IEEE 2888 표준화 현황과 메타버스 관련 미래 ICT 표준화 이슈

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IEEE 2888 WG Scope (unofficial)

- Developing interface standard (data formats and APIs) for interfacing cyber and physical worlds
- Developing reference architecture of applications interfacing cyber and physical worlds
- Developing visualization interface for cyber and physical world
- Relevant application domain may include digital twins, smart-X (farm, factory, city, etc), and metaverse

IEEE 2888 WG Structure

IEEE 2888

- **IEEE 2888.1** Specification of Sensor Interface for Cyber and Physical Worlds
- **IEEE 2888.2** Standard for Actuator Interface for Cyber and Physical Worlds
- **IEEE 2888.3** Standard on Orchestration of Digital Synchronization between Cyber and Physical Worlds
- **IEEE 2888.4** Standard on Architecture for Virtual Reality Disaster Response Training System with Six degrees of Freedom (6 DoF)
- **IEEE 2888.5** Standard for Virtual Training System Evaluation Methods
- **IEEE 2888.6** Standard for Holographic Visualization for Interfacing Cyber and Physical Worlds
- **IEEE P2888.7** Standard for Architecture of a Digital Twin System for Carbon Emission Management

IEEE 2888 WG Membership

- Open Committee
- Based on Individual membership
- Voting Member (23)
  - Attend 2 meetings from recent 4 meetings to acquire voting privilege
  - Lose voting privilege after missing 3 meetings from recent 4 meetings
  - Lost voting privilege after missing 2 of last 3 WG letter ballots
- Non-Voting Member (12)
  - Start of the 2nd Attending meeting
  - Lose membership after missing 4 consecutive meetings
- Observer (23)
  - By requesting
  - Till the start of the 2nd attending meeting

IEEE 2888 WG Officers

- Chair
  - Kyoungro Yoon (Prof. Konkuk University, JTC 1 SC 29 Korean NB HoD)
- Vice Chairs
  - Sang-Kyun Kim (Prof. Myongji University)
  - Sangkwon Peter Jeong (CEO, Joyfun)
- Secretary and Treasurer
  - Sangkwon Peter Jeong (CEO, Joyfun)

Introduction to Each Project

Standard 2888.1-2023: IEEE Standard Specification of Sensor Interface for Cyber and Physical Worlds (1/5)

IEEE 2888

- Project Title: Specification of Sensor Interface for Cyber and Physical World
- PAR Approval Date: 05 Sep. 2019
- Standard Approval Date: 8 Nov. 2023
- Standard Publication Date: Jan. 2024
- Scope: This standard defines the vocabulary, requirements, metrics, data formats and APIs for acquiring information from sensors, enabling definition of interfaces between the cyber world and physical world.
- Chair: Prof. Sang-Kyun Kim (Myongji University)
- Editor: Min Hyuk Jeong (Myongji University)

Standard 2888.1-2023: IEEE Standard Specification of Sensor Interface for Cyber and Physical Worlds (2/5)

IEEE 2888

- Data format for interfacing sensor data
  - The root schema structure and data format for individual sensor are defined.
  - The standard provides data format for describing 31 sensor data as follows:
    - Audio-visual sensors: microphone sensor, color camera sensor (2)
    - Biosensors: blood pressure sensor, heart rate sensor (2)
    - Environment-related sensors: ambient light, ambient noise, pressure, temperature, humidity, wind, gas, dust, precipitation, insolation, soil moisture, soil tension, electrical conductivity, acidity (14)
    - Location and position-related sensors: GPS, compass, orientation, position, distance, altitude (6)
    - Large space VR training system input sensors: button, analog, dial, glove, IMU, rigidbody, bend (7)

Standard 2888.1-2023: IEEE Standard Specification of Sensor Interface for Cyber and Physical Worlds (3/5)

IEEE 2888

- Data format for describing sensor capability
  - The standard provides data format for describing capability of sensors.
- Application programming interface for sensor
  - The standard provides APIs to exchange sensor data and its capability.
  - The sensor data and its capability can be acquired using APIs.
- The advantage of the standard is
  - describing sensor data from a physical world with a standard data format that can be interoperable in different cyber worlds
  - offering the capabilities of a sensor from a physical world in the standard way to adapt the sensor data in the cyber worlds

Standard 2888.1-2023: IEEE Standard Specification of Sensor Interface for Cyber and Physical Worlds (4/5)

IEEE 2888

- Sensor data example

```
"temperatureSensorData": {
 "type": "object",
 "properties": {
   "sensorDataBaseAttributes": {
     "$ref": "#/definitions/sensorDataBaseAttributes"
   },
   "value": {
     "type": "number"
   },
   "unit": {
     "$ref": "#/definitions/unitType"
   }
 },
 "additionalProperties": false
},
```

Figure 1. Syntax of temperature sensor data

Name	Definition
temperatureSensorData	It provides a structure for describing sensor data acquired by a temperature sensor
value	It describes the temperature with the unit d efined in the unit attribute
unit	It specifies the unit of the temperature as a reference to a term that shall be using the unitType(Celsius or Fahrenheit)

Figure 2. Semantics of temperature sensor data

```
{
 "temperatureSensorData": {
   "sensedInfoBaseAttributes": {},
   "value": 36.5,
   "unit": "celsius"
 }
}
```

Figure 3. Example of temperature sensor data instance

Standard 2888.1-2023: IEEE Standard Specification of Sensor Interface for Cyber and Physical Worlds (5/5)

IEEE 2888

- Sensor capability example

```
"temperatureSensorCapabilityData": {
  "type": "object",
  "properties": {
    "sensorCapabilityBaseAttributes": {
      "$ref":
"#/definitions/sensorCapabilityBaseAttributes"
    }
  },
  "additionalProperties": false
},
```

Figure 4. Syntax of temperature sensor capabilities

Name	Definition
TemperatureSensor CapabilityData	Tool for describing a temperature sensor capability

Figure 5. Semantics of temperature sensor capabilities

```
{
  "temperatureSensorCapabilityData": {
    "sensorCapabilityBaseAttributes": {
      "unit": "celsius",
      "minValue": 0,
      "maxValue": 50
    }
  }
}
```

Figure 6. Example of temperature sensor capabilities instance

Standard 2888.2-2023: IEEE Standard for Actuator Interface for Cyber and Physical Worlds (1/5)

