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(54) **DIGITAL TWIN FEDERATION APPARATUS AND METHOD**

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(57) **ABSTRACT**

Disclosed herein are a digital twin federation apparatus and method. The digital twin federation apparatus includes memory configured to store at least one program, and a processor configured to execute the program, wherein the program performs extracting at least two digital twin systems corresponding to digital twin types matching a service purpose, received from an application service layer, from a pre-registered digital twin system list, obtaining pieces of data from the extracted at least two digital twin systems, respectively, synchronizing the pieces of data obtained from the extracted at least two digital twin systems, respectively, so that the pieces of data are linked in an identical time slot and in an identical unit, and delivering the linked data to the application service layer.

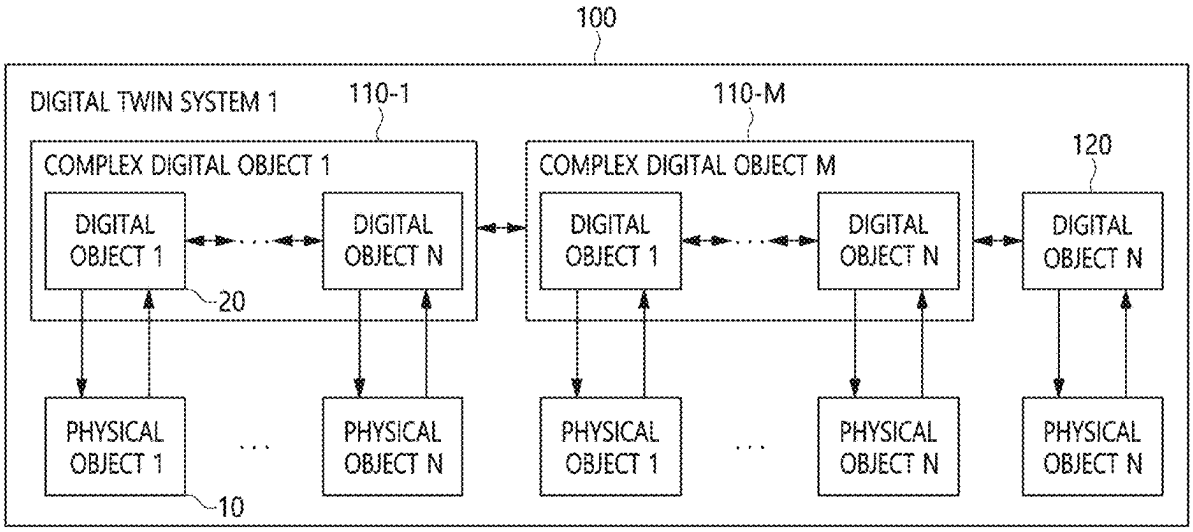


FIG. 1

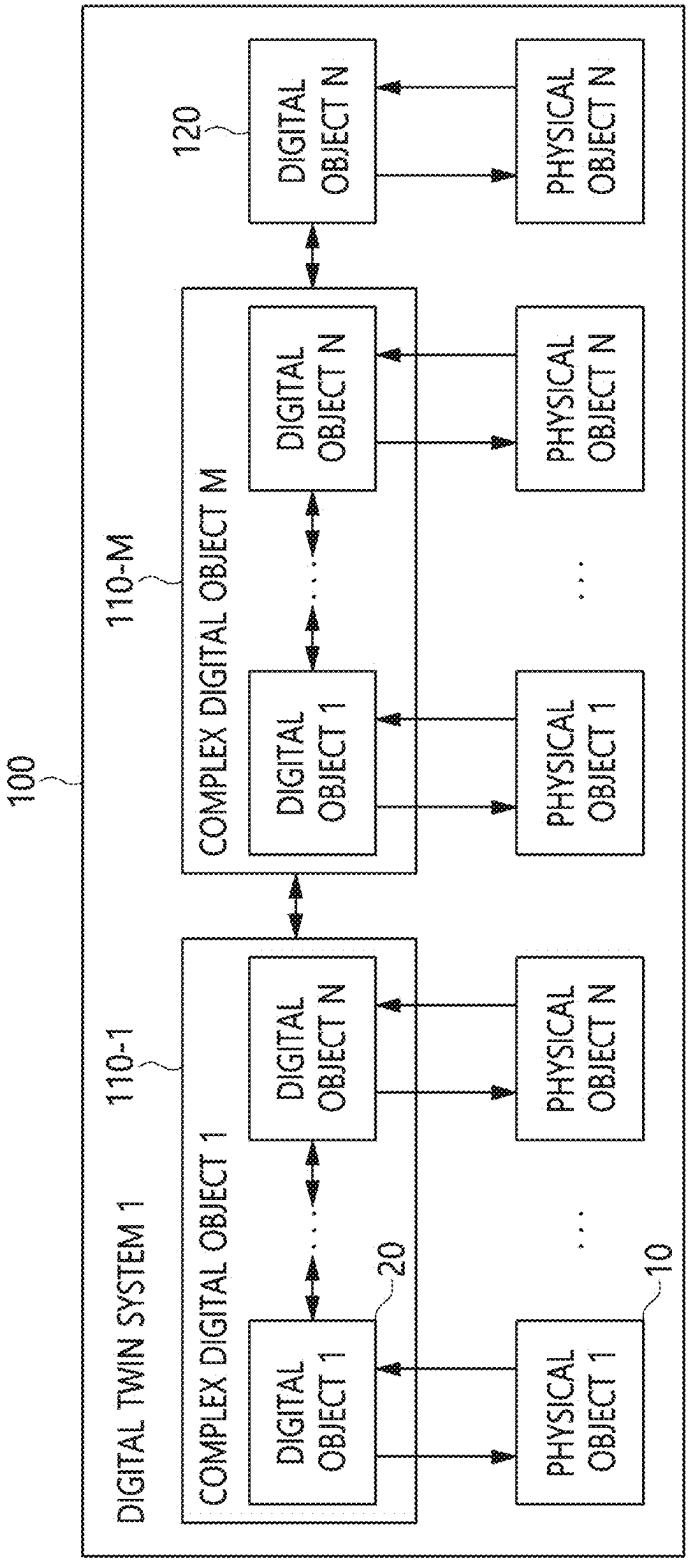

100
DIGITAL TWIN SYSTEM 1
110-1
COMPLEX DIGITAL OBJECT 1
DIGITAL OBJECT 1
20
DIGITAL OBJECT N
PHYSICAL OBJECT 1
10
PHYSICAL OBJECT N
110-M
COMPLEX DIGITAL OBJECT M
DIGITAL OBJECT 1
DIGITAL OBJECT N
PHYSICAL OBJECT 1
PHYSICAL OBJECT N
120
DIGITAL OBJECT N
PHYSICAL OBJECT N

FIG. 2

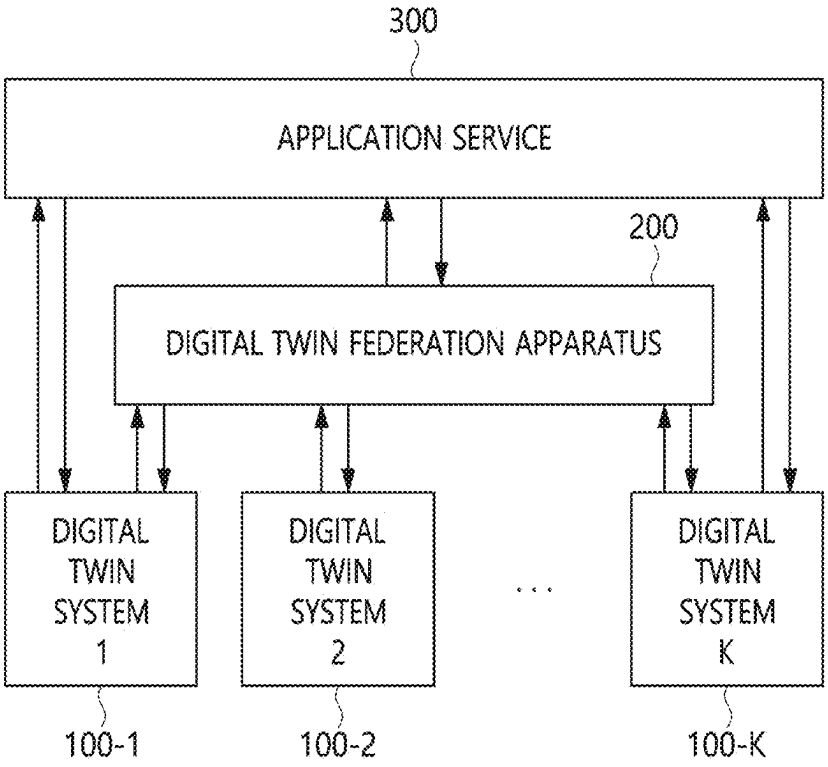

300
APPLICATION SERVICE
200
DIGITAL TWIN FEDERATION APPARATUS
DIGITAL TWIN SYSTEM 1
DIGITAL TWIN SYSTEM 2
DIGITAL TWIN SYSTEM K
100-1
100-2
100-K

