IEEE Open Category: Beach Cleaner

Team PUCP – Team Description Paper, LARC 2013

Francisco Cuellar
Department of Engineering – Mechatronics
Pontifical Catholic University of Peru
Lima, Peru
cuellar.ff@gmail.com

Michel Siguenza
Department of Engineering – Mechatronics
Pontifical Catholic University of Peru
Lima, Peru
michel.siguenza@pucp.edu.pe

Franco Guillen Basantez
Department of Engineering – Mechatronics
Pontifical Catholic University of Peru
Lima, Peru
franco.guillen@pucp.pe

Elizabeth Gutierrez
Department of Engineering – Mechatronics
Pontifical Catholic University of Peru
Lima, Peru
e.gutierrezr@pucp.pe

Dante Arroyo López
Department of Engineering – Mechatronics
Pontifical Catholic University of Peru
Lima, Peru
darroyo@pucp.edu.pe

***Abstract* — This paper presents the hardware and software used by team PUCP to develop and autonomous robot capable of collecting garbage and avoiding obstacles. The robot must be able to move through a scenario that simulates an island, as defined by the rules on IEEE Open Category of the XII Latin American Robotics Competition (LARC).**

Keywords* — *cleaner robot, suspension system;

I. Introduction

Nowadays, pollution has become one of the main concerns in modern society. Littoral zones have been the most affected including beaches, due to garbage generation and drainage discharges. These types of problems have a great impact in the ecosystem and constitute a serious risk for human beings and marine life.

In the last years, mobile autonomous robots have been developed in order to solve human problems, being the service robots the most popular, those are robust machines that integrate several science of study such as control engineering, mechanic design, computer vision, computer science, etc., in order to collect and dispose garbage in specific deposits. These robots are designed to be functional although they are not visually accepted by humans.

The IEEE Open category of LARC 2013 proposes the design of an autonomous robot able to gather 12 fl oz. aluminum cans and dispose them in a defined deposit area. The robot must be able to move in an uneven sandy terrain, avoiding the sea water and obstacles such as mannequins, umbrellas and chairs. The scenery simulates a contaminated beach, where the autonomous robot has to collect and discharge all the cans in the field [1]. We propose a functional and aesthetical design that seeks to foster human acceptance. This robot was called 砂殺 – Sunaya (Killer Sand). (See Fig. 1).

Fig. 1. Sunaya

The design and implementation project was developed by undergraduate students with an advisor professor. Researches are mainly conducted by undergraduate students and implemented in the Mechatronic Engineering Section of the Department of Engineering of the Pontifical Catholic University of Peru (PUCP). This section aims to develop interdisciplinary robotics' research projects that promote the integration and collaborative work of different careers to find solutions to specific problems.

The following paper gives an overview of the hardware used, the software implemented and future improvements for the project.

II. SYSTEM OVERVIEW

The robot is based in the conceptual design used in the National Aeronautics and Space Administration (NASA) called Rocker-Bogie [2], which provides an all-terrain and functional robot. In attempt to implement a visually accepted by humans design, the manufacturing wasn't realized by conventional materials such as steel or aluminum.

ULTEM* 9085 and polycarbonate were the raw material chosen to manufacture the main parts of the robot. Most of the mechanical structure was manufactured by a 3D Printer, Fortus 400mc from Stratasys Company; technology used to give Sunaya a aesthetically design.

In order to avoid obstacles such as persons, chairs, umbrellas, etc., the robot sense periodically its environment using ultrasonic sensors and a webcam.

A graphic user interface allows an easy handling of the user. The robot is constantly running a real-time image processing with the less CPU timing consume, using a free open source computer vision library (OpenCV) which is written C++.

The overall system function is shown in the block diagram as seen in Fig. 2.

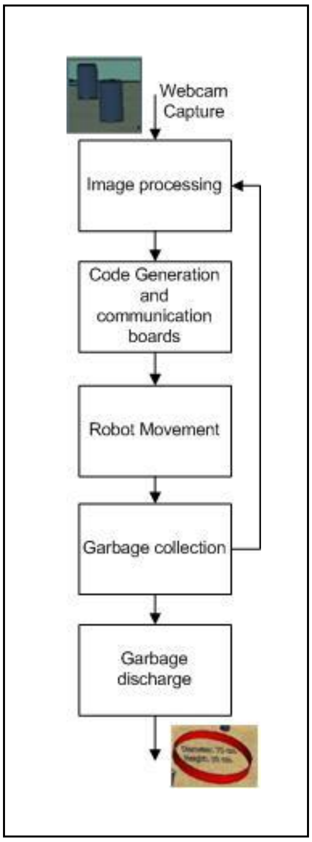

Fig. 2. Block Diagram

III. MECHANICAL STRUCTURE

For the purpose of accomplishing the designated mission for the robot, the mechanical design was subdivided in different modules. Each module was designed with a specific task, this allows an efficient and practical way to manufacture, test and repair the components, maintaining an aesthetical model.

