SLAM maps builder system for domestic mobile robots navigation

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Mobile domestic robots require information to navigate throw an assigned exploration area, this work provide a solution using the pattern recognition of icons distributed in a house to identify rooms and build an array used as a text topological map, allowing to realize explorations in a previously known way displaying the angle, direction and viability.

Artificial vision, Robotic navigation, SLAM, RGB.

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1. Introduction

Today diverse disciplines in the robotics field require navigation in environments, to find objects, and get references for decision making as guidebots, nursebots and contests as robo-home, were not enough just to have sensors to avoid obstacles or cameras for pattern recognition, it must have a system capable to create maps simultaneously navigates in a new environment as a house, allowing an automatic recognition of assigned rooms with icons.

2. Artificial vision navigation

Robotic navigation is a research area and a very used technology for artificial intelligence; in cognitive robotics the main goal is build a technique composed with the better vision algorithms or characteristics to get a performance evaluation in data obtaining navigation in a real environment.

The maps are used to represent a zone using a simple form plane or to analyze conditions in a represented area, also depending kind of map it will the number of details, representations to have, and information to contains.

Coordinates are those points inside a map can locate an object in a specific zone of the represented area, the description of the extension from one point to another.

An image is a cell composed of pixels, which are the smallest components of a digital image, each pixel is a space in the computer memory that stores a number which represents the definition of color and brightness of an image area, being able to define a unique single color simultaneously.

On the other hand, the number of pixels defines the information contained in an image. To represent an RGB image an array of $M \times N$ dimensions is formed with vector classes elements, where each vector is composed of 3 items which are the RGB channels, whose interval's values are included between 0 and 255 in a closed interval.

Vision systems are those able to capture images used for the machine vision process in a computer system, or visual information acquisition of items in an environment.

The basic parameters in the vision systems development are the view field, resolution, depth, focal length, contrast, modulation transfer function and distortion.

Map builder systems are intended to solve complex problems in navigation creating geographical models using specialized software and hardware to capture storage and manage the obtained data.

A guidance system for navigation builds routes with the initially provided elements as antennas and satellite maps, used as references to build routes and reaching a goal.

Topological navigation is an anthropomimetic technique to plan robot movements, travels, and find goals or objectives without a graphical map using instructions with descriptions, marks and environment conditions as doors, throws and crossroads. The landmarks are descriptions of perceptual interest in some objects as a room for the domestic roboticist, and this could be natural or artificial as the icons or draws.

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The maps builder system for domestic mobile robots navigation, group the recognized labels distributed in a house representing a room each one.

One of the most common techniques used in robots navigation is the SLAM (Simultaneous Localization and Mapping), this allows a robot to know its own position and make "simultaneously" a model of the world building a map, calculate distances, routes and travel through an environment.

The system can be used as a tool for the roboticist in task planning, topological navigation, maze solving, SLAM applications, graphs, search, trajectory experiments or any, independently of the architecture and programming language used in the robot. The maps builder system creates a text file in real time and simplifies the programming work to read the text chain and link to conditions in the robot behaviors.

3. The maps builder system

The system begins with the image acquisition captured by a camera with a resolution of 640 x 400 pixels; this image is sent to the corresponding module to build a route through the line detection using the Hough transform, obtaining the parameters for the robot navigation.

The same image is processed by the pattern recognition module. Using the previously learned labels, the system will search rooms' images stored, which match with the new acquired ones; the block brings the result of direction and founded labels name and simultaneously getting the movement and location of the label, at the same time build a stack array as map as shown in Figure 1.

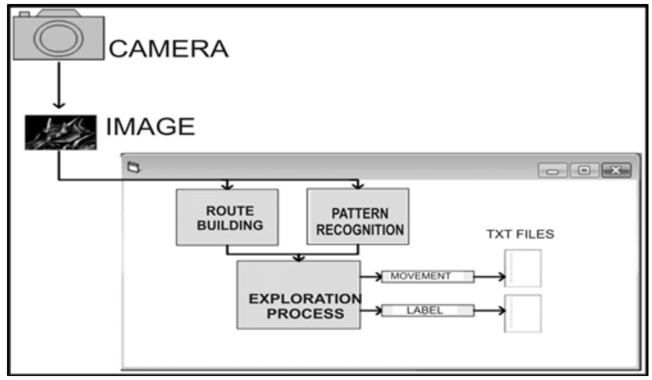

Figure 1

A. Concatenation

Simulink have a video input device detection module and allows the use of custom outputs as one channel or three colors.