FIG. 3

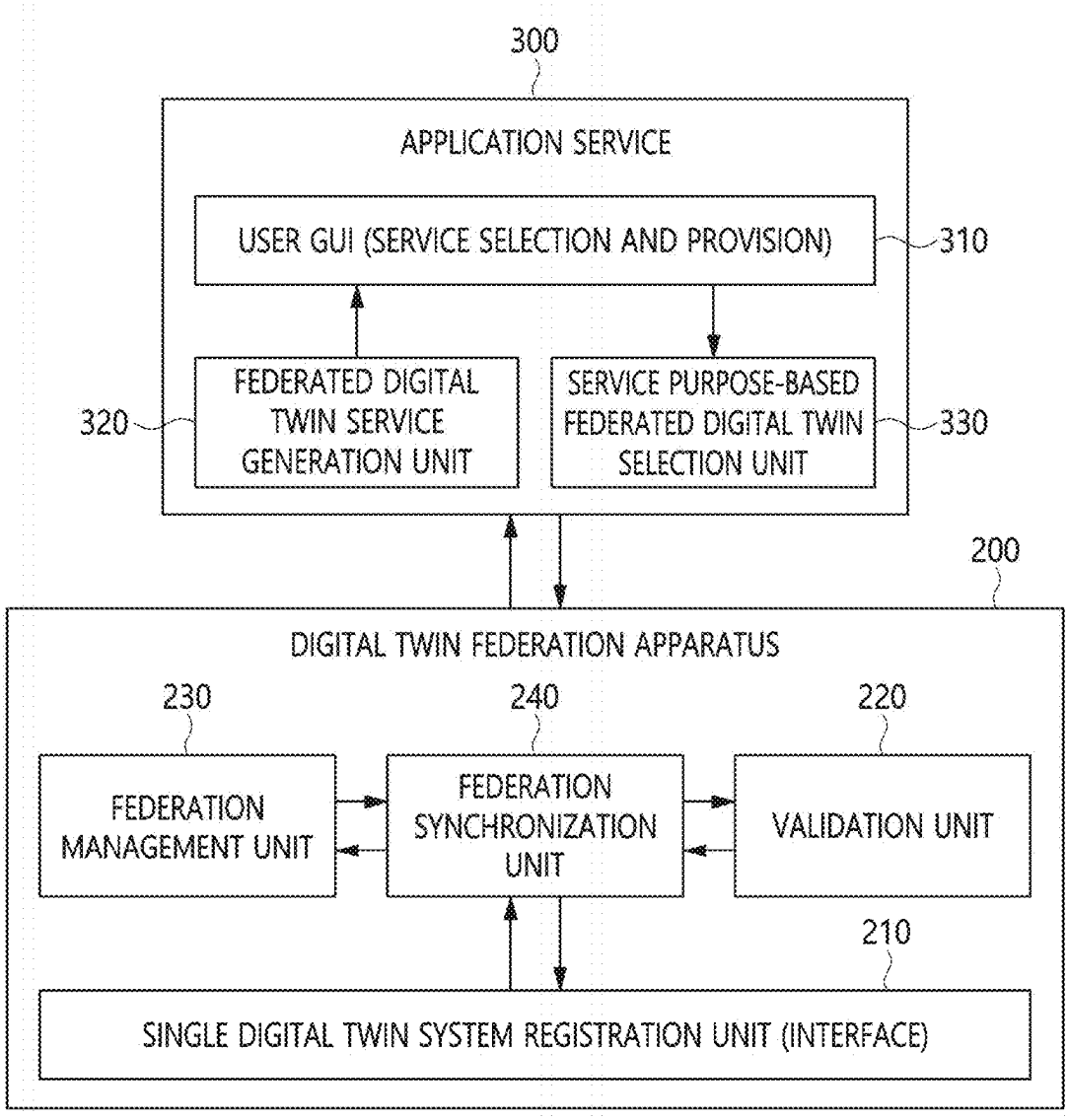

300
APPLICATION SERVICE
USER GUI (SERVICE SELECTION AND PROVISION)
310
FEDERATED DIGITAL TWIN SERVICE GENERATION UNIT
320
SERVICE PURPOSE-BASED FEDERATED DIGITAL TWIN SELECTION UNIT
330
200
DIGITAL TWIN FEDERATION APPARATUS
230
240
220
FEDERATION MANAGEMENT UNIT
FEDERATION SYNCHRONIZATION UNIT
VALIDATION UNIT
210
SINGLE DIGITAL TWIN SYSTEM REGISTRATION UNIT (INTERFACE)

