mazna S.H. Al Saidi<sup>3</sup>, Ammar S. Al Hosni<sup>4</sup>, Ali K. Al Kharusi<sup>5</sup>

Department of Engineering  
Al Musanna College of Technology  
Muladdah, Sultanate of Oman

<sup>1</sup>analene@act.edu.om, <sup>2</sup>bindu@act.edu.om,  
<sup>3</sup>2J13302@act.edu.om, <sup>4</sup>52S12127@act.edu.om,  
<sup>5</sup>52S1264@act.edu.om

Rodrigo S. Jamisola Jr.<sup>6</sup>

Mechanical, Energy and Industrial Engineering Department  
Botswana International University of Science and Technology

Palapye, Botswana  
<sup>6</sup>jamisolar@biust.ac.bw

**Abstract**— This work presents the design and implementation of an autonomous trash collector VEX Clawbot attached with a loading bin that is controlled by Arduino microcontroller. Features of the robot include GSM and GPS modules for localization and status update, as well as automatic wireless charging from solar power source. The robot prototype travelled an entire path of 3.5m, with an average time 30 sec, where a waste segregator is located at the end of the path. Average time to pick up each type of trash and place in backside loading bin is 20 seconds with an 80% accuracy.

**Keywords**— Waste collection, VEX clawbot, Arduino microcontroller, GSM/GPS monitoring, wireless charging, solar power

## I. INTRODUCTION

Manual waste collection and segregation of waste materials is still done in many countries like Oman, India and Philippines [1] - [5]. According to [4], human rag pickers and garbage collectors are still extensively employed in the gathering and disposing of solid waste. However, they are susceptible to skin infections, allergic disorders, respiratory and gastrointestinal problems [5]. To contribute to the solution of waste collection with minimum human involvement, a self-driving trash collector robot was designed and implemented.

This research allows waste collection to be done with minimal health hazard and safety risk to humans using engineering technology. The robot is battery operated which can be charged wirelessly using a solar energy power source, making the system eco-friendly.

In this paper, Section II cites the recent developments in the design and implementation of autonomous trash collector robots. Section III describes the design, set-up and implementation of the autonomous trash collector robot with wireless charger, GSM and GPS monitoring system. In Section IV, the experimental data are presented to show the performance and response time of the designed robot in promoting a clean and green campus environment. Lastly, Section V concludes the paper and presents the future directives of the robotic system for extensive waste management program.

## II. RECENT DEVELOPMENTS IN THE DESIGN AND IMPLEMENTATION OF A TRASH COLLECTOR ROBOT

Several researches are done about autonomous garbage collecting robot with one common goal which is to pick trash and deposit it to its appropriate recycle bin [6]-[17]. The design methods and implementation of these robots may vary depending on the application.

A study in [6] presented a line following mobile garbage collector that will gather wastes from three bins, then deposits the waste in an automatic sorter system. The system was implemented using PIC microcontroller interfaced with line following sensor, H-bridge motor drive and DC motors. The robot completed the task of collecting and delivering the trash in 4 minutes and 36 seconds [6]. Line following robots are simple to implement but have slow speed and instability with different line width or stiff angles [7].

Another PIC-based robot was developed for collecting the garbage at the beach [8]. Bluetooth and Adhoc wireless communication technologies were applied to the robot for remote controlled operation at an average speed of 0.5 m/s on the sand [8]. The trash collector robot can be easily controlled using push button switch or mobile phone using Bluetooth technology, but the user can only operate it at a limited distance [9].

An automatic garbage collector named AGATOR shown in [10] was developed to limit the accumulation of wastes in a river under weak or no water flow condition. The system uses ATmega16 as master robot controller, while ATmega8 read signal from ultrasonic sensor to determine the position of the garbage and communicate serially with the master controller for necessary trash collecting operation [10]. This system is not capable of tracking the location of AGATOR when working on the river, so the use RFID as a monitoring tool was recommended by the researchers.

