Prometeo: Beach Cleaner Robot

Oscar Cieza, Carlos Ugarte, Elizabeth Gutiérrez, Javier García, José Tafur

***Abstract*— Prometeo is a mobile robotics research group. For this opportunity it has been designed a robot to counter the environmental pollution problem; in this case the robot is able to navigate on the beach, collect cans found in this area and transport them to a deposit. Esperanza Negra is a differential wheeled robot with a transmission based on a chain system (2), each one driven by a DC motor (Pittman Express - GM14904S104 model). Additionally it has an excavator arm driven by servomotors, a reservoir of cans, a 3D camera (Minoru) and a embedded computer, the last two in order to perform stereoscopic algorithms to identify Scenario Limits and the position and shape of the objects.**

I. Introduction

The progress in various fields of robotics improves people quality life and their environment. In the current context of environment protection and care, waste collectors robots loom large, because they locate, collect and dispose garbage in a controlled, autonomous and fast way. In this specific case it was implemented an autonomous robot capable to navigate in sand, collecting cans and transporting them to a particular deposit. Developing waste collectors robots is currently a research and investment matter, so this document presents an efficient solution to the problem of accumulation of garbage on the beaches.

Prometeo is a team for developing mobile robots by the Mechanical Engineering section, Faculty of Science and Engineering, Pontificia Universidad Catolica del Peru, Peru. The following report presents the preparation of the mobile robot prior to their participation in the Open category of LARC (Latin American Robotics Competition) 2012.

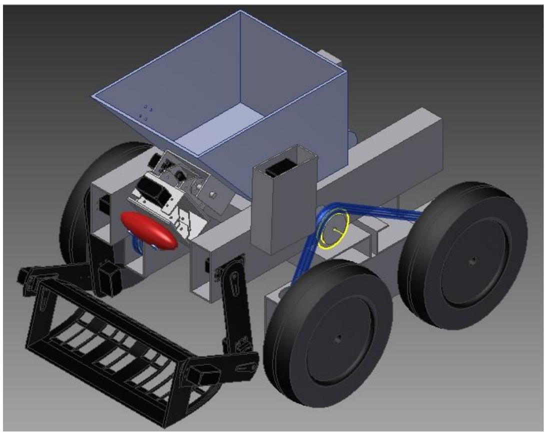

Figure 1. Esperanza Negra robot.

This paper is focus on a brief Systems Overview, the mechanical structure and the vision system.

II. System Overview

In order to deal with the objectives proposed by the OPEN LARC, the beach cleaner robot require of a Mechanical structure, a control system, a vision system and; a decision making and trajectory planning system.

The following explains the operation of the global system, as seen in Fig. 2.

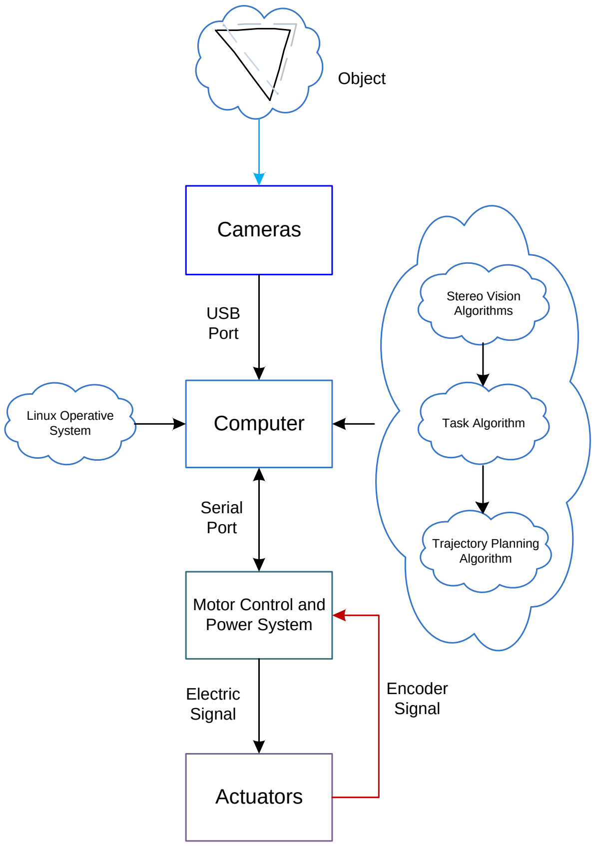

Figure 2. System Overview in the operation's cyclic mode

In a cyclic operation of The System starts with a 3D camera, it sends the images by USB port to an embedded computer who processes all the System's algorithms. The acquired images are processed by a Stereoscopic Vision Algorithm and an object recognition algorithm. This both algorithms allow the robot define the scenario limits, found and recognize the objects in the working area and calculate the relative position of the objects to the robot. The Vision System had been developed using the OPEN CV libraries.

