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Robotics — Performance criteria and related test methods for service robots —

Part 1: Locomotion for wheeled robots

Robotique — Critères de performance et méthodes d'essai correspondantes pour robots de service —

Partie 1: Locomotion des robots à roues

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Foreword

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The committee responsible for this document is Technical Committee ISO/TC 299, *Robotics*.

A list of all the parts in the ISO 18646 series can be found on the ISO website.

Introduction

This document is intended to facilitate understanding of performance of wheeled robots between users and manufacturers. It defines the important performance characteristics, describes how they are specified and recommends how to test them.

The characteristics for which test methods are given in this document are those considered to affect robot performance significantly. Users of this document are intended to select the performance characteristics to be tested, in accordance with the specific requirements.

The performance criteria specified in this document are not intended to be interpreted as the verification or validation of safety requirements. This document deals with indoor environments only.

Robotics — Performance criteria and related test methods for service robots —

Part 1: Locomotion for wheeled robots

1 Scope

This document describes methods for specifying and evaluating the locomotion performance of wheeled robots in indoor environments.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at http://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
robot
programmed actuated mechanism with a degree of autonomy, moving within its environment, to perform intended tasks

Note 1 to entry: A robot includes the control system and interface of the control system.

Note 2 to entry: The classification of robot into industrial robot or *service robot* (3.2) is done according to its intended application.

[SOURCE: ISO 8373:2012, 2.6, modified]

3.2
service robot
robot (3.1) that performs useful tasks for humans or equipment excluding industrial automation applications

Note 1 to entry: Industrial automation applications include, but are not limited to, manufacturing, inspection, packaging, and assembly.

Note 2 to entry: While articulated robots used in production lines are industrial robots, similar articulated robots used for serving food are service robots.

[SOURCE: ISO 8373:2012, 2.10]

3.3
mobile robot
robot (3.1) able to travel under its own control

Note 1 to entry: A mobile robot can be a *mobile platform* (3.5) with or without manipulators.

[SOURCE: ISO 8373:2012, 2.13]

3.4
wheeled robot
mobile robot (3.3) that travels using wheels

[SOURCE: ISO 8373:2012, 3.16.1, modified]

3.5
mobile platform
assembly of all components of the *mobile robot* (3.3) which enables locomotion

Note 1 to entry: A mobile platform can include chassis which can be used to support a *load* (3.7).

Note 2 to entry: Because of possible confusion with the term "base", it is advisable not to use the term "mobile base" to describe a mobile platform.

[SOURCE: ISO 8373:2012, 3.18]

3.6
travel surface
terrain on which the *mobile robot* (3.3) travels

[SOURCE: ISO 8373:2012, 7.7]

3.7
load
force and/or torque at the mechanical interface or *mobile platform* (3.5) which can be exerted along the various directions of motion under specified conditions of velocity and acceleration

Note 1 to entry: The load is a function of mass, moment of inertia, and static and dynamic forces supported by the *robot* (3.1).

[SOURCE: ISO 8373:2012, 6.2.1]

3.8
rated load
maximum *load* (3.7) that can be applied to the mechanical interface or *mobile platform* (3.5) in *normal operating conditions* (3.9) without degradation of any performance specification

Note 1 to entry: The rated load includes the inertial effects of the end effector, accessories and workpiece, where applicable.

[SOURCE: ISO 8373:2012, 6.2.2]

3.9
normal operating conditions
range of environmental conditions and other parameters which can influence *robot* (3.1) performance (such as electrical supply instability, electromagnetic fields) within which the performance of the robot specified by the manufacturer is valid

Note 1 to entry: Environmental conditions include, for example, temperature and humidity.

[SOURCE: ISO 8373:2012, 6.1]

3.10
stopping distance
maximum distance travelled by the *mobile platform* (3.5) origin between the initiation of the stop and the full stop of the mobile platform

3.11
rated speed
maximum speed of the *mobile platform* (3.5) equipped with the *rated load* (3.8) in *normal operating conditions* (3.9)

3.12
turning
turn
movement of the *mobile platform* (3.5) causing a change of orientation of the mobile platform coordinate system

Note 1 to entry: Turning is typically accompanied by a change in direction of travel of the mobile platform.

3.13
spin turn
spinning
in-place rotation, or rotation about the *mobile platform* (3.5) origin without translation

3.14
turning width
minimum width of the rectangular passage within which the *mobile platform* (3.5) can complete a specific type of *turning* (3.12)

3.15
reverse turning width
turning width (3.14) for the *mobile platform* (3.5) with a 180° turn

3.16
U-turn width
U-shaped reverse turning width
reverse turning width (3.15) for the *mobile platform* (3.5) with a U-shaped turning path

Note 1 to entry: See Figure A.1.