Another design of trash collector robot is done in [11] using Arduino microcontroller interfaced with ultrasonic and infrared sensors. The sensors are used to detect and avoid obstacle in the robot's path using the combination of S-shaped and wall follow algorithms. A vacuum cleaning device was used for waste collection by means of suction [11]. To improve robot vision in

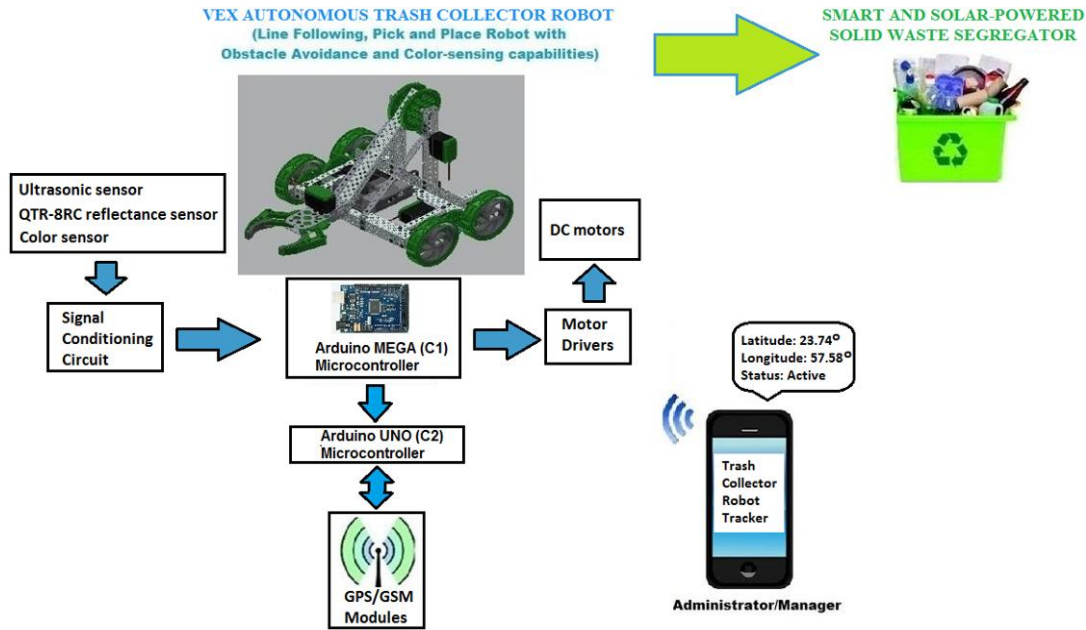


Fig.1. Block Diagram of the trash collector robot

detecting trash if it is biodegradable or not, image processing technique is employed by Ranganath et al. [12]. Raspberry Pi serves as the master controller where image processing program is executed, and the instructions are sent serially to Arduino which acts as a slave that will control the robot movement [12].

Robot localization, activity status update and motion planning of trash collecting robot may be implemented using Wi-Fi [13],[14], GPS [15] and GSM [15],[16] technologies. An access point or Wi-Fi Board must be installed to the robot in order to connect to a WLAN and a high speed internet connection is needed for real time transmission of status update and robot's location [9]. For robot absolute localization, GPS [15] or optical beacons [17] may be used. However, GPS signal is weak indoors and its accuracy is poor for small distances [18]. According to [16], GSM can be used in monitoring robots due to its established long range, secure, fast and reliable connection.

### III. AUTONOMOUS TRASH COLLECTOR ROBOT CONTROL AND MONITORING SYSTEM DESIGN CONSIDERATIONS

#### A. Block Diagram of the Trash Collector Robot

Referring to Fig.1, the trash collector robot (TCR) system is an autonomous line follower robot that utilizes color sensors, QTR reflectance sensors, ultrasonic sensors and DC motors to properly pick-up recyclable waste materials such as aluminum cans, plastic bottles, glass bottles and papers along its path, drop the trash in its backside loading bin then bring it to the receiving

end of a Solid Waste Segregation System (SWSS). The wastes are dumped by the robot to the elevator conveyor which will transfer the trash to the horizontal belt conveyor for sorting. The Arduino MEGA (C1) is the master controller which reads and processes data from various sensors, and actuates the motors to perform a controlled robotic operation. The Arduino UNO (C2) is a slave microcontroller used for robot localization and status update. A GPS shield is connected to the microcontroller C2 for monitoring the location of the TCR. A GSM modem is interfaced with the microcontroller C2 that sends SMS message to the administrator about the latitude and longitude coordinates of the robot, status of the robot and if breakdown is detected in the TCR. Moreover, the robot is charged wirelessly from a solar power source as it parks at the docking bay.

