LOCALIZATION OF A MOBILE ROBOT USING NATURAL LANDMARKS AND SENSOR FUSION

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ABSTRACT

In this study, localization of a mobile robot is accomplished using laser range finder, compass and natural landmark. Corners in a room are used as natural landmarks. It is assumed that mobile robot is positioned to sense corners and there is no other corner like objects in the environment. Once a corner is sensed, the position of this corner is determined using the robot heading which is indicated by the compass. Experiments are conducted to show the effectiveness of the proposed algorithm.

I. INTRODUCTION

Localization is an important problem ([1]-[2]) for mobile robot systems. Distance traveled by the robot may be recorded using encoders, but this information is not reliable. For example, wheels may slip on slippery surfaces and robot will travel more than the distance that encoders indicate. Robot may get stuck in the mud; wheels turn and indicate that robot moves. These types of errors are cumulative and will grow as the robot moves. In order to eliminate these errors, different kinds of the sensors and landmarks may be used depending on the working environment.

Sensory information obtained using range sensors, image sensors etc, may be used directly ([3], [4]) or fused ([5]-[8]) to give more accurate results. On the other hand, active beacons, artificial [9] or natural landmarks are used as reference points. In this paper, fusion of a laser range finder and a compass is used with a natural landmark to localize a mobile robot. It is assumed that, robot can see the landmark all the time and there is no similar object to the landmark in the environment.

II. ASSUMPTIONS ABOUT THE ENVIRONMENT

In this study, corners in a room are used as natural landmarks. Width of the side walls of a corner should be long enough in order to be sensed by the range finder. Using the dimensions of the laboratory and scan resolution of the SICK LMS laser range finder, it is decided that width of the side walls of a corner should be greater than 30-cm.

Assumptions about the working environment are as follows [10]:

- Mobile robot moves on a smooth surface in a closed environment,
- Laser can always measure the distance of walls,
- Walls start from the surface and intersect at a right angle,
- There is no corner like object in the environment.
- Robots always see at least one corner.

III. SENSORS USED IN THE STUDY

In this study, a SICK LMS laser range finder and a Compass which are mounted on a PIONEER 3AT robot are used (Figure 1). Laser range finder measures the distance of an object using the time-of-flight information. Using a rotating mirror, it measures the distance of objects with 0.5 or 1 degree resolution in a $\pm 90^0$ region. Without using additional reflectors, maximum measuring distance is 30 m with a resolution of 10 mm. Data is transferred to the mobile robot using serial communication. Compass gives heading angle of the robot with respect to the magnetic north of the world with 1 degree resolution.

Figure 1: PIONEER 3-AT Robot, SICK LMS 200 Laser and Compass

System resolution

In order to sense an object in the environment, it is not enough to know only the properties of the laser range finder, but also the resolution of the system based on the distance and orientation of the object relative to the robot.

Since the number of beams hitting an object should change depending on the relative distance and orientation of the object and laser, a resolution function should be determined. Assume that the object is orthogonal to the laser and the width of the object scanned by the laser with an angle of θ is h cm. (Figure 2). Distance between the laser and the object is *l*. Then the resolution of this scan can be calculated as

$$res = \frac{h}{\theta} = \frac{\tan\theta \, l}{\theta} \text{ cm.} \quad (1.a)$$

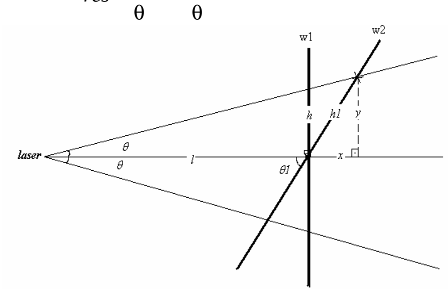

Figure 2: Scan of a vertical object at a distance of *l*

If the laser scans in 1^0 steps, using expression (1), resolution can be calculated as

$$res = 0.0175 \, l \text{ cm} \quad (1.b)$$

If the object rotates by an angle q_1, resolution becomes

$$res = \frac{h_1}{\theta} \quad (2)$$

Where $h_1 = \sqrt{(x^2 + y^2)}$ and x, y can be determined using identical triangles (in Figure 2) as:

$$\frac{h}{y} = \frac{l}{x+l}, \text{ and } \tan(\theta_1) = \frac{y}{x} \quad (3.a)$$

$$h_1 = \frac{h\,l}{\cos(\theta_1)(\tan(\theta_1) l - h)} = \frac{\tan(\theta) l^2}{\cos(\theta_1)(\tan(\theta_1) l - \tan(\theta) l)} \quad (3.b)$$