With the scenario limits and the objects positions, the robot formulates a task or verifies a previous one. A task could be: collecting cans or leaving them in the dumpster if it has been found before, else the robot will begin the task of searching.

Once the robot have defined a task, if it is far from the desired object, it calculate the trajectory planning to move the robot to the cans avoiding the obstacles and meeting the constraints of the robot, else it calculate the trajectory to move its excavator arm to collect the cans and put them into the reservoir; then the trajectories are sending by serial port RS-232 to the motors drive.

All the robot's algorithms have been implemented in a Linux operating System with an embedded computer VIA Pico-ITX.

Esperanza Negra has two powered motors for locomotion and nine servomotors for the excavator arm, the pan tilt camera system and the reservoir.

The Motor drive based on ATMEGA 328 microcontroller has a PI velocity control algorithm, a conditioning system for the incremental encoders and can generate the required PWM for all the servomotors. Besides it is connected with the Power System (MD22) to drive the Powered Motors.

III. MECHANICAL STRUCTURE

Esperanza Negra is a robotic system designed in base of a standard aluminum tube (1½ by 3¼ inches) to reduce the cost and weight. The robot's weight is less than 12 kilograms, its size is 440 by 450 by 440 millimeters, has wheels of 21cm diameter and has an excavator arm of 40cm workspace radius. Its main parts are described below:

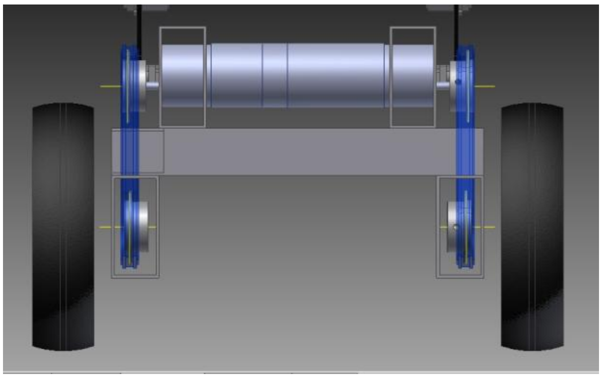

Figure 3. Lower robot mechanical structure

The robot has been planned according to the VDI 2221 (German standard of design). [1]

A. Locomotion

Esperanza Negra is a differential wheeled robot which uses a chain mechanism for its movement. This system is characterized by a nearly constant transmission ratio (due to there is no slip). Each drivetrain is composed of two driven shafts and 1 drive shaft, which is coupled to a DC motor.

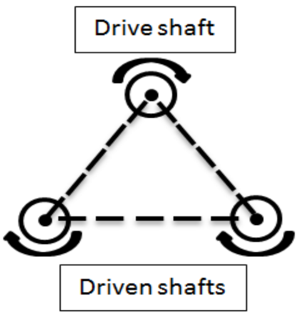

Figure 4. Transmission system scheme

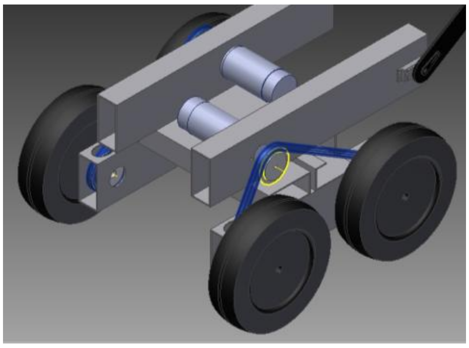

Figure 5. General chain arrangement

This system was performed in order to have an elevated structure at a considerable height from the surface of competence to avoid problems with the sandy terrain relief. A high structure (greater than 14 centimeters) avoids problems with sand mounds present in the competition area.

