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NAVIGATION PERFORMANCE STANDARD FOR MOBILE SERVICE ROBOTS

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Standards on the performance criteria and associated test methods play an important role in the works of international standardization. Recently, studies that intend to specify the performance criteria and test method for navigation of mobile service robots have gained many attentions. The pose characteristics is an important factor for the navigation of service robots. In this paper, we summarized the navigation performance standard, which includes the pose accuracy and repeatability of the mobile robot.

1. Introduction

The international standardization activity in the robotic field mainly consists of a few areas, such as mutual understanding, safety, performance, and interoperability [1]. The mutual understanding standards includes vocabulary and coordinate system. The safety standards deal with the safety aspect of the industrial robots and service robots and it is used as mandatory requirements in most of countries. The interoperability standards deal with the modularity of the software and hardware aspects so that these can be interchangeably used.

The performance standard is mainly used to measure the effectiveness of the robotic products in the objective and reproducible manner. While manufacturers wanted to show the superiority of their products, the customers would like to make sure the robots they are purchasing met their level of accuracy to perform the intended task of their applications. The international standard for the performance criteria and its test methods for industrial robots, ISO 9283, is historically widely utilized both by manufacturers and customers [2]. ISO 9283 mainly focused on the performance of the manipulator, such as pose accuracy and repeatability. The most widely utilized item in this standard can be the repeatability of the manipulator which effectively show the accuracy of the position and orientation of the manipulator.

As the mobile robots are widely adopted in the service robot application, the need to develop the performance standard for mobile robots is raised in the last decade. ISO 18646-1 deals with the locomotion performance of the wheeled mobile robots [3]. It includes the test methods to measure the rated speed, stopping characteristics, maximum slope angle, maximum speed on the slope, mobility over the sill, and turning width. ISO 18646-2 deals with the navigation performance of mobile service robots, such as pose accuracy and repeatability of the mobile platforms, obstacle detection, and obstacle avoidance [4]. ISO 18646-3 deals with the manipulation performance of service robots, including grasp size, grasp strength, grasp slip resistance, and use cases of opening a hinged door and opening a sliding door [5].

In this paper, we summarized the navigation performance standard of the mobile robots, ISO 18646-2. Navigation performance is usually measured by pose accuracy and repeatability, as well as the ability to detect and avoid obstacles. The criteria and related test methods are applicable only to mobile platforms that are in contact with the travel surface. To test the navigation performance three perspectives [3] are usually considered.

Firstly, the pose characteristics, which include pose accuracy and pose repeatability, is presented. Pose accuracy and pose repeatability indicate the ability of the robot to reach the command pose.

Secondly, the obstacle detection which is to determine the ability of mobile robots to detect the obstacle and measure the distance to obstacles of different geometry and material. Test parameters are based on the manufacturer specified minimum and maximum sensing ranges. The robot does not necessarily recognize the kind of obstacle.

Thirdly, the obstacle avoidance which is to determine the ability of a robot to prevent a collision with a static or dynamic obstacle, either by stopping or by conducting an appropriate evasion movement. In the case of stopping, the robot is expected to stop before physical contact between the obstacle and any part of the robot occurs. In the case of an evasion movement, a minimum distance between the obstacle and any part of the robot, as specified by manufacturer, shall be maintained.

2. Experimental conditions

All performance should be measured under normal operating conditions, and if the performance is measured in other conditions, those conditions shall be declared. Unless otherwise specifications, robot shall be tested at the rated speed and equipped with the rated load, for all tests. Additionally, the external equipment, such as landmarks, shall be supplied according to the specifications of the manufacturer and information on the external equipment, such as locations and types of landmarks, shall be provided for the navigation of mobile platforms. All test paths are parameterized with respect to the sizes of mobile platforms. Furthermore, length unit (LU) which defines as the maximum of the width *w* and the length *l* of the mobile platform, also shall be clarified in the test report. In the experiment, three types of paths are considered including straight path, rectangular path, and composite path as shown in Figures 1, 2 and 3.

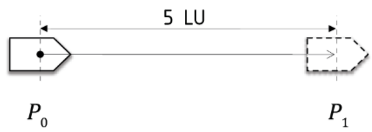

Figure 1. Straight path.