3.17
three-point-turn width
three-point reverse turning width
reverse turning width (3.15) for the *mobile platform* (3.5) using one initial forward travel, one backward travel and one final forward travel

Note 1 to entry: See Figure A.2.

3.18
L-turn width
right angle turning width
turning width (3.14) for the *mobile platform* (3.5) with a 90° turn to pass through the L-shaped passage

Note 1 to entry: See Figure A.3.

4 Test conditions

4.1 General

The robot shall be completely assembled and sufficiently charged and operational. All self-diagnostic tests shall be satisfactorily completed. It should also be ensured that the robot operates in a safe manner throughout the tests.

The tests shall be preceded by the preparations for operation as specified by the manufacturer.

All conditions specified in Clause 4 should be satisfied for the tests described in this document, unless it is stated otherwise in the specific clauses.

Each test described in each clause of this document may have different test configurations which require separate test procedures. For each test configuration, multiple trials can be conducted, if specified in the test procedure.

4.2 Environmental conditions

The following environmental conditions shall be maintained during all tests:

— ambient temperature: 10 °C to 30 °C

— relative humidity: 0 % to 80 %

If the environmental conditions specified by the manufacturer are outside the given conditions, then this shall be declared within the test report.

4.3 Travel surface conditions

A hard and even surface with a coefficient of friction between 0,75 and 1,0 (measured according to ISO 7176-13) shall be used.

4.4 Operating conditions

All performance shall be measured under normal operating conditions. When the performance is measured in other conditions, this shall be declared within the test report.

For all tests, the robot shall be tested at the rated speed equipped with the rated load, unless otherwise specified.

5 Rated speed

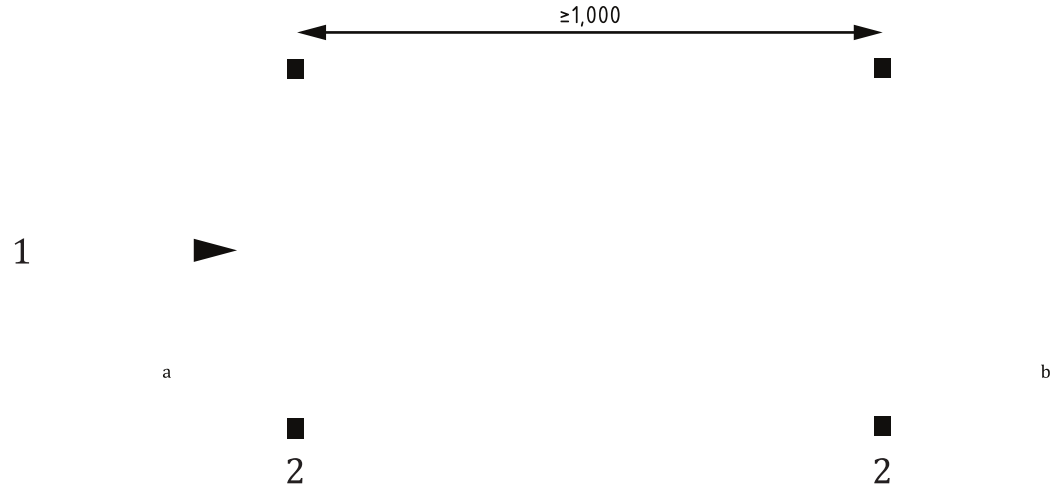
5.1 Purpose

The purpose of this test is to determine how fast a robot can travel to its destination. Rated speed is an indication of how fast the robot can generally perform tasks that are related to travelling. In the test described in 5.2 to 5.4, the rated speed is determined from a series of measurements on horizontal travel surface.

5.2 Test facility

The setup for this test is shown in Figure 1. The speed measurement test area shall be at least 1 000 mm in length and of sufficient width. Enough space shall be provided at each end of the test area for acceleration and deceleration. Sensors should be allocated at each end of the speed measurement test area to measure the start time and finish time of the wheeled robot.

Dimensions in millimetres



Key

1	mobile robot
2	sensor
a	acceleration area
b	deceleration area

Figure 1 — Test area for rated speed

5.3 Test procedure

This test consists of one test configuration. Each trial shall follow the procedure below.

a) The wheeled robot equipped with the rated load is placed at the initial position.

b) The robot starts from its initial position and accelerates so that it reaches the final attained speed before the start line.

c) While the robot moves in a straight line through the speed measurement test area, the speed of the robot is determined with the measurement system.

d) After the robot reaches the finish line, it decelerates until it stops.

