Designation: F3381 – 19

Standard Practice for Describing Stationary Obstacles Utilized within A-UGV Test Methods[1]

This standard is issued under the fixed designation F3381; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

Automatic, automated, or autonomous unmanned ground vehicles (A-UGVs) in many scenarios encounter obstacles or objects that obstruct or impair their intended movement. This practice is used to describe stationary objects that serve as obstacles in ASTM Committee F45 test methods, both for existing, real world obstacles and for test artifacts that can be constructed to serve as representative obstacles. Examples of using obstacles in test methods include adding an obstacle into the Test Method F3244 – 17 apparatus or verifying a sensor's ability to detect an obstacle. Several physical characteristics of stationary obstacles are defined in this standard, such as geometry, surface, and configuration. The characteristics specified herein can be used to describe common, real world obstacles that A-UGVs typically interact with, such as pallets on the ground, desks and tables, and other A-UGVs. This practice only covers obstacles or objects that exist on or above the ground plane and remain stationary while the A-UGV is performing its task.

1. Scope

1.1 This practice specifies physical characteristics that can be used to describe obstacles utilized within ASTM Committee F45 test methods. The obstacle characteristics specified in this practice are not described with respect to the manner in which they will be sensed or detected by an A-UGV. Rather, the obstacles are described according to their real world characteristics. For example, the real world characteristics of a wooden box that is flat black on one side can be described according to its actual dimensions, material, and color. An A-UGV with a lidar sensor may have difficulty detecting the side of the box that is flat black, which could make the obstacle appear smaller to the A-UGV compared to its actual dimensions in the real world. However, this may not be the case for other A-UGVs due to the wide variety of sensors used to detect obstacles, so the actual, real world characteristics are used to describe it instead.

1.2 Real world, existing objects can be used as obstacles and described using this practice. The characteristics specified herein can also be used to construct test artifacts to use as representative obstacles that are intended to have similar characteristics to that of real world obstacles. The obstacles that can be described using this practice may be found in indoor and outdoor environments.

1.3 This practice does not purport to cover all relevant obstacle characteristics that may have an effect on A-UGV performance. The characteristics specified in this practice are limited to the physical properties which are considered to be the most salient in terms of the effects they can have on A-UGV performance. As such, the user of this standard may select the level of detail to use in order to describe the characteristics of an obstacle in such a way. The characteristics are also limited to those which are more easily measurable and replicable when comparing test method results that use similar obstacles.

1.4 This practice only covers obstacles that exist on or above the ground, sometimes referred to as positive obstacles, and remain stationary while the A-UGV is performing tasks. Stationary real world obstacles of this type include pallets on the ground, desks and tables, and other A-UGVs. This practice does not include obstacles that exist below the ground (for example, holes), sometimes referred to as negative obstacles. This practice does not cover boundaries or features in an environment that are unchanging and known prior to an A-UGV task, such as walls, racks, or other infrastructure.

1.5 This practice specifies a variety of physical characteristics of an obstacle, including shapes, dimensions, and surface

[1] This test method is under the jurisdiction of ASTM Committee F45 on Driverless Automatic Guided Industrial Vehicles and is the direct responsibility of Subcommittee F45.03 on Object Detection and Protection.

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qualities. This practice does not specify the location properties of an obstacle within a test method apparatus aside from measurements in reference to the ground plane of the environment.

1.6 When constructing a test artifact as an obstacle representative of a genuine obstacle (see 4.1), a combination of characteristics can be selected and used to guide fabrication. The use of similar genuine obstacles (that is, real world objects) may decrease reproducibility of testing conditions compared to using artifact obstacles (that is, those that are fabricated for the purposes of testing), unless the same real world object is used between multiple tests.

1.7 This practice does not specify A-UGV performance in the presence of obstacles. The intent of this practice is to enable comparisons between tests that use obstacles with similar characteristics.