#### B. Design Considerations for the Trash Collector Robot Mechanism

The wheels, body chassis and arms of the trash collector robot (TCR) were assembled using a VEX Clawbot kit [19] as presented in Fig. 2. At the back of the TCR, a loading bin constructed to carry aluminum cans, plastic bottles, papers and glass bottles towards the receiving end of a solid waste segregation system (SWSS).

A gravity actuated unloading design was adopted instead of a motor actuated to significantly reduce the overall weight of the robot by eliminating the motor and additional battery. The swinging door of the bin can be opened or closed by a small electromagnet which will be activated by the microcontroller. The loading bin for the trash collector robot is shown in Fig. 2.

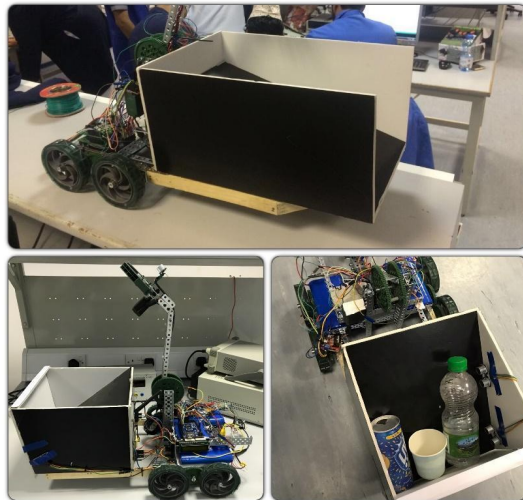


Fig. 2. Trash collector VEX Clawbot with backside loading bin

### C. Control System of Trash Collector Robot

The line following, pick and place and obstacle avoidance tasks of the trash collector robot (TCR) are accomplished using the following sensors: (a) QTR-8RC reflectance sensor that detects black and white line in the robot's path; (b) color sensor that detects the unloading point at the SWSS area marked by red color, and (c) Ultrasonic sensor that detects objects along the robot's path and identifies if the trash bin is full or not.

The Arduino MEGA (C1) microcontroller was programmed to read and process data from various sensors that would determine the robot's path and movement. The robot consists of two motors activated by the Arduino microcontroller through the LN298 driver circuits based on the sensor readings. The program flowchart for the TCR is shown in Fig. 3.

Microcontroller C1 continuously reads all sensors connected to its input pins. When the color sensor output reaches a predefined value, the microcontroller sends sequence of control signal for unloading the trash. If the color sensor value is not in the range of detection, it checks the ultrasonic output. Ultrasonic sensor monitors the obstacles in front and if the distance is less than the cutoff value, microcontroller C1 sends signal to stop the robot. The control signals needed for pick and place the object is send by the microcontroller. The robot follows the assigned path based on the line tracking sensor output values. It continuously monitors the QTR output values and decisions on its left, right, forward and reverse movement is done.

The designed trash collector robot (TCR) can follow a path with a black line on a white surface using QTR 8A reflectance sensor array. The robot uses an array of 3 IR LED as emitter and phototransistor as receiver, which are facing the ground to sense the line. The output of the sensors is an analog signal which depends on the amount of light reflected. This analog signal is fed to the microcontroller input pin. The microcontroller C1 decides the next movement based on the program written and the input obtained from the line tracking sensors.