FIG. 4

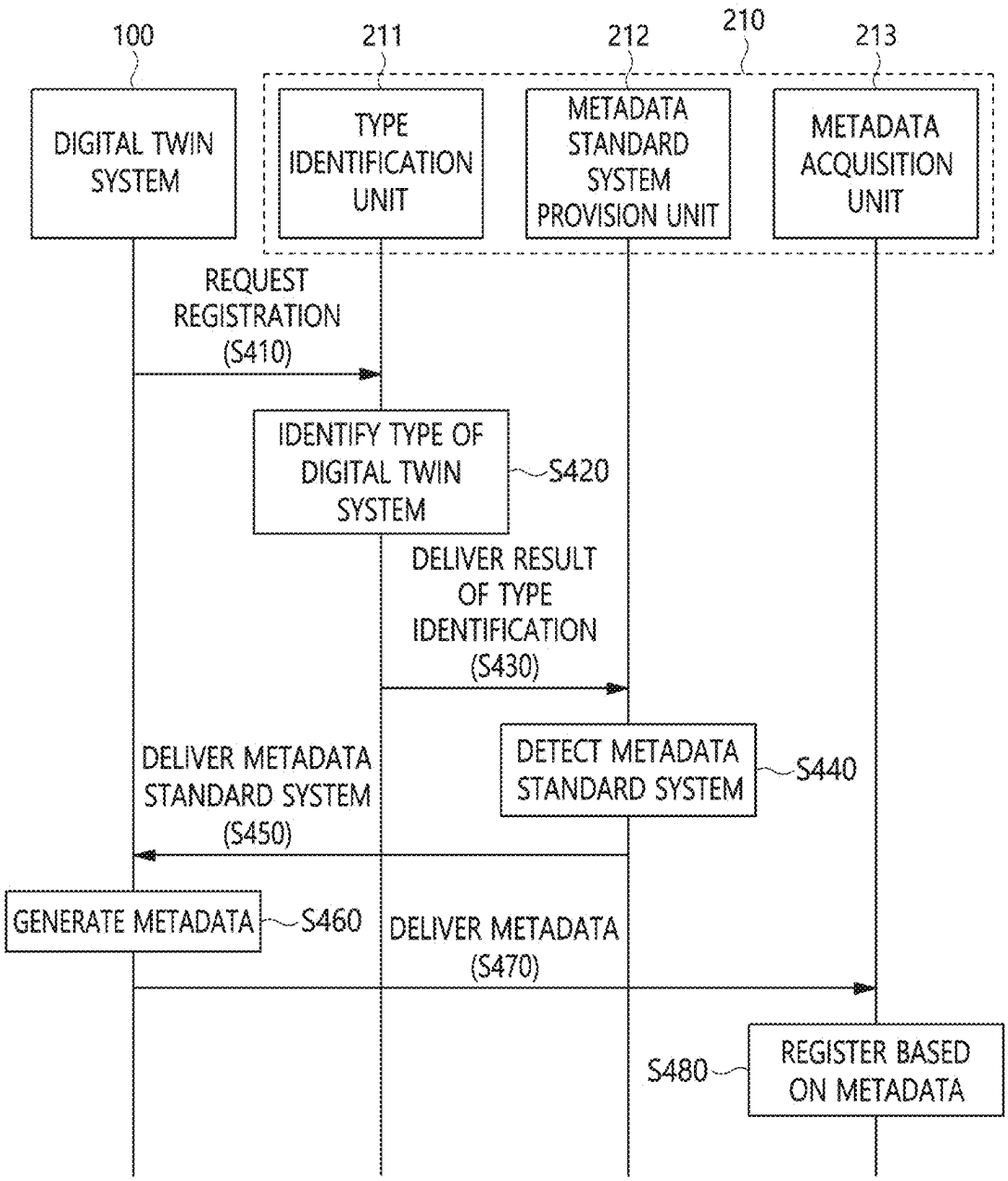

100
211
212
210
213
DIGITAL TWIN SYSTEM
TYPE IDENTIFICATION UNIT
METADATA STANDARD SYSTEM PROVISION UNIT
METADATA ACQUISITION UNIT
REQUEST REGISTRATION (S410)
IDENTIFY TYPE OF DIGITAL TWIN SYSTEM
S420
DELIVER RESULT OF TYPE IDENTIFICATION (S430)
DETECT METADATA STANDARD SYSTEM
S440
DELIVER METADATA STANDARD SYSTEM (S450)
GENERATE METADATA
S460
DELIVER METADATA (S470)
S480
REGISTER BASED ON METADATA

FIG. 5

1	TRANSPORTATION DIGITAL TWIN
1-1	CONFIGURATION INFRASTRUCTURE
1-1-1	VEHICLE TRAFFIC LIGHT
1-1-2	PEDESTRIAN TRAFFIC LIGHT
. . .	. . .
. . .	. . .

FIG. 6

2	WEATHER DIGITAL TWIN
2-1	RAINFALL
2-1-1	HOURLY RAINFALL
2-1-2	MAXIMUM RAINFALL OF CORRESPONDING DAY
2-1-3	RAINFALL DURATIONAN
. . .	. . .

FIG. 7

3	RIVER DIGITAL TWIN
3-1	WATER LEVEL
3-1-1	HOURLY RIVER WATER LEVEL
3-1-2	MAXIMUM WATER LEVEL OF CORRESPONDING DAY
...	...
...	...