1.8 This practice does not require that certain obstacle characteristics be used as part of a test method. The test requestor can elect specific obstacle characteristics to be used as part of a test method.

1.9 Obstacles described using this practice can be utilized in test methods specified by other ASTM Committee F45 standards, such as Test Method F3244 – 17. In the appendix, a baseline test is described that can be used to determine if an obstacle is able to be detected by an A-UGV's sensors prior to utilizing the obstacle in another ASTM Committee F45 test method (see X1.2).

1.10 The values stated in SI units are to be regarded as the standard. The values given in parentheses are not precise mathematical conversions to imperial units. They are close approximate equivalents for the purpose of specifying material dimensions or quantities that are readily available to avoid excessive fabrication costs of test apparatuses while maintaining repeatability and reproducibility of the test method results. These values given in parentheses are provided for information only and are not considered standard.

1.11 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.12 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

F3200 Terminology for Driverless Automatic Guided Industrial Vehicles

F3218 Practice for Documenting Environmental Conditions for Utilization with A-UGV Test Methods

F3244 Test Method for Navigation: Defined Area

2.2 *Other Standards:*

ANSI/ITSDF B56.5 2016, Safety Standard for Rough Terrain Forklift Trucks

IEC 61496-1:2012 Safety of machinery - Electro-sensitive protective equipment

ISO 20471:2013 High visibility clothing - Test methods and requirements

3. Terminology

3.1 *For this practice, the term* ***obstacle*** *refers to stationary objects that exist on or above the ground (see Terminology F3200 – 18).*

4. Significance and Use

4.1 This section lists and explains the characteristics that are used to describe a stationary obstacle.

4.2 It is essential that sufficient information about the obstacle is recorded using this practice so that the obstacle can be replicated. This will allow comparisons to be made between test method performances that use obstacles with similar characteristics.

4.3 *Class:*

4.3.1 When describing an obstacle to be utilized in ASTM Committee F45 test methods, two classes are defined:

4.3.1.1 *Genuine*—The obstacle being described is an existing real world object (for example, a chair, table, machinery, or equipment). Any identifying information, such as make, model, SKU, etc., should be recorded.

4.3.1.2 *Artifact*—The obstacle being described has been constructed according to the characteristics outlined in this section. Obstacles of this class are intended to be replicable.

4.4 *Parts of the Obstacle:*

4.4.1 Each characteristic can be used to describe a property of the entire obstacle or a part of the obstacle. All parts of the obstacle must be uniquely named and identified in the test report described in Section 6.

4.5 *Shape:*

4.5.1 The shape refers to the relationships between the external, physical boundaries of the obstacle. All shapes can be in contact with the ground or elevated above the ground (see Fig. 1, Fig. 2, and Fig. 3). The unique obstacle shapes are:

4.5.1.1 Bar (for example, column)

4.5.1.2 Panel (for example, sign, pallet, shelf)

4.5.1.3 Cuboid

4.5.1.4 Sphere

4.5.1.5 Cone

4.5.1.6 *Other*—Obstacle shapes that do not fall into one of the above categories (for example, a pile of fabric). An obstacle can use a single shape to describe its overall volume or multiple shapes to describe parts of the obstacle. For example, the shape of a desk could be described as an elevated horizontal panel with two vertical panels spanning from the ground to the horizontal panel or the shape of a table could be described as