The principal mechanical components of the robot are the body, drive train, suspension and wheels. The lateral sides of the system were designed to contain the electronic components and the laptop for image processing. The frontal and backward sides provide a mounting placement for the ultrasonic rangefinder sensor. In addition, the batteries and the differential steering box are placed at the bottom of the robot in order to keep the mass center as low as possible.

Design goals:

- Demonstrate that functionality and esthetics can be integrated in robot designs.
- Utilize and explore the capabilities of the 3D printing technology in the manufacture of the robot components.
- Apply and test the performance of the rocker bogie suspension system.
- Simplification of an actual rocker boogie Mars rover system.

A. Rocker Bogie Suspension System

The rocker bogie suspension is used to maintain the body at the average of the two rockers and maintain a constant normal force on each wheel. The term 'rocker' is referred to the side beams where each wheel motor is located. These rockers are connected through the robot body by a differential gearbox. Some other rovers such as the Mars pathfinder use a differential bar to achieve the same principle. Since the dimension constraints are small, the differential gearbox was chosen to save space inside the robot. Rocker-Bogie suspension has no spring or bumpers, decreasing the overall complexity and allowing the robot to climb over obstacles and moving in uneven terrains. For a good performance of the system, the robot speed should not exceed 15 cm/s, the rocker bogie system was chosen for its mechanical robustness and climbing capabilities.

The overall design is composed by four motors, two in each rocker. The motors and their wiring have been installed inside the structure in order to protect them from the sand and other environmental hazards which can potentially damage these components. By designing a four wheel rocky bogie gearbox as seen Fig. 3, we could achieve a less complex system and a light suspension system; in comparison with the conventional Rocker-Bogie system which has a differential gearbox and six independent motors distributed in six wheels [3] [4].

Fig. 3. Rocker Bogie Suspension

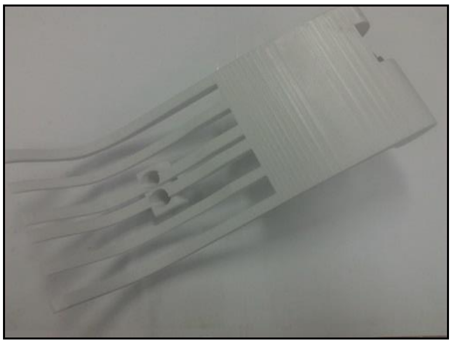

Fig. 4. Collector Mechanism

B. Desgin and Manufacturing

One of the main objectives of the project was testing the capabilities and features of 3D printing in the manufacturing of functional parts for robotics systems. 3D printer capabilities allow creating complex form factors in order to foster human acceptance of robots in daily work.

The 3D printer used was a Fortus 400 by Stratasys. This printer is able to extrude ABS, polycarbonate and ULTEM with 0.1 mm. precision. The material chosen for the rocky bogie suspension was ULTEM, due to its mechanical features.

Concerning the robot design, each rocker is composed of three main components and other five auxiliary ones. It was designed as a single piece in order to increase the robustness and aesthetics characteristics of the design. The rocker gathers the two motors in an asymmetrical configuration relative to the hub and their wiring through internal channels. The additional components are the two bushing adapters that relieve the flexion stress in the motor shaft and increase the structural stability of the design. Finally, the auxiliary parts are the protection covers that isolate the motors from the exterior.

C. Wheel Selection

Another important aspect in the locomotion of the robot was the suitable choice of the wheels. By taking in consideration the uneven and sandy terrain, a high contact area and an adaptable surface were the most important factors in order to maintain a high traction on each wheel. Taking these factors in consideration, the wheels selected were HPI 1:8 monster trucks, specially designed for uneven terrains.

A special kind of coupling was manufactured for each wheel. These couplings allow wheel connection to motors and serve as bushings, which reduces flexion stress on the internal bearing on the motor gearbox.

D. Collector Mechanism

The can collector mechanism is based in an excavator truck, it is designed to dig out the cans from the sand and deposit them in an internal deposit where cans are gathered until the discharge sequence is initialized.

