

3D Map Building using a 2D Laser Scanner

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Abstract. In this paper we present a technique to build 3D maps of the environment using a 2D laser scanner combined with a robot's action model. This paper demonstrates that it is possible to build 3D maps in a cheap way using an angled 2D laser. We introduce a scan matching method to minimize the odometer errors of the robotics platform. Some experimental results and conclusions are presented.

1 Introduction

Laser scanners and range sensors are widely used in mobile robotics applications such as obstacle avoidance, object tracking, map building, feature extraction or self-localization.

A 2D laser scanner provides distances and angles to the surrounding objects by scanning the environment in a plane, usually parallel to the ground. This technique is not enough to detect obstacles like stairs, a land irregularity or floor level variations. These kinds of problems are overcome with the new 3D laser scanners. With these sensors, all features are directly extracted in 3 dimensions. In the other hand, their price is much more expensive than the first ones. Another solution for these problems is a combination of a 2D laser and a pan-tilt unit but, on the contrary, this system requires more time to move the pan-tilt unit [1].

There is a cheaper solution by means of using 2D laser angled down toward the ground in front of the robot combined with the robot's action model to extract the 3D features from movement [2]. While the sensor is scanning, the mobile robot is moving and then the system assembles each slice into a 3D points cloud. The main problem of this cloud is that it can be affected by the dead reckoning errors [3]. There are two kinds of errors: non-systematic and systematic. The first ones are consequence of the slipping and skidding produced in the turns of the robot or by the irregular ground, like cracks or bumps. The second ones are particularly damaging, because they are accumulated constantly and they are due to the irregularity of the robot mechanic, like the unequal wheel diameters or the uncertainty about the distance between the contact points of the wheels and the floor because that wheels contact the floor not in one point [4]. Scan matching techniques try to solve these problems [5].

In this paper we use an angled 2D laser to extract a three dimensional map of the environment and a Seekur Jr. outdoor robot platform. In addition, we propose a scan matching method to overcome the dead reckoning errors.

The paper is organized in the next sections: this section explains the problem and the related works, next section describes the proposed method, section 3 shows the obtained results and finally conclusions and future works are shown in section 4.

2 Description of the proposed system

When a laser sensor is placed angled towards ground, we can assume that it forms a tetrahedron like is shown in Figure 1. Figure shows an example of feature measure and the similarity of triangles to obtain the 3D pose of the measure.

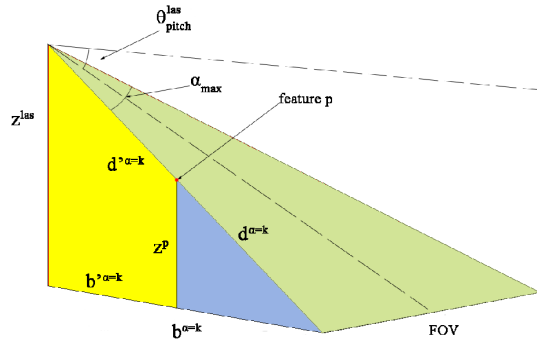


Fig. 1. Example of tetrahedron formed by laser scanner and the ground

Where z^{las} is the height of the laser, z^p is the height of the measured feature p , $d^{\alpha=k}$ is the distance from laser to ground in an angle $\alpha = k$, $d^{\alpha=0}$ is the distance measured from laser to the feature, $b^{\alpha=k}$ and $b^{\alpha=0}$ are the projections of the previous distances, α_{max} is the angle range of measure, θ_{pitch}^{las} is the pitch angle for the radial axis ($\alpha = 0$) and FOV is the Field of View over the ground.