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

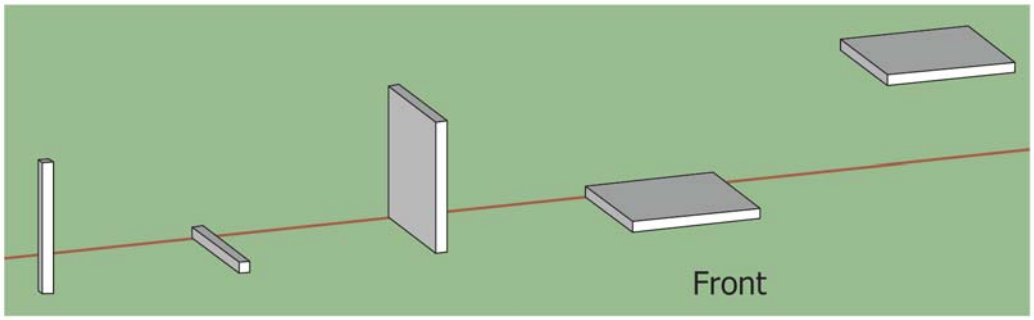

FIG. 1 Obstacle Shapes, Shown with Hard Edges in Varying Directions (Left to Right): Vertical Bar, Horizontal Bar, Vertical Panel, Horizontal Panel, Elevated Horizontal Panel

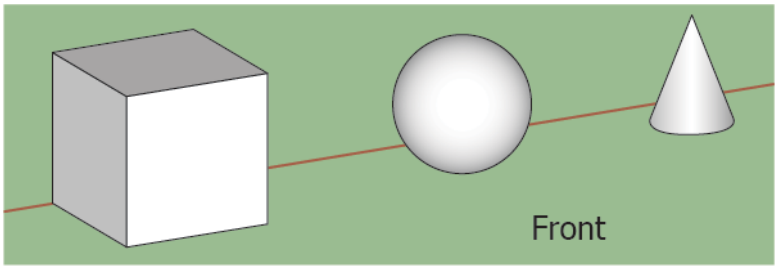

FIG. 2 Obstacle Shapes (Left to Right): Cuboid (Shown with Hard Edges), Sphere, Cone

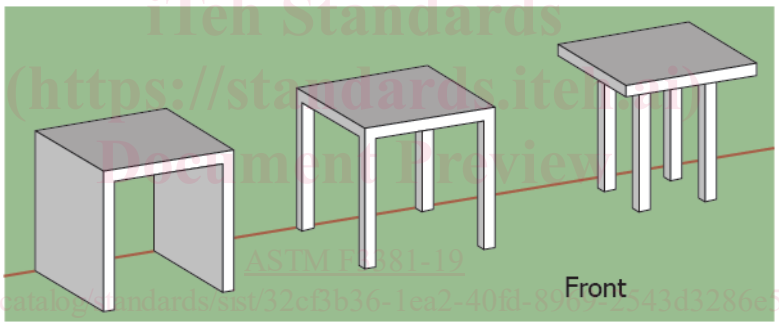

FIG. 3 Example Combinations of Obstacle Shapes, Shown with Hard Edges (Left to Right): Elevated Horizontal Panel with Two Vertical Panels Spanning from the Ground to the Horizontal Panel (for example, Desk), Elevated Horizontal Panel with Four Vertical Bars Spanning from the Ground to the Horizontal Panel (for example, Table), the Same as the Previous but with Inset Vertical Bars (for example, Table)

an elevated horizontal panel with one or more vertical bars spanning from the ground to the horizontal panel (see Fig. 3).

4.6 *Face Quality:*

4.6.1 The faces of each obstacle can either be closed (that is, it has a surface that fills that face) or open (that is, it has no surface on that face).

4.6.2 This characteristic can vary for each face of the obstacle or part of the obstacle: top, bottom, front, back, left, right. Some obstacles may not have clearly discernible faces (for example, sphere, cone).

4.6.3 See Fig. 4 for examples of obstacles with closed and open faces.

4.7 *Taper:*

4.7.1 If the boundaries of any part of the obstacle change dimension and narrow toward one end, it is considered tapered.

