Designation: E3064 – 16

Standard Test Method for Evaluating the Performance of Optical Tracking Systems that Measure Six Degrees of Freedom (6DOF) Pose[1]

This standard is issued under the fixed designation E3064; 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.

1. Scope

1.1 *Purpose*—This test method presents metrics and procedures for measuring, analyzing, and reporting the relative pose error of optical tracking systems that compute the pose (that is, position and orientation) of a rigid object while the object is moving.

1.2 *Usage*—System vendors may use this test method to determine the performance of their Six Degrees of Freedom (6 DOF) optical tracking system which measures pose. This test method also provides a uniform way to report the measurement errors and measurement capability of the system. System users may use this test method to verify that the system's performance is within the user's specific requirements and within the system's rated performance.

1.3 *Test Location*—The procedures defined in this standard shall be performed in a facility in which the environmental conditions are within the optical tracking system's rated conditions.

1.4 *Test Volume*—This standard shall be used for testing an optical tracking system working volumes of 3000 mm long by 2000 mm wide by 2000 mm high, 6000 mm long by 4000 mm wide by 2000 mm high, or 12 000 mm long by 8000 mm wide by 2000 mm high.

1.5 *Units*—The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.6 *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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E2919 Test Method for Evaluating the Performance of Systems that Measure Static, Six Degrees of Freedom (6DOF), Pose

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

2.2 *ASME Standard:*[3]

B89.4.19 Performance Evaluation of Laser-Based Spherical Coordinate Measurement Systems

2.3 *ISO/IEC Standards:*[4]

ISO/IEC Guide 99:2007 International Vocabulary of Metrology—Basic and General Concepts and Associated Terms (VIM: 2007)

ISO/IEC Guide 98–3:2008 Uncertainty of measurement—Part 3: Guide to the expression of uncertainty in measurement (GUM: 1995)

IEC 60050-300:2001 International Electro technical Vocabulary—Electrical and electronic measurements and measuring instruments

JCGM 200:2012 International Vocabulary of Metrology Basic and General Concepts and Associated Terms (VIM), 3rd edition

3. Terminology

3.1 *Definitions:*

3.1.1 *degrees of freedom, DOF, n*—any of the minimum number of translation or rotation components required to specify completely the pose of a rigid object. **E2919**

3.1.1.1 *Discussion*—

[1] This test method is under the jurisdiction of ASTM Committee E57 on 3D Imaging Systems and is the direct responsibility of Subcommittee E57.02 on Test Methods.

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[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.

[3] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Two Park Ave., New York, NY 10016-5990, http://www.asme.org.

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

(1) In a 3D space, a rigid object can have at most 6DOF, three translations and three rotations.

(2) The term "degree of freedom" is also used with regard to statistical testing. It will be clear from the context in which it is used whether the term relates to a statistical test or the rotation/translation aspect of the object.

3.1.2 *measurement error, error of measurement, and error, n*—measured quantity value minus a reference quantity value. **(JCGM 200:2012)**

3.1.3 *metrology bar, n*—a rod of a known length having markers (active or passive) attached to both ends and used to estimate the errors of an optical tracking system.

3.1.4 *optical tracking system, n*—a tracking system that uses measurements obtained from camera images.

3.1.5 *pose, n*—a 6DOF vector whose components represent the position and orientation of a rigid object with respect to a coordinate frame. **E2919**

3.1.6 *precision, n*—the closeness of agreement between independent test results obtained under stipulated conditions. **E177**

3.1.7 *rated conditions, n*—manufacturer-specified limits on environmental, utility, and other conditions within which the manufacturer's performance specifications are guaranteed at the time of installation of the instrument. **ASME B89.4.19**

3.1.8 *reference system, n*—a measurement instrument or system used to generate a reference value or quantity. **E2919**

3.1.9 *relative pose, n*—change of an object's pose between two poses measured in the same coordinate frame. **E2919**

3.1.10 *repeatability, n*—precision under repeatability conditions. **E177**

3.1.11 *repeatability conditions, n*—conditions where independent test results are obtained with the same method on identical test items in the same laboratory by the same operator using the same equipment within short intervals of time. **E177**

3.1.12 *tracking system, n*—a system that is used for measuring the pose of moving objects and supplies the data as a timely ordered sequence.

3.1.13 *work volume, n*—a physical space, or region within a physical space, that defines the bounds within which a rigid object tracking system is acquiring data. **E2919**

4. Summary of Test Method

4.1 This test method provides a set of statistically based performance metrics and a test procedure to quantitatively evaluate the performance of an optical tracking system.

4.2 The measurement errors include the positional and orientation error components. Specifically, the test procedure measures the relative pose between two marker sets rigidly attached to the opposing ends of a fixed-length metrology bar as shown in Fig. 1. The relative pose is then decomposed into positional and angular components. Measurement errors are calculated from the positional and angular components as the artifact is moved about the work volume.

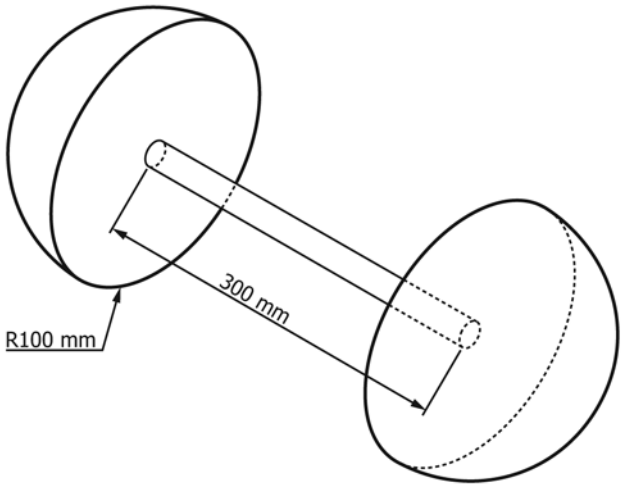

FIG. 1 Drawing of the artifact showing critical dimensions of the bar length and the maximum hemispherical volume inside which the markers can be placed.

5. Significance and Use

5.1 Optical tracking systems are used in a wide range of fields including: video gaming, filming, neuroscience, biomechanics, flight/medical/industrial training, simulation, robotics, and automotive applications.

5.2 This standard provides a common set of metrics and a test procedure for evaluating the performance of optical tracking systems and may help to drive improvements and innovations of optical tracking systems.

5.3 Potential users often have difficulty comparing optical tracking systems because of the lack of standard performance metrics and test methods, and therefore must rely on the claims of a vendor regarding the system's performance, capabilities, and suitability for a particular application. This standard makes it possible for a user to assess and compare the performance of candidate optical tracking systems, and allows the user to determine if the measured performance results are within the specifications with regard to the application requirements.

6. Apparatus

6.1 *Artifact:*

6.1.1 A 300 mm long bar with markers rigidly attached to each end of the metrology bar shall be used as the 6DOF artifact. The bar shall have stiffness and thermal expansion characteristics such that the deflection is less than or equal to 0.01 mm. For example, the metrology bar shown in Fig. 2 satisfies these requirements.

6.1.2 A constant relative 6DOF pose is formed between the two clusters of markers located at the ends of the metrology bar. All markers shall be contained within hemispherical volumes with a maximum radius of 100 mm from the ends of the bar (see Fig. 1). Examples of metrology bars that can be used to evaluate optical tracking systems are shown in Fig. 2 (Ref (**1**))[5].

[5] The boldface numbers in parentheses refer to a list of references at the end of this standard.