IEEE 2888

- Project Title: Standard for Actuator Interface for Cyber and Physical Worlds
- PAR Approval Date: 03 Dec. 2020
- Standard Approval Date: 8 Nov. 2023
- Standard Publication Date: Jan. 2024
- Scope: This standard defines the vocabulary, requirements, metrics, data formats and application program interfaces (APIs) for describing characteristics of, setting up parameters for, and commanding actuators enabling definition of interfaces between the cyber world and physical world. These actuators shall be defined in cyber and physical world.
- Chair: Dr. Taebeom Lim (KETI)
- Editor: Dr. Shin Kim (Konkuk University)

Standard 2888.2-2023: IEEE Standard for Actuator Interface for Cyber and Physical Worlds (2/5)

IEEE 2888

- Data format for commanding actuator
  - The root schema structure and data format for individual actuator are defined.
  - The standard provides data format for controlling following 16 actuators:
    - light actuator, flash actuator, scent actuator, heating actuator, cooling actuator,
    - piezo vibration actuator, LRA vibration actuator, ERM vibration actuator,
    - generic vibration actuator, sprayer actuator, fog actuator, wind actuator,
    - bubble actuator, step motor actuator, character display actuator,
    - and unmanned moving platform actuator.

Standard 2888.2-2023: IEEE Standard for Actuator Interface for Cyber and Physical Worlds (3/5)

IEEE 2888

- Data format for describing actuator capability
  - The standard provides data format for describing capability of the actuator.
- Application programming interface for actuator
  - The standard provides APIs to exchange actuator command and its capability.
  - The actuator can be commanded or can provide its capability using APIs.
- The advantage of the standard is
  - enabling transferring a command to a physical world with a standard data format that can be interoperable in different cyber worlds
  - offering the capabilities of an actuator in the standard way to adapt actuator commands in the physical world

Standard 2888.2-2023: IEEE Standard for Actuator Interface for Cyber and Physical Worlds (4/5)

IEEE 2888

- Cooling Actuator

```
"coolingCommand": {
  "type": "object",
  "properties": {
    "commandInfoBaseAttributes": {
      "$ref": "#/definitions/commandInfoBaseAttributes"
    },
    "intensity": {
      "$ref":
"#/definitions/genericCommand/genericIntensityCommand"
    }
  },
  "additionalProperties": false
},
```

Figure 1. Syntax of cooling actuatorcommand

```
{
  "coolingCommand": {
    "commandInfoBaseAttributes": {
      "id": "C00000020”,
      "actuatorIdRef": "DC-04”
    },
    "intensity": {
      "unit": "celsius",
      "value": -2
    }
  }
}
```

Figure 2. Example of cooling actuator command

Standard 2888.2-2023: IEEE Standard for Actuator Interface for Cyber and Physical Worlds (5/5)

IEEE 2888

- Step Motor Actuator

```
"stepMotorCommand": {
  "type": "object",
  "properties": {
    "commandInfoBaseAttributes": {
      "$ref": "#/definitions/commandInfoBaseAttributes"
    },
    "speed": {
      "type": "integer",
      "minimum": 0
    },
    "steps": {
      "type": "integer",
      "minimum": 0
    },
    "orientation": {
      "type": "integer",
      "enum": [
        1,
        -1
      ]
    }
  },
  "additionalProperties": false
},
```

Figure 1. Syntax of step motor actuator command

```
{
  "stepMotorCommand": {
    "commandInfoBaseAttributes": {
          "id": "C00000020",
          "actuatorIdRef": "DC-21"
        },
    "speed": 10,
    "steps": 32,
    "orientation": -1
  }
}
```

Figure 2. Example of step motor actuator command

Standard 2888.3-2024 Standard on Orchestration of Digital Synchronization between Cyber and Physical Worlds (1/3)

IEEE 2888

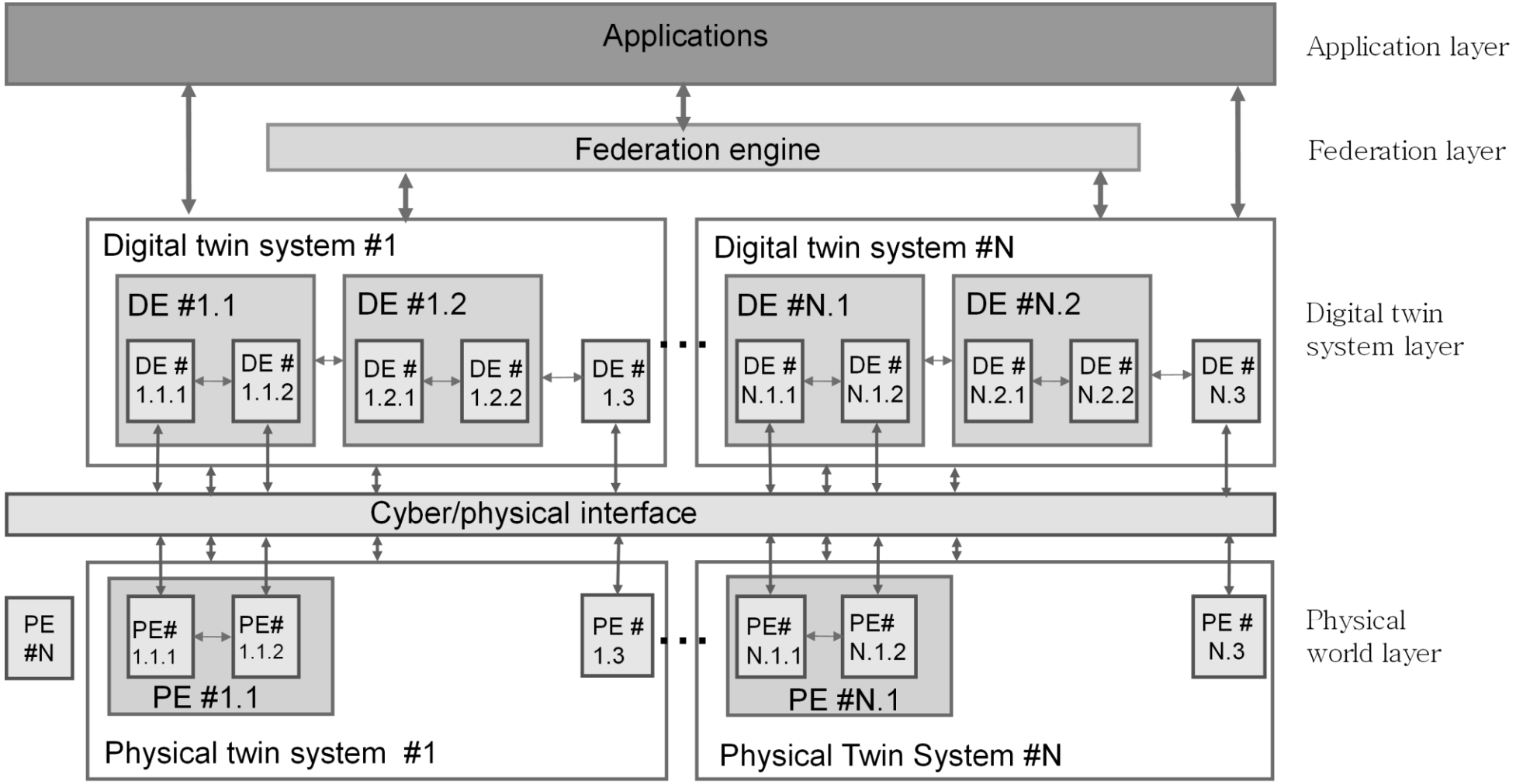
- Project Title: Standard for Actuator Interface for Cyber and Physical Worlds
- PAR Approval Date: 03 Dec. 2020
- PAR Expiration Date: 31 Dec. 2024
- SA Ballot Approved Date: 13 Sept. 2024
- Final Approval Expected on 26 Oct. 2024
- Scope: This standard defines the vocabulary, requirements, metrics, data formats and application program interfaces (APIs) for setting up parameters for and communicating with digital objects to provide sequences of synchronization and interaction with physical objects.
- Chair: Prof. Kyoungro Yoon (Konkuk University)
- Editors: Dr. Changseok Yoon (KETI), Dr. Misuk Lee (ETRI)