B. Excavator Arm

This system allows the robot to pick up the cans in any position. It has 3 DOF (degrees of freedom) driven by 6 Tower Pro MG995 servomotors (4.8V: 10.00 kg-cm). In addition, the excavator arm (Fig. 6) can pick up cans buried in the sand. The arm end effector is designed to filter out sand and transport cans into the reservoir.

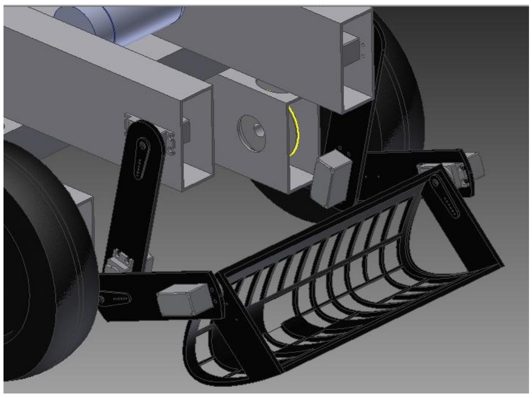

Figure 6. Excavator arm structure

C. Pan Tilt Camera

In order to have a 180 FOV (Fill of view) and the possibility to focus a desired object it has been designed a pan tilt system (2 DOF) that can support the Minoru camera. The pan tilt is inclined 50° to the horizontal plane because it is coupled to the inclined plane of the cans reservoir (Fig. 7).

The first DOF allows a vertical displacement of -85° to 5° with respect to ground and the second allows a horizontal displacement of -45° to 45°.

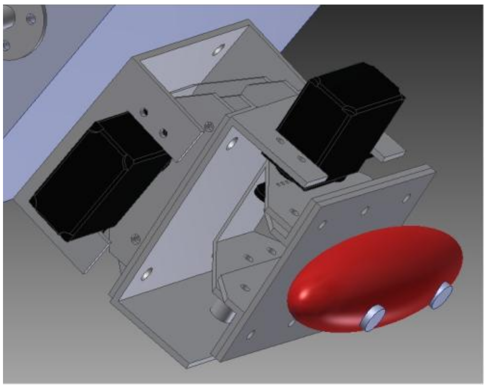

Figure 7. Pan tilt camera design

IV. VISION SYSTEM

One of the biggest challenges of Esperanza Negra is establishing the scenery's limit and the position of all the objects on the beach, actually there are several methods of obtaining these coordinates based on techniques such as pattern recognition, image segmentation, support vector machine, among others; however, it is very important to get the coordinates location of the cans with such precision that allows Esperanza Negra to go to the location of them and pick them up and not waste energy or lost it on the beach. Another important factor is the speed at which data is processed; the idea is that Esperanza Negra doesn't spend a long time to collect few cans on the beach.

In response to this problem, the development of a stereoscopic vision system is presented as a suitable solution, because the implementation of geometric relationships and vector operations allow obtaining the coordinates with a precision that Esperanza Negra will be positioned in right places. These systems are characterized by their level of reliability through the use of two or more images, the use of adequate computational resources.

The following explains the operation of the vision system, as seen in Fig. 8.

The solution related the vision of the robot is to identify both Scenario Limits and the position and shape of the objects in the sand using stereoscopic vision. First of all, the 3D camera makes an image acquisition, then the computer uses the preprocessing and rectification algorithms to prepare the pictures to be analyzed for the Stereoscopic and Scenario algorithms, the last one searches the line that separate the sand with the sea using the blue frame of the RGB frames. The next step is to make a segmentation of the scenario objects, then make the recognition of the cans and or garbage depot and finally to identify the position of the cans to be carried. Finally all the data calculated is send to the Making Decision algorithm.