A trial shall be considered to fail if the robot does not reach the finish line of the test area or if it deviates from the designated travel direction by more than 10 % of the length of the speed measurement test area. The rated speed, specified in metres per second, shall be selected as the minimum speed value from three consecutive successful trials.

5.4 Test result

Rated speed along with the specific test conditions, including friction conditions, shall be declared in the test report.

6 Stopping characteristics

6.1 Purpose

The purpose of this test is to determine stopping distance and stopping time that indicate the ability of the robot to navigate in a reliable way in its environment. A high stopping performance generally supports the manoeuvrability of the robot as it allows fast cessation of motion and turning manoeuvres.

In the test described in 6.2 to 6.4, the stopping distance and stopping time are determined from a series of measurements on horizontal travel surface.

6.2 Test facility

A sufficiently large test area with horizontal travel surface shall be available.

The length of the test area should be sufficient for the robot to reach the rated speed and to stop safely. The test facility shall be equipped with means to determine the motions of the robot in time. They shall be able to measure the position of the robot with an accuracy of 2 % of a typical stopping distance. For example, the following apparatuses can be used:

— the wall behind can be painted with wide stripes perpendicular to the direction of travel at every 100 mm and narrow stripes at every 10 mm;

— the test can be recorded by a video camera, preferably of digital type, placed as far as possible to minimize the positional errors in measuring the stopping characteristics;

— an advanced positioning device such as 3D motion tracking systems can be used.

6.3 Test procedure

This test consists of one test configuration. Each trial shall follow the procedure below.

a) The robot equipped with the rated load is placed at the initial position.

b) The robot moves in a straight line from its initial position until it reaches the rated speed.

c) A stop command is initiated either manually (e.g. by emergency stop) or automatically (e.g. by detecting obstacles), as specified by manufacturer. Stop category of 1 or 2 according to IEC 60204-1 should be used in order to guarantee stable stoppage.

NOTE The initiation of the stop signal needs to be measured with the measuring apparatus. For example, pushing the emergency stop button can be recorded by the video camera, or an electrical output signal can be used to synchronize with the motion tracking device.

d) The stopping distance and the stopping time are recorded by measuring the distance travelled and the time elapsed between the initiation of the stop and the full stop of the mobile platform. The full stop means the complete cessation of motion of the whole body of the mobile robot. For mobile platforms requiring stability control (e.g. inverted pendulum type robots), the motion needed for stability control is still allowed after the full stop is completed.

The stopping distance and stopping time shall be selected as the maximum values from the first three trials.

6.4 Test result

Stopping distance and stopping time along with specific test conditions, including the rated speed, the accuracy of measurement device, stop category and friction conditions, shall be declared within the test report.

7 Maximum slope angle

7.1 Purpose

The purpose of this test is to determine the maximum slope angle on which the mobile robot can travel in specified directions.

7.2 Test facility

Test shall be performed on a slope of specific angle with a precision of ±0,5°.

7.3 Test procedure

The test consists of five test configurations, as listed in Table 1.

Table 1 — Test configurations

Test configuration	Path of the robot relative to the slope	Driving direction of the robot
1	upward	forward
2	upward	backward
3	downward	forward
4	downward	backward
5	lateral (perpendicular)	forward

Each trial of the test shall follow the procedure below.

a) The slope is set to the specific angle.

b) The robot equipped with rated load is placed at the initial position on the slope.

c) The robot moves in a straight line for at least 1 000 mm at its speed declared by the manufacturer.

d) The robot shall stop on the slope after it reaches the goal position.

A trial shall be considered to fail if the robot does not reach the finish line of the test area or if it deviates from the designated travel direction by more than 20 % of the length of the speed measurement test area. The slope angle used in the test procedure shall be declared as the maximum slope angle for the test configuration after three consecutive successful trials from the first three trials.

7.4 Test result

The maximum slope angles along with the specific test conditions, including friction conditions and commanded speeds, shall be declared within the test report using Table 2.

Table 2 — Maximum slope angles

Travel direction	upward/ forward	upward/ backward	downward/ forward	downward/ backward	lateral/ forward
Maximum slope angle					

8 Maximum speed on the slope

8.1 Purpose

The purpose of this test is to determine the maximum speed of the mobile robot on slopes with a fixed set of angles in specified directions.