For $\theta = 1^0$ degree scan step, using expressions (2) and (3) resolution can be calculated as

$$res_{h1} = \frac{0.0175 l^2}{\cos(\theta_1)(\tan(\theta_1) l - 0.0175 l)} = \frac{0.0175 l}{\sin(\theta_1) - 0.0175 \cos(\theta_1)} \quad (4)$$

where θ_1 is the angle between the laser beam and the object (in Figure 2), and can be determined as follows: Assume the line equation for the object is $y = mx + b$, the intersection coordinates of an orthogonal line drawn from the laser scanner to the object can be determined as follows:

$$X_p = \frac{-mb}{m^2+1} \text{ and } Y_p = \frac{b}{m^2+1} \quad (5)$$

$$\tan\theta_1 = \frac{\sqrt{X_p^2 + Y_p^2}}{\sqrt{(X_p - X_L)^2 + (Y_p - Y_L)^2}} \quad (6)$$

Using coordinates given by (5) and expression (6), θ_1 can be calculated.

Algorithm

Localization algorithm given in Figure 3 uses fusion of Laser range finder and Compass data. Laser range finder scan data is used to make calculations and to find corners in robot coordinate system. Later, compass is used to match these results in global coordinate system.

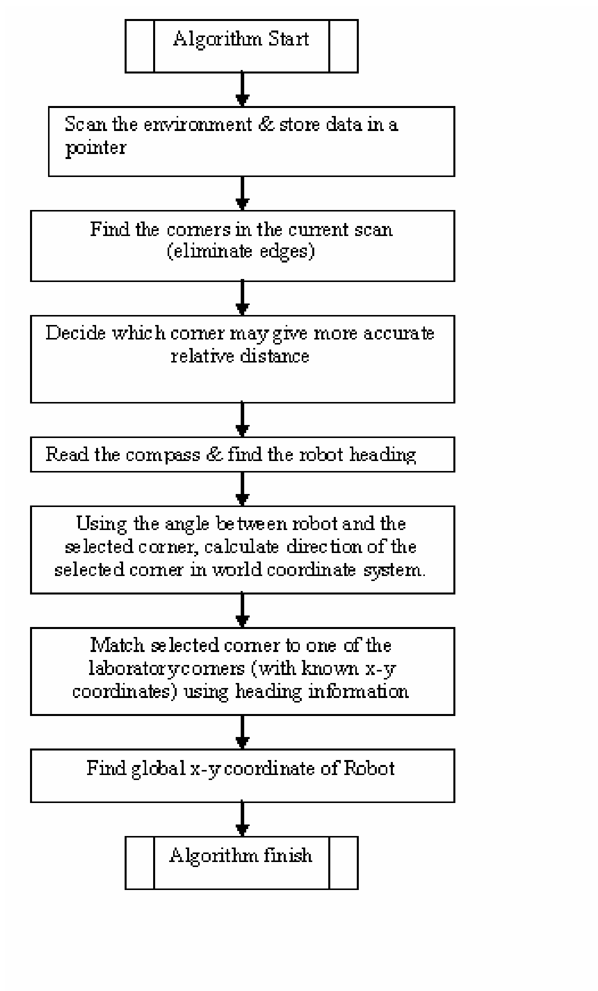

Figure 3: Localization Algorithm

To summarize the algorithm, firstly, the environment is scanned using Laser range finder. Then, using assumptions about the environment and expressions (1-6), possible corners and corresponding errors are calculated. Among the candidates, the one with the smallest error is assumed as the base corner, and the position and orientation of the robot relative to this corner is calculated. All calculations are performed in the robot coordinate system. Secondly, compass is used to find the orientation of the robot in global (world) coordinate system. Thus, the robot determines the corresponding corner in the world coordinate system to the base corner. Using this information, robot localizes itself in the world coordinate system.

IV. EXPERIMENTS

The algorithm is tested in the laboratory environment (Figure 4.a-b) using a PIONEER 3-AT mobile robot. Figure 4 a-b shows the corners in the laboratory.

Figure 4.a: Laboratory corners 1 and 2

Figure 4.b: Laboratory corners 3 and 4

In figures 5 a-d, scan data of the laser range finder for each corner are shown. As seen from figures, walls intersect each other at right angles and there is at least 30 cm-width side walls for each corner.