Standard 2888.3-2024 Standard on Orchestration of Digital Synchronization between Cyber and Physical Worlds(2/3)

IEEE 2888

- Architecture for Digital Synchronization Between Cyber and Physical Worlds
  - 4-layer architecture designed to organize and manage a digital twin system and requirements of each layer to conduct effective digital synchronization between the cyber and physical worlds
    - Physical world layer
    - Digital twin system layer
    - Federation layer
    - Application layer

Standard 2888.3-2024 Standard on Orchestration of Digital Synchronization between Cyber and Physical Worlds(3/3)

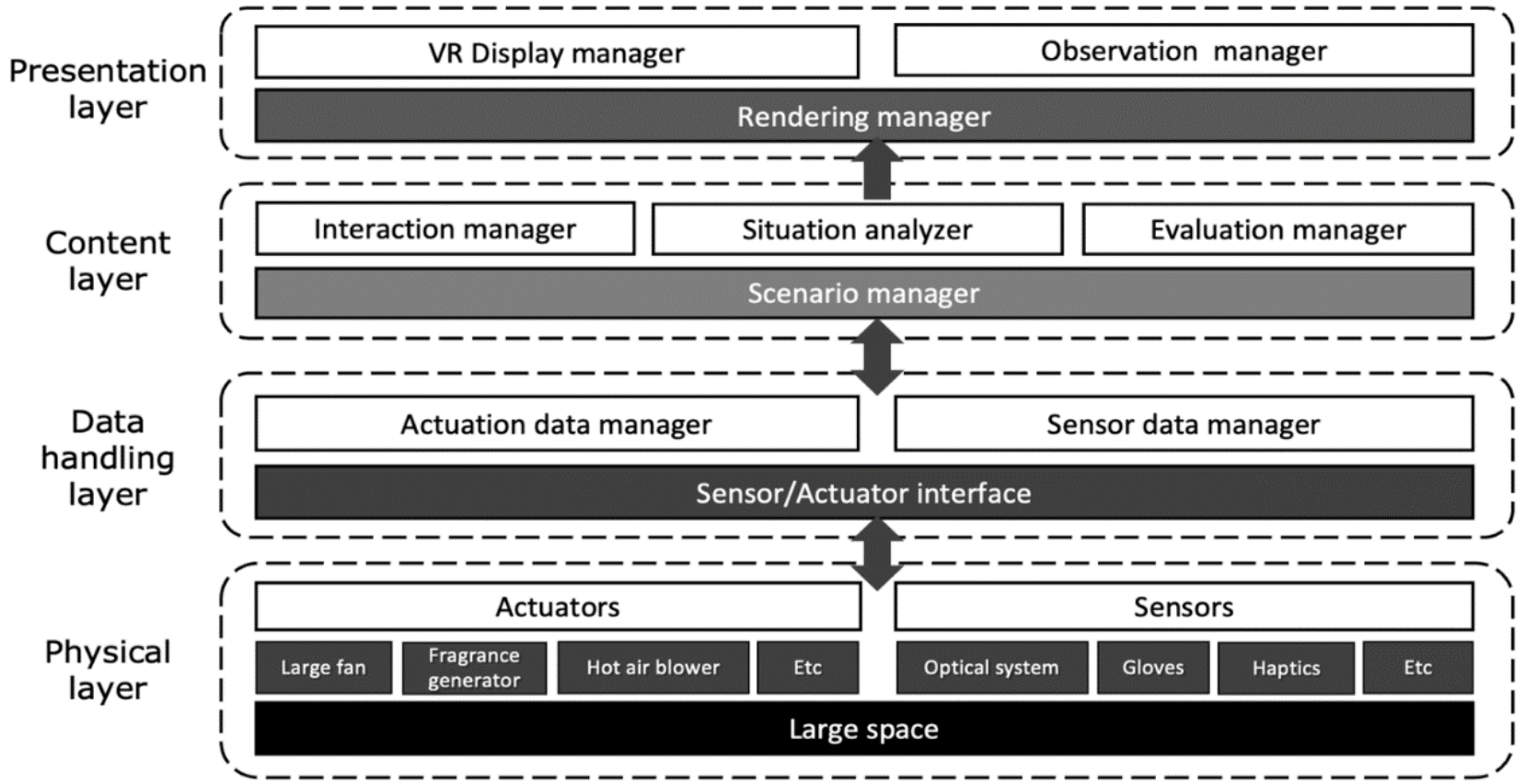


Standard 2888.4-2023: IEEE Standard for Architecture for Virtual Reality Disaster Response Training System with Six degrees of Freedom (6 DoF) (1/6)

- Project Title: Standard on Architecture for Virtual Reality Disaster Response Training System with Six degrees of Freedom (6 DoF)
- PAR Approval Date: 03 Dec 2020
- Standard Approval Date: 06 Dec 2023
- Standard Publication Date: Feb. 2024
- Scope: This standard defines an architecture required to implement a virtual reality system that can simulate responses to possible disasters in physical spaces, where users can actually move around with six degrees of freedom, for training. This reference architecture includes the physical-to-virtual component that transfers sensor data in the physical space to the virtual world, the virtual-to-virtual component that conveys the data between virtual world objects, and the virtual-to-physical component that transfers the simulated responses in the virtual world to actuators in the physical world.
- Chair: Mr. JeongHwoan Choi (Skonec Entertainment Co. Ltd.)
- Editor: Prof. HyeonWoo Nam (Dongduk Women's University), Prof. Sang-Kyun Kim (Myongji Univ.)

