Mobile Robotic Platform for Simultaneous Localization and Mapping (SLAM) Experiments Based on Range Sensors

Jeanette del Pilar Ureña-Aguirre, Javier Chiza López, Mayra Maya Nicolalde, Andrés Cruz Herrera
Carrera de Ingeniería Industrial
Facutad de Ingeniería en Ciencias Aplicadas
Universidad Técnica del Norte
Ibarra, Ecuador
jdurena@utn.edu.ec, fjchiza@utn.edu.ec, mamaya@utn.edu.ec, arcruz@utn.edu.ec

Edisson Iván Aldás Serrano
Departamento de Mantenimiento Electromecánico del Poliducto Tres Bocas-Pascuales-Cuenca
Empresa Pública de Hidrocarburos del Ecuador, EP Petroecuador
edisson.aldas@eppetroecuador.ec

Abstract

The general objective of the project consisted in the design of mobile robotic platform that allows to perform 2d SLAM experiments with range sensors, for this purpose a probabilistic approach was used with estimation techniques and Bayesian filters. On the other hand, we also investigated the elements (hardware) that allow to develop this project. Using a range sensing sensor in conjunction with a Raspberry Pi 3 as a robot brain and a modified commercial robotic platform as a base structure, RasPi_mBot was developed and through packages in the robotic operating system called Hector_Slam and Gmapping_slam were run simultaneous localization and mapping experiments in controlled environments.

Keywords
Platform, robotics, mobile, mapping, range, sensors

1. Introduction

The guidance and purpose pursued by robotics and Artificial intelligence lies in expanding the range of applications of robots, however, this is possible only if we endow them. With higher degrees of autonomy, that is why mobile robots require Get data from your environment and process them quickly to make effective decisions with minimal intervention from a human operator. In this context, one of the biggest problems facing this type of robots is the localization and mapping of environments. At present, different techniques have been developed to solve this problem.

In recent years, mobile robots have been the subject of preferred research in many laboratories and universities. This is because they are excellent teaching platforms and application of theories and techniques, also having applications in many fields of industry, militia, and even home.

In Ecuador, institutions of higher education, where technical careers related to robotics are offered are insufficient and do not have specific equipment for the realization of practices. Most of these are only made up of industrial robots, consisting of articulated arms that are subject to a base. According to the above, the research carried out in the country's universities is also scarce. Proof of this, there are few antecedents related to research within the field of autonomous robots discussed below: In the PUCESA has implemented a multipurpose platform based on a robot explorer as didactic material for School of Systems (Hernández, 2015); The University of Azuay has developed a robot for mapping and exploration of underground mines (Cabrera & Delgado, 2014); And in the ESPOL was designed and implemented a team of autonomous robots that plot decisions in real time applied to robotic soccer (Villarroel, 2015). This project implements a mobile robotic platform based on range sensors, to be used as a useful tool for testing current solutions and generate new in terms of localization and simultaneous mapping applicable to robots Autonomous.

1.2 Mobile Autonomous Robots

A mobile robot is an automatic machine that is able to move in any environment. Contrary to industrial robots, which usually, consist of articulated arms subject to a surface with actuators at their ends, mobile robots have the ability to move without restriction by any location. (Gopalakrishnan & Tirunellayi, 2014).

The autonomous functioning of a robot implies the capacity to adapt to the changes in the environment, in varied conditions and without the supervision of a human. (Murphy, 2000)
This capacity is necessary for a robot to solve the problems posed by the scientific community. In the industry this capability is evidenced in commercial products such as Roomba, the vehicle without Google driver, among others.

Roomba's project, Roomba's suction robots are powered by a complete set of intelligent sensors that automatically guide the robot around your home. The robot takes 60 decisions every second, navigating under the furniture and around the clutter to completely clean its floors. (IRobot, S.F.).

Google's unmanned vehicle, the Google company in 2014unveiled the world the prototype of its unmanned vehicle, the same that lacks pedals and steering wheel. The vehicle uses a combination of radar and laser sensors, as well as a camera, to drive independently. (BBC, 2014).

WAYMO project, currently Google is still working on the manufacture of fully auto-managed cars. In 2016 is released WAYMO. These cars have sensors and software that are designed to detect pedestrians, cyclists, vehicles, road work and more from a distance of up to two football fields in all directions. (WAYMO, S.F.)