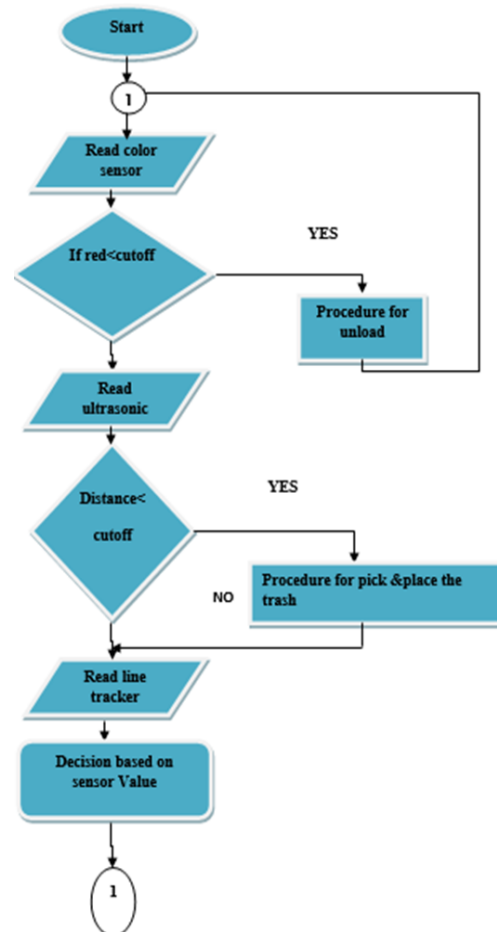


Fig. 3. Program flowchart for the trash collecting robot

For the pick and place task of TCR, two DC motors were utilized. One motor is used for the arm movement and the other one for the claw movement. These two motors are interfaced to the microcontroller using motor driver IC LN298. The PWM pins of microcontroller C1 is used for sending control signal for the arm and claw movements, as control of movement speed can be done through these pins. Normally, the arm will be in the down position with claw open. When the ultrasonic sensor identifies the trash, the microcontroller sends signal to grab and hold the trash. Consequently, the claw closes and control signal is given to move the arm up, until it reaches the back bin. The microcontroller C1 sends signals for opening the claw to keep the trash in the bin. After placing the trash in the bin, the arm is moved back to its original down position, with claw open.

For the overall control of the TCR, the three reflectance sensors connected to microcontroller C1 gives information about the path that the robot must follow. Depending on these sensor output values, the microcontroller sends signals for

forward, left and right movement of the TCR. The TCR movement is performed using a pair of motors, interfaced through the motor driver IC with the microcontroller C1. The ultrasonic sensor connected to the microcontroller gives information about the trash ahead in its path. When it identifies a trash, a sequence of control signals is sent to pick the trash on its path and for placing it in the robot backside bin. An ultrasonic sensor is connected to the microcontroller C1 for determining whether the backside loading bin of robot is empty or full of trash. If it is full the robot goes to the final destination marked with a red post. The color sensor interfaced with the microcontroller gives information about the final destination where the trash is transferred to the conveyor for segregation. When the TCR identifies the assigned color for destination, control signals are sent to keep the robot near to the conveyor belt. After reaching the conveyor belt, the microcontroller C1 sends signals to energize the relay, which in-turn deactivates the electromagnet and opens the back bin to drop the trash in the elevator conveyor. Microcontroller C1 generates digital output signals to indicate the status of the robot and backside loading bin.

For the power management of the TCR, microcontroller C1 reads the voltage level of the battery from one of its analog pins. If the voltage level is below 7.0 V, TCR is programmed to go to the starting point where a docking bay is installed for wireless charging.

#### D. Monitoring System of Trash Collector Robot

For monitoring purposes, A GSM modem SIM900 is interfaced with Arduino UNO (C2) microcontroller to send SMS message to the administrator about the status of the robot, its activity and if breakdown has occurred in the TCR. A GPS shield is also interfaced with microcontroller to monitor the location of the Trash Collector. To determine if robot is active, fault has occurred or the trash bin is full, the microcontroller C2 reads status signal sent by microcontroller C1. Fig. 4 shows the actual implementation of the TCR monitoring system.

#### E. Wireless Charging System of Trash Collector Robot

Referring to Fig. 5, the solar panel connected to charge controller charges the 12 V, 200 Ah deep cycle battery. A DC to DC converter is connected to solar power source to step down the voltage from 12 V DC to 5 V DC in order to meet the transmitter circuit requirement. The transmitter circuit converts the DC voltage into a high frequency alternating current then it is fed to the transmitting coil [25]. The high frequency AC signal flowing within the transmitter coil creates an alternating magnetic flux which extends to the receiver coil when the two coils are placed within a specified distance [26]. As the robot

parks in the docking area, the magnetic flux is transmitted from the transmitter coil mounted in the floor to the receiver coil placed in the bottom of the robot by electromagnetic induction.