8.2 Test facility

Tests shall be performed on slopes with angles of 3°, 6° and 10°, as appropriate. The angles shall be set within ±0,5°.

NOTE The angles of 3°, 6° and 10° are typical in wheelchair test, as specified in ISO 7176-2.

The test facility shall be equipped with a measurement system able to measure the speed of the robot. The speed measurement test area shall be at least 1 000 mm in length and of sufficient width. Enough space shall be provided at each end of the test area for acceleration and deceleration.

8.3 Test procedure

The test consists of five travel patterns, as listed in Table 3, each for three slope angles of 3°, 6° and 10°. Therefore, a maximum of 15 test configurations shall be tested.

Table 3 — Travel patterns

Travel pattern	Path of the robot relative to the slope	Driving direction of the robot
1	upward	forward
2	upward	backward
3	downward	forward
4	downward	backward
5	lateral (perpendicular)	forward

For each test configuration, each trial shall follow the procedure below.

a) The robot equipped with the rated load is placed at the initial position on the slope of 3°, 6°, or 10°.

b) The robot moves in a straight line while it is accelerating, moving with maximum speed and decelerating.

c) The speed of the robot is determined with the measurement system in the maximum speed area.

d) The robot shall stop on the slope after it reaches the goal position.

A trial shall be considered to fail if the robot does not reach the finish line of the test area or if it deviates from the designated travel direction by more than 20 % of the length of the speed measurement test area. The maximum speed on the slope angle for each test configuration shall be selected as the minimum speed value from three consecutive successful trials.

8.4 Test result

For each test configuration, the maximum speeds on each slope along with the specific test conditions, including friction conditions, shall be declared within the test report using Table 4.

Table 4 — Maximum speed

Travel direction	upward/ forward	upward/ backward	downward/ forward	downward/ backward	lateral/ forward
Maximum speed at 3° slope angle					
Maximum speed at 6° slope angle					
Maximum speed at 10° slope angle					

9 Mobility over the sill

9.1 Purpose

The purpose of this test is to determine the maximum sill heights that the robot can pass over. In order to pass over a long sill, the robot needs to be able to climb up and down the sill without any damage. For

short sills, the robot should also have a sufficient ground clearance so that the body of the mobile robot (other than the wheels) does not touch the sill while passing over it.

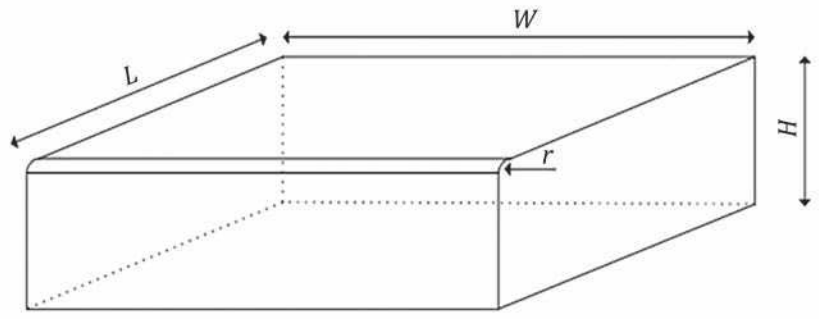
9.2 Test facility

The test facility shall have two sills:

— a short sill;

— a long sill.

The diagram of a sill is shown in Figure 2. The height of the sill, *H*, shall be set to a specific value. The width of the sill, *W*, should be greater than the width of the robot. The length of the sill, *L*, shall be determined considering the robot size and its application environment. Typical lengths are 100 mm for a short sill and at least 1 000 mm for a long sill, in order to be able to accommodate all wheels over the top of the long sill. The front edge of the sill shall be smooth and its radius, *r*, shall be a maximum of 3 mm.



Key

H	height of sill
L	length of sill
r	radius of sill
W	width of sill

Figure 2 — Dimensions of the sill

9.3 Test procedure

The test consists of two test configurations:

— a short sill;

— a long sill.

For both test configurations, each trial shall follow the procedure below.

a) The height of the sill is set to the specific value.

b) The wheeled robot equipped with the rated load is placed at the initial position where the robot can achieve the designated speed before reaching the sill.

c) The robot moves in a straight line perpendicular to the front edge of the sill, unless otherwise required by its manufacturer, at its designated speed

d) The robot shall pass completely over the sill.

A trial shall be considered to fail if the robot does not pass completely over the sill or the body of the mobile platform other than the wheels touch the travel surface during the trial. The height of sills used

in the test procedure shall be declared as the maximum sill heights for the test configuration after three consecutive successful trials from the first three trials.