As shown in Fig. 4, the mechanism has cavities and a flexible geometry in an attempt to sift the sand.

IV. ELECTRONIC SYSTEM

A. Hardware

1) Ardupilot Mega v2.5

Ardupilot Mega (See

Fig. **5**) is an open source board compatible with Arduino software, commonly used for unmanned mobile robots such as scale planes, multi-copters, four-wheel robots, etc. Data processing, control and communication are monitored by the Atmega2560, microcontroller assembled in this board. Ardupilot Mega is connected to a notebook using a USB cable.

Fig. 5. Ardupilot Mega v2.5

2) Roboclaw v2.0

Roboclaw-15A v2.0 (See Fig. 6) motor driver has a PID model used to control the four motor responsible of the robot movement. The board is connected to the Ardupilot Mega via serial and can be programmed using Arduino software [5].

3) Arduino Motor Shield

Arduino Motor Shield (See Fig. 6) is a two motor driver open-source board used to control the motor coupled to the collector mechanism. The limit current per channel is 1A [6]. Arduino Motor Shield sets a PWM and stops when the limit switcher sensor assembled to the body of the robot is HIGH.

Fig. 6. Left: Roboclaw v2.0 - Rigth: Arduino MotorShield

4) Servomotor

Using a 15 kg.cm Tower Pro servomotor the collector mechanism discharge the cans previously stored at the respective zone.

5) Ultrasonic Sensors

The obstacles detection is provided by the ultrasonic sensor SRF04 (See Fig. 7) with a range of 10.7 meter. The measure of distance sets a flag HIGH if the object is closer to the robot [6].

6) Webcam

The image acquisition is provided by a Logitech C525 webcam (See Fig. 7*)*, chosen for its good performance in outdoor environments with a variable light intensity.

Fig. 7. Left: Ultrasonic Sensor - Right: Webcam

7) Power Resource

The Ardupilot Mega is powered by the notebook previously mentioned. Arduino Motor Shield digital hardware, the ultrasonic sensors, and the limit switcher are powered by the power pins in the Ardupilot Mega. Drivers board are powered by the batteries ZIPPY Flightmax 8000mAh 3S1P 30C.

B. Data Acquisition and Communication

The sensing of cans , obstacles and border limits made by the webcam and processing in the netbook generates a code that is sent to the microcontroller via serial USB. Ardupilot verifies each part of the code, if one variable differs of the settings of the program the robot automatically stops. Once the code was received, the microcontroller sets the parameters of the roboclaw libraries and sent the commands via UART.

The ultrasonic sensors, servomotor, limit switcher and the Arduino motor shield are connected to the digital pins of the Ardupilot to acquire and sent data.

V. VISION SYSTEM

A. Robot Hardware

Computing power is provided by a notebook running Microsoft Visual Studio C++ using OpenCV open-source library in Windows 7. In order to capture frames for image processing, a webcam is connected to the notebook via USB. The camera has been installed in the middle-top of the robot with an adjustable mount.

B. Image Processing

Image processing guides the robot through the competition area and approximates the final position of the located garbage [5] (See

Fig. **8**). Using digital image processing we are able to identify the difference between humans and other obstacles.

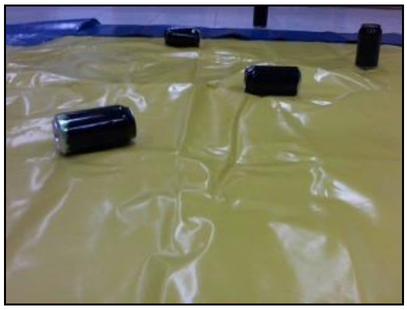

Fig. 8. Competition Area with Garbage

The webcam captures three layers, Red, Green and Blue, containing unnecessary information. In attempt to discard this data, the three layers are transformed into one grayscale layer.

Smoothing and a Gaussian Filter are applied to the image, in order to eliminate information that is unnecessary for the application such as noise and other elements of the environment. In order to segment the garbage, the application uses an adaptive threshold [5]. This method takes the difference between the target object and the background, obtaining a binary image where garbage can be recognized.

Ultimately, using OpenCV [6]the position x and y in pixels can be known by the Moment Theory algorithm. (See Fig. 9).