The data acquisition subsystem detects RGB colors and builds the group of spectra concatenation getting the labels detection as shown in Figure 2.

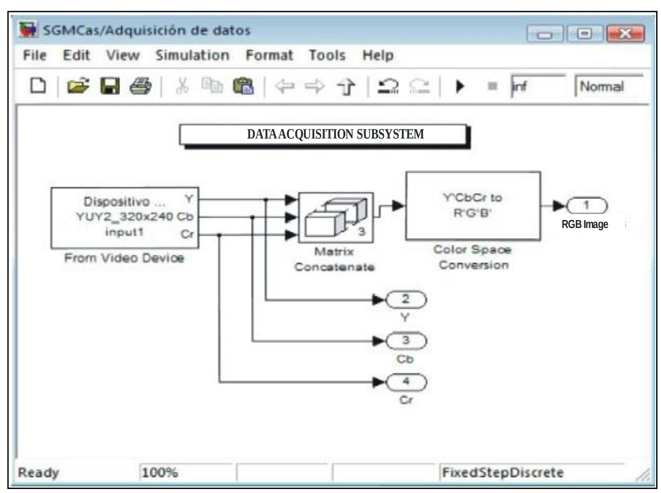

Figure 2

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B.Tracking

The tracking kernel is obtained through Hough transform; it takes a representation of the parameters and compares it with the geometrical figures acquired through the vision system building a statistical location and sampling points to determine their membership respect to a segment, indicating the existence of a doorway or an entrance to another room.

Using the Hough transform block to find lines in an image, it can maps points in the Cartesian image to curves in parameters for the Hough´s block, where Theta means the columns and Rho the rows, by the formula: $Rho = (x (\cos\theta)) + (y (\sin\theta))$ [1].

This subsystem generates a binary image $M \times N$, where Pd and θd are vectors containing discrete values from the parametric space by P, θ, $P \in (0, \frac{(M2+N2)}{2})$ and $\theta \in (0,180)$.

The algorithm segments an image and detects which lines forms an entrance as a room. The detection begins with the comparison of frame sequences with different intensity and the pixels location with more intensity to build two segments, the intersection of both, form one angle. The block returns parameters named as “detected line”, “drew line”, “valid line”, “invalid line” and “rotation angle” as shown in Figure 3.

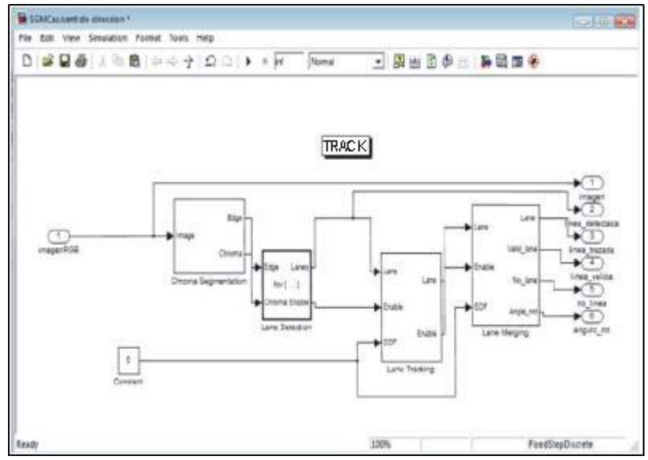

Figure 3

C Movement

Using two intersection lines the movement module uses the tracking subsystem obtained variables to draw arrows and indicate the direction where a room is detected.

“Rotation angle” variable inherited of the tracking subsystem draws the viability arrow and the chain containing the direction-angle.

If the system can´t find any line, or finds 3 walls, it sends an error message with an *“X”* indicating there is no door or viability.

When is found, an arrow with his respective “rotation angle” will be displayed.

This is a combination in real time of the arrow's video module and the angle module, indicating which way the robot must take to travel and find a recognized pattern as a room.

