Designation: E2566 – 17

Standard Test Method for Determining Visual Acuity and Field of View of On-Board Video Systems for Teleoperation of Robots for Urban Search and Rescue Applications[1]

This standard is issued under the fixed designation E2566; 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

The robotics community needs ways to measure whether a particular robot is capable of performing specific missions in unstructured and often hazardous environments. These missions decompose into elemental robot tasks that can be represented individually as standard test methods and practices. The associated test apparatuses and performance metrics provide a tangible language to communicate various mission requirements. They also enable repeatable testing to establish the reliability of essential robot capabilities.

The ASTM International Standards Committee on Homeland Security Applications (E54) specifies standard test methods and practices for evaluating individual robot capabilities. These standards facilitate comparisons across robot models, or across various configurations of a particular robot model. They support robot researchers, manufacturers, and user organizations in different ways. Researchers use them to understand mission requirements, encourage innovation, and demonstrate break-through capabilities. Manufacturers use them to evaluate design decisions, integrate emerging technologies, and harden systems. User organizations leverage the resulting robot capabilities data to guide purchasing, align deployment objectives, and focus training with standard measures of operator proficiency. An associated usage guide describes how such standards can be implemented to support these various objectives.

The overall suite of standards addresses critical subsystems of remotely operated response robots, including maneuvering, mobility, dexterity, sensing, energy, communications, durability, proficiency, autonomy, logistics, safety, and terminology. This test method is part of the sensing test suite and addresses the acuity of onboard cameras.

1. Scope

1.1 This test method covers the measurement of several key parameters of video systems for remote operations. It is initially intended for applications of robots for Urban Search and Rescue but is sufficiently general to be used for marine or other remote platforms. Those parameters are (*1*) field of view of the camera system, (*2*) visual acuity at far distances with both ambient lighting and lighting on-board the robot, (*3*) visual acuity at near distances, again in both light and dark environments, and (*4*), if available, visual acuity in both light and dark environments with zoom lens capability.

1.2 These tests measure only end-to-end capability, that is, they determine the resolution of the images on the display screen at the operator control unit since that is the important issue for the user.

1.3 This test method is intended to be used for writing procurement specifications and for acceptance testing for robots for urban search and rescue applications.

1.4 This test method will use the Snellen fraction to report visual acuity; readers may wish to convert to decimal notation to improve intuitive understanding if they are more familiar with that notation. Distances will be given in metres with English units in parentheses following.

1.5 *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 and health practices and determine the applicability of regulatory limitations prior to use.*

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[1] This test method is under the jurisdiction of ASTM Committee E54 on Homeland Security Applications and is the direct responsibility of Subcommittee E54.09 on Response Robots.

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2. Terminology

2.1 *Definitions:*

2.1.1 *field of view, n*—angle subtended by the largest object that can be imaged with the video system.

2.1.2 *optotype, n*—character used on a chart for testing visual acuity.

2.1.2.1 *Discussion*—Optotypes are generally built on a 5 by 5 grid, with the size for "standard" vision subtending a square 5 min of arc on a side. This makes one grid element 1 min of arc square.

2.1.3 *tumbling E, n*—specific optotype that can be drawn in various orientations (facing left, right, up, or down) and in various sizes to create an eye chart (see Fig. 1).

2.1.3.1 *Discussion*—This optoptype is reported in the literature as being maximally distinguishable. Eye charts with Tumbling Es are available commercially for use at different distances.

2.1.4 *standard vision, n*—ability to resolve target features subtending 1 min of arc.

2.1.5 *visual acuity, n*—ability to resolve features subtending some angle, as compared with "standard" vision measured at the same distance.

2.1.5.1 *Discussion*—An angle Θ subtends a feature of size h at a distance d, of size 2h at a distance of 2d, of size 3h at a distance 3d, and so on. If 2d is the "standard" measurement distance of 6 m (20 ft), an eye chart for use at 3 m (10 ft) would have characters of h high rather than 2h high and the measurement of visual acuity would be the same. See Fig. 2 for an illustration of the angle/distance relationship.

2.1.6 *Snellen fraction, n*—a measure of visual acuity.

2.1.6.1 *Discussion*—The subject is placed a standard distance from an eye chart, typically 6 m (20 ft). The subject is asked to identify the line with the smallest characters that he can resolve. The Snellen fraction is the ratio of the distance at which that line would be resolved by a subject with standard vision to the standard test distance. Thus, a subject with standard vision would have 6/6 (20/20) vision.

2.1.7 *remote operation, n*—act of controlling a distant robot on a continuous or intermittent basis via tethered or radio-linked devices while being provided with sensory information (for example, visual information through cameras onboard the robot).

2.1.7.1 *Discussion*—Remote operation includes teleoperation as well as forms of intermittent autonomy or assisted autonomy.

3. Units for Reporting Visual Acuity

3.1 The commonly used distance for measuring visual acuity is 20 ft in the United States. This leads to the "Snellen fraction" as the common measure of visual acuity: 20/20, 20/40, and so on. The Snellen fraction is also used in England, referred to 6 m as the standard measurement distance (6/6, 6/12, etc.), while the rest of Europe generally used the decimal fraction equivalent: 20/20 = 6/6 = 1.0; 20/40 = 6/12=0.5, etc. Measurements may be taken at any distance and the result scaled to the common distance.

3.2 The meaning of 6/12 (20/40 or 0.5) is that features that can be resolved at 6 m (20 ft) by the test subject are of a size such that a person with "standard" visual acuity could resolve them at 12 m (40 ft). The characters on the 6/12 (20/40, 0.5) line of an eye chart are twice the size of the characters on the 6/6 (20/20, 1.0) line. The best human vision is not 6/6 (20/20, 1.0), resolving 1 min of arc (1/60° = .016°) but more like 6/3.6 (20/12, 1.7), resolving about 0.01°.

4. Significance and Use

4.1 Responder-defined requirements for these test methods are documented in a preliminary document entitled "Statement of Requirements for Urban Search and Rescue Robot Performance Standards."[2]

4.2 Field of View is important in terms of the ability of the operator to drive the robot. Looking at the world through a zoom lens is like "looking through a soda straw." Looking with a 30 or 40° field of view lens is like "driving with blinders on." On the other hand, using a very wide field of view lens (with a field of view of 120 or 150°), the operator's use of optic flow to cue depth perception is severely degraded and navigating in a tight environment is very difficult. Multiple cameras are recommended, with one providing a very wide field of view or all together providing a very wide field of view.

4.3 Far Vision Visual Acuity is important for both unmanned air vehicles (UAVs) and ground vehicles for wide area survey. Zoom is required for ground vehicles for wide area survey.

4.4 Near Vision Visual Acuity is important for ground vehicles for wide area survey in examining objects at close range and also for small robots which operate in constrained spaces.

4.5 Testing in the dark is important for small robots since they must sometimes operate in spaces with no ambient lighting.

5. Hazards

5.1 There are no hazards and no environmental issues associated with this test method.

[2] Messina, E., et al., "Statement of Requirements for Urban Search and Rescue Robot Performance Standards," http://www.isd.mel.nist.gov/US&R_Robot_Standards/Requirements Report (prelim).pdf

FIG. 1 Tumbling E Optotype in Various Orientations

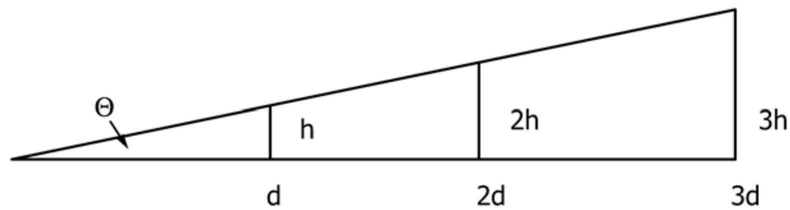

FIG. 2 Angle Subtended by Various Size Objects at Various Distances

6. Procedure

6.1 *Field of View:*

6.1.1 The test environment for 6.2 below is established, with eye charts on a wall and the robot located at a set test distance 6 m (20 ft) away from the wall (see Fig. 3). Vertical lines are drawn on the wall subtending fields of view from the test distance of 20 to 60° (or more if space allows) in increments of 10° and labeled.

6.1.2 Taking the line from the robot camera to the center of the eye chart as the center line, field of view lines need only be drawn to one side because of symmetry.

6.1.3 Determine field of view and record the result.

6.1.4 If the camera lens has a field of view beyond 60°, and test site space does not allow further reference marks, the field of view can be calculated using trigonometry (see Fig. 4).

$$\textit{Field of View} = 2\,\phi = 2\ \tan^{-1}(h/d)$$

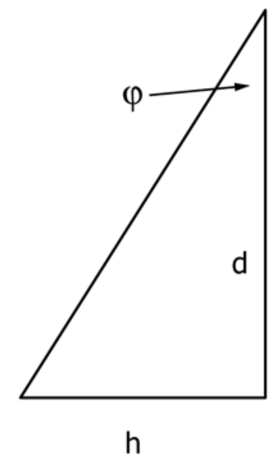

FIG. 4 Geometry of Field of View Determination

FIG. 3 Test of Visual Acuity and Field of View