In the wireless receiver side, the receiver coil receives the energy as an induced alternating voltage in accordance to Faraday's Law of Induction [24]. Rectifier, filter and linear regulator are used to convert the induced AC voltage into a stable DC voltage required by the robot's battery [27]. The prototype for the Robot Wireless Charging System is shown in Fig. 6. The robot parks in the docking bay to charge its battery.

### IV. EXPERIMENTAL DATA AND ANALYSIS OF RESULTS FOR THE SELF-DRIVING TRASH COLLECTOR ROBOT SYSTEM

#### A. Experimental Set-up and Test Results of the Control and Monitoring System for the Autonomous Trash Collector Robot

Prior to the actual testing, the sensors attached to the microcontroller C1 of the trash collector robot (TCR) such as QTR sensor, color sensor and ultrasonic sensors were calibrated to perform task accurately. A 3.5-meter arena is set-up to test the performance of the TCR. Table I shows the performance and response time of the robot in completing the task of following the black path, identifying trash along its path, picking and placing the trash to its backside loading bin and identifying the final destination point going to the SWSS area for 5 test runs. Each test run is done with 5 trials.

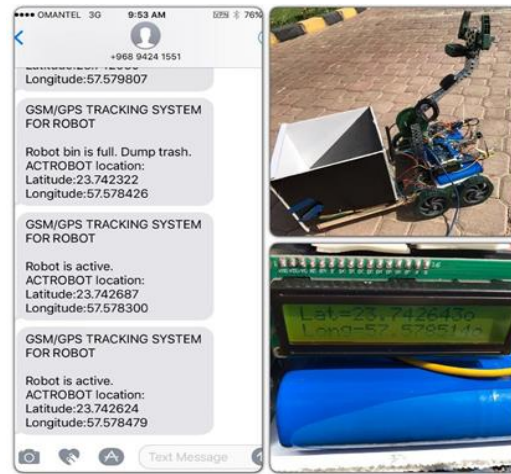


Fig. 4. Trash collector robot monitoring system

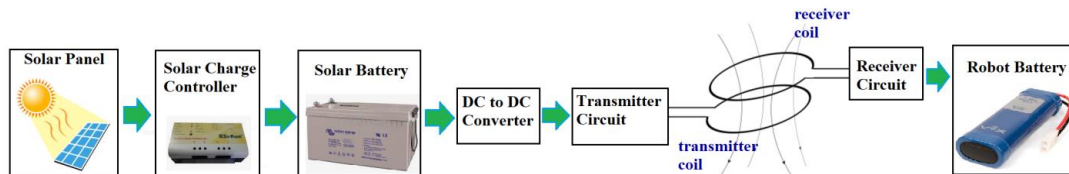


Fig. 5. Robot Wireless Charging System Block Diagram

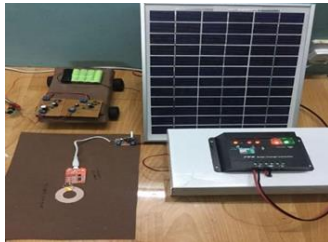


Fig. 6. Wireless charging system of the trash collector robot

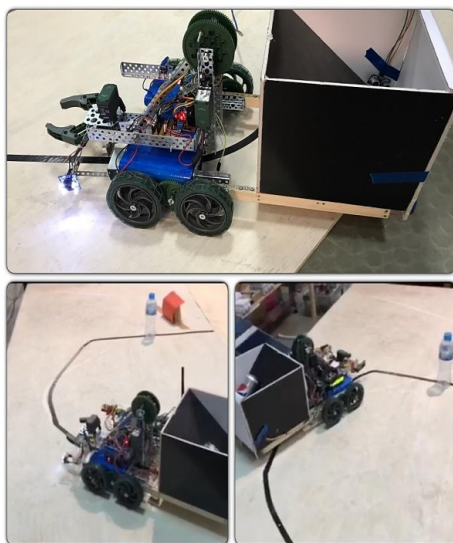


Fig. 7. Line following operation of the trash collecting robot

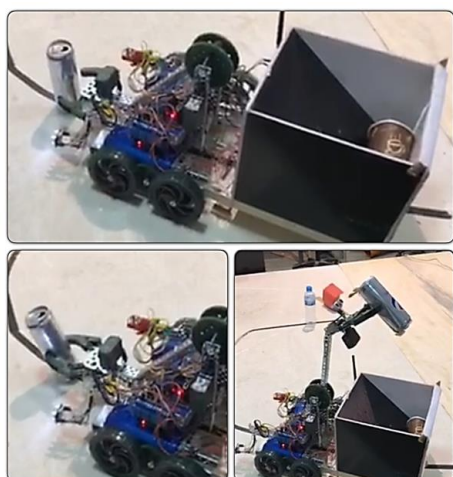


Fig. 8. Pick and place operation of the trash collector robot

Fig. 7 shows the line following operation of the TCR using QTR. The robot followed the path with black line with an 88% reliability as seen in Table I. The failure rate was due to the instability of the robot in following stiff curve.

Fig. 8 presents how the robot performs the pick and place task with a reliability of 80%. The ultrasonic sensor connected to the microcontroller gives information about the trash along the robot's path. When it identifies a trash, a sequence of control signals is sent to pick the trash on the path and place it in the backside loading bin of the robot. The failure rate in picking the trash is due to the position of the trash along the path.

As seen in Fig. 9, color sensor interfaced with the microcontroller gives information about the final destination where the trash is transferred to the conveyor for segregation. When the TCR identifies the red color for final destination, control signals are sent to make the robot move backwards going to the elevator conveyor. From Table I, the robot was able to detect the red colored post for the final destination with 80% reliability.

