UNIVERSIDAD CARLOS III DE MADRID

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GRADO EN INGENIERÍA DE SISTEMAS DE COMUNICACIONES

CONTROL CENTRALIZADO DE FLOTAS DE ROBOTS

CENTRALIZED CONTROL FOR ROBOT FLEETS

ABSTRACT

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1. Introduction

Nowadays, in robotics there exist very powerful and robust path planning algorithms. Despite the existence of these algorithms, the application of them in an experimental environment is not such simple and it takes so much effort. Systems involving a lot of individual robots, with infinity of data provided by their sensors increase the complexity turning the decision making into a difficult problem. Simplifying the problem is always a good idea and building a stable system is the base to construct later more complex ones.

The objective is to design a system involving artificial intelligence (AI) and robotics for experimental purposes in path planning. In an experimental environment and through a web cam be able to identify and localize a fleet of robots as well as control it by radiofrequency communication. The initial problem is reduced to one where the robot sees the rest of the objects as obstacles. These obstacles can be passive like a wall or active like other robot of the fleet, but it does not matter the nature of the obstacle itself because when doing path planning we will have to avoid both of them.

2. State of the Art

Mobile robots came up as a tool for exploring inaccessible areas for human beings because of it remoteness location or for being dangerous or expensive. Some tasks are only possible for robots and with a few rare exceptions there is only one robot in the working area. Fleets of robots are the most common distribution used in space exploration, warfare, rescue missions or data acquirement in unexplored territories.

One of the most important subjects when working with fleets of robots is to synthesize cooperative behaviors between them. Cooperative robotics has been an active research filed in recent years due to the importance of organization when developing tasks. Using a group of robots working cooperatively to execute tasks not only increases robustness and efficiency of task execution but also allows doing some tasks a priori impossible to do with a single robot.

When working with fleets of robots two solutions are presented:

- Centralized control: A central unit is responsible of controlling, supervising and establishing the actions concerning the robots in the fleet. All path planning and decisions are taken in the central unit or computer. It is necessary to establish a communication system between the central unit and the robots in the fleet. The advantages of this centralized control are that all conflicts concerning the robots are solved easily by the central unit and the orders can be transmitted directly by this unit to the fleet. The problem with this system is that if there is a failure in the central unit the whole system will be down. The importance of centralized control can be seen in real time applications where cooperative work is necessary to achieve a common goal [1].

- Autonomous robots: In this solution the robots do not depend in any central unit, they depend on their selves. They have to be able, through sensors, to characterize the environment and take their own decisions such as movements to do the tasks. Currently, path planning algorithms for autonomous robots are based in fuzzy logic [2]. Communication is also needed here in order to speak with the other robots in the fleet. In general these robots are big, with multiple sensors and with self-localization and self-planning systems integrated. The main advantage of this solution is that if there is any problem and one robot gets broken it is not any problem at all for the rest of the fleet. The other robots will consider it as a passive obstacle and will avoid it as if it was a rock. The disadvantage is that this solution is extremely complicated because you have to control a lot of variables. You have to prepare the robots to deal with any circumstance and to think independently as well as teach them how to take the best decisions not only in movement but also in wireless communication to communicate with the rest of the fleet.

At the moment, the tendency is to reduce the dependence in a centralized system in order to make the fleets more autonomous to deal with unexpected obstacles or events [3].

Since the guidance of a mobile robot involves its localization in a determined environment we decide for this project to build a centralized system involving vision algorithms to analyze the working area and detect the robots in the fleet as well as it position and orientation. Then through the same computer be able to drive the robots wirelessly by radiofrequency communication. The vision algorithm should be capable to tracking the movement and represent the coordinates of the robots in real time conditions.

3. The project

The objective is to construct a centralized system for experimental purposes. The requirements that we will demand to our system will be robustness, being intuitive for the final user, low cost, capable of identifying several robots and low percentage of false positives when detecting. Some restrictions have to be considered since we are working in a limited area. We will have to design simple and small prototypes in order to obtain good results.

The project is divided in two main parts, the one concerning the vision system with the algorithm to detect the robots and the one concerning the electronics and the construction of the robots. Both parts are based in Open Source tools. We believe that these Open Source platforms help spreading knowledge. These projects are worldwide accessible and everyone can benefit from them. This encourages other people to develop and publish so in the end large communities grow with the only objective of teaching and sharing knowledge without cost. As one of the objectives of the project is to make a low cost system we decided that the best way to do it was basing it in these tools.

3.1 Vision

This part is devoted to the development of the algorithm capable of tracking the robots. The design of the algorithm is based in color identification. Each robot will have at it top a label consisting in three smaller color labels. This will allow the system to know the position of the robots in the working area as well as its orientation.

The algorithm has three main parts:

- Calibration. The first part of the algorithm is calibration. As we are detecting colors this step is absolutely necessary to guarantee good results. The user is asked to place in a determined area a card of the color identifying the first robot. Then the same is asked for the second color, which will identify the second robot. We can see the calibration step in figure 3.1.

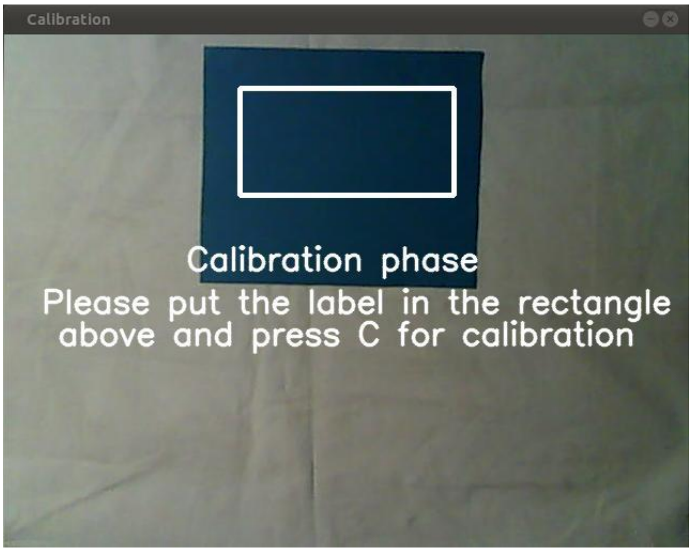

Figure 3.1: Calibration phase

- Segmentation. Next step is to get rid of all useless information of the image provided by the webcam. With the values obtained in the calibration we perform a segmentation that will lead in a binarized image where the white pixels will tell us that the color is in the working area and the black pixels telling that the color is not. In figure 3.2 we can see the image provided by the webcam with some extra information that we will explain in the next part of the algorithm. In figure 3.3 we can see the binarized image resulting of applying this second part of the algorithm to the previous figure detecting green color.

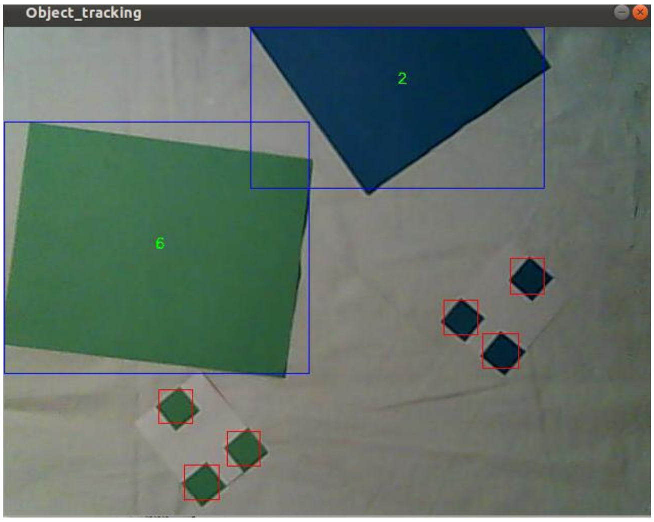

Figure 3.2: Label identification

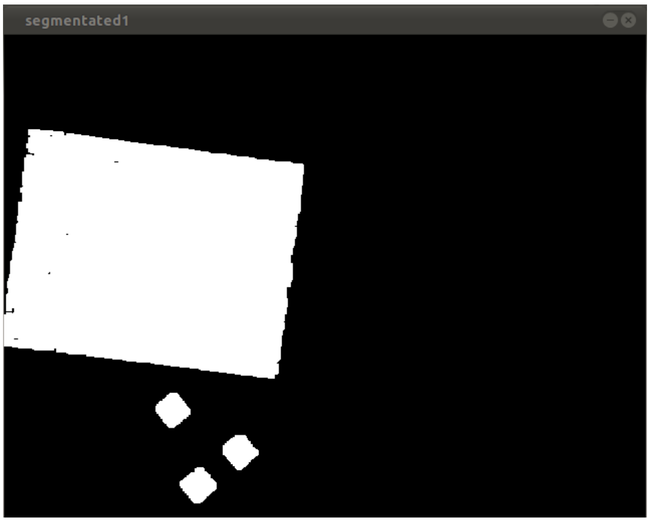

Figure 3.3 Green color segmentation

- Labeling. The final part of the algorithm searches for pixels conforming unique labels. This is done by grouping sets of pixel that are near to each other. If we apply this label to figure 3.3 the result is in figure 3.2 where all green labels are correctly identified. Note that also blue labels are identified. This is due to the calibration process, the second color calibrated is the blue one and this will identify later the second robot.

3.2 Electronics

This part is devoted to the design, construction and programming of a mobile robot capable of communicating with a computer and interpreting movement orders for it teleoperation. The design chosen is a simple one based on a chassis and two wheels. The third supporting point of the robot is a marble of 16mm of diameter that is fit into the structure and provides mobility.

The electronics that will provide the structure mobility and communication are based in Arduino development platform. An Arduino UNO board, containing Atmega328P microcontroler will be the brain of our robot and will be the responsible of transmitting movement orders to the servos as well as communicating with the computer. The radiofrequency communication will be provided by MaxStream XBEE modules based in Zigbee technology. These modules, through an Arduino shield will be directly connected to the board and will provide the robot with wireless communication. In figure 3.4 we can see two robots completely built.

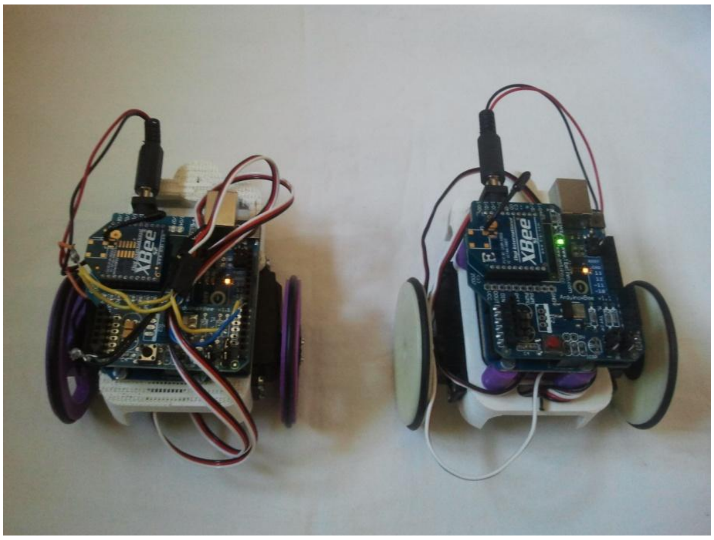

Figure 3.4: Robots

4. Results

In this chapter we will explain the results obtained. The algorithm also represents in two virtual maps the position of the robots in the working area as well as the space occupied by them. In figure 4.1 we can see the representation of the color labels by circles and the union between them forming a triangle represents the presence of a robot. A small point between the circles represents the centroid of the robot; this is the theoretical center of the robot. And a black line is also represented in order to show the direction where is heading the robot. In figure 4.2 we see another virtual map representing the boundaries of the experimental area as well as the space that will occupy the robots that would be carrying the labels.

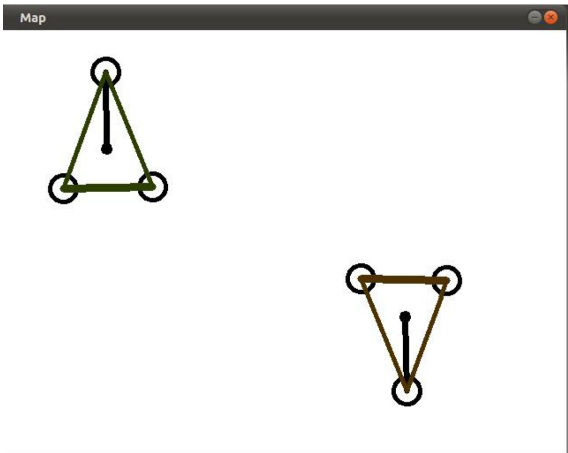

Figure 4.1: Position and orientation of the robots

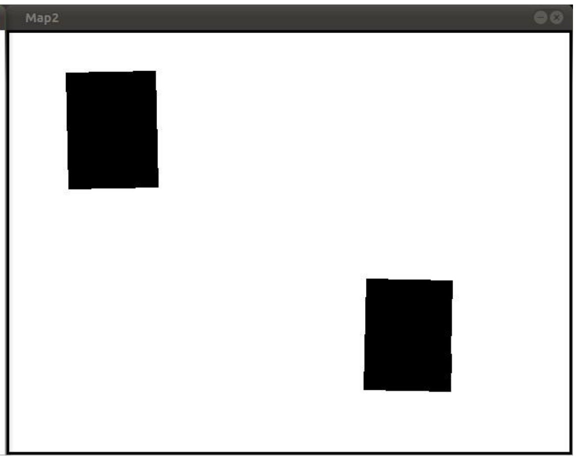

Figure 4.2: Space occupied by the robots

Also the coordinates of the centroid are printed in terminal both in pixel coordinates as well as real coordinates of the working area. Note that the center of coordinates is situated in the upper left corner of the image.

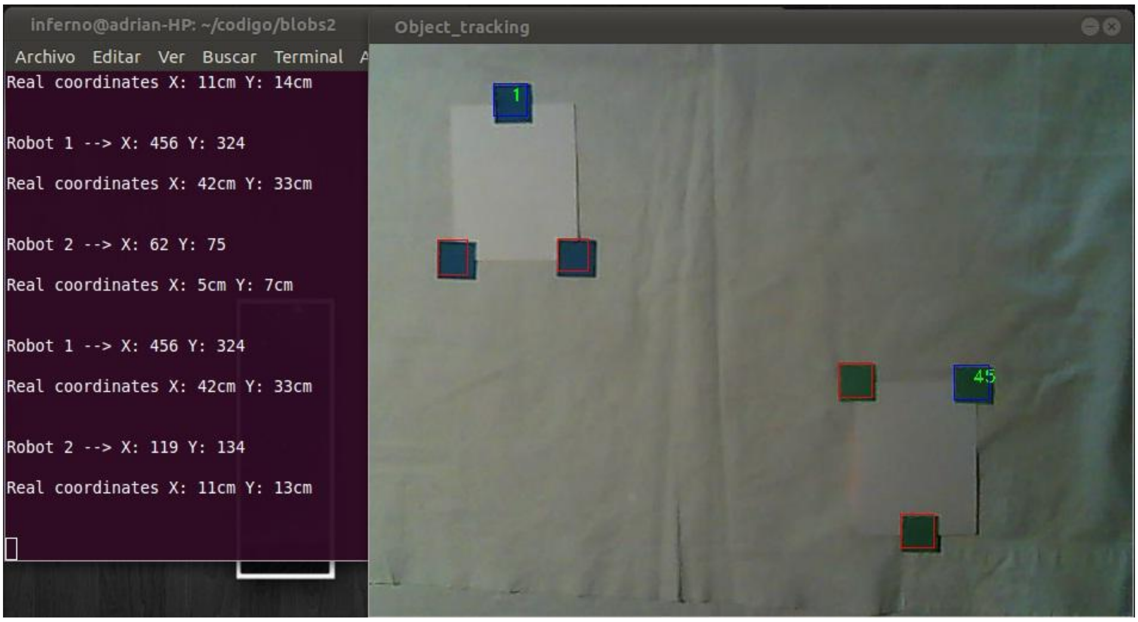

Figure 4.3: Centroid coordinates of each of the robots.

By doing several tests we determine that the lighting conditions are essential for the correct performance of the algorithm. A well lit area increases the detection getting tracking percentages above 90%. This data is measured by computing the ratio between the number of frames where both robots are tracked and the total number of frames. In the following figures we can see how the algorithm is capable of tracking the robots when moving. The robots have at the top of them the previous labels used by testing the algorithm.

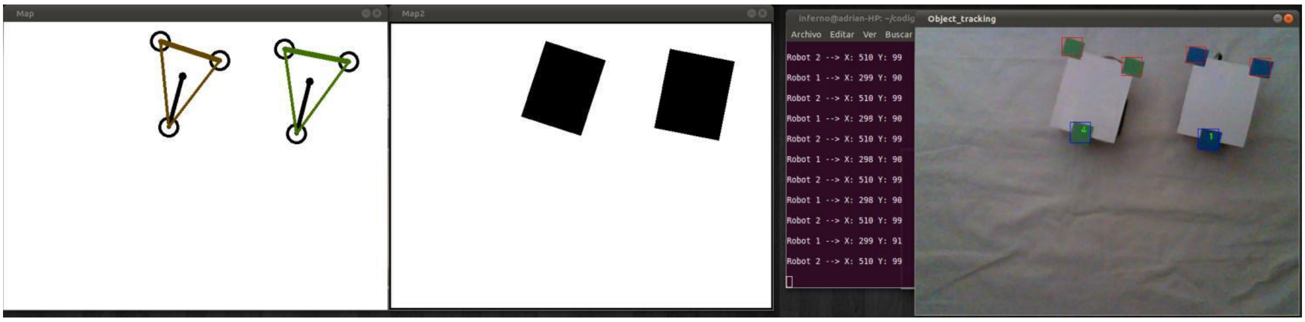

Figure 4.4: Frame 1 of the movement sequence and results

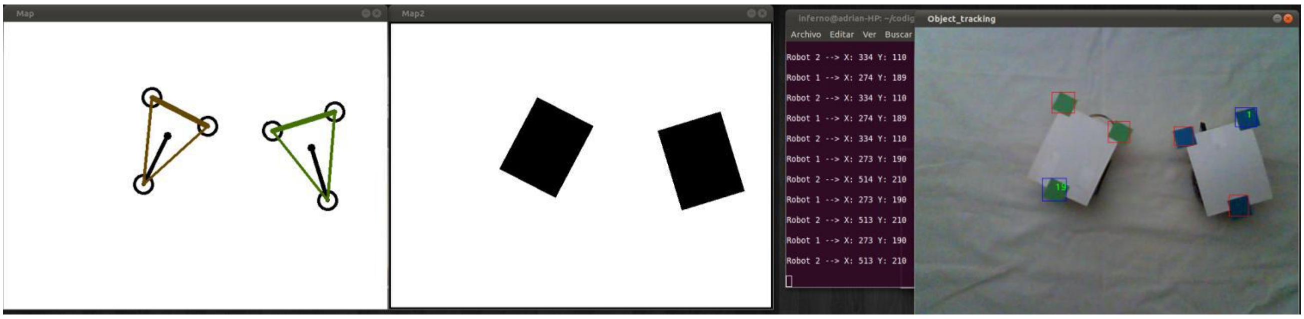

Figure 4.5: Frame 2 of the movement sequence and results

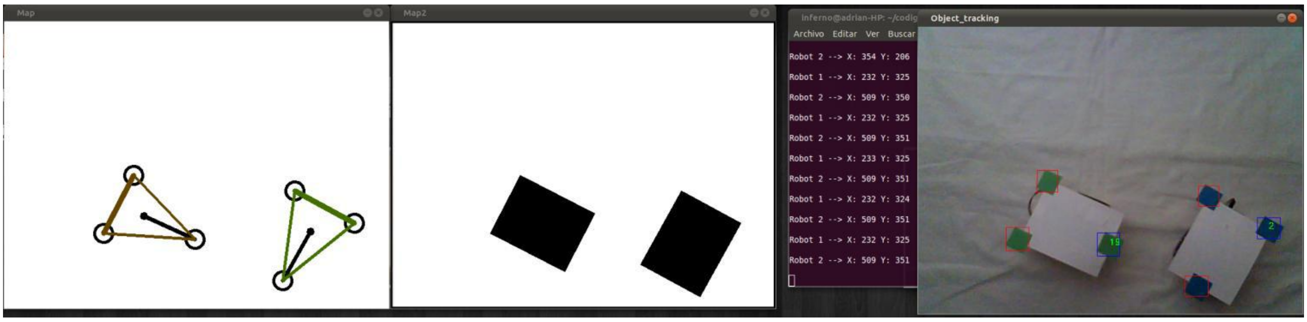

Figure 4.6: Frame 3 of the movement sequence and results

Processing time is measured in order to see how long it takes the algorithm to analyze and process each frame provided by the camera. The result is that the processing time is independent of the movement of the labels and is around 60 ms/frame not depending if the labels are static or are moving around the working area. This makes sense since each frame is processed individually. Figure 4.7 shows through a histogram the processing time of the algorithm.

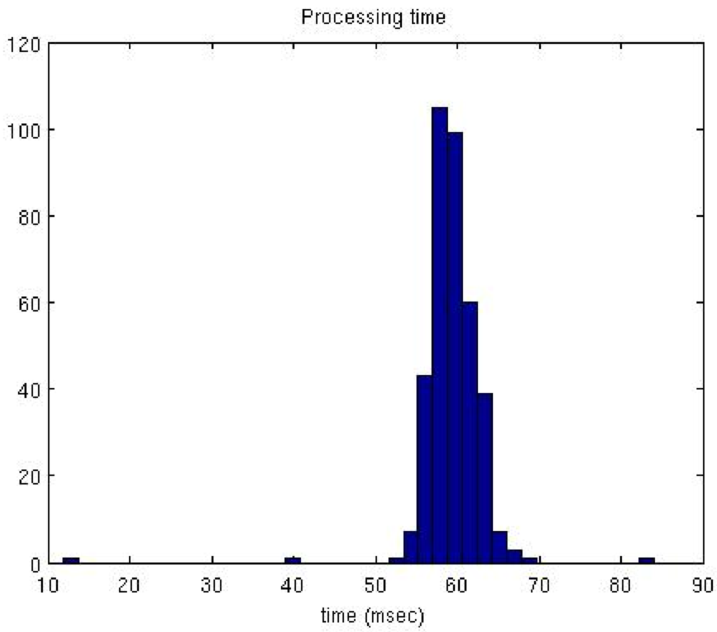

Figure 4.7: Processing time for each frame

5. Conclusions

The objectives achieved with the project are the following:

- Creating an experimental platform with a vision system capable of localizing robots in a working area.
- Prototype construction.
- Being able to integrate Arduino boards to our robots providing them with movement and communication through servos and radiofrequency modules.
- Stablishing serial communications between the Arduino board and the computer.
- Being able to teleoperate robots wirelessly.

Despite centralized control is a solution already developed for controlling robot fleets with this project is proved that it is possible to build a reliable low cost system based on Open Source tools. With a vision system formed by a webcam and a computer we are able to achieve tracking percentages above 90%. This work has been thought to be the basis to construct more complex systems in the future.

Arduino platform has been proven to be an excellent solution for mobile robot construction. The easiness for connecting sensors and modules in these boards removes obstacles for developers making the learning experience even more enjoyable.

Future projects based on this one will be based in path planning. One of the maps represented by the tracking algorithm shows the areas occupied by the robots in the working environment as well as the area boundaries. This information can be very useful when planning trajectories because you know directly which space is occupied. When planning a trajectory from one point to another you will have to avoid these areas in order not to crash with walls or other robots of the fleet.

References

[1] Norman Weiss, Lars Hildebrand. An exemplary robot soccer Vision System, CLAWAR/EURON Workshop on Robots in Entertainment, Leisure and Hobby, 2004.

[2] Vamsi Mohan Peri. Fuzzy logic controller for an Autonomous Robot, master thesis, Department of Electrical and Computer Engineering, Cleveland State University, 2002.

[3] R. Alami, S. Fleury, M. Herrb, F. Ingrand, F. Robert. Multi Robot Cooperation in the Martha Project, IEEE Robotics & Automation Magazine, Mar 1998, vol 5, pages 36 - 47.