FIG. 8

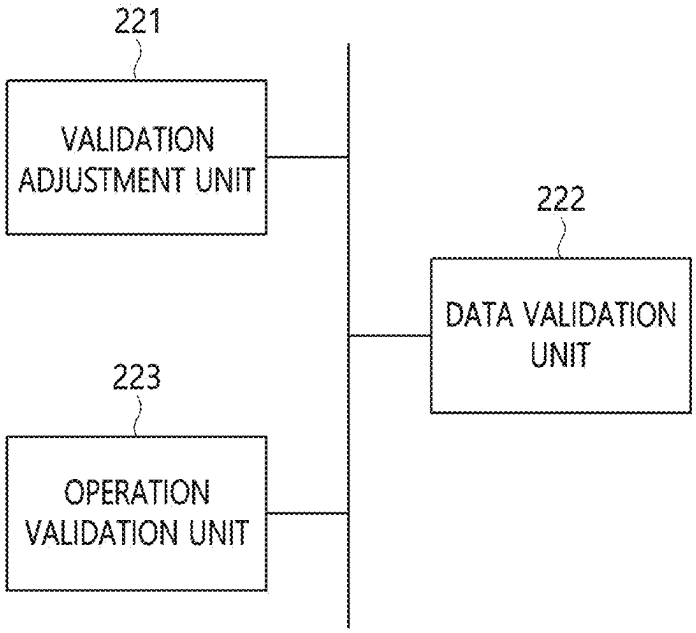


FIG. 9

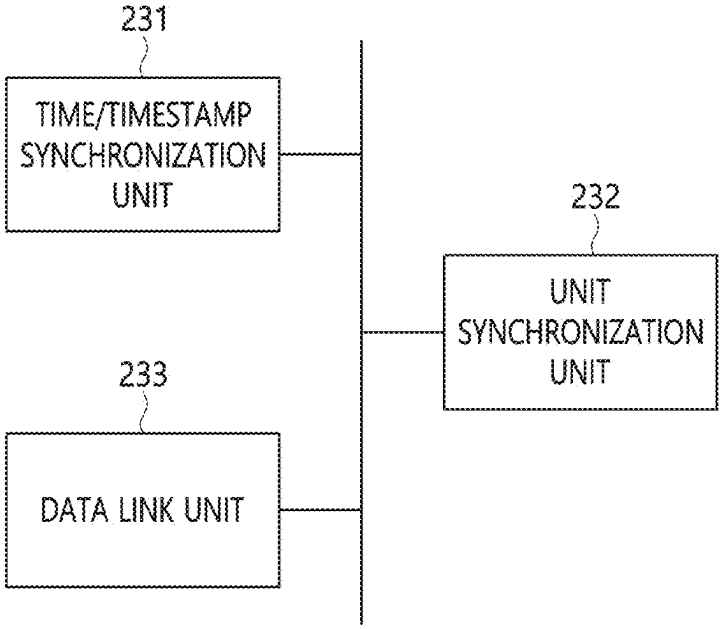

231
TIME/TIMESTAMP SYNCHRONIZATION UNIT