1.3 The slam problem

SLAM comes from the English simultaneous localization and mapping, or in Spanish: simultaneous location and mapping or simultaneous localization and modeling. It is a technique used by robots and autonomous vehicles to build a map of an unknown environment in which it is located, while estimating its trajectory when moving within this environment. (Montemerlo, 2003)

There are times when you know in advance the medium in which the robot will move and it is possible to provide a map of it. On the other hand, there are scenarios in which a robot must move in an unknown environment, but it has precise information about its location. This location can be provided by global vision or satellite positioning. In this situation, the robot supports in the information of its location to assemble a map of the environment. (Andrade & Llofriu, 2013)

However, more complex scenarios exist, where the environment is not known and there is no information about the exact location of the robot. In this case, the robot will have to generate a map and maintain its location in the same concurrently. This task is complicated by the fact that in order to be able to be pinpointed you need a map, and on the other hand, in order to create a map, it is essential to be located in precise form. This is the task that studies the SLAM. (Tejada & Benavides, 2014).

To give a solution to the SLAM problem, there are approaches, bioinspired and probabilistic. The way they process input information is the main difference between the two approaches. Currently, the probabilistic approach dominates the field and has achieved implementations in large and complex environments. (Milford & Wyeth, 2008).

SLAM bioinspired, this type of solutions seeks to mimic the neurological systems of some laboratory animals such as a peasant rats, but most cannot be operated in real environments. (Sanderhauf & Protzel, 2010). SLAM Probabilistics, the key to these methods lies in determining the probability distribution of the robot's position and the map of the environment over time. (Thrun, Burgard, &Fox, 2005)

Among the main techniques probabilistic are the following: Kalman filters, particle filters and optimization on graphs. The Kalman filter is a set of equations that provide an efficient solution to the problem of least squares. The filter is very powerful in different respects as it provides an estimation for past, present and future moments, even when the exact nature of the system is unknown a priori. The FKE (Extended Kalman filter) is a linearization technique for non-linear dynamic models to be able to apply the Kalman filter on them. With these conditions the FKE is used to create a map of the environment that will be used simultaneously to locate the robot (green).

Particle filters, the particle filter algorithm provides a simple and effective way to model stochastic processes with probability distribution functions and arbitrary propagation models. They are based for this in sequential methods of Monte Carlo and to represent the density of probabilities are used mass points "particles" that are possible states of the process, distributed on their space of States (Carpenter & Fearnhead, 1999).

Optimization on graphs, rather than filters, the graph SLAM or named GraphSLAM solves the problem used by a brand as algorithm. For this, the problem of SLAM is modeled as a graph, where the positions of the robot Xi and my marks are represented by nodes. (Strawberry, 2006)

1.4 Robotic operating System (ROS)

ROS, the robot's operating system, is an open-source framework to get robots to do things. ROS is destined to serve as a common software platform for people who are building and using robots. This common platform allows people tosh are code and ideas more easily and, perhaps more importantly, means that you don't have to spend years writing the software infrastructure before your robots start moving. (Quingley, Gerkey, & Smart, 2016)

The basic components of the ROS framework are ROS packages and come with ready-to-use capabilities such as SLAM and AMCL (Adaptive Monte Carlo localization). These packages in ROS are used to perform autonomous navigation in mobile robots and the package for the movement planning of manipulative robots. (Lentin, 2015)

ROS has several packages to perform SLAM, either using camera vision or using range sensors such as radars and lasers, among them we can mention the following: Vslam, Gmapping, Kar to and, Hector_slam.

Vslam, is a research code in experimental state, is not actively supported, and should be used at your own risk. Visual SLAM uses the disperse beam adjustment technique and cameras as a data collector. (ROS.org, S.F.)

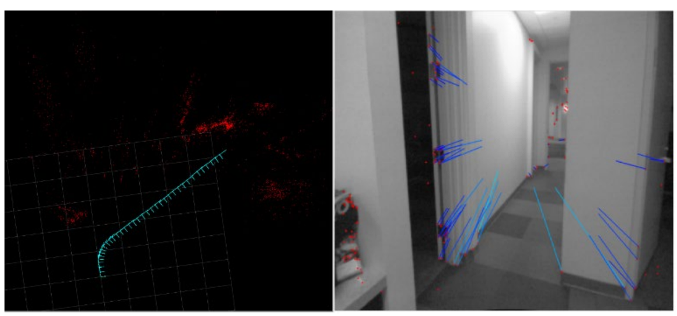

Figure 1. Performance of VSLAM

Gmapping, this package contains a ROS wrapper for the Open Slam Gmapping external package. The package provides simultaneous localization and mapping based on the information of a 2d laser mounted on the robot. This allows you to create a 2d occupancy grid map (similar to a floor plan of a building) from the data that comes from the laser and the position information collected by the mobile robot. (Shaved,2016)

Karto, the preliminary version of this package was open source, but in June 2010, SRI International, an independent research and technological Development Organization originally part of Stanford University, announced Karto 2.0. SRI describes Karto2.0 as the highest-performing SLAM system available. Commercially sold, Kar to is an advanced development project within the AI Center in SRI International. (RBR, S.F.).