9.4 Test result

The maximum sill heights for each sill, along with specific test conditions, including dimensions of sills, approach angle to the front edge, friction conditions and commanded speeds, shall be declared within the test report.

10 Turning width

10.1 Purpose

The purpose of this test is to determine the turning width for the specific type of turning of the mobile platform.

Turning width is determined not only by mechanical characteristics (e.g. steer angle of the wheels) but also by the ability of the control system to execute the turn.

In this test, three types of turns are used:

— U-turn;

— three-point-turn;

— L-turn.

U-turn and three-point-turn are not applicable to mobile platforms that are able to perform a spin turn. Instead, for such platforms, the reverse turning width for spin turn shall be determined.

10.2 Test facility

The boundaries of the passage for each type of turning shall be physical walls with heights higher than the robot. The collision avoidance functionality of the mobile robot shall be activated.

10.3 Test procedure

The test consists of three test configurations (U-turn, three-point-turn and L-turn) as illustrated in Figures A.1 to A.3. Each trial shall follow the procedure below.

a) The width between the walls is set to the specific value.

b) The wheeled robot equipped with the rated load is placed at the initial position.

c) The robot starts from its initial position until it reaches the speed designated by the manufacturer for the specific type of turning.

d) The robot initiates the turn.

e) After the robot has completed the turn, it decelerates until it stops. Turning is considered completed when the robot reaches the designated orientation.

A trial shall be considered to fail if the robot touches the wall of test area during turning or the robot does not reach the designated orientation. The width between walls used in the test procedure shall be declared as the turning width for the test configuration after three consecutive successful trials from the first three trials. The turning time shall be selected as the maximum value from the first three successful trials.

10.4 Test result

The turning width for each type of turning, along with specific test conditions, including friction conditions, commanded speeds and turning time, shall be declared within the test report.

Annex A
(informative)

Examples of test configurations for turning widths

The three test configurations (U-turn, three-point-turn and L-turn) for the test for turning width are illustrated in Figures A.1 to A.3, where *w* indicates the width of the physical wall.

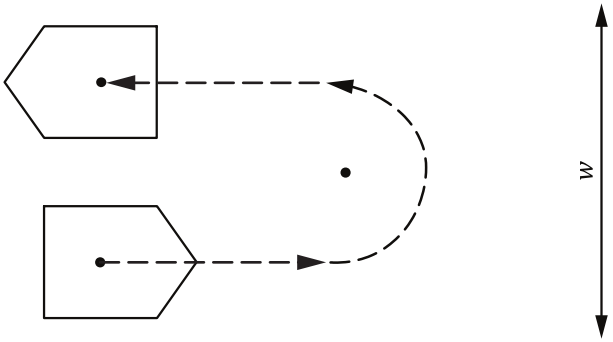


Figure A.1 — U-turn width for mobile platform

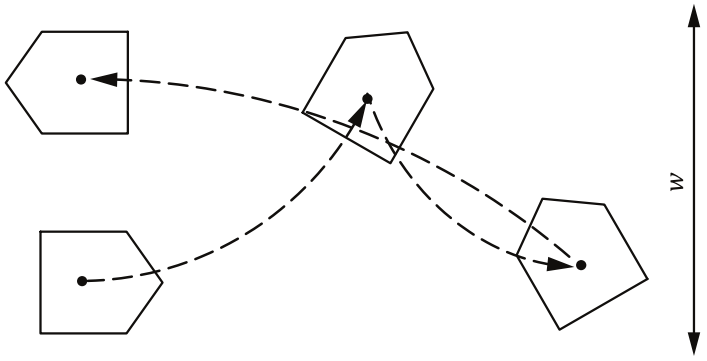


Figure A.2 — Three-point-turn width for mobile platform

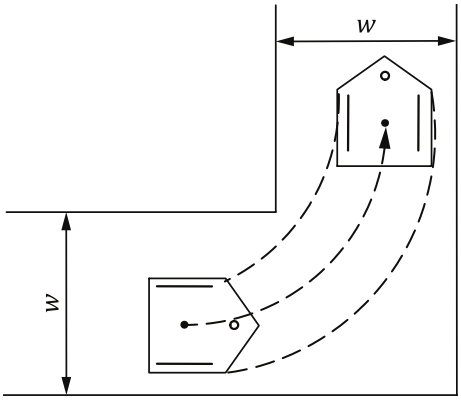


Figure A.3 — L-turn width for mobile platform

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