232
UNIT SYNCHRONIZATION UNIT
233
DATA LINK UNIT

FIG. 10

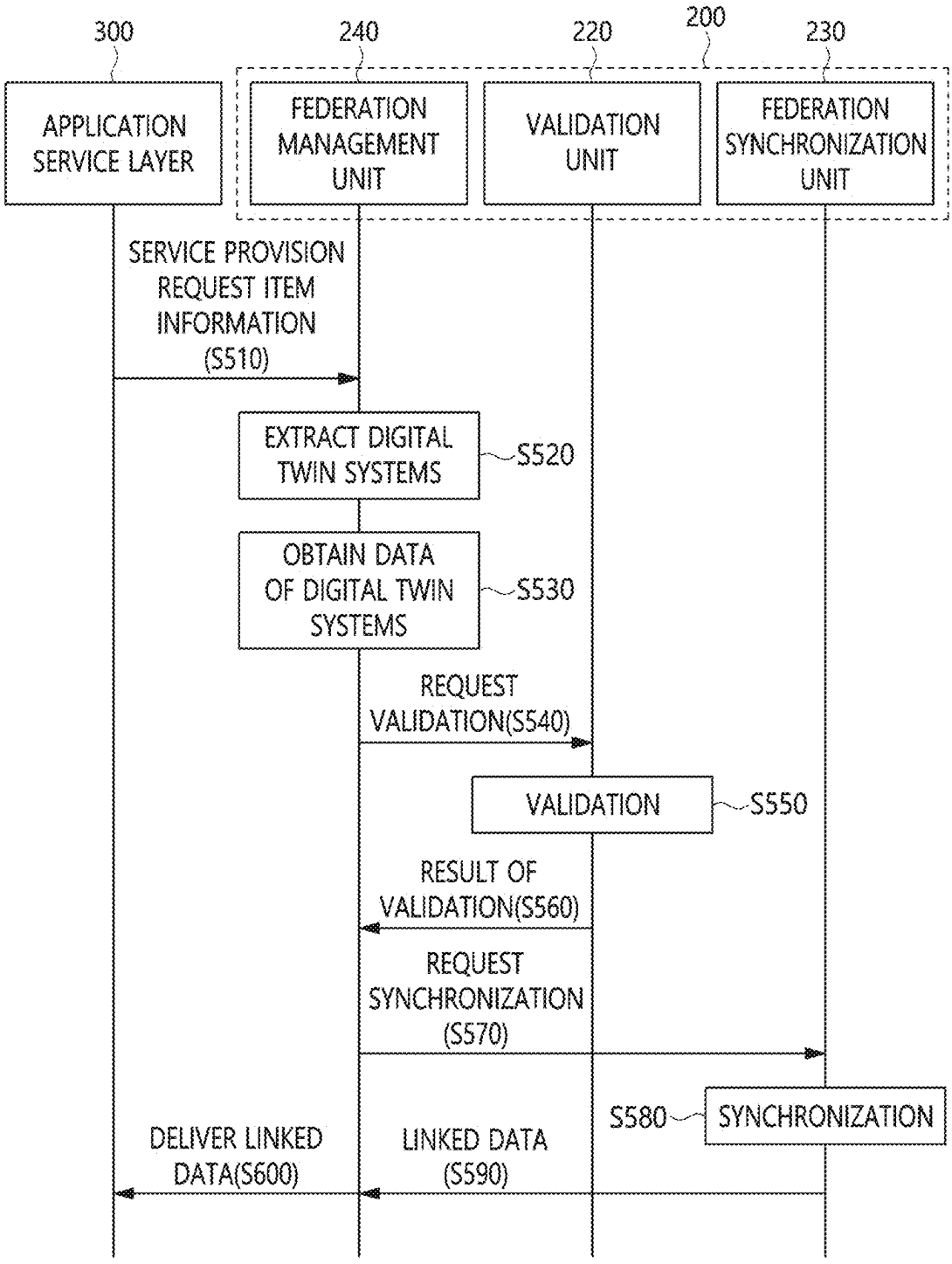
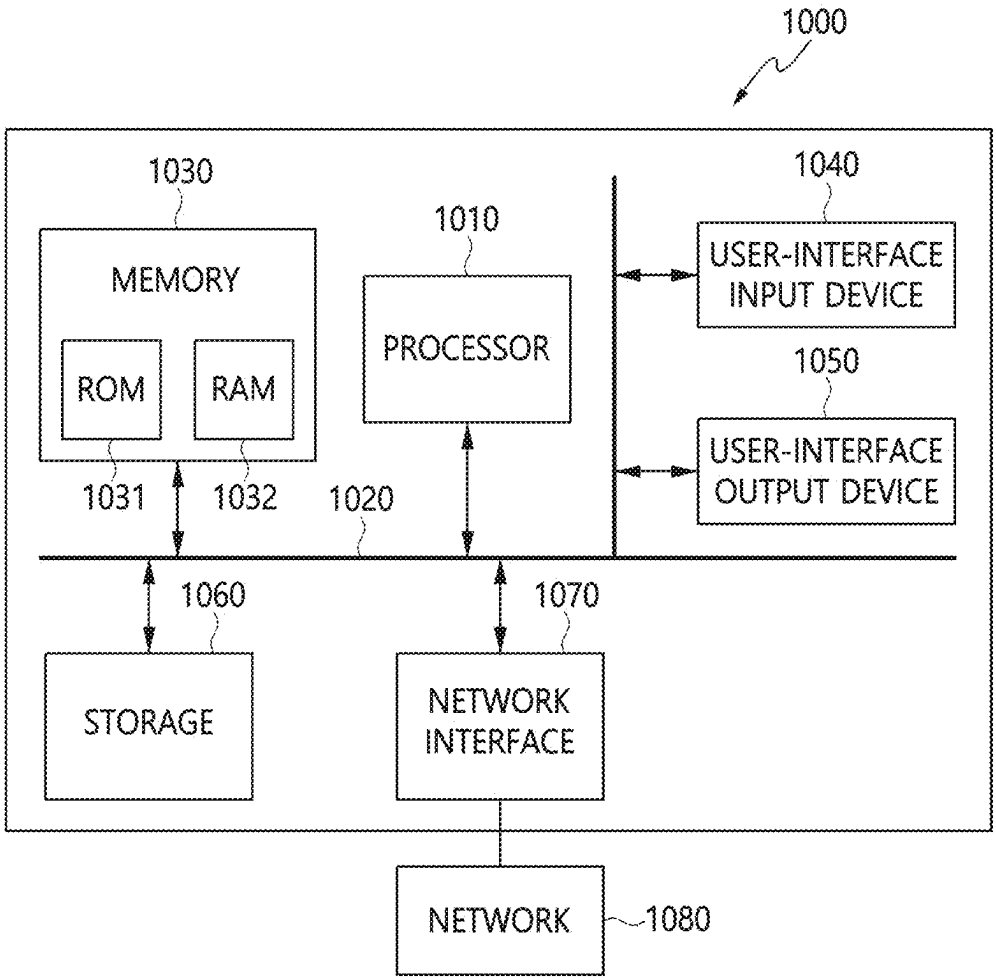