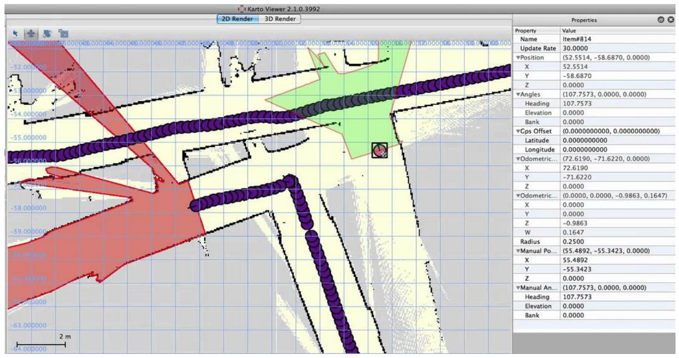

Figure 2. Map generated with Karto SDK

Hector SLAM contains packages of ROS related to the execution of slam in unstructured environments such as those found in the urban search and Rescue (use) scenarios of the Robo Cup Rescue contest. (Team_Hector, S.F.).

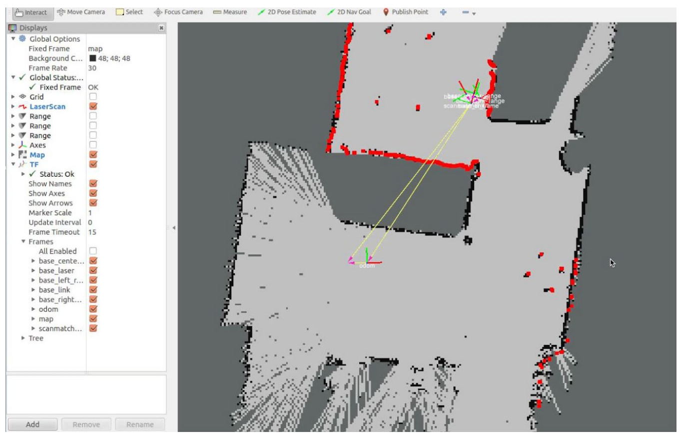

Figure 3. Map generated with HECTOR SLAM

2. Method

2.1 Design

Figure 4, shows the general outline of this project which serves as the basics for the detail design

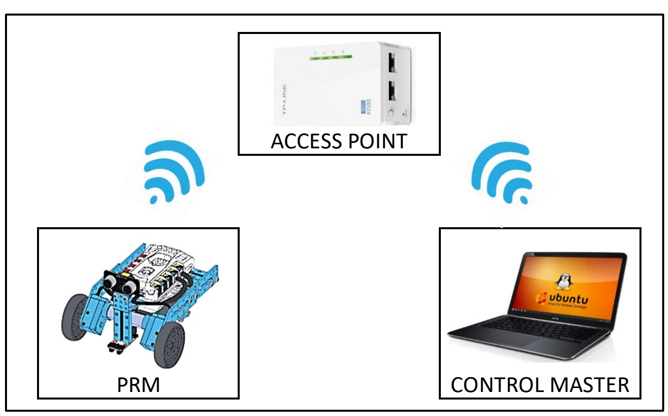

Figure 4. Overall scheme of the project

As can be seen in the figure 4, the subsystem called PRM (Mobile Robotics Platform), is the primary objective of the project and its design was based on the simple premise of making it accessible to the economy of an average high education student, but That incorporates the characteristics of an autonomous or semiautonomous robot with the ability to enhance SLAM. Depending on the foregoing, the project has been divided in to the following sections: structure, design of the hard ware control and design of the software control.

2.2 Structure

As base structure was selected the kit of educational robotics called MBot Ranger, manufactured and distributed by Makeblock.

2.3 Hardware control Design

The PRM has the following functional blocks:

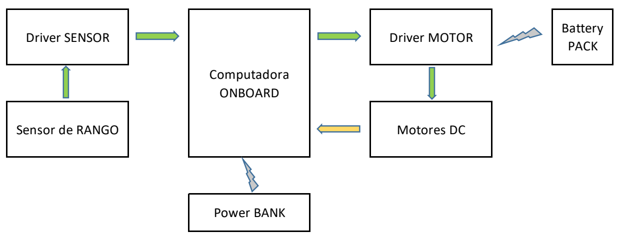

Figure 5. Design considerations of the PRM

The function of each of the blocks is explained below:

- ONBOARD computer: Responsible for managing the movements of the PRM, collecting the data from the range sensor and publishing it on an internal network.
- Range Sensor: Gets the distance and position of the objects in the environment at 360
- Sensor Driver: Allows communication between the range sensor and onboard computer.
- DC Motors: Provide the driving force to the PRM.
- Motor Driver: manages power for engines
- Power BANK: Provides 5v regulated power for the onboard computer.
- Battery PACK: Provides approximate 9v power for engines.

Once the components have been selected, the conceptual design of the PRM has materialized in the RasPi_mBot. The figure 6 presents the updating of the functional blocks:

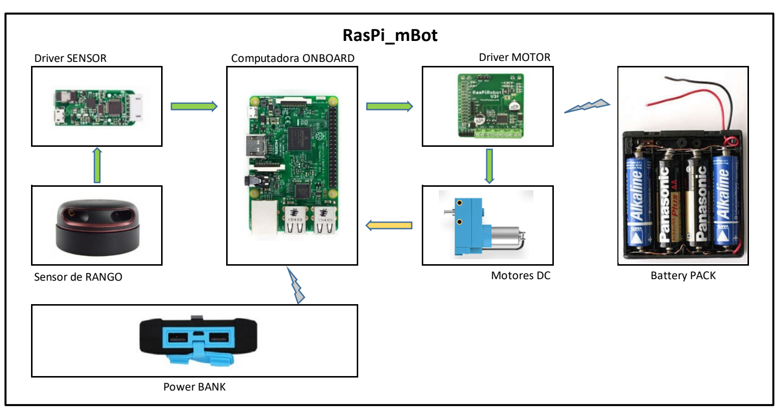

Figure 6. Functional blocks of the RasPi_mBot

2.4 Design Control Software

In order for the RasPi_mBot to perform SLAM, it is necessary to perform several tasks at the software level in the following components:
• MASTER Control Computer
• Onboard computer

MASTER Control Computer Setup, A Laptop with Intel CORE i7 processor with 8Gb of RAM, will perform the functions of the MASTER Control computer, which is responsible for sending operation orders to the RasPi_mBot, so it is necessary to execute the following operations: Ubuntu installation 14.04, ROS Indigo installation and SLAM packages, Static IP configuration.

Computer Setup Onboard, The Raspberry Pi 3 is the onboard computer of the RasPi_mBot so it is necessary to execute the following operations:
• Ubuntu MATE installation
• Installation of ROS Kinetic
• Creation and configuration of the rplidar_ros package
• Installation of rrb3 library
• Static IP configuration

3. Results

Next, the test protocol to which the RasPi_mBot was submitted is represented in the table 1:

Table 1. Test Protocol

Test	Objective
Test Remote Access	Access via SSH to the RasPi_mBot from the Control Master computer.
Test Remote Access of movements(Teleoperation)	Remotely activate the engines of the RasPi_mBot
Test Rplidar	Remotely activate the laser sensor and visualize data in a graphic environment.
Test SLAM - Rplidar	Obtain the map of the environment by applying ROS SLAM packages using Rplidar.

The first three tests are immersed in the final test, which is why we will only refer to it. At this point, the RasPi_mBot must be assembled in its entirety. To proceed with the test, you must first execute the following commands in different terminal windows:

Window 1 (Computer MASTER):
roscore
Window 2:
shh pi@192.168.1.8
roslaunch rplidar_ros rplidar.launch
Window 3:
shh pi@192.168.1.8
rosrun control_raspirobot raspirobot_listener.py
Window 4:
shh pi@192.168.1.8
rosrun control_raspirobot raspirobot_talker.py
Window 5 (Computer MASTER):
roslaunch hector_slam_launch tutorial.launch

Finally, in the following figure 7, the result of the test is shown:

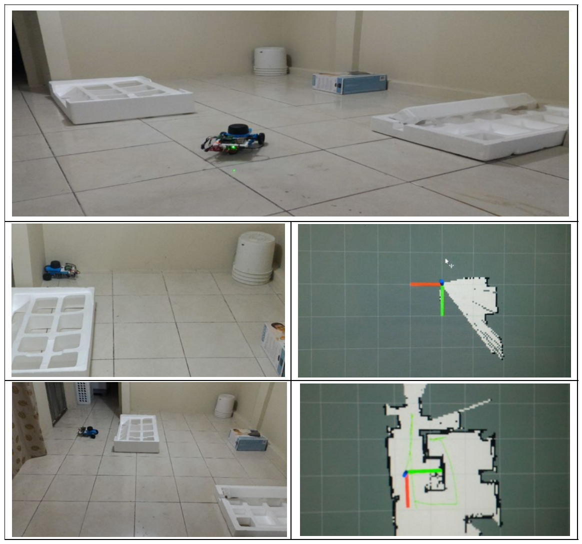

Figure 7. RasPi_mBot performing SLAM

4. Conclusions

- Through bibliographic research, it is determined that the methods currently used for localization and instantaneous mapping in autonomous mobile robots have two approaches, the bio-inspired and the probabilistic. Of which, those based on probability estimation techniques are the most developed to date. It is important to emphasize that, thanks to the existence of ROS, many of these techniques have been able to translate into algorithms computations that are distributed in the form of open source license packages. Between the SLAM packages of ROS the 'gmapping' and 'hector_slam' stand out.

- To determine the hardware and software requirements of the mobile robotic platform, some criteria were established, of which the robustness, scalability and price were the most imposing. As a base structure, an educational platform was used for its expansion capacity and the inclusion of dc motors; As a computer on board, the well-known Raspberry Pi in its version 3 model B was chosen for its ROS support and its wireless communication capabilities; and as a main sensor element, a Lidar sensor for its ROS support and its 360 ° scan capability.

- In the assembly of the mobile robotic platform, the main challenge was the provision of hardware components, so it was necessary to make adaptations of the commercial platform, mainly adding support for the Lidar sensor and for the onboard computer.

- Finally, to evaluate the operation of the mobile robotic platform, a test protocol was established, which consisted of individual test of components and an integral test, in which ROS SLAM packages were executed in different controlled environments with good results.

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Biographies

Jeanette del Pilar Ureña-Aguirre is a researcher/professor of the Industrial Engineering Career, at the Universidad Técnica del Norte, Ibarra, Ecuador. Industrial Engineering degree and a Master in Cleaner Production and Master in Industrial and Environmental Safety and Hygiene degree from Universidad Técnica de Ambato, in Ecuador. Specialist in cleaner production. She is member of the FOCAPRO and GePRO research groups. She has participated in projects in the field of industrial and environmental safety, as well as energy efficiency

Edisson Iván Aldás-Serrano was a researcher/professor of the Mechatronic Engineering Career, at the Universidad Técnica del Norte, Ibarra, Ecuador. Electronic Engineering degree and a Master in Nets and Telecomunication degree from Universidad Técnica de Ambato, and Master in Control System and Industrial Automation degree from Escuela Politécnica de Chimborazo in Ecuador. He currently serves as Instrumentation and Control Supervisor for EP Petroecuador Company.

Fausto Javier Chiza-López is a researcher/professor of the Industrial Engineering Career, at the Universidad Técnica del Norte, Ibarra, Ecuador. Systems Engineering degree and a Master in Software Engineering of Universidad Técnica del Norte, in Ecuador. Specialist in software and Telecommunications. He has participated in projects in the field of Developing of software and systems security, he has experience in Administration Public how Systems Director of the TICS for the government of Ecuador and provincial government of Imbabura.

Mayra Alexandra Maya-Nicolalde is a researcher / professor of Industrial Engineering at the Universidad Técnica del Norte, Ibarra, Ecuador. Industrial Engineer, Master in Operations Management and Industrial Safety from the University of the Americas, in Ecuador. She is a member of the FOCAPRO research group. She has participated in projects in the field of industrial safety, social innovation and good manufacturing practices in the food sector, through process optimization.

Andrés R. Cruz Herrera is a Researcher Professor of the Industrial Engineering Career, at the Universidad Técnica del Norte, Ibarra, Ecuador. Electronic Engineer and Master's in Industrial Engineering and Productivity from the National Polytechnic School (Cum Laude), Quito Ecuador. Specialist in Industrial production and Sustainable technology, Recycling and Process Optimization. He is member of the FOCAPRO research group.