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Information technology — Computer graphics, image processing and environmental representation — Sensor representation in mixed and augmented reality

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National foreword

This British Standard is the UK implementation of ISO/IEC 18038:2020.

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Contents

Page

Foreword ... **v**
Introduction ... **vi**
1 Scope ... **1**
2 Normative references ... **1**
3 Terms and definitions ... **1**
4 Concepts ... **4**
4.1 Overview ... 4
4.2 Scope of physical sensor representation ... 5
4.3 Physical sensor types ... 6
4.3.1 General ... 6
4.3.2 Camera sensor ... 7
4.3.3 Chemical sensor ... 7
4.3.4 Electric sensor ... 8
4.3.5 Environment sensor ... 8
4.3.6 Flow sensor ... 8
4.3.7 Force sensor ... 9
4.3.8 Light sensor ... 9
4.3.9 Movement sensor ... 10
4.3.10 Navigation sensor ... 10
4.3.11 Particle sensor ... 11
4.3.12 Position sensor ... 11
4.3.13 Pressure sensor ... 12
4.3.14 Proximity sensor ... 12
4.3.15 Sound sensor ... 13
4.3.16 Temperature sensor ... 13
4.3.17 Other sensors ... 14
4.4 Sensor representation ... 14
4.4.1 Overview ... 14
4.4.2 Precise location and orientation of a physical sensor ... 16
4.4.3 Sensor properties and interface ... 19
4.4.4 Sensor representation data model ... 19
5 Sensor 3D scene graph ... **19**
5.1 Definition of a sensor 3D scene graph ... 19
5.2 Physical properties and interfaces with real worlds ... 21
5.2.1 General ... 21
5.2.2 Physical properties of a physical sensor ... 21
5.2.3 Physical interfaces with real worlds of a physical sensor ... 22
5.2.4 A data structure for the physical properties and interfaces for a physical sensor ... 23
6 System architecture for physical sensor representation ... **25**
6.1 System architecture for physical sensors ... 25
6.2 System framework ... 26
6.2.1 General ... 26
6.2.2 3D MAR world representation ... 27
6.2.3 GNSS synchronized 3D virtual worlds ... 27
6.2.4 Sensor devices and their properties ... 28
6.2.5 Interfaces with 3D sensor objects ... 28
6.2.6 Interfaces with physical sensor devices ... 28
7 XML definition of physical sensor representation ... **28**
7.1 Structure of mixed and augmented reality scene ... 28
7.1.1 MARScene ... 28
7.1.2 MARObject ... 28

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AVA Documents
Document Sharing Hub
Full document details: BS ISO/IEC 18038:2020

7.1.3 3D object ... 28
7.1.4 Shape ... 28
7.1.5 Physical sensor ... 28
7.1.6 Sensor type ... 28
7.1.7 Physical properties ... 29
7.1.8 Physical interface ... 29
7.2 XML schema definition ... 29
7.2.1 MARSceneType ... 29
7.2.2 GeoPositionType ... 30
7.2.3 LatitudeType and LongitudeType ... 30
7.2.4 GeoBoundingBoxType ... 31
7.2.5 LengthType ... 32
7.2.6 OrientationType ... 33
7.2.7 MARObjectType ... 35
7.2.8 ThreeDObjectType ... 35
7.2.9 ShapeType ... 36
7.2.10 AbstractSensorType ... 37
7.2.11 PhysicalPropertiesType ... 40
7.2.12 UUIDType, EventType and ControlType ... 40
7.2.13 PhysicalInterfaceType ... 41
7.2.14 IPAddressType and PortType ... 43

8 Conformance ... 44
8.1 Conformance criteria ... 44
8.2 Conformance area ... 45

Annex A (informative) **Examples of physical sensor types and parameters ... 46**

Annex B (informative) **Schema for sensor MAR representation ... 54**

Annex C (informative) **Example XML schema extension for physical sensor representation ... 55**

Annex D (informative) **Example of sensor MAR representation based on the sensor MAR schema ... 56**

Annex E (informative) **Implementation examples of sensor MAR representation ... 57**

Bibliography ... 61

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Document Sharing Hub
Full document details: BS ISO/IEC 18038:2020

Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT)

This document was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 24, *Computer graphics, image processing and environmental data representation*.