300
240
220
200
230
APPLICATION SERVICE LAYER
FEDERATION MANAGEMENT UNIT
VALIDATION UNIT
FEDERATION SYNCHRONIZATION UNIT
SERVICE PROVISION REQUEST ITEM INFORMATION (S510)
EXTRACT DIGITAL TWIN SYSTEMS
S520
OBTAIN DATA OF DIGITAL TWIN SYSTEMS
S530
REQUEST VALIDATION(S540)
VALIDATION
S550
RESULT OF VALIDATION(S560)
REQUEST SYNCHRONIZATION (S570)
S580
SYNCHRONIZATION
DELIVER LINKED DATA(S600)
LINKED DATA (S590)

FIG. 11


1000
1030
MEMORY
ROM
RAM
1031
1032
1010
PROCESSOR
1020
1040
USER-INTERFACE INPUT DEVICE
1050
USER-INTERFACE OUTPUT DEVICE
1060
STORAGE
1070
NETWORK INTERFACE
NETWORK
1080

DIGITAL TWIN FEDERATION APPARATUS AND METHOD

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of Korean Patent Application Nos. 10-2024-0023726, filed Feb. 19, 2024 and 10-2024-0115032, filed Aug. 27, 2024, which are hereby incorporated by reference in their entireties into this application.

BACKGROUND OF THE INVENTION

1. Technical Field

[0002] The following embodiments relate to digital twin technology.

2. Description of the Related Art

[0003] A digital twin is technology that digitally replicates various objects (people, things, and spaces) in the real world and solves or optimizes the problems of the real world by conducting various simulations in the digital world at low cost based on the replicated objects.

[0004] Until now, digital twin technology has been designed and developed to target a single system or a single process.

[0005] The concept of the digital twin has continued to evolve and is primarily developed and utilized to optimize industrial processes or equipment in manufacturing fields. Additionally, the number of cases where digital twins are applied to public services, such as river management and port management, at the government level is gradually increasing.

[0006] However, there is a need to construct a large-scale digital twin so as to construct digital twins at the city or national level, or to solve complex problems and optimize systems. In large-scale digital twin construction, the number of objects included in the digital twin, the number of target models, etc. increase significantly, thus leading to an exponential rise in the complexity of implementation and management.

SUMMARY OF THE INVENTION

[0007] An embodiment is intended to facilitate the construction of a digital twin targeting a large-scale physical world at the city or national level.

[0008] An embodiment is intended to reduce cost, time and complexity attributable to the construction of a large-scale digital twin.

[0009] In accordance with an aspect, there is provided a digital twin federation apparatus, including memory configured to store at least one program, and a processor configured to execute the program, wherein the program performs extracting at least two digital twin systems corresponding to digital twin types matching a service purpose, received from an application service layer, from a pre-registered digital twin system list; obtaining pieces of data from the extracted at least two digital twin systems, respectively; synchronizing the pieces of data obtained from the extracted at least two digital twin systems, respectively, so that the pieces of data are linked in an identical time slot and in an identical unit, and delivering the linked data to the application service layer.

[0010] The program may further perform registering at least one digital twin system, and providing a data input/output interface of the registered at least one digital twin system.

[0011] The program may perform, in registering, identifying a type of a digital twin system requested to be newly registered, delivering a metadata system corresponding to the identified type of the digital twin system to the corresponding digital twin system, and receiving metadata generated by the digital twin system based on the metadata system.

[0012] The program may perform, in identifying, determining whether the identified type of the digital twin system is included in types of previously held digital twin systems.

[0013] The program may perform, in delivering, when the identified type of the digital twin system is a type of a previously held digital twin system, delivering a previously held metadata system to the digital twin system.

[0014] The program may perform, in delivering, when the identified type of the digital twin system is not a type of a previously held digital twin system, delivering a metadata standard system of a digital twin system having a type similar to that of the corresponding digital twin system to the digital twin system.

[0015] The program may further include determining whether an error occurs in the obtained data and validating an operation of the corresponding digital twin system.

[0016] The program may perform, in validating, simply determining only whether an error and an anomaly are present in data requiring near real-time processing.

[0017] The program may perform, in validating, when data has high importance, validating pieces of data of the two or more digital twin systems using individual units or validating the pieces of data by linking the data based on a correlation.

[0018] The program may perform, in synchronizing, checking metadata, unifying units of pieces of data when the units of the pieces of data are different from each other, and linking the pieces of data by synchronizing times or output timestamps between the pieces of data so that the pieces of data are federated and used.

[0019] In accordance with another aspect, there is provided a digital twin federation method, including extracting at least two digital twin systems corresponding to digital twin types matching a service purpose, received from an application service layer, from a pre-registered digital twin system list, obtaining pieces of data from the extracted at least two digital twin systems, respectively, synchronizing the pieces of data obtained from the extracted at least two digital twin systems, respectively, so that the pieces of data are linked in an identical time slot and in an identical unit, and delivering the linked data to the application service layer.

[0020] The digital twin federation method may further include registering at least one digital twin system, and providing a data input/output interface of the registered at least one digital twin system.