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D Labels detection

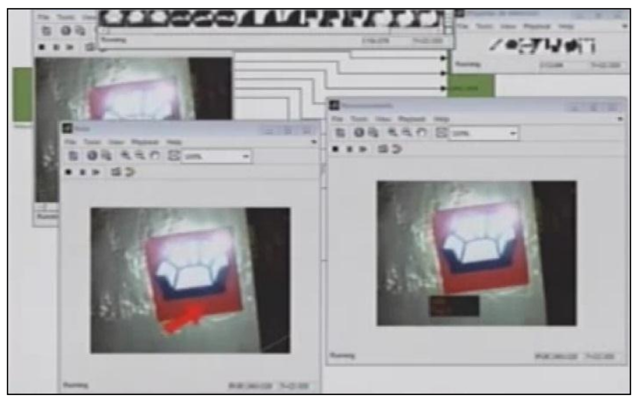
Labels are images as icons and represent semantically a location in the house, using topology and are linked to a chain. The system's user can build or customize his owns labels linked to a chain to will read from the text file when the label contains features to be considered as a pattern, and has been stored at least with three instances[2] with different angle. These images can be customized with any icon by the user to be used in robot navigation; the images must have a size of *90 x 90* pixels, red background and one black and white icon.

The exercise was made with 7 images labeled "Entrance", "Dinner room", "Kitchen", "Closet", "Bathroom", "Living room" and "Laundry room". Video input is formed by three channels and uses the Cr (Channel red) bringing data of red color intensity. "Labels detection" subsystem uses the modules of "detection" and manages the red color making an interruption with a call to the "icons' analysis" module. The second one to activate is "Draw" and measures the label dimensions. "Recognition" is the next module and compares a pattern "room" formed by the image instances data base named "labels" with different angle if the camera has captured one label, identified it, processed it and recognized it by the comparison of the icons' knowledge base using the previously stored labels library, then the label will be semantically linked to the corresponding chain's name of the room and stored in the map text file.

E. Storing icons as labels

Labels are patterns that identify a place in map. To create one label's library previously stored to identify rooms in navigation, must be created some artificial landmarks to act as image labels storing the described features; they can be packed in a .mat file and storing the images knowledge data base. Each label must be stored using 3 shots with the degrees: *0*, *45* and *-45*, increasing the accurate probability considering the mechanical break system and the stability of the attached to the robot camera. The system displays the executed windows when it's running as shown in Figure 4.

Figure 4



The knowledge base icons of the .mat file are located at the top frame, below it, is the detection window displaying the intersection between two lines.

The graphic result window is located at the bottom left and displays an arrow with the angle or the "X" symbol if it corresponds. At the bottom right is displayed a window describing with a stack the name of the identified labels.

The created file allows to the robot to travel and to navigate indicating graphically the access viability and writes a text file with the corresponding rotating angle, variables and the associated label with the name of the identified room.

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With this information the robot is able to know where it is, the sites where it has been, viability[3], and if some landmarks are stored. The knowledge can be used to program path's commands indicating conditions as the order in which the nodes must be visited and stops in a place using tracking and searching techniques.

If the robot is located in front of a wall, the arrows and text file will indicate the viable exits in real time. If it is located in the middle of the wall, the rotate viability to left or right will be equiprobable[4], and the roboticist is able to program the robot to select a rotate tendency in maze solving problems and searches experiments or choose the most tendency recorded angle in one sampling period[5].

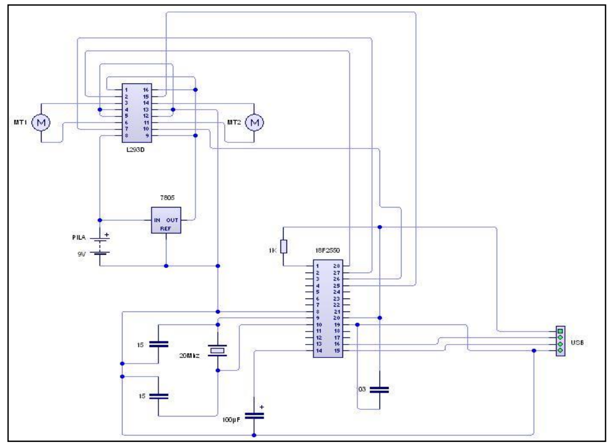
When the system is executed to build the map text file, it creates one .m or script function with .txt format. If a chain is detected the system writes on the text file, forming a stack.

4. Exercises with a domestic mobile robot

To verify the correct system operation, it was realized a manual navigation experiment with a small computer-controlled mobile robot, built with the USB "Human Interface Device" technology and allowing a real plug and play control system with a 18f2550 PIC microcontroller, a camera and a motor driver. The robot was placed in a house scale model with labels attached to the doors as landmarks to find its position.

The electronics scheme of the "domestic" robot experiment is shown in figure 5.