Standard 2888.4-2023: IEEE Standard for Architecture for Virtual Reality Disaster Response Training System with Six degrees of Freedom (6 DoF) (2/6)

- The VR DRTS for large spaces shall consist of four layers:
  - Physical layer, Data handling layer, Content layer, and Presentation layer.

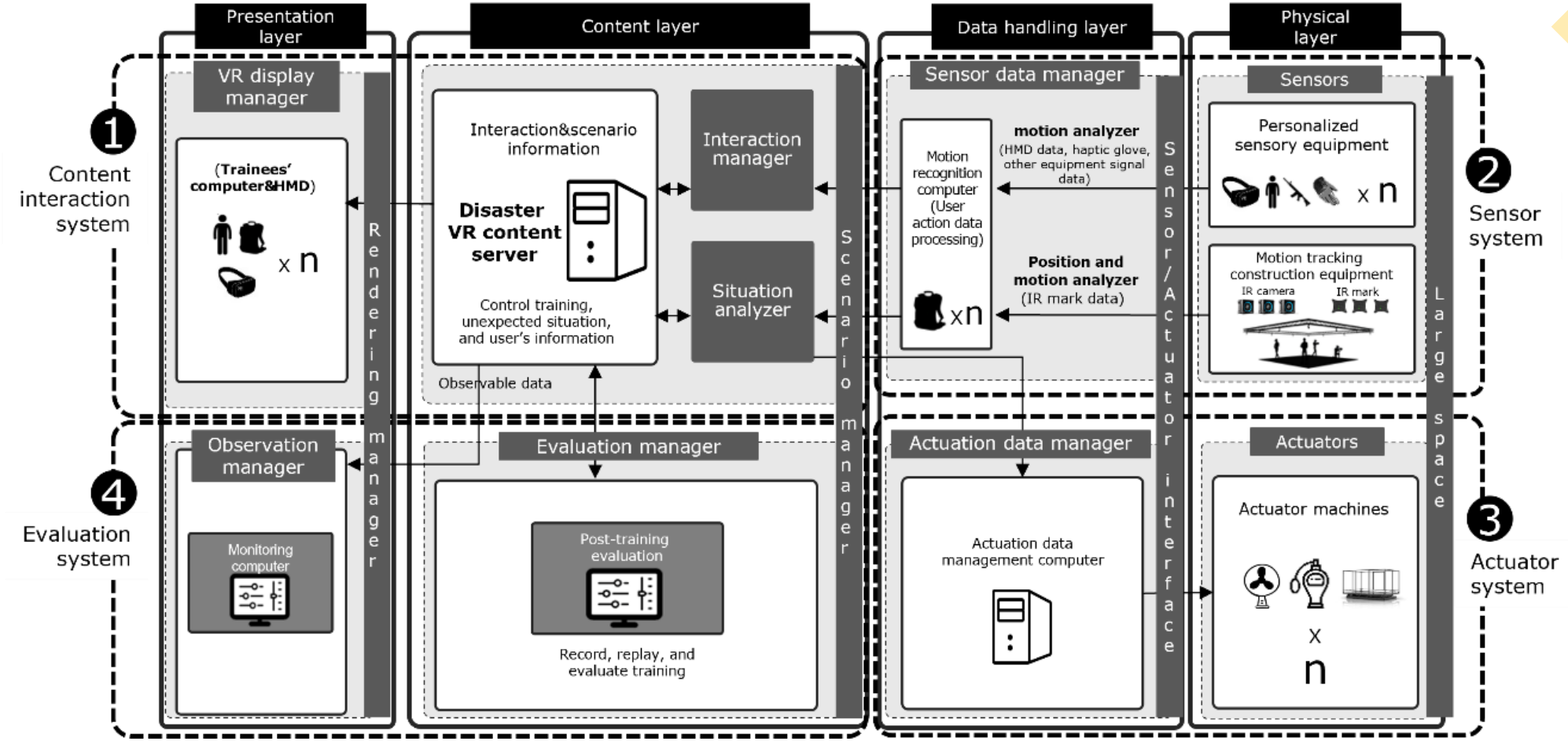


Standard 2888.4-2023: IEEE Standard for Architecture for Virtual Reality Disaster Response Training System with Six degrees of Freedom (6 DoF) (3/6)

- Requirements (8)
  - It shall provide large physical spaces for disaster response training,
  - It shall provide sensor data that capture trainees' full-body motion and position,
  - It shall support audio-visual display realizing 3D VR spaces,
  - It shall provide a VR walkthrough for user experience (UX) in movement,
  - It shall support the specification of 3D accuracy,
  - It should provide the trainees with means to interact with content,
  - It should provide 4D effects stimulating human senses, and
  - It should support the evaluation of the training result.