4.8 *Edge Quality.*

4.9 The quality of the vertices where the boundaries of the shape meet (see Fig. 5), which can be internal or external on the obstacle. The edge characteristics can be:

4.9.1 Hard edges:

4.9.1.1 Cornered (the angle between the two surfaces forming the edge is 90°)

4.9.1.2 Chamfered (the angle between the two surfaces forming the edge is greater than 90°)

4.9.2 Rounded:

4.9.2.1 Fillets (partially rounded)

4.9.2.2 Cylindrical (completely rounded, eliminating one or more faces of the shape)

4.10 *Direction:*

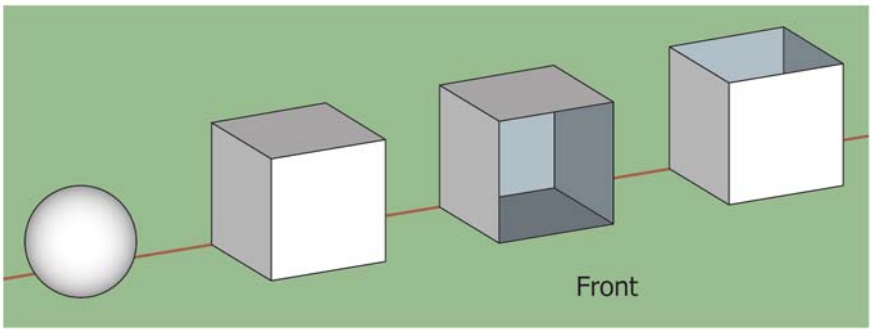

FIG. 4 Examples of Obstacle Face Variations (Left to Right): Sphere with Closed Faces, Cuboid with All Closed Faces, Cuboid with Open Front Face, and Cuboid with Open Top Face

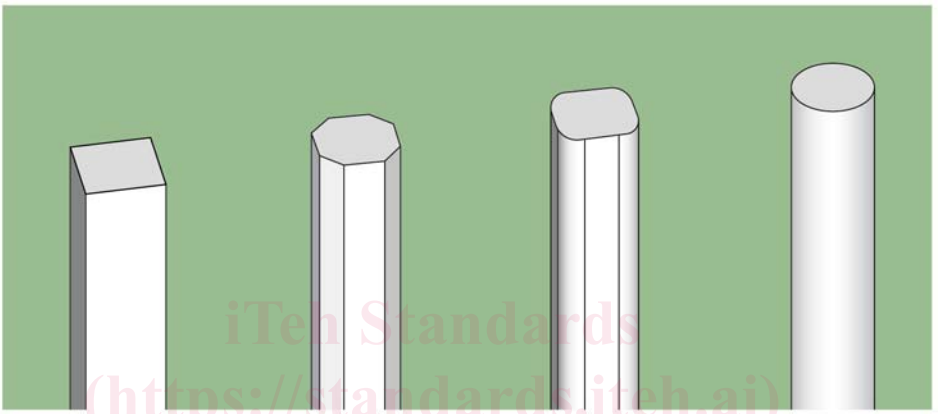

FIG. 5 Obstacle Shape Edge Variations, Shown on a Vertical Bar (Left to Right): Cornered, Chamfered, Fillets, and Cylindrical

4.10.1 The direction of the obstacle is dependent on which side is its front. This characteristic will be referenced in other standards when specifying how to orient the obstacle within a test method apparatus.

4.11 *Dimensions:*

4.11.1 The size of the obstacle overall (that is, its entire volume) and of its individual parts (for example, for an obstacle whose shape is a plane with legs, the size of the horizontal plane, the vertical bars, and the inset of the vertical bars from the edge of the horizontal plane) can be described according to the following characteristics:

4.11.2 Width

4.11.3 Length/depth

4.11.4 Height

4.11.5 Elevation (from ground to bottom edge boundary)

4.11.6 Taper (if applicable)

4.11.6.1 Location on the obstacle where the taper begins (that is, when the boundaries begin to narrow)

4.11.6.2 Length of the part of the obstacle that is tapered

4.11.6.3 Angle of the taper

4.11.7 Edge (if not cornered)

4.11.7.1 Setback distance of chamfered edge (if applicable)

4.11.7.2 Radius of rounded edge (if applicable)

4.11.8 The units used to measure the dimensions of the obstacle and the approximate accuracy of those measurements shall be reported.