Figure 5



The robot was controlled through the rooms in the scale model while the maps builder system recognized each label and creates a text file to be used as a map.

In another experiment it was programmed a .NET control interface to be used with an autonomous robot version allowing to search a room and stops when it is found.

The experiment founds the user must consider developing an anti-bounce camera system before to use the maps builder, because bouncing causes wrong data acquisition when brakes are applied.

After that, it was programmed a depth first search technique graphs navigation experiment using 8 nodes[6] with a damping system attached to the robot camera to get slow movements avoiding the bounce and noise problems.

The .NET GUI storing text stacks is shown in Figure 6.

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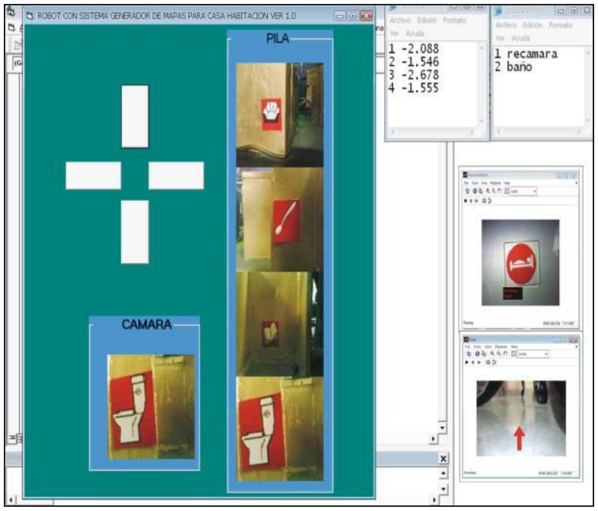

Figure 6

Mobile robot system interface shows the camera and the stack array, simultaneously in "posicion.txt" the file stores all the recognized tags writing a text-map of the inside's house scale model, "movimiento.txt" file contains the angles to get the robot motion, the tags Matlab recognition window shows the recognized labels as valid, and the path window where the red arrow image appears shows the navigation route, based on the obtained angle from the 2 lines intersection located in the Hough transform.

The robot experiment proved the system allows to starts in a dynamic root, travel and arrive to a goal in a graphs map, storing the visited nodes successfully.

Anyway the user must consider the system needs to communicate with some sensors to build a real "model of the world", using RNA`s techniques to assign a weight to the maps builder system, as the brain do to vision and not exclude the touch sense, getting a whole biomimetics dynamics system if the motor outputs as A PWM signal or some analogical techniques as the DAC.

When the system is executed to build the map text file, it creates one .m or script function with .txt format. If a chain is detected the system writes on the text file, forming a stack.

5. Conclusions and future work

Using the navigation acquisition parameters algorithm formed by the subsystems: data segmentation, Hough transform's line detection and line drawn; it allowed programming the data acquisition area limits.

The SLAM maps builder system gets real time navigation and indicates the location of a robot, learning the appearing order of labels storing in a stack structure and brings the data to deduce how to travel to any place, the corresponding angle and the possible viabilities to find an entrance.

The average time of room's icons recognition taken is of 3.5 seconds in a constantly illuminated environment using matte paper.

The system has an error rate when the used colors are over of 20%, and the recognition process must be performed when the robot is completely stopped. We suggest the use of buffers in robotics implementations, an anti-bounce system in the camera device or an adaptive fuzzy control system on implementations[7].

Using an algorithm based on a 9 x 9 potential pixels matrix detection to be compared with an icon pattern matrix previous knew; it can be matched by the recognition and labeling subsystem.

The algorithm based on the recognized label's name write a text file the chain acquisition data allows to program a map builder system of a previously travelled road with any external language capable to read the array.

The system was adapted to a robot prototype and brings the ability to navigate in the open spaces of a house scale model; it was controlled by the programming of a .NET application dedicated to the map text file reading and connected to a 18F25550 PIC microcontroller board using the USB HID technology, allowing to control and explore an area, get a location, searching dynamics, controlling user's GUI, labels identification, angles and direction with the text file's chain in a real time language reading.

This data array may used with A.I. cost searching techniques embedding devices as encoders or ultra sonic sensors to add weight by measurement in a neural network embedding to the algorithm.

Currently the CIUSC and ENSM automatic control research group is building a body for a robot-home competition prototype using the SLAM maps builder system with the A.I. group; they will incorporate the vision and sensors as weights in a neural network model to take navigation decisions in the robot.

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