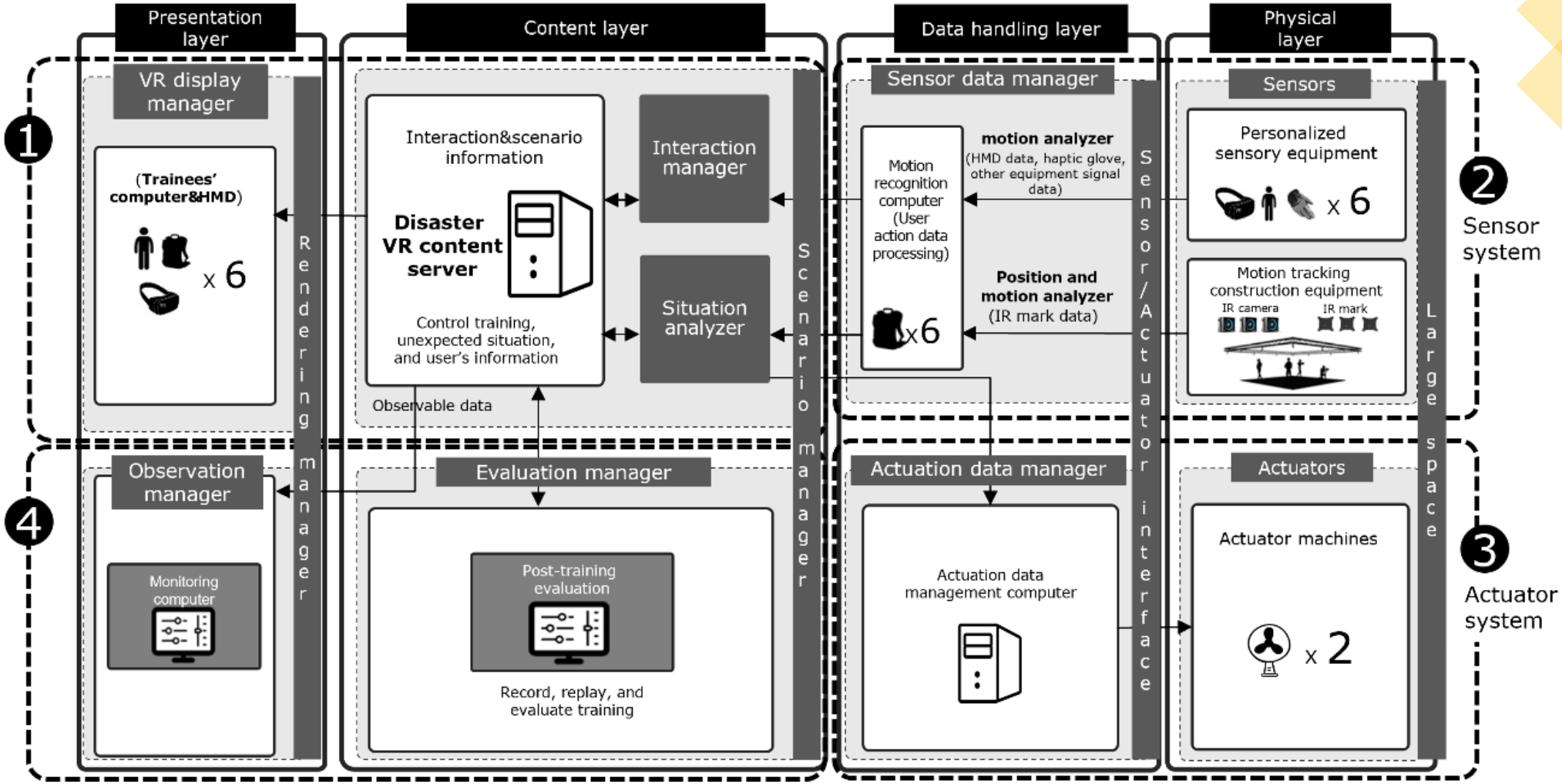
Standard 2888.4-2023: IEEE Standard for Architecture for Virtual Reality Disaster Response Training System with Six degrees of Freedom (6 DoF) (4/6)

- System Design with four subsystems: Content interaction system, Sensor system, Actuator system, and Evaluation system.



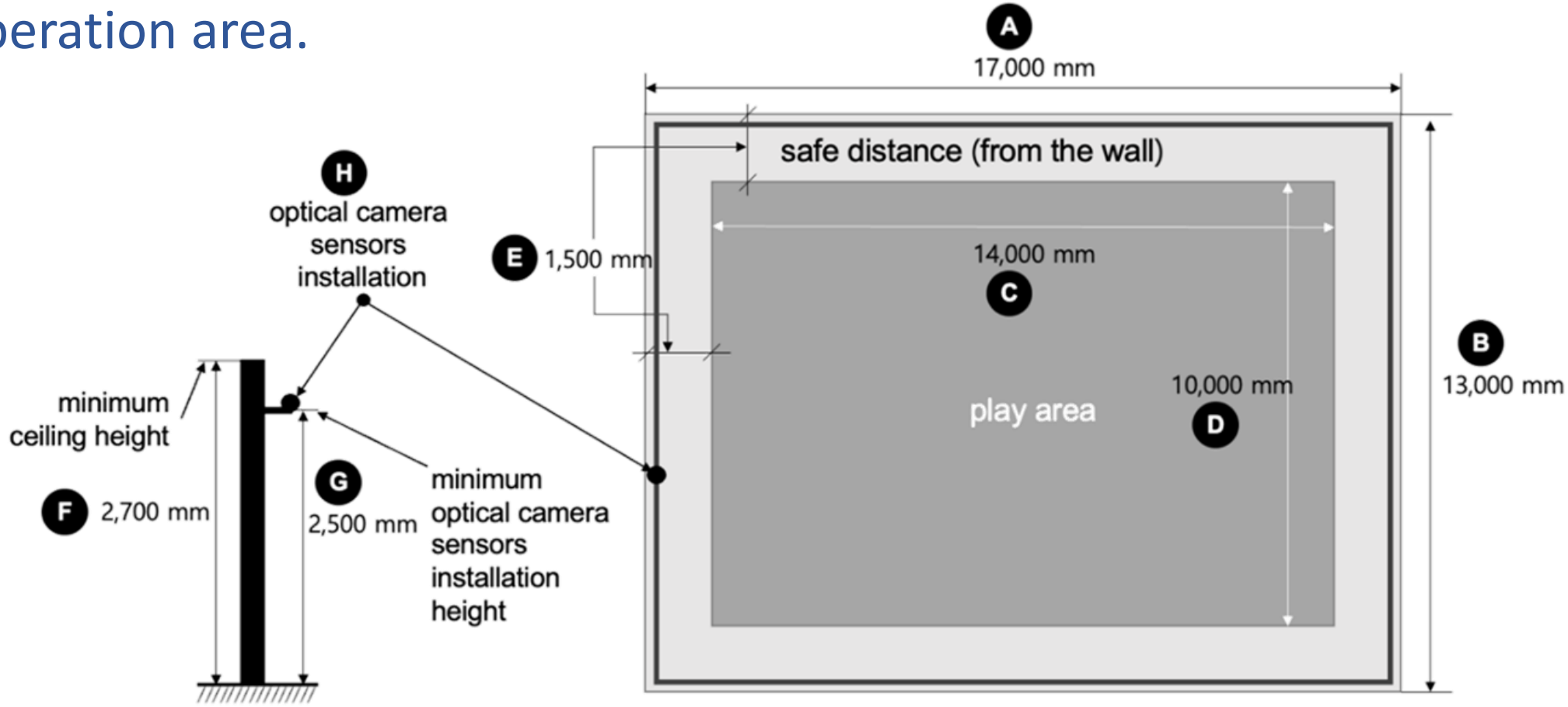
Standard 2888.4-2023: IEEE Standard for Architecture for Virtual Reality Disaster Response Training System with Six degrees of Freedom (6 DoF) (5/6)

- The use case of the chemical incident response training



Standard 2888.4-2023: IEEE Standard for Architecture for Virtual Reality Disaster Response Training System with Six degrees of Freedom (6 DoF) (6/6)

- Construction guidelines for the space of VR DRTS provides information on Training area, Optical camera sensors, and Operation area.