The monitoring system for the TCR was done using GSM and GPS shields interfaced with Arduino microcontroller. The sample SMS received by the administrator for monitoring the robot status, activity and location is shown in Fig. 4. Also, the location of the robot in terms of latitude and longitude are displayed in the LCD installed in the TCR.

TABLE I. PERFORMANCE AND RESPONSE TIME OF THE TRASH COLLECTOR ROBOT

Test Run	Robot task	Average time taken to complete the task in seconds	Reliability
1	Pick and place	Object1	Unsuccessful
		Object2	Unsuccessful
		Object3	24 sec
	Following the path	19 sec	60%
2	Pick and place	Object1	24 sec
		Object2	Unsuccessful
		Object3	13 sec
	Following the path	22 sec	80%
3	Pick and place	Object1	24 sec
		Object2	23 sec
		Object3	13 sec
	Following the path	24 sec	100%
4	Pick and place	Object1	13 sec
		Object2	24 sec
		Object3	25 sec
	Following the path	24 sec	100%
5	Pick and place	Object1	24 sec
		Object2	23 sec
		Object3	13 sec
	Following the path	28 sec	100%
	Identifying the destination by using color sensor	5 sec	100%



Fig. 9. Color sensing operation of the trash collector robot

**B. Experimental Set-up and Test Results of the Wireless Charger System for the Trash Collector Robot**

At the transmitter side of the wireless charger, the circuit was tested by taking its frequency and voltage readings. The transmitter was able to generate a high frequency AC signal as seen in Table II. The receiver circuit was able to charge the 7.2 V battery of the VEX robot in a time of 100 minutes. Fig.10 shows how the robot parks in the docking bay found at the starting point for wireless charging operation.



Fig 10. Robot parks in the docking bay for wireless charging operation

TABLE II. FREQUENCY AND VOLTAGE OUTPUT OF TRANSMITTER CIRCUIT

Frequency (KHz)	Voltage (V)
172	21
185	20.8
209	23
211	26

**V. CONCLUSION**

The recent researches in the design and implementation of a trash collector robot are presented in this paper with one mutual aim which is to gather waste materials and deposit them in their appropriate garbage bins with minimal health and safety risks. The design and implementation of an Autonomous Arduino-based Trash Collector Robot (TCR) was accomplished which allow solid wastes to be gathered and delivered for waste segregation. The line following, pick and place and obstacle avoidance tasks of the TCR are accomplished using QTR-8RC reflectance sensor, color sensor and ultrasonic sensor. In the pick and place operation, proper placement of trash in the lined path plays a crucial part in determining the accuracy of the TCR. Real-time monitoring of the robot's status and location were achieved using wireless communication technologies. A GPS shield is connected to the microcontroller for robot localization. GSM modem is connected to microcontroller to send SMS message to the waste administrator about the status, location and any malfunction of the TCR. A wireless charging module powered from a solar source was successfully designed and implemented to charge the TCR batteries as needed when it parks in the docking bay.