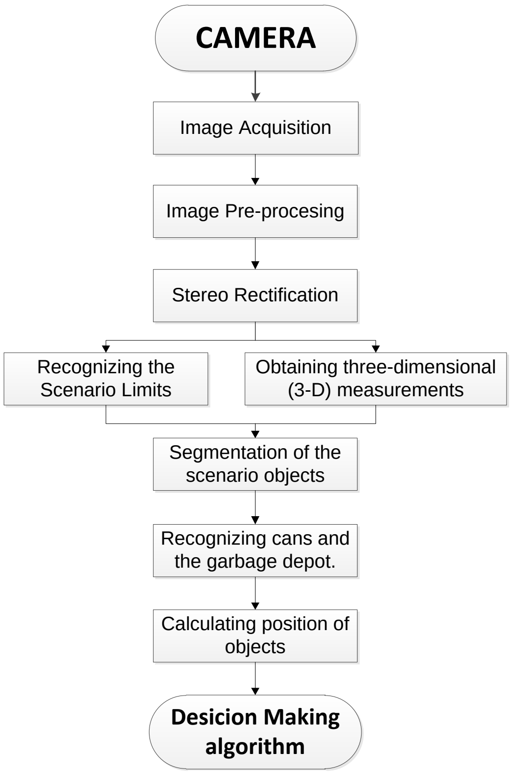

Figure 8. Designed Vision System

A. *3D Camera*

As we mentioned, the system will use Minoru 3D camera [2], which has as its main characteristic the use of two cameras (synchronized with each other), which provide two images (stereo pair), with which it can estimate the location of the cans mentioned. Obtaining two images is very important, because it will facilitate the estimation of the depth of the object with respect to the location of the camera. Another important feature is that the camera will be working from the Linux operative system with the help of the Open CV library.

Figure 9. Minoru: 3D Camera

B. *Stereoscopic Vision*

Stereo vision refers to the ability to infer information of a particular structure in space from two or more images taken from different viewpoints. [4]

The algorithm consists of various steps like: Recognition camera, par stereo rectification, correspondence and triangulation to obtain the coordinates of the objects.

To deal with it, was taken into account, important considerations how the intrinsic and extrinsic parameters defined by the point in space of the can and its projection, these are represented in the following equation:

$$p = MP \ [3] \qquad (1)$$

Wherein:

p = Point projection in the image plane coordinates of the can (x y w)

M = Intrinsic parameters matrix.

P = Point in space with coordinates(X Y Z).

From the above equation, we have the matrix M which contains all the intrinsic parameters of the Minoru 3D camera, focal length and image center for this reason is known as intrinsic matrix.

The extrinsic parameters describing the position and relative orientation of the two cameras (left and right) which has Minoru 3D, then we have the translation matrix (T) which indicates the displacement of one relative to the other camera; so, we have to the rotation matrix (R) which tells the relative orientation of the cameras. Both variables are related by the following equation:

$$P_r = R(P_l - T)[4] \qquad (2)$$

Wherein:

P_r: Projection of point P on the right camera.

P_l: Projection of point P on the left camera.

R: System Rotation Matrix.

T: System Translation Matrix.

It also should consider the effects of radial and tangential distortion coefficients to obtain the correct position of the coordinates in space. These coefficients try to correct the errors that possess the estimation by inherent effects of the camera and positioning sensors capture, among others.

Rectification

Considering various factors, like the errors in the manufacture or position of the planes of the images are not coplanar, then we must re projecting these images so that the rows of images are perfectly aligned; for that reason, once obtained the system model, it should applicable to rectify the images, however, as the position of the images in spatial changes due to rectification process, then we must recalculate the intrinsic and extrinsic parameters of the grinding system. In conclusion, the correction system process is to bring the pairs stereo to a plane parallel, also eliminate or reduce distortion effects (radially and tangentially), with the purpose to reduce the mathematical calculations for obtaining the coordinates.

Disparity and Distance

Applying geometric relations above expressions, the following equations are obtained which allow obtaining the coordinates of the can in the space:

$$X = Z\left(\frac{x_D}{f}\right), Y = Z\left(\frac{y_d}{f}\right), Z = f\left(\frac{T}{x^l - x^r - (c^l - c^r)}\right) \qquad (3)$$

Whereas:

x_D : Distance in pixels of the point p on the image with respect to the center thereof on axis X.

f : Focal distance in pixels.

y_d : Distance in pixels of the point p on the image with respect to the center thereof on axis Y.

T : Translation matrix.

x^l, x^r : Origins coordinate plans images. Subtraction of the two data is called "disparity"

$c^l - c^r$: Centers of the planes of the images on the right and left.

Finally it has been implemented these features with the Graph Cut Theory which allow calculate the Dense stereo for the 3D reconstruction. The OPEN CV library has this algorithm, simplifying the implementation. [7]

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