Standard 2888.5-2024: IEEE Standard for Virtual Training System Evaluation Methods (1/7)

IEEE 2888

- Project Title: Standard for Virtual Training System Evaluation Methods
- PAR Approval Date: 08 Dec. 2021
- Standard Approval Date: 20 May 2024
- Standard Publication Date: Dec. 2024
- Scope: This standard defines evaluation methods for virtual training systems. Both subjective as well as objective evaluation methods are defined, together with evaluation criteria, evaluation questionnaires and evaluation metrics that can be used to evaluate the effectiveness, efficiency and satisfaction of virtual training systems. This standard also defines experimental methods for evaluation including setting the experiment's environment, selecting test subjects, configuring the test subject group, designing the experiment, and the experimental procedures.
- Chair: Prof. Sang-Kyun Kim (Myongji University)
- Editor: Dr. Suhhee Yoo (KEA), Mr. Jonghyun Yuk (Skonec Entertainment Co. Ltd.)

Standard 2888.5-2024: IEEE Standard for Virtual Training System Evaluation Methods (2/7)

- Purpose: standardized guidelines for the evaluation of VR training systems, which can be applied in various industrial areas
- Scopes: This standard defines the evaluation framework for virtual training systems. The evaluation framework is including plan, design, data, test, and analysis

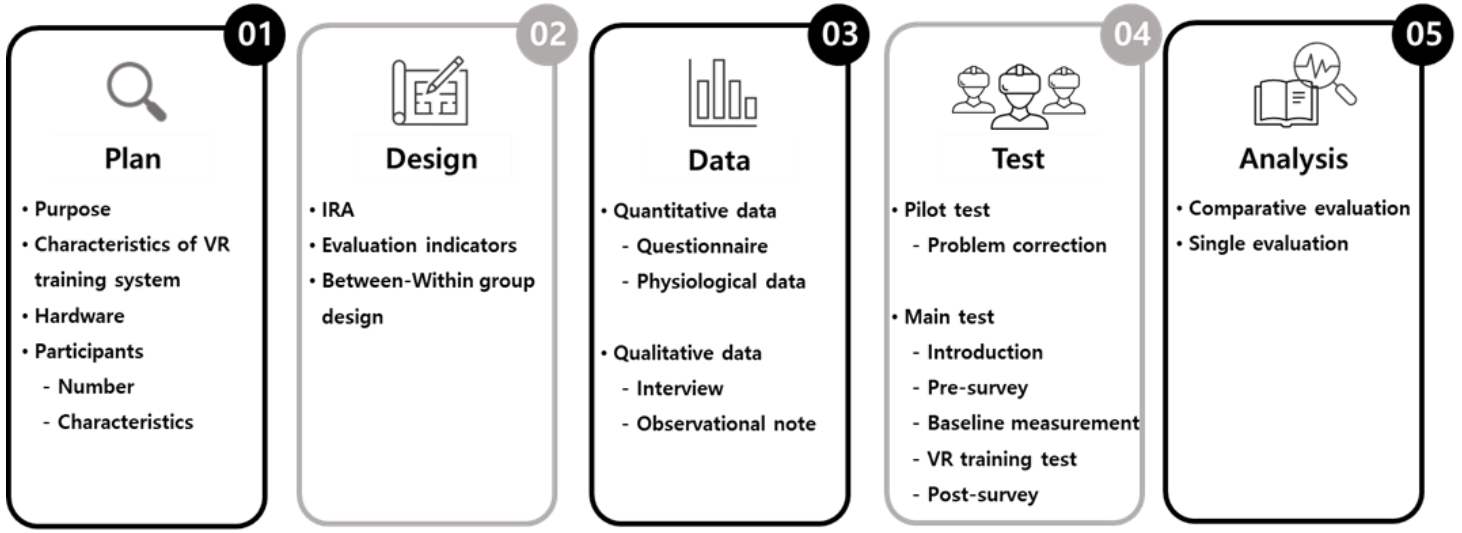


Fig.1. Framework of the evaluation methods for virtual training systems

Standard 2888.5-2024: IEEE Standard for Virtual Training System Evaluation Methods (3/7)

- Plan: Four items shall be considered to conduct evaluation for VR training systems effectively
  - Purpose of evaluation and goal of the VR training system
  - Characteristics of the VR training system
  - Hardware of the VR training system
  - Participants

Standard 2888.5-2024: IEEE Standard for Virtual Training System Evaluation Methods (4/7)

IEEE 2888

- Design: determine experimental design for the evaluation of the VR training
  - IRA: IRA(International review board approval) should be provided to conduct evaluation scientifically and ethically
  - Evaluation indicators: they can be selected after considering purpose and characteristics of a VR training system
    - Effectiveness: immersion level, task performance, user engagement
    - Usability: learnability, visibility
    - Acceptability: purchase and recommendation intention
  - Experimental design:
    - Between group design
    - Within group design

Standard 2888.5-2024: IEEE Standard for Virtual Training System Evaluation Methods (5/7)

IEEE 2888

- Data
  - Quantitative data refers to numerical data that can draw objective data from participants
    - Questionnaires
    - Physiological data such as EEG, PPG and Eye tracking
  - Qualitative data refers to non-numerical data that can draw detailed information from participants
    - In-depth interview
    - Focus group interview
    - Observational notes

Standard 2888.5-2024: IEEE Standard for Virtual Training System Evaluation Methods (6/7)

IEEE 2888

- Test
  - Pilot test: A small scale version of the main test to assess feasibility of the evaluation design and find any problems before the main test
  - Main test

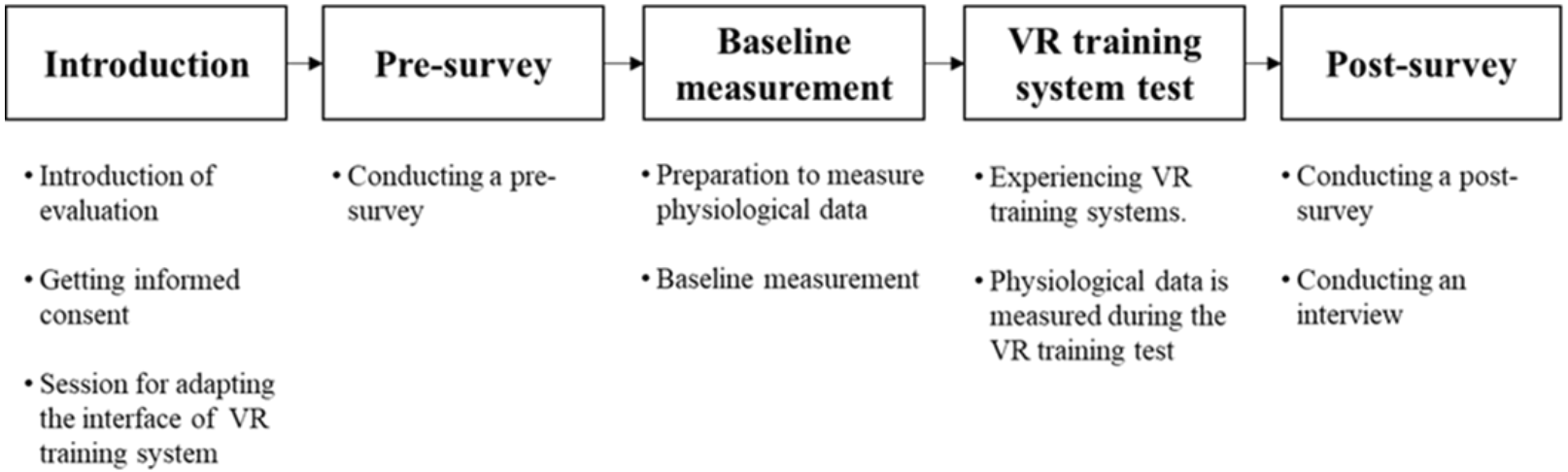


Fig.2. Flow chart of the main test

Standard 2888.5-2024: IEEE Standard for Virtual Training System Evaluation Methods (7/7)

- Analysis
  - Comparative evaluation: comparing different conditions to objectively present the evaluation results
  - Single evaluation: conducted to gain valuable insights from participants without comparing to other conditions

PAR 2888.6 Standard for Holographic Visualization for Interfacing Cyber and Physical Worlds (1/4)

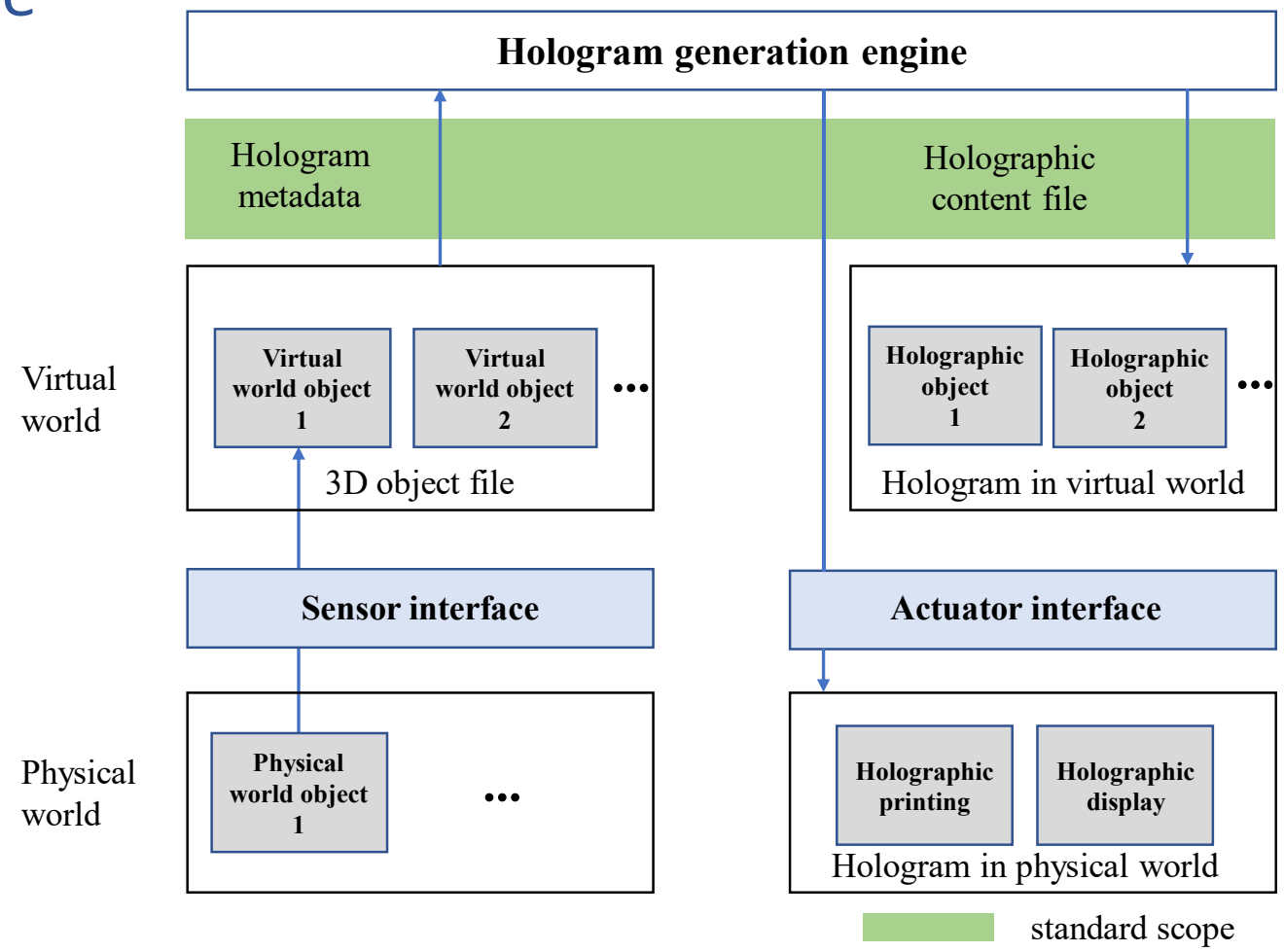
IEEE 2888

- Project Title: Standard for Holographic Visualization for Interfacing Cyber and Physical Worlds
- PAR Approval Date: 08 Dec. 2021
- PAR Expiration Date: 31 Dec. 2027
- Scope: This standard defines representations of holographic content to provide interfaces between Cyber and Physical Worlds for objects, which may exist either in Cyber or Physical Worlds. This includes following formats and scheme:
  - Holographic printing file format
  - Holographic contents encoding format
  - Holographic representation scheme
- Current Status: Preparing WG ballot
- Chair: Prof. HyeonWoo Nam (Dongduk Women's University)
- Editor: Dr. Youngmin Kim (KETI)