[0021] The registering may include identifying a type of a digital twin system requested to be newly registered, delivering a metadata system corresponding to the identified type of the digital twin system to the corresponding digital twin system, and receiving metadata generated by the digital twin system based on the metadata system.

[0022] The identifying may include determining whether the identified type of the digital twin system is included in types of previously held digital twin systems.

[0023] The delivering may include, when the identified type of the digital twin system is a type of a previously held digital twin system, delivering a previously held metadata system to the digital twin system.

[0024] The delivering may include, when the identified type of the digital twin system is not a type of a previously held digital twin system, delivering a metadata standard system of a digital twin system having a type similar to that of the corresponding digital twin system to the digital twin system.

[0025] The digital twin federation method may further include determining whether an error occurs in the obtained data and validating an operation of the corresponding digital twin system.

[0026] The validating may include simply determining only whether an error and an anomaly are present in data requiring near real-time processing.

[0027] The validating may further include, when data has high importance, validating pieces of data of the two or more digital twin systems using individual units or validating the pieces of data by linking the data based on a correlation.

[0028] The synchronizing may include checking metadata, unifying units of pieces of data when the units of the pieces of data are different from each other, and linking the pieces of data by synchronizing times or output timestamps between the pieces of data so that the pieces of data are federated and used.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029] The above and other objects, features and advantages of the present disclosure will be more clearly understood from the following detailed description taken in conjunction with the accompanying drawings, in which:

[0030] FIG. **1** is a schematic block configuration diagram of a digital twin system to which an embodiment is applied;

[0031] FIG. **2** is a schematic block configuration diagram of a federated digital twin system according to an embodiment;

[0032] FIG. **3** is a schematic block configuration diagram of a digital twin federation apparatus associated with an application service layer according to an embodiment;

[0033] FIG. **4** is an operation flowchart between detailed components of a registration unit according to an embodiment;

[0034] FIGS. **5** to **7** illustrate examples of a metadata standard system according to an embodiment;

[0035] FIG. **8** is a block diagram illustrating the internal configuration of a validation unit according to an embodiment;

[0036] FIG. **9** is a block diagram illustrating the internal configuration of a federation synchronization unit according to an embodiment;

[0037] FIG. **10** is a flowchart for explaining a digital twin federation method according to an embodiment; and

[0038] FIG. **11** is a diagram illustrating the configuration of a computer system according to an embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0039] Advantages and features of the present disclosure and methods for achieving the same will be clarified with reference to embodiments described later in detail together with the accompanying drawings. However, the present disclosure is capable of being implemented in various forms, and is not limited to the embodiments described later, and these embodiments are provided so that this disclosure will be thorough and complete and will fully convey the scope of the present disclosure to those skilled in the art. The present disclosure should be defined by the scope of the accompanying claims. The same reference numerals are used to designate the same components throughout the specification.

[0040] It will be understood that, although the terms "first" and "second" may be used herein to describe various components, these components are not limited by these terms. These terms are only used to distinguish one component from another component. Therefore, it will be apparent that a first component, which will be described below, may alternatively be a second component without departing from the technical spirit of the present disclosure.

[0041] The terms used in the present specification are merely used to describe embodiments, and are not intended to limit the present disclosure. In the present specification, a singular expression includes the plural sense unless a description to the contrary is specifically made in context. It should be understood that the term "comprises" or "comprising" used in the specification implies that a described component or step is not intended to exclude the possibility that one or more other components or steps will be present or added.

[0042] Unless differently defined, all terms used in the present specification can be construed as having the same meanings as terms generally understood by those skilled in the art to which the present disclosure pertains. Further, terms defined in generally used dictionaries are not to be interpreted as having ideal or excessively formal meanings unless they are definitely defined in the present specification.

[0043] A digital twin is a technology convergence platform that replicates or reproduces the physical world (real world) in the digital world to solve complicated problems and create new industrial and service ecosystems. More specifically, the digital twin is a convergence technology that synchronizes physical entities and their digital entities simulating the physical entities across time and space, analyzes situations for various purposes, and optimizes the physical entities by making predictions based on simulation results. Therefore, when the digital twin is utilized, limitations in time, cost, space, and information to solve the problems of the real world may be overcome.

[0044] Until now, the digital twin has the form of a single digital twin. The single digital twin refers to a form in which a digital twin is constructed and operated by targeting a single system or a single process. Examples of such a single digital twin include a river digital twin that predicts river flooding and a manufacturing digital twin that forecasts productivity in a jet engine production plant. To construct the single digital twin, multiple objects or variables required by the target system need to be considered as inputs. In the river digital twin, rainfall, snowfall, flow velocity, water volume, and the like may be considered as input variables. In the manufacturing digital twin, multiple raw material parts, production equipment, manufacturing processes, and

the like may be considered as input values. In the river digital twin, whether the river will flood may be considered as an output variable. In the manufacturing digital twin, the production time required for a single manufactured jet engