Enchancing SLAM method for mapping and tracking using a low cost laser scanner

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***Abstract*— This paper presents a SLAM technique that does not use odometer information. It is based on HECTOR SLAM method from Technische Universitat of Darmstadt, but using a different hardware from the proposed and finally without the use of IMU device. The method is based on modified settings of the HECTOR SLAM method and manages to optimize the method based on COTS hardware.**

Keywords—SLAM, Robotic Vision, ROS, laser scanner

I. Introduction (*Heading 1*)

Nowadays, robotic technology provides remarkable solutions and opportunities for disabled people. However, many services are offered to a limited extent due to navigation and operation problems that arise to indoor environments like a store or a super market. Focusing on the latter, we can easily deduce that the way most super markets are organized does not allow the efficient operation of robotic platforms for supporting disabled people. This is mainly due to the fact that most corridors are lengthy and narrow with products located at places that are difficult for disables person to reach.

In order to increase the freedom of movement of disabled persons in supermarkets we have developed a robotic platform [1] that allows the secure accommodation of the person's wheelchair and allows him/her to move independently within the supermarket. In order to navigate efficiently, the robotic platform employs the SLAM method for mapping the indoor environment. The result of the mapping process is that the robotic platform is able to perform obstacle avoidance and identify its position with map coordinates.

SLAM method, uses the information from the odometer sensor and the laser scanner, and employs Kalman and Particle filters for combining the information acquired. There are several studies and implementations of the SLAM method taking into account the information of the odometer [2], which in our case do not apply because the robotic platform proposed does not include an odometer. It should be emphasized that the movement of the platform is achieved by analogue motors that are manually driven by the user. Few studies have been presented in this area, such as the use of the Stereo-Camera-Based-SLAM [3] method and Scan Matching [4], which calculates the percentage of motion provided by the Laser Distance Sensor. Technische Universitat of Darmstadt has also developed a SLAM method called HECTOR SLAM, which is employed in the context of the proposed platform.

The rest of the paper is organized as follows: Section II presents the existing SLAM methods; Section III & IV outline the experimental set up of the proposed infrastructure and Section V provides the experimental evaluation of the several SLAM methods, including HECTOR, in the context of the targeted indoor environment. Finally, Section VI concludes and presents future work.

II. SLAM and Methods

A. Simultaneous Localization And Mapping

Simultaneous localization and mapping, (SLAM), is the process of creating a map using a robotic platform that navigates that environment while using the map it generates. SLAM is the technique behind robotic platform mapping or robotic cartography. The robotic platform or vehicle plots a course in an area, but at the same time, it also has to figure out where its own self is located in the place. The process of SLAM uses a complex algorithms and sensors information (such as Laser Scanners, stereoscopic cameras, inertial measurement units, GPS etc.) inputs, to navigate around a previously unknown environment or to revise a map of a previously known environment.

With SLAM method, the robotic platform attempts to map an unknown environment while figuring out where it is. The complexity originates from doing both of them at once. The robotic platform needs to know its position before answering the question of what the environment looks like. The robotic platform has also to figure out where it is without the benefit of already having a map. Simultaneous localization and mapping, developed by Hugh Durrant-Whyte and John L. Leonard [5], is a way of solving this problem using specialized equipment and techniques.

The process of solving the problem begins with the robotic platform itself. The type of robotic platform used must have an exceptional odometry performance. Odometry is the measure of how well the robotic platform can estimate its own position. Odometry information normally is calculated by the robotic platform using the position of its wheels. However, there are several robotic platforms that do not have wheels and consequently, another method for identifying the position of the robotic platform has to be used. In the rest of the section, various SLAM methods are presented:

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B. SLAM with Odometer

Creating a map using odometer information, is the most common and simplest method. This method is based on the information transmitted by the wheels and in particular, on the quantitative rotation of each wheel. To obtain a map with the use of odometer, it is necessary to have knowledge of the motion model of the robotic platform in order to combine the acquired information and calculate the current position of the platform [6,7,8,9,10,11].

On one hand, odometer information simplifies the mapping method and locates the platform on it, but on the other hand it introduces positional errors that have to do with wheel slipping or moving on uneven ground, which, over time, increases the position error.

A representative mapping method that includes the use of an odometer is Gmapping. It is a popular robotics framework in Robotic platform Operation System (ROS) which provides laser-based SLAM and creates a 2-D grid map [12]. This approach uses the laser scanner and poses data which are collected from a mobile robot. GMapping algorithm is based on Rao-Blackwellized particle filter (RBPF). It has equally with good performance in indoor and outdoor environments [13].

C. SLAM without Odometer

1) Visual SLAM

Visual slam refers to the method where allowing to doing a map, where the image is used as the only data input to construct a map and place the robotic platform in space. Approaches for Visual SLAM are depending on what equipment we use. There are several researches with different techniques, the most common ones being: Monocular Visual SLAM, Stereo Visual SLAM and RGB-D SLAM. [14]

The Visual SLAM techniques deliver a major failure because it is quite difficult to extract the depth from the data collected by the camera, and this is shown in the internal mapping environments where there are very dark and very sparse areas. It is also characterized problematic in situations where it has to deal with external environments, dynamic environments, environments with too many or few important properties, large-scale environments and irregular camera movements. [15,16,17,18,19,20]

- **HECTOR Slam (with proposed hardware):** HECTOR SLAM is an open source implementation of the 2D SLAM technique. The technique is based on using a laser scan to build a grid map of the surroundings. To use HECTOR mapping, we need a laser scanner and a node which transforms scan data. The scan matching algorithm used in HECTOR SLAM is based on the Gauss-Newton approach. HECTOR SLAM does not provide an explicit loop closure approach. Nevertheless, it requires low computation and avoids major changes to the map during runtime [21]. From hardware side, HECTOR method uses a Hokuyo UTM-30LX LIDAR system, an Intel Atom Z530 based CPU board and a low-cost Inertial Measurement Unit (IMU) as depicted in (Fig 5).

The HECTOR method, for creating the map, among others, some semantic settings such as:

- *The map resolution in meters*, which is the length of a grid cell edge.
- *The size of map*, which is the number of cells per axis of the map.
- *The threshold for performing map updates in meters*, which means how much the platform should travel in meters or experience an angular change (as described by the map_update_angle_thresh parameter) since the last map update.
- *The limit for the map update to radians*. This parameter displays an angular path change (as defined by map_update_distance_thresh parameter) since the last map update.
- *The map publish period in seconds*.
- *The minimum distance in meters for laser scan endpoints* to be used by the system, where scan endpoints closer than this value, are ignored.
- *The maximum distance in meters for laser scan endpoints* to be used by the system, where scan endpoints farther away than this value, are ignored.
- *The minimum and the maximum height [m] relative to the laser scanner frame for laser scan endpoints* to be used by the system. Scan endpoints lower and higher than this value are ignored.
- *The queue size of the scan subscriber*.
- *The update rate [hz] for the saved trajectory*.

Fig 5. HECTOR Method Handheld Device

III. SLAM TESTING SYSTEM

For the testing of HECTOR SLAM method performance, a system has been developed that includes a Hokuyo UST10 laser scanner sensor, which is inferior with respect to the typical laser scanner sensor. The basic differences with the proposed sensor are given in (Table 1).

Model	Accuracy	Ambient luminance	Distance	Repeated accuracy
UST-10LX	+-40 mm	15k lux	0.06-10 m	σ < 30mm
USTM-30LX	+-50 mm	100k lux	0.1-30 m	σ < 10mm

Table 1. Basic differences between Laser scanners

Furthermore, the testing system does not include information from the IMU device, which is necessary for HECTOR SLAM method. The processing unit which is used is the mini-pc Intel NUC (the characteristics of the whole system are detailed in the next section). Ubuntu 16.04 is used as operating system, with a framework the Robotic Operating System (ROS) [22] in kinetic version.

The proposed configuration

To achieve the tests using the UST-10LX laser and without using an IMU, the original HECTOR method settings have been modified.

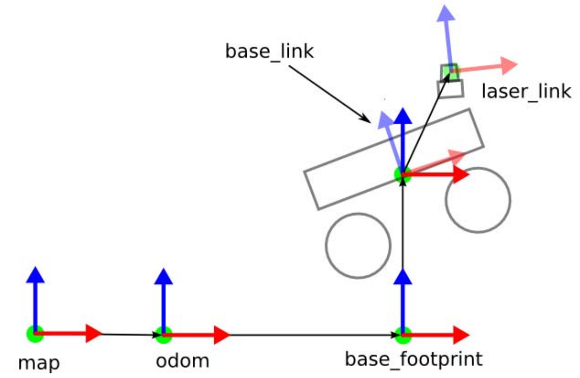
The first setting modified was the the parameter that defines the basic frame of the robotic platform. Thus, the parameter was set from *base_frame* to *base_link.* This is the frame used for localization and for transformation of laser scan data. So, the change was

<arg name="base_frame" default="base_link"/>

The second parameter modified was the odometer information. This parameter has been defined to use the same frame as the base, which is the base_link frame.