PAR 2888.6 Standard for Holographic Visualization for Interfacing Cyber and Physical Worlds (2/4)

IEEE 2888

- Base Architecture



PAR 2888.6 Standard for Holographic Visualization for Interfacing Cyber and Physical Worlds (3/4)

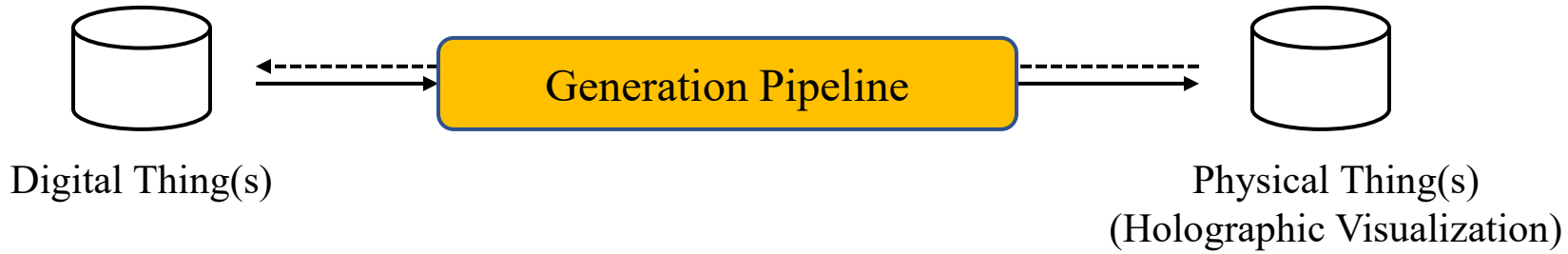
IEEE 2888

- Requirements
  - Holographic printing
    - It shall provide static 3D image.
    - It shall provide full-parallax 3D views within its viewing angle, defined by demagnified pixel pitch of the hogel and the recording wavelength.
  - Holographic display
    - It shall provide dynamic 3D videos.
    - It shall provide CGH patterns corresponding to the type of the used SLM, whether it is amplitude-only or phase-only.
  - Numerical reconstruction
    - It shall provide a function to check the hologram representation from digital thing(s) in the cyber world to realize hologram in the physical world.

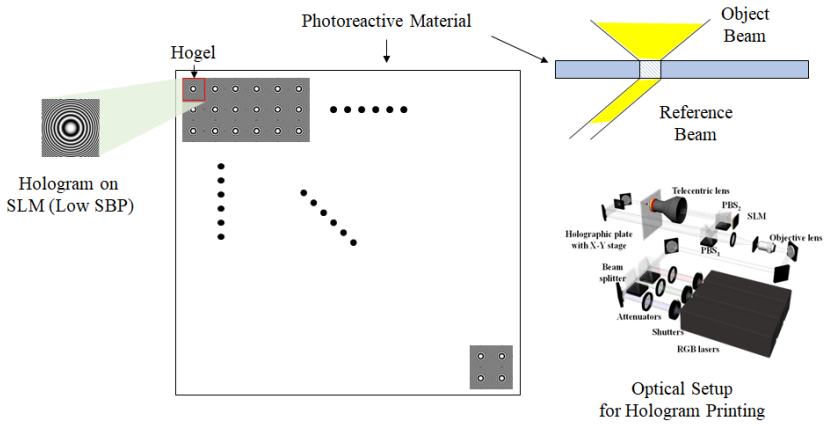
PAR 2888.6 Standard for Holographic Visualization for Interfacing Cyber and Physical Worlds (4/4)

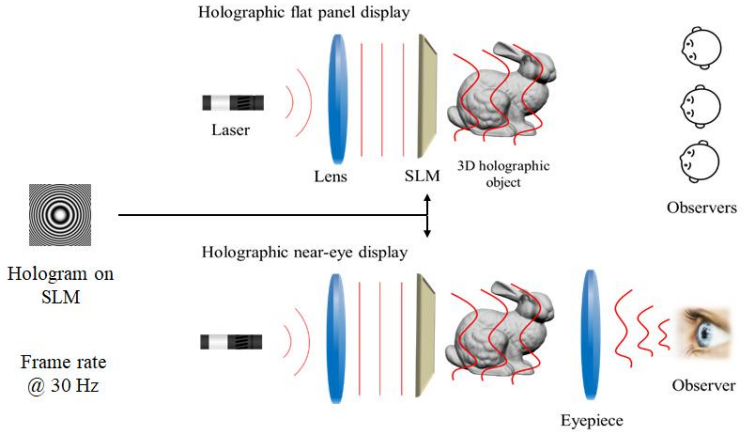
IEEE 2888

- Use cases



HP(Holographic Printing)
HD(Holographic Display)





Future Issues

New PARs under developing

- PAR 2888.7
  - Standard for Architecture of a Digital Twin System for Carbon Emission Management
- PAR 2888.1a (Amendment)
  - IEEE Standard for Specification of Sensor Interface for Cyber and Physical Worlds Amendment: Binary Representation of Data Formats for Interfacing Sensors and their Capabilities
- PAR 2888.2a (Amendment)
  - IEEE Standard for Actuator Interface for Cyber and Physical Worlds Amendment: Binary representation of data formats, application programming interfaces and definition of additional actuators

New PARs under developing

- PAR 2888.5a (Amendment)
  - IEEE Standard for Virtual Training System Evaluation Methods Amendment: Physiological evaluation method for virtual training systems
- PAR 2888.3a (Amendment)
  - Security Requirements on Digital Twin Architecture based on Zero Trust Principles (TBC)

Issues to be resolved

- Interface format between layers of P2888.3
- Security issues related to sensors/actuators
- Further development of P2888.3 for the Orchestration
- Real-time synchronization for Digital Twin
- Physical AI?

Thank You!

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