Based on performance and response time testing of the TCR, this work recommends an improvement on its pick and place capability by using additional ultrasonic sensors and high-powered DC motors [6], as well as integration of camera and image processing techniques [12]. It is also recommended that for relative and indoor localization of TCR, on-board sensors such as gyroscope, accelerometer and encoders may be used [18].

**ACKNOWLEDGMENT**

Special thanks to Al Musanna College of Technology (ACT) for the full support given to this multi-disciplinary project, and The Research Council (TRC) of Oman for funding major part of this project. Thanks to SWSSTCR team members: Eugene Vega, Cesar Mendoza, Omar Rashid Al Maqbali, Ammar Yousuf Al Farsi, Tasnim Khasif Al Mughhaizwi, Raja Muhammed Al Rawahi, Emanuel Rances, Jefferson Zason, Rolando Cabais, Jorge Ramos, Alex Boral, Ericson Recamata for all their support and cooperation.

**REFERENCES**

- [1] T.M. Palanivel and H. Sulaiman, "Generation and Composition of Municipal Solid Waste (MSW) in Muscat, Sultanate of Oman," APCBEE Procedia, Vol. 10, Pages 96-102, 2014
- [2] Zafar, S. (2015). Solid Waste Management in Oman. [Online] Available: <http://www.ecomena.org/solid-waste-oman> [Accessed: March 2, 2016]
- [3] M. Joubert (2013). National Strategy for Waste Management. [Online] Available: <http://omanobserver.om/national-strategy-for-waste-management> [Accessed: March 2, 2016]