<arg name="odom_frame" default="base_link"/>

The image below shows the frames in a simplified 2D view of a robotic platform travelling through terrain, leading to roll and pitch motion of the platform.



The base_footprint frame provides no height information and represents the 2D pose of the robotic platform (position and orientation).

The next parameter modified was the threshold in meter where the platform must travel or experience an angular change to update the map. The default value was 0.4.

<param name = "map_update_distance_thresh"

value="0.7"/>

The next parameter setting was the change in value of the map update period in seconds, where the default is 2sec.

<param name=" map_pub_period" value="0.5"/>

Finally, the parameters modified were the features of the laser scanner, which were adapted for the Hokuyo UST-10LX as opposed to the one proposed, (Hokuyo USTM-30LX).

IV. Evaluation of Standar and Proposed Hector Slam Algorithm

The algorithm evaluations were conducted at Ambient Assisted Living Laboratory [25] of the Embedded System Design and Applications Laboratory. It is important to emphasize that HECTOR algorithm, in order to work well, the areas where the mapping is taking place must have as many different characteristics such as angles, turns, furniture etc.

A. Standar HECTOR Algorithm Metrics

The tests performed with the default settings [26] of HECTOR algorithm, without using IMU, did not produce satisfactory results. (Figs. 7-9), present the obtained maps from two different places, where it clearly shown that there is misalignment of the map continuity. The problem is exacerbated when the moving speed of the mobile platform and executed increased turn.

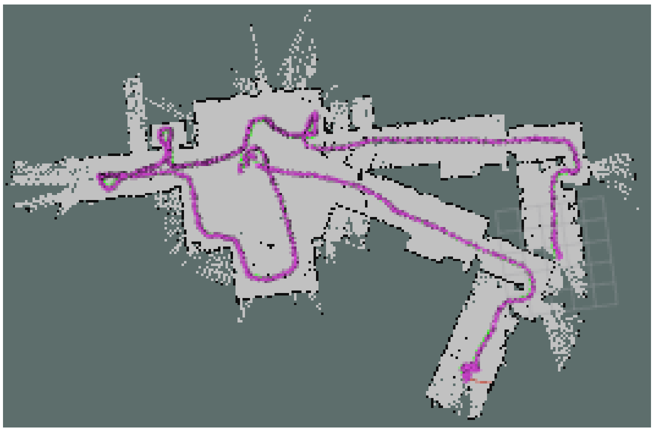


Fig 7. Mapping with standard settings (a)

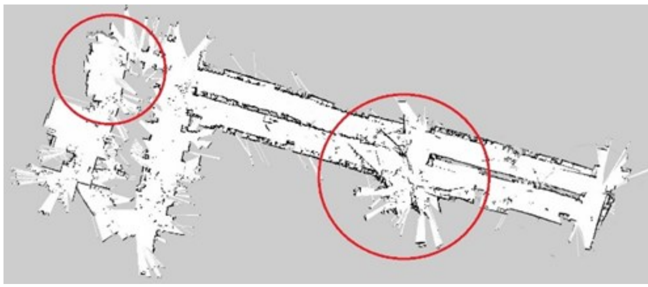


Fig 8. Mapping with standard settings from A.B. Super Market with a lot of manually correction (c)

A. Results and Metrcs with proposed configs

The tests performed with the modified settings of the original HECTOR algorithm are shown in the (Figs. 10-12), where significant improvement in the continuity of the map in relation to the different settings used is shown.

The obtained results exhibit a 97% accuracy, which outperforms the typical algorithm set up. A problem that still remains is the speed of the robotic platform. In speeds more than 10 kilometers per hour, the algorithm still shows some alignment faults, which in our super market environment are not significant, wince the average movement speed is less than 7 kilometers per hour.

Fig 10. Mapping with modified settings (a)

Fig 12. Mapping with modified settings (c)

I. CONCLUSION

In the previous sections we presented an overview of the variations of SLAM method for the localization of robotic platforms in indoor environments. As part of the paper, we presented several evaluation set ups of HECTOR SLAM algorithm which were evaluated in a real world indoor environment. The proposed set up exhibited high accuracy in the different testing scenarios used. As part of the future work, we plan to experiment with robotic platforms in harsh outdoor environments and to deal with the accuracy problem in robotic platform speed more than 10 Km.

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