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Introduction

This document defines a representation model for physical sensors to be included in a 3D mixed-reality world. It defines 3D modelling, rendering, simulation, and interfaces for physical sensors. It defines a set of principles, concepts, and functionalities for physical sensors applicable to the complete range of 3D mixed reality standards. It includes the following content:

— terms and definition for sensor interfaces;

— requirements and scope;

— a representation model of physical sensors that can be included in a 3D scene;

— 3D modelling, rendering, and simulation of physical sensors in a 3D scene;

— representation of the attributes of physical sensors in a 3D scene;

— representation of I/O data streaming of physical sensors in a 3D scene;

— representation of the interfaces for controlling physical sensors in a 3D scene;

— functionalities and base components;

— relevant physical sensor properties;

— interfaces with virtual and real worlds;

— use cases.

The objectives of this document are as follows:

— provide a reference model for physical sensor-based 3D mixed-reality applications;

— manage and control physical sensors with their physical properties in 3D mixed reality environments;

— provide an exchangeable information model necessary for transferring and storing data between sensor-based mixed-reality applications;

— support user interfaces with 3D mixed-reality worlds;

— support physical sensor interfaces with 3D mixed-reality worlds.

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1 Scope

This document defines the framework and information reference model for representing sensor-based 3D mixed-reality worlds. It defines concepts, an information model, architecture, system functions, and how to integrate 3D virtual worlds and physical sensors in order to provide mixed-reality applications with physical sensor interfaces. It defines an exchange format necessary for transferring and storing data between physical sensor-based mixed-reality applications.

This document specifies the following functionalities:

a) representation of physical sensors in a 3D scene;

b) definition of physical sensors in a 3D scene;

c) representation of functionalities of each physical sensor in a 3D scene;

d) representation of physical properties of each physical sensor in a 3D scene;

e) management of physical sensors in a 3D scene;

f) interface with physical sensor information in a 3D scene.

This document defines a reference model for physical sensor-based mixed-reality applications to represent and to exchange functions of physical sensors in 3D scenes. It does not define specific physical interfaces necessary for manipulating physical devices, but rather defines common functional interfaces that can be used interchangeably between applications.

This document does not define how specific applications are implemented with specific physical sensor devices. It does not include computer generated sensor information using computer input/output devices such as a mouse or a keyboard. The sensors in this document represent physical sensor devices in the real world.

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 https://www.iso.org/obp

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

3.1
3D object
collection of vertices in 3D space, connected by various geometric entities such as triangles, lines, curved surfaces, etc.

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3.2
augmented reality
AR
interactive experience of a real-world environment whereby the objects that reside in the real world are augmented by computer-generated perceptual information

3.3
camera sensor
sensor (3.26) that detects and converts an optical image into an electronic signal

3.4
closed-circuit television
CCTV
video surveillance which uses video cameras to transmit a signal to a specific place on a limited set of monitors

3.5
chemical sensor
sensor (3.26) that can analyse and provide information about the chemical composition of its environment, that is, a liquid or a gas phase

3.6
electric sensor
sensor (3.26) that examines the change in electrical or magnetic signals based on an environmental input

3.7
environment sensor
sensor (3.26) that monitors relative ambient humidity, illuminance, ambient pressure and ambient temperature

3.8
flow sensor
sensor (3.26) for detecting the rate of fluid flow

3.9
force sensor
sensor (3.26) for force detecting resistor whose resistance changes when force or pressure is applied

3.10
globally navigation satellite system
GNSS
satellite navigation system with global coverage

3.11
globally unique identifier
GUID
unique reference number used as an identifier in computer systems

3.12
light sensor
photodetector which detects changes in quantities of optical signal

3.13
mixed and augmented reality
MAR
integration of real and virtual worlds including *mixed reality* (3.14) and *augmented reality* (3.2)

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3.14
mixed reality
MR
merging of real and virtual worlds to generate new environments where physical and synthetic objects co-exist and interact

3.15
mixed reality system
system that can process *mixed reality* (3.14) applications with manipulation functions such as read, write, import, export, modify, display, etc.