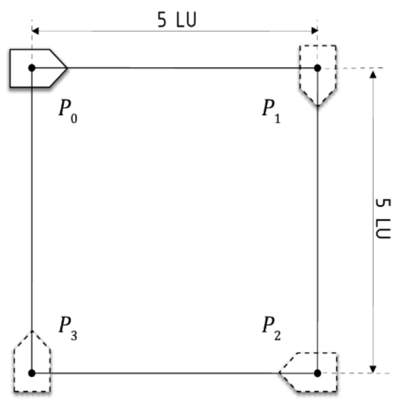

Figure 2. Rectangular path.

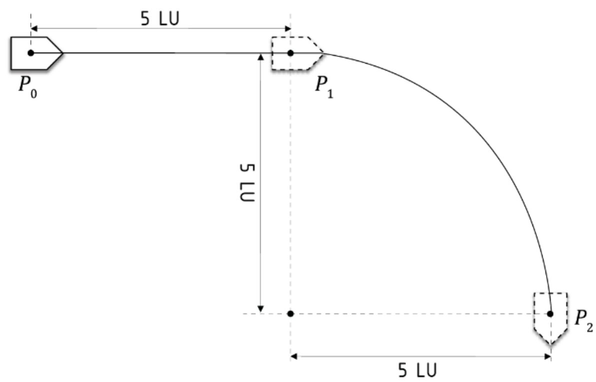

Figure 3. Composite path.

3. Pose characteristics

3.1. *Goal*

The goal of this test is to verify the performance of the navigation for service robot in terms of pose characteristics. It contains two main parts: pose accuracy and pose repeatability, which indicate the ability of the robot to reach the target pose of command.

3.2. *Pose accuracy and repeatability*

Pose accuracy is defined as the deviation between the localization poses and the achieved poses when the robot travels from the initial pose to the goal pose after n repeated visits.

Pose accuracy is divided into

1. Position localization accuracy: the difference between the position of the barycenter of the localization determined by robot and the position of the barycenter of the attained position, as shown in Figure 4.
2. Orientation localization accuracy: the difference between the average orientation of the localization determined by robot and the average of the attained orientations, as shown in Figure 5.

To Position localization accuracy (LA_p) is calculated by following formula.

$$\mathrm{LA_p} = \frac{1}{n}\sum_{j=1}^{n}\sqrt{\left(x_j - \hat{x}_j\right)^2 + \left(y_j - \hat{y}_j\right)^2} \tag{1}$$

where x_j, y_j are *x* and *y* values of the attained position of the *j-th* trial, $\hat{x}_j, \hat{y}_j$ are x and y values of localization determined by the robot of the *j-th* trial, and *n* is the number of trials.

Orientation localization accuracy (LA_o) is calculated by following formula, where the absolute value is then recast into the range (-180, +180).

$$\mathrm{LA_o} = \frac{1}{n}\sum_{j=1}^{n}\left|o_j - \hat{o}_j\right| \tag{2}$$

Here o_j is the angle of the attained pose of the *j-th* trial, $\hat{o}_j$ is the angle of localization determined by the robot of the *j-th* trial, and *n* is the number of trials.

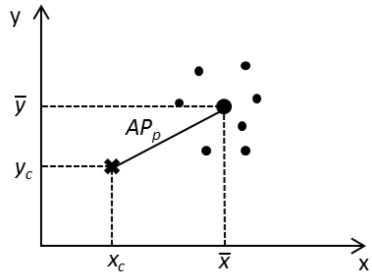

Figure 4. Position localization accuracy.

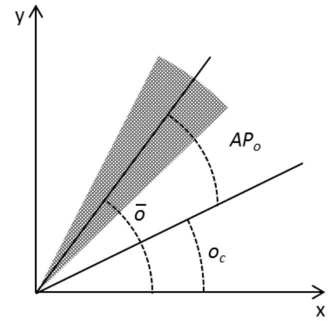

Figure 5. Orientation localization accuracy.

3.3. *Test facility*

The test facility is equipped with a measurement system which suitable for measuring position and orientation with sufficient accuracy with respect to the intended use of the robot, e.g. a 3D camera system or a laser tracker. The type and accuracy of the measurement system shall be included in the test report.

3.4. *Test procedure*

This test consists of six test configurations of a straight path, a rectangular path and a composite path (see Figure 1, 2, and 3) with no load and with the rated load. Each trial follows the procedure below.

1. The mobile platform with a specified load is placed on the initial position P0 of the respective path.
2. The mobile platform is commanded to follow the path autonomously with the rated speed.
3. When it reaches the goal position, position and orientation are measured with the external measurement system. Also, the localization determined by the robot is recorded.

The trial is repeated 30 times for each path and load condition. Position localization accuracy and orientation localization accuracy are calculated from the collected data.

References

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