If we assume that laser is in a well-known pose over the robot, the measured distance in $\alpha = 0$ shall be a constant ($d^{\alpha=0}$) and it can be obtained like (1). Using this constant, we can obtain FOV with (2). Concluding that a higher z^{las} or α_{max} and smaller θ_{pitch}^{las} can obtain a higher distance and FOV.

$$d^{\alpha=0} = \frac{z^{las}}{\sin(\theta_{pitch}^{las})} \quad (1)$$

$$FOV = 2 \cdot d^{\alpha=0} \cdot \text{tg} \frac{\alpha_{max}}{2} \quad (2)$$

Using this information and the robot's action model, we can build the map assembling all the slices in a 3D points cloud. The method depends strongly on the odometry error, and then we propose a scan-matching method based on [6] to improve the results. This method is known like Iterative Closest Point

(ICP). It is used to minimize the difference between two clouds of points. We use it to reconstruct the 3D surfaces from different scans. The algorithm is conceptually simple and is commonly used in real-time. It iteratively revises the transformation (translation, rotation) (3) needed to minimize the distance between the points of two raw scans.

$$\begin{bmatrix} \cos(\theta_{yaw}^{las})\cos(\theta_{pitch}^{las}) & R_{12} & R_{13} & 0 \\ -\sin(\theta_{yaw}^{las}) & \cos(\theta_{yaw}^{las})\cos(\theta_{roll}^{las}) & \cos(\theta_{yaw}^{las})\sin(\theta_{roll}^{las}) & 0 \\ \cos(\theta_{yaw}^{las})\sin(\theta_{pitch}^{las}) & R_{32} & R_{33} & 0 \\ x^{las} & y^{las} & z^{las} & 1 \end{bmatrix} \quad (3)$$

$$\begin{aligned} R_{12} &= \sin(\theta_{yaw}^{las})\cos(\theta_{pitch}^{las})\cos(\theta_{roll}^{las}) + \sin(\theta_{pitch}^{las})\sin(\theta_{roll}^{las}) \\ R_{13} &= \sin(\theta_{yaw}^{las})\sin(\theta_{pitch}^{las})\sin(\theta_{roll}^{las}) - \sin(\theta_{pitch}^{las})\cos(\theta_{roll}^{las}) \\ R_{32} &= \sin(\theta_{yaw}^{las})\sin(\theta_{pitch}^{las})\cos(\theta_{roll}^{las}) - \cos(\theta_{pitch}^{las})\sin(\theta_{roll}^{las}) \\ R_{33} &= \sin(\theta_{yaw}^{las})\sin(\theta_{pitch}^{las})\sin(\theta_{roll}^{las}) + \cos(\theta_{pitch}^{las})\cos(\theta_{roll}^{las}) \end{aligned}$$

3 Implementation and Results

The Test-Bed environment was established in the surroundings of the Polytechnic School of the University of Alcalá. It has a surface of 60m x 40m. The robot used in the experimentation was a Seekur Jr. by Mobilerobots, with the following configuration: MacBook Pro with Ubuntu 9.10 operating system, Player/Stage 3.0.1 control software, angled Hokuyo URG-04LX laser, bumpers and encoders in all wheels. They are shown in Figure 2.



Fig. 2. Test-bed and real prototype used in the experimentation

Figure 3 shows an example of 3D reconstruction of the test-bed with one trail of the robot. Color is clearer when features are closer to the ground. It has been extracted a reconstruction detail of a bench.

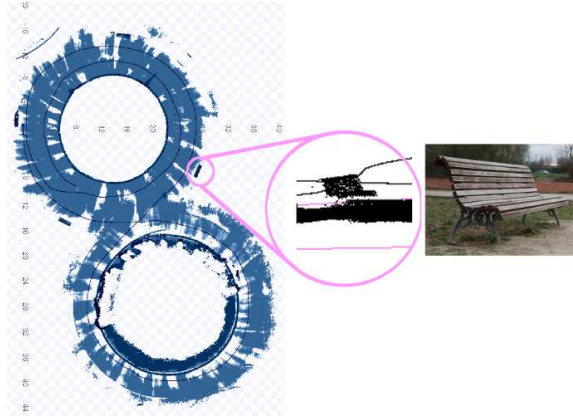


Fig. 3. 3D map building results

4 Conclusions and future works

In this work we have presented a 3D map building using a 2D laser scanner and an action model of a real robotic platform. We have demonstrated that it is possible to build a 3D features cloud using 2D laser scanner in a real application. In the near future, we have the intention of improving this system using a calibration method inside the scan-matching process.

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