- [4] V. K. Ojha, V. Tripathi and V. Krishna, "Role of rag pickers in solid waste management: a case study of Mirzapur, UP," *International Journal of Environmental Technology and Management*, 17(2-4), 134-142, 2014.
- [5] S. Dwivedi, M. Fernandes and R. D'souza, "A Review on PLC based Automatic Waste Segregator," *International Journal of Advanced Research in Computer Engineering & Technology (IJARCET)*, vol.5, no. 2, 280-285, 2016
- [6] F. G. Ang, M.K.A. Gabriel, J. Sy, J. J. O. Tan and A. C. Abad, "An Automated Waste Sorter with Mobile Delivery Waste System," presented at 2013 DLSU Research Congress. DLSU, Manila, 2013
- [7] Line Follower Robot. [Online] Available: <https://www.pantechsolutions.net/robotics-projects/line-follower-robot> [Accessed: April 11, 2019]
- [8] S. Wattanasophon, S. Ouitrakul, "Garbage Collection Robot on the Beach using Wireless Communications," *Int. Proc. Chem. Biol. Environ. Eng.*, vol. 66, pp. 92-96, 2014.
- [9] S. Kahar, R. Sulaiman, A. S. Prabuwono, N. A. Ahmad and M. A. Abu Hassan, "A Review of Wireless Technology Usage for Mobile Robot Controller," 2012 International Conference on System Engineering and Modeling (ICSEM 2012) IPCSIT vol. 34, pp. 7-12, 2012.
- [10] O. Nurlansa, D. A. Istiqomah and M. A. S. Pawitra, "AGATOR (automatic garbage collector) as automatic garbage collector robot model," *International Journal of Future Computer and Communication*, 3(5):367-371, 2014.
- [11] G. Sivasankar, B. Durgalakshmi and K. Seyatha, "Autonomous Trash Collecting Robot," *International Journal of Engineering and Technology*, 6(4):162-165, 2017.
- [12] R. Ranganath, B. Sharma, P. AR, R. C. Jadhav, A. A., "Autonomous Garbage Collecting Robot Wall-E," *International Journal of Scientific Research and Development*, 5(4):524-526, 2017.
- [13] V. T. Wilson, M. Venkatesh, S. Panicker, S. G. Bhat and R. Sanjeetha, "Smart waste Collecting Hopper (SWaCH): A service for all," 2015 Twelfth International Conference on Wireless and Optical Communications Networks (WOCN), Bangalore, 2015, pp. 1-4.
- [14] Kison, B. S. B. Dewantara and F. Ardilla, "Self-Monitoring, Failure-Detection and Decision-Making System to Support E-TrashBot (EEPIS Trash Bin Robot) Operations: Preliminary Report," 2018 10th International Conference on Information Technology and Electrical Engineering (ICITEE), Kuta, 2018, pp. 1-6.
- [15] A.M. Nagayo, M. S. H. Al Saidi, O. R. Al Maqbali, A. Y. Al Farsi, A. K. Al Kharusi, A. S. Al Hosni, T. K. Al Mughazwi, R. M. Al Rawahi, "A Smart Solar-powered Waste Segregation System with Integrated Self-driving Robot Collector towards Environmental Sustainability in School Campus," presented at the National Research Forum, TRC, Sultanate of Oman, December 2017, unpublished.
- [16] B. N. Binoy, T. Keerthana, P. R. Barani, A. Kaushik, A. Sathees and S. N. Aswathy, "A GSM-based versatile Unmanned Ground Vehicle," *INTERACT-2010*, Chennai, 2010, pp. 356-361.
- [17] G. Ferri, A. Manzi, P. Salvini, B. Mazzolai, C. Laschi and P. Dario, "DustCart, an autonomous robot for door-to-door garbage collection: From DustBot project to the experimentation in the small town of Peccioli," 2011 IEEE International Conference on Robotics and Automation, Shanghai, 2011, pp. 655-660.
- [18] P. Goel, S.I. Roumeliotis, and G.S. Sukhatme, "Robot Localization using Relative and Absolute Position Estimates," in *Proc IEEE Int. Conference on Robots and Systems*, Kyongju, Korea, 1999.
- [19] VEX Clawbot. [Online] Available: <https://www.robotmesh.com/vex-clawbot-kit> [Accessed: October 1, 2016].
- [20] F. Kaiser, S. Islam, W. Imran, K. H. Khan and K. M. A. Islam, "Line follower robot: Fabrication and accuracy measurement by data acquisition," 2014 International Conference on Electrical Engineering and Information & Communication Technology, Dhaka, 2014, pp. 1-6.
- [21] Yuta, S. I., Suzuki, S., & Iida, S., "Implementation of a small size experimental self-contained autonomous robot—sensors, vehicle control, and description of sensor-based behavior," *Experimental Robotics II*, 344-358, 1993.
- [22] T. Kothhauser and G. F. Mauer, "Vision-based autonomous robot control for pick and place operations," 2009 IEEE/ASME International Conference on Advanced Intelligent Mechatronics, Singapore, 2009, pp. 1851-1855.
- [23] K. Bhagat, S. Deshmukh, S. Dhonde & S. Ghag, "Obstacle Avoidance Robot," *International Journal of Science, Engineering and Technology Research (IJSETR)*, 5(2), 439-442, 2016.
- [24] Chin-Sheng Wu, "Obstacle avoidance of autonomous mobile robots," *Proceedings IEEE 31st Annual 1997 International Carnahan Conference on Security Technology*, Canberra, ACT, Australia, 1997, pp. 158-160.
- [25] A. Parmar and S. Khurana. Wireless Charging. [Online] Available: <https://medium.com/swlh/wireless-charging-c0a35351ffe8> [Accessed: October 1, 2016].
- [26] Sam Sattel. Wireless Charging: How Qi Charging works. [Online] Available: <https://www.autodesk.com/products/eagle/blog/wireless-charging-qi-charging-works/> [Accessed: April 11, 2019].
- [27] Introduction to Wireless Battery Charging. [Online] Available: <https://www.idt.com/products/power-management/wireless-power/introduction-to-wireless-battery-charging> [Accessed: April 11, 2019].