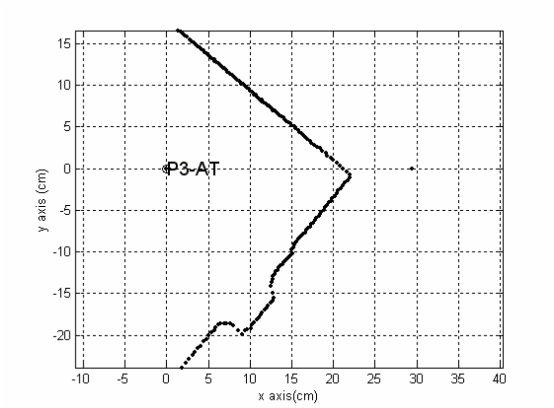

Figure 5.a- Robot position- the scan results for corner 1 in robot coordinate system

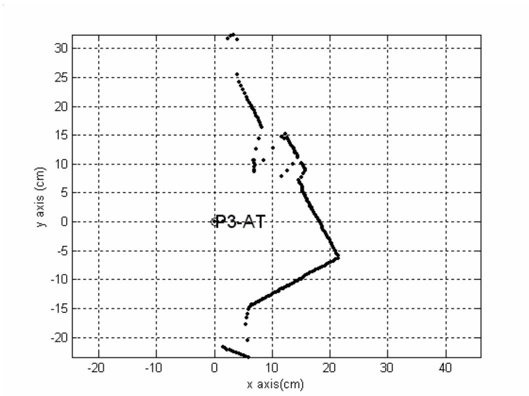

Figure 5.b- Robot position- the scan results for corner 2 in robot coordinate system

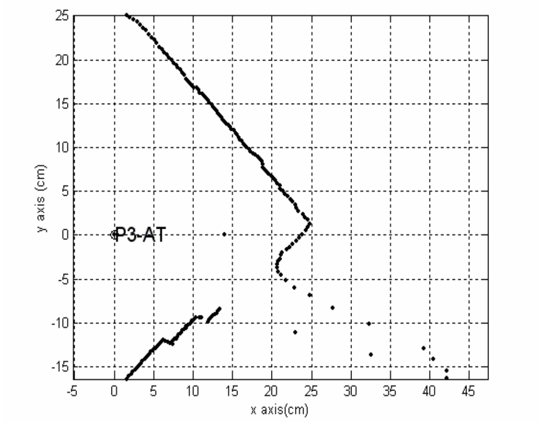

Figure 5.c- Robot position- the scan results for corner 3 in robot coordinate system

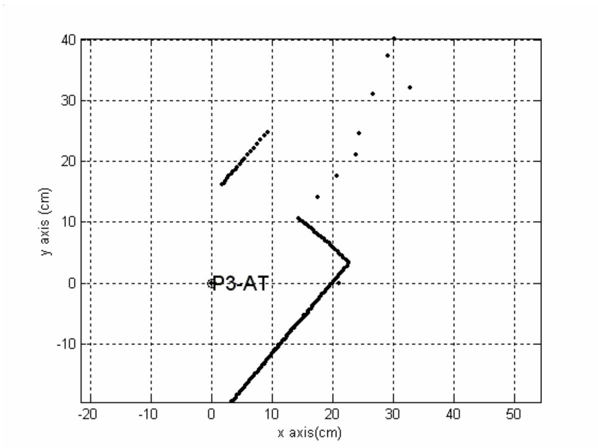

Figure 5.d- Robot position- the scan results for corner 4 in robot coordinate system

In Table 1, results of some experiments are listed for each corner. In the first and second rows, global coordinates of the corners and the robot are given, respectively. The results of the algorithm are given in the third row. The last row represents the error between the actual global coordinate and the algorithm's result.

	Corner 1 (x,y)	Corner2 (x,y)	Corner3 (x,y)	Corner4 (x,y)
Corners	(0,0)	(570,0)	(570,660)	(0,660)
Robot	(110,170)	(157,129)	(185,140)	(130,160)
Algorithm	(108,163)	(154,123)	(177,134)	(123,161)
Error	(2,7)	(3,6)	(8,6)	(7,1)

Table 1: Test results

As seen from the figures 5.a-d and Table 1, although robot positioned at different points of the laboratory, our algorithm is able to localize the robot using laser range finder and compass with small errors under given assumptions.

V. CONCLUSION

In this study, a solution is proposed for localization problem of a PIONEER 3-AT mobile robot based on natural landmarks and sensor fusion. Corners are detected by a laser range finder and compass. The proposed algorithm gave satisfactory results under given assumptions. In the future works, we plan to enlarge the working area of the algorithm, and reduce the error in localization using other features of the environment.

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