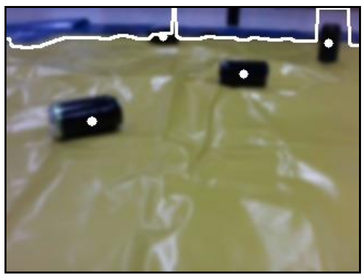

Fig. 9. Can Detection

C. Navigation and Control

Two different programs are running on parallel to navigate and control the robot, Visual C++ for image processing and Arduino software for Ardupilot programming. Both are communicated via USB serial port. For the purpose of having successful results, the system operates an algorithm as shown in the flow chart diagram. [6] (See

Fig. 10).

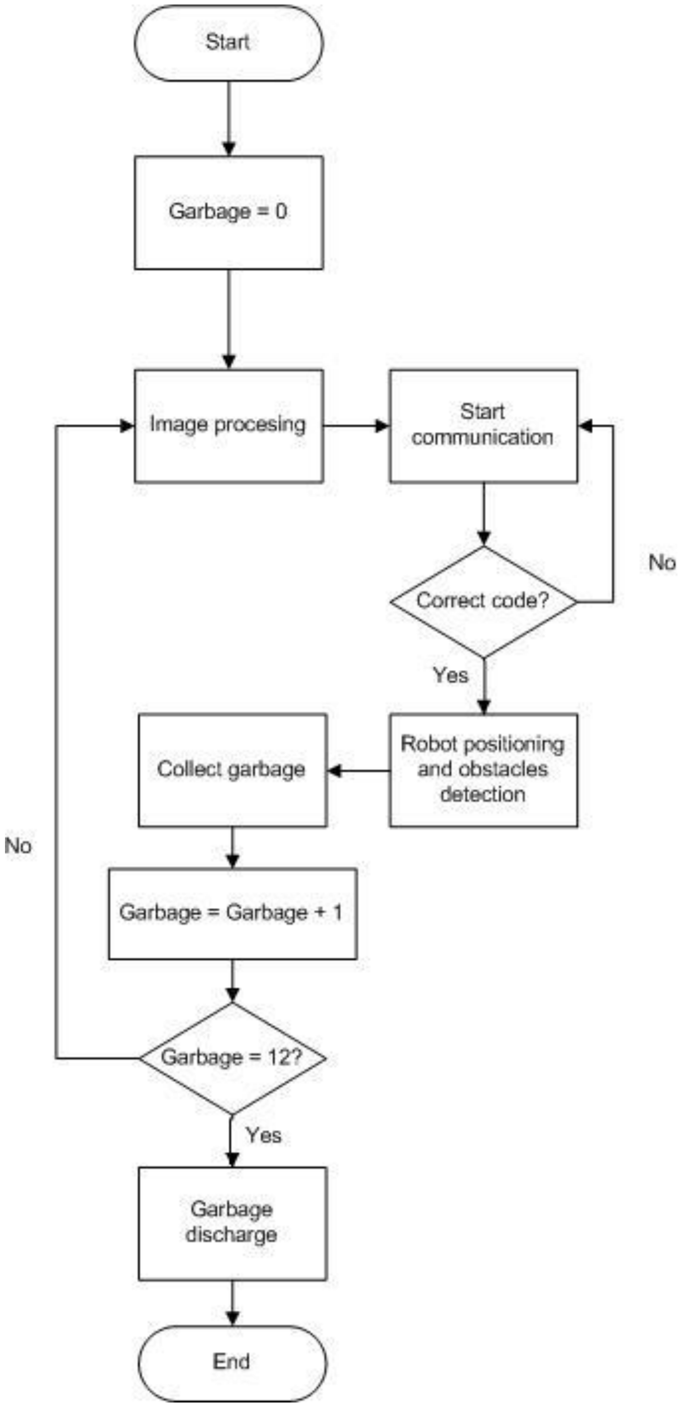

Fig. 10. System Algorithm

D. Blue canvas and trash deposit detecting

The working area of the robot is limited by a blue canvas that represents the ocean, meanwhile, a 70mm diameter red deposit is located at any position. First we have to be sure the application must be able to detect any change in the intensity of blue and red. So we try to detect the color using HSV transformation, Hue-Saturation-Value. Those results will be combined into RGB in ranges filters. So our little improvement will locate red and blue with HSV layers, however we will eliminate the noise with a ranger in RGB layers.

VI. Conclusion

The mechanic and electronic design of Sunaya was an interdisciplinary program research, that simulates work in life, on parallel, represents a key for pollution problems.

Future Work involves the implementation of new research programs in subjects such as Human Robot Interaction, Cleaner Robots, Mars Rocker Bogie Suspension Systems, etc.

The interdisciplinary design of this work could improve students' abilities concerning mechanical and electronic design, computer vision algorithms and group work.

Acknowledgment

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