4.12 *Material:*

4.12.1 The material(s) the obstacle is made of: metal, wood, foam, glass, plastic, fabric, composite materials, etc.

4.12.2 If the material is intended to block or reflect a certain type of sensor, this should be stated on the test report.

4.12.3 If the density of the material is known and is relevant for the test method in which the obstacle is utilized, this should be stated on the test report.

4.13 *Surface:*

4.13.1 Characteristics of the obstacle's surface include, but are not limited to:

4.13.2 Color

4.13.3 Reflectivity

4.13.4 Opacity (for example, glass, plexiglass)

4.13.5 Porosity—Solid (for example, wood, steel) or non-solid surface with repeated perforations or openings (for example, fencing)

4.13.6 Uniformity—Uniform or variable (that is, patterned, striped)

4.13.7 Other—Obstacle surface qualities that do not fall into one of the above categories.

4.14 Note—Test pieces from other standards can be described using this practice. For example, the cylindrical test pieces from ANSI/ITSDF B56.5 can be described as vertical or horizontal bars with cylindrical edges and flat black surface qualities.

4.15 Examples of common surface characteristics referenced in other standards are listed in the appendix (see X1.1).

4.16 *Other Relevant Features:*

4.16.1 Any other relevant characteristics that pertain to the physical nature of the obstacle should be recorded. For example, if the obstacle features lights, produces air flow, or emanates sound.

4.17 *Obstacle Description Persistence:*

4.17.1 When the obstacle is utilized in a test method, the characteristics of the specific obstacle that are recorded shall not vary for the duration of the test, except if the obstacle contains flexible material, which may cause its shape or dimensions to vary. For example, a soft partition may move due to air flow in the environment. If the obstacle becomes damaged during testing causing its shape or dimensions, or both, to change, an A-UGV may now interact with the obstacle differently than it did before it was damaged. If any characteristics of the obstacle change, it is considered a new and different obstacle from what was previously utilized.

5. Procedure

5.1 The test requestor elects either a genuine obstacle or artifact obstacle.

5.2 If an artifact obstacle is to be used and needs to be constructed, select the specified obstacle characteristics from Section 4 and fabricate it according to those specifications. If a genuine obstacle is to be used, select it and then measure its characteristics as outlined in Section 4.

5.3 Record the characteristics of the obstacle using the report described in Section 6.

5.4 Photos of the obstacle should be taken from multiple angles.

5.5 If a 3D model or other technical drawing of the obstacle is available, it should be included with the test report.

5.6 Before the obstacle is utilized in a test method, it is recommended that the test technician determine if the obstacle can be detected by the A-UGV. The appendix of this document describes a baseline obstacle detection test that can be performed for this purpose (see X1.2).

6. Report

6.1 Note—The implementation of a report form is not standardized. As such, the resulting forms can be different while conforming to this specification. Fig. 6 provides an illustration of an example blank test form for this practice.

6.2 Some example completed report forms can be found in Appendix X1.

7. Keywords

7.1 A-UGV; automatic guided vehicle; mobile robot; obstacles

ASTM International Committee F45 on Driverless Automatic Guided Industrial Vehicles

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DATE: _____ OBSTACLE NAME: _____

LOCATION: _____

DIMENSIONED AND LABELED IMAGES OF OBSTACLE:

(technical drawings, 3D renderings, or photos of the obstacle may be included here; dimensions of the entire obstacle and parts of the obstacle should be marked; the front of the obstacle should be marked in all images; each part of the obstacle should be labeled)

OBSTACLE MEDIA: (filenames for 3D drawings, photos, videos, or other media can be accessed)

TEST TECHNICIAN: _____

FIG. 6 Example Test Report for Recording Obstacle Characteristics