3.16
movement sensor
detector to detect a change in position of an object relative to its surroundings or the change in the surroundings relative to an object

3.17
oxygen sensor
electronic device that measures the proportion of oxygen (O_2) in the gas or liquid being analysed

3.18
particle sensor
detector to detect, track, and/or identify high-energy particles

3.19
physical device
real device containing a *sensor* (3.26) which is represented by a virtual device in a virtual environment

3.20
physical sensor
Internet of things (IoT) *sensor* (3.26) which has the functionality of a *physical device* (3.19) in a 3D virtual world

3.21
position sensor
sensor (3.26) that permits position measurement

3.22
pressure sensor
sensor (3.26) that measures pressure, typically of gases or liquids

3.23
programmable logic controller
PLC
digital computer used for automation of typically industrial electromechanical processes, such as control of machinery on factory assembly lines, amusement rides, or light fixtures

3.24
proximity sensor
sensor (3.26) able to detect the presence of nearby objects without any physical contact

3.25
radio frequency identification
RFID
wireless use of electromagnetic fields to transfer data, for the purposes of automatically identifying and tracking tags attached to objects

3.26
sensor
device to detect events or changes in its environment and send the information to other electronics

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3.27
sound sensor
sensor (3.26) used to detect the sound intensity of the environment

3.28
temperature sensor
sensor (3.26) to detect a change in temperature

3.30
universally unique identifier
UUID
globally unique identifier
128-bit number used to identify information in computer systems

3.32
virtual world
collection of one or more virtual reality (VR) files and other multimedia content that, when interpreted by a VR browser, presents an interactive experience to the user consistent with the author's intent

Note 1 to entry: Virtual reality (VR) is understood as an interactive computer-generated experience taking place in a synthetic and simulated environment.

4 Concepts

4.1 Overview

This clause describes the concepts of sensor-based mixed and augmented reality, including definition, objectives, sensor type, physical sensor representation, system functions for mixed and augmented reality (MAR), MAR objects, MAR scene graph, and MAR world.

A mixed-reality world consists of a 3D virtual world and real-world sensors represented as 3D objects with their physical properties. As a simple example, the conceptual scene of a mixed-reality world is represented in Figure 1. It displays a heritage site represented by a 3D virtual world with a global navigation satellite system (GNSS) sensor and a CCTV sensor. The virtual world is of a real heritage location in a city and the character represents a tourist. GNSS information is displayed for the tourist and a real CCTV device is located at its real physical location at the heritage site.

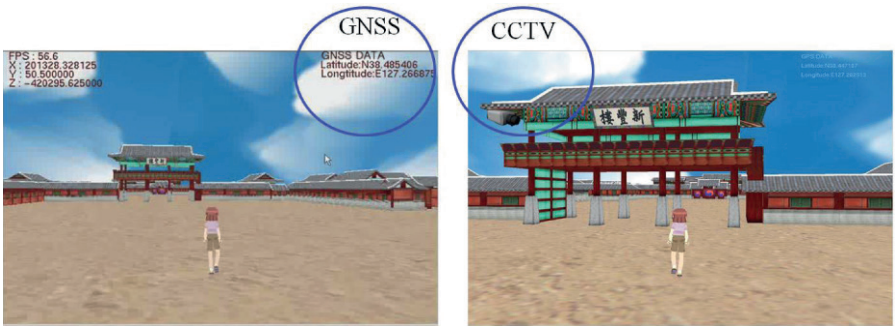

Figure 1 — Example sensor-based mixed-reality world

Once real physical sensors are integrated into a 3D virtual world, their physical properties can be represented precisely in the virtual world. Sensor-based mixed reality is obtained by this convergence of 3D with physical sensors in the real world. For sensor-based mixed reality, sensors in a 3D virtual world are defined, and their information should be able to be transferred between applications, and between a virtual world and a real world. This work is intended to define how to exchange AR/MR application data in heterogeneous computing environments, and how physical sensors can be managed and controlled with their physical properties in a 3D virtual world.

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Physical sensors in the real world are many and varied[11][14][18]. In order to control them in a 3D scene, these physical sensors are classified based on their information types and functions. Types of physical sensor devices include acoustic and sound, automotive and transportation, chemical, electric and magnetic, environment and weather, flow and fluid, radiation and particle, navigation, position and angle, speed and acceleration, optical and light, pressure, force and density, thermal and temperature, proximity and presence, and video. Each sensor is represented as a physical device in a 3D scene visually and/or functionally depending on the application and the type of sensor. Figure 2 shows an indoor and an outdoor scene, each with many physical sensors. Each scene represents a corresponding real world. The information and function of each sensor can be represented in the scenes. MAR scenes with physical sensors can be used for representing and simulating the functions of the sensors and, therefore, for managing the sensors using the 3D scene. These can also be used for facility management in a real world[3].

This document focuses on how to represent physical sensors in a 3D scene, what to represent about each physical sensor, what each sensor can do and the reason why each sensor needs this specification. When representing a physical sensor in a 3D scene, having the sensor appear in the scene is optional depending on the type of sensor and the application. Precise location and orientation of a sensor should be able to be represented and units for each sensor should be specified. A 3D scene should be able to be changed by the function of a physical sensor and simulated accordingly. The reason why such representation is needed is to provide a 3D scene with capabilities that can manage and control various physical sensors, for information services or security purposes.

Key

1	camera sensor	4	environment sensor	7	navigation sensor	10	sound sensor
2	chemical sensor	5	flow sensor	8	pressure sensor	11	temperature sensor
3	electric sensor	6	light sensor	9	proximity sensor		

Figure 2 — MAR worlds representation with physical sensors

4.2 Scope of physical sensor representation

Many types of physical sensors are currently in use in the real world and it is expected that the number of sensors and their types will increase with advancements in physical sensor technologies. Physical sensors integrate with 3D virtual worlds by way of information convergence technologies, including mixed and augmented reality. These technologies will be further developed and progressed based

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on industry need. While physical sensor devices continue to advance technologically, current sensor devices are being integrated into 3D virtual worlds for use in various real-world simulation applications.

It is not easy and, in fact, unnecessary to define every possible type of sensor that can be integrated into a 3D virtual world because these vary and constantly are updated based on the progression of sensor technology. Although the number of types of physical sensors will increase, a common interface for all sensor types is necessary in order to integrate them with a 3D scene. The interface should have the following features:

— the appearance, properties, location and orientation of a physical sensor should be represented in a 3D virtual world. The 3D virtual world should represent a copied scene of a real world;

— the functions of a physical sensor should be visualized or represented in a 3D virtual world;

— all other sensors that cannot be represented in a 3D virtual world visually and/or functionally are excluded.

In order to provide a 3D virtual world with common physical sensor interfaces, an abstracted physical sensor data model is necessary to represent and simulate these physical sensors[13]. This document defines the data model for representing physical sensors in 3D MAR worlds. The data model defines an abstracted interface that can be used for any type of sensors, not including specific attributes of a particular sensor type such as organization of a data stream.

In this document, the scope of sensor representation includes the following topics:

— concepts of physical sensors in a 3D scene;

— how to represent physical sensors in a 3D scene;

— how to organize a 3D scene with physical sensors;

— how to define an abstract model for representing physical sensors in a 3D scene;

— how to define a system architecture for physical sensors in a 3D scene;

— how to use physical sensors in a 3D scene;

— types of physical sensors for sensor representation.

4.3 Physical sensor types

4.3.1 General

Generally, physical sensors and their related devices can be classified as follows:

— acoustic, sound, vibration;

— automotive, transportation;

— camera, image;

— chemical;

— electric current, electric potential, magnetic, radio;

— environment, weather, moisture, humidity;

— flow, fluid velocity;

— ionizing radiation, subatomic particles;

— navigation instruments;

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— position, angle, displacement, distance, speed, acceleration;

— optical, light, photon;

— pressure;

— force, density, level;

— thermal, heat, temperature;

— proximity, presence.

Each sensor type can be defined based on its physical properties and related devices that can be represented and simulated in a 3D virtual world. Typical parameters for the physical properties of each sensor type are described in Annex A. The sensor types are classified (in alphabetical order) in 4.3.2 to 4.3.17.

4.3.2 Camera sensor

This sensor type integrates real world camera and images into a 3D virtual world. A camera sensor is represented as a camera device that converts an optical image into an electronic signal. It is used for digital cameras, phone cameras, camera modules, and other imaging devices, including CCTV (Figure 3). An abstract data model concerning the visual, functional, and physical properties of this sensor type should be defined to represent and simulate them in a 3D virtual world.

Figure 3 — Camera sensors

4.3.3 Chemical sensor

This sensor type integrates real world chemical detection devices into a 3D virtual world. All chemical detection devices, such as smoke detectors, are included. An abstract data model concerning the visual, functional, and physical properties of this sensor type should be defined to represent and simulate them in a 3D virtual world.

A chemical sensor is a self-contained analytical device that provides information about the chemical composition of its environment, that is a liquid or a gas phase (Figure 4). The information is provided in the form of a measurable physical signal that is correlated with the concentration of a certain chemical species (termed an analyte). For example, an oxygen sensor (or lambda sensor) is an electronic device that measures the proportion of oxygen (O_2) in the gas or liquid being analyzed.

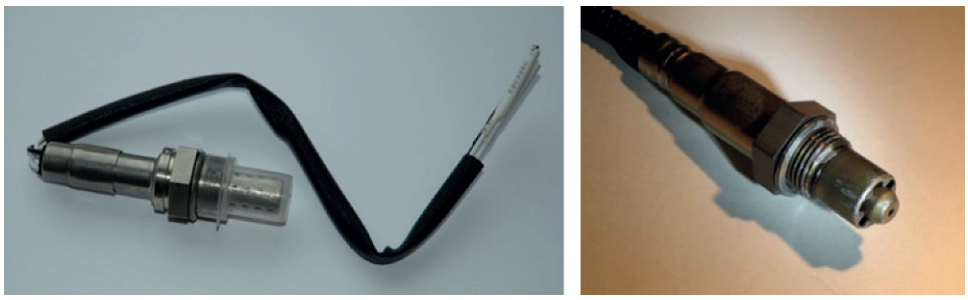

Figure 4 — Chemical sensor (oxygen sensor)

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4.3.4 Electric sensor

This sensor type integrates real-world electric and electronic signals into a 3D virtual world. All electrical devices, such as electricity and voltage detectors, are included. An abstract data model concerning the visual, functional and physical properties of this sensor type should be defined to represent and simulate them in a 3D virtual world.

An electric sensor is a manually or automatically operated electrical switch designed to protect an electrical circuit from damage caused by overload or short circuit (Figure 5). Its basic function is to detect a fault condition and interrupt current flow. Unmanned security system and RFID sensors are included.

Figure 5 — Electric sensors

4.3.5 Environment sensor

This sensor type integrates real world environmental change in weather, humidity, barometric air pressure as well as air quality measuring into a 3D virtual world. An abstract data model concerning the visual, functional, and physical properties of this sensor type should be defined to represent and simulate them in a 3D virtual world.

An environment sensor measures and represents earth surface characteristics and supports the information requirements for effective environment management (Figure 6). As a system, the Earth's environment comprises a collection of interdependent elements such as lithosphere, hydrosphere, biosphere, and atmosphere. A single instrument can be used to measure liquids and solids, and granular, slurry or open-channel flow without changing the transducer. Environment sensors can detect dust, gas, humidity, ambient light and weather.

Figure 6 — Environment sensors

4.3.6 Flow sensor

This sensor type integrates real world flow in air and fluid into a 3D virtual world. All flow detectors, such as air flow and fluid sensors, are included. An abstract data model concerning the visual, functional, and physical properties of this sensor type should be defined to represent and simulate them in a 3D virtual world.

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A flow sensor is a device that senses the rate of fluid flow. Typically, a flow sensor is the sensing element used in a flow meter, or flow logger, to record the flow of fluids. Flow measurement is necessary for representing the function of a flow sensor. An example of a flow sensor is a water meter (Figure 7). Water metering is the process of measuring water use. Water meters can be used at the water source, at a well or throughout a water system, to determine flow through a particular portion of the system.

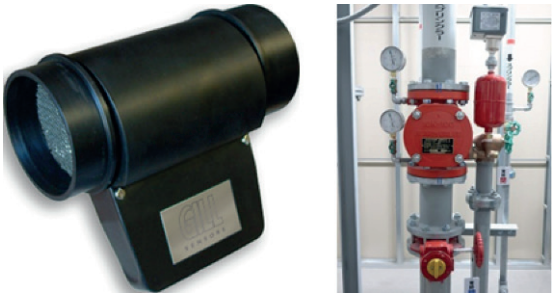

Figure 7 — Flow sensors

4.3.7 Force sensor

This sensor type integrates real-world force, density and level measurements into a 3D virtual world. All force sensors, force transducers and liquid and gas density and level measurement sensors are included. Level sensors detect the level of substances that flow (including liquids), slurries, granular materials and powders. An abstract data model concerning the visual, functional, and physical properties of this sensor type should be defined to represent and simulate them in a 3D virtual world.

A force-sensing resistor is a device whose resistance changes when force or pressure is applied (Figure 8). It is also known as a force-sensitive resistor. Force-sensing resistors consist of a conductive polymer which changes resistance in a predictable manner following application of force to its surface. In a 3D scene, a force sensor device can be represented with some motion based on its functions.

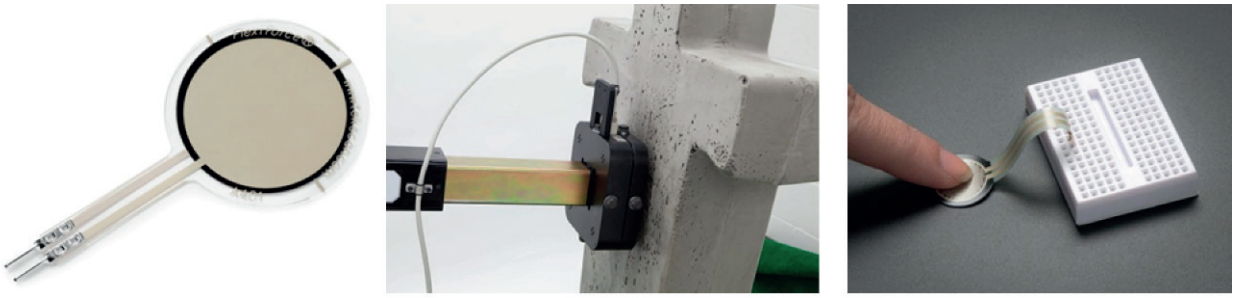

Figure 8 — Force sensors

4.3.8 Light sensor

This sensor type integrates real-world optical, light and photon measurements into a 3D virtual world. All optical, light and photon detectors are included. An abstract data model concerning the visual, functional and physical properties of this sensor type should be defined to represent and simulate them in a 3D virtual world.

A light sensor is a device that is used to detect light. Photosensors or photodetectors are sensors of light or other electromagnetic energy. In this document, a light sensor includes optical detectors and photo resistors, or light-dependent resistors (LDR), which change resistance according to light intensity (Figure 9). In a 3D scene, the light sensor represents the physical intensity of light based on the functions of the device. In a 3D scene, the light sensor itself is not typically represented. Rather, a 3D object that uses a light sensor, such as a light bulb, fluorescent light, or street light, is represented. It is controlled based on the functions of the included light sensor.

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Figure 9 — Light sensors

4.3.9 Movement sensor

This sensor type integrates real world moving objects into a 3D virtual world. Cars, robots, and fans are examples of devices whose movement can be detected. An abstract data model concerning the visual, functional and physical properties of this sensor type should be defined to represent and simulate them in a 3D virtual world.

A typical example of a movement sensor is an electronic motion detector which contains a motion sensor that transforms the detection of motion into an electric signal (Figure 10). This is achieved by measuring optical changes in the field of view. A motion detector can be connected to a burglar alarm that is used to alert a home owner or security service after it detects motion. Such a detector can also trigger a red light camera. Some of these applications include motion-activated outdoor lighting systems, motion sensor street lamps, and motion sensor lanterns.

Figure 10 — Movement sensors

4.3.10 Navigation sensor

This sensor type integrates real world navigation into a 3D virtual world. All navigation sensors that detect current position, orientation and other navigation information are included. An abstract data model concerning the visual, functional and physical properties of this sensor type should be defined to represent and simulate them in a 3D virtual world.

A navigation sensor is a component of an inertial navigation system (INS) that uses a computer, motion sensors (accelerometers) and rotation sensors (gyroscopes) to continuously calculate via dead reckoning the position, orientation and velocity (direction and speed of movement) of a moving object without the need for external references (Figure 11). It is used on ships, aircraft, submarines, guided missiles and spacecraft, for example. In a 3D scene based on the application, the navigation sensor itself is optionally represented.

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Figure 11 — Navigation sensors

4.3.11 Particle sensor

This sensor type integrates real-world ionizing radiation and subatomic particles into a 3D virtual world. All ionizing radiation and subatomic particle detectors are included. An abstract data model concerning the visual, functional and physical properties of this sensor type should be defined to represent and simulate them in a 3D virtual world.

A particle sensor is represented by a particle detector in experimental and applied particle physics, nuclear physics and nuclear engineering (Figure 12). It is also called a radiation detector and is used to detect, track and/or identify high-energy particles, such as those produced by nuclear decay, cosmic radiation or reactions in a particle accelerator. Modern detectors are also used as calorimeters to measure the energy of detected radiation. They can also be used to measure other attributes such as momentum, spin, charge, etc., of the particles. Detectors designed for modern accelerators are huge, both in size and in cost. The term “counter” is often used instead of detector when the detector counts the particles but does not resolve their energy or ionization.

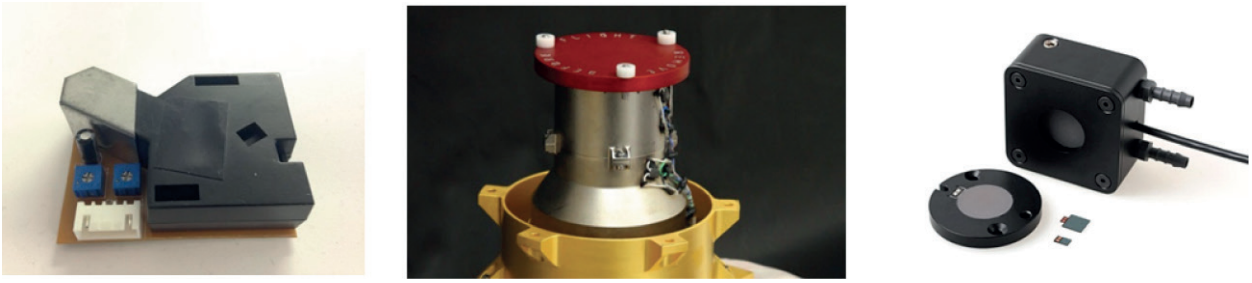

Figure 12 — Particle sensors

4.3.12 Position sensor

This sensor type integrates real-world measurements of position, angle, displacement, distance, speed and acceleration into a 3D virtual world. All measurement sensors (such as position, angle and oscilloscope, displacement, distance, speed and acceleration detectors) are included. An abstract data model concerning the visual, functional, and physical properties of this sensor type should be defined to represent and simulate them in a 3D virtual world.

A position sensor is any device that permits position measurement (Figure 13). It can either be an absolute position sensor or a relative one (displacement sensor). Position sensors can be linear, angular or multi-axis. In determining a position, the method can use:

— "distance", which would be the distance between two points such as the distance travelled or moved away from some fixed point; or

— "rotation" (angular movement), for example, the rotation of a robot's wheel to determine its distance travelled along the ground.

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Either way, position sensors can detect the movement of an object in a straight line using linear sensors or angular movement using rotational sensors.

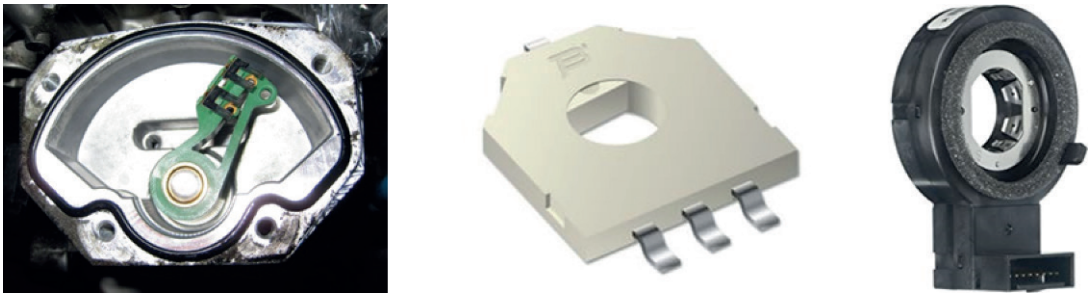

Figure 13 — Position sensors

4.3.13 Pressure sensor

This sensor type integrates real world pressure measurement into a 3D virtual world. All pressure sensors and pressure transducers are included. An abstract data model concerning the visual, functional and physical properties of this sensor type should be defined for representing and simulating them in a 3D virtual world.

A pressure sensor measures pressure, typically of gases or liquids (Figure 14). Pressure is an expression of the force required to stop a fluid from expanding and is usually stated in terms of force per unit area. A pressure sensor usually acts as a transducer – it generates a signal as a function of the pressure imposed. For the purposes of this document, such a signal is considered to be electrical. Pressure sensors are used for control and monitoring in many applications. Pressure sensors can also be used to indirectly measure other variables such as fluid/gas flow, speed, water level and altitude.

Figure 14 — Pressure sensors

4.3.14 Proximity sensor

This sensor type integrates real-world proximity and presence measurements into a 3D virtual world. An abstract data model concerning the visual, functional and physical properties of this sensor type should be defined to represent and simulate them in a 3D virtual world.

A proximity sensor detects the presence of nearby objects without any physical contact (Figure 15). It typically emits an electromagnetic field or a beam of electromagnetic radiation (infrared, for instance) and looks for changes in the field or return signal. Proximity sensors are also used in machine vibration monitoring to measure the variation in distance between a shaft and its support bearing.

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Figure 15 — Proximity sensors

4.3.15 Sound sensor

This sensor type integrates real-world sound into a 3D virtual world. Devices such as speakers, microphones, hearing aids, and vibrating instrumentation devices are included. An abstract data model concerning the visual, functional and physical properties of this sensor type should be defined to represent and simulate them in a 3D virtual world.

A sound sensor detects and measures sound waves and performs the function of a dynamic microphone (Figure 16). A microphone is an acoustic-to-electric transducer or sensor that converts sound into an electrical signal. Microphones are used in many applications [such as telephones, tape recorders, karaoke systems, hearing aids, motion picture production, live and recorded audio engineering, FRS (family radio service), megaphones, radio and television broadcasting] and to record voice for speech recognition and VoIP. This also includes non-acoustic purposes, such as ultrasonic checking or knock sensors. Most microphones today use electromagnetic induction (dynamic microphone), capacitance change (condenser microphone), piezoelectric generation or light modulation to produce an electrical voltage signal from mechanical vibration.

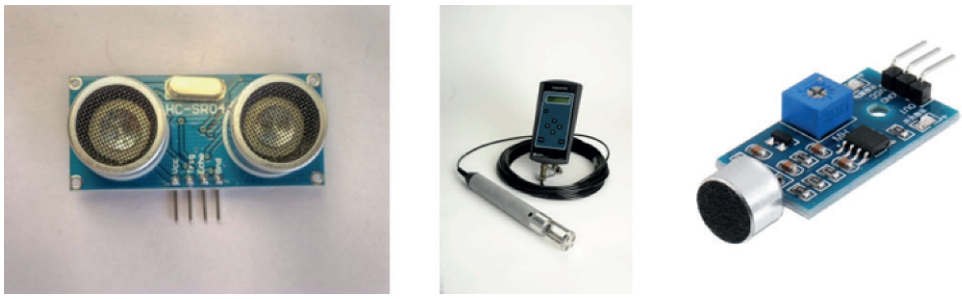

Figure 16 — Sound sensors

4.3.16 Temperature sensor

This sensor type integrates real-world temperature into a 3D virtual world. A thermometer is a device that measures temperature or a temperature gradient. An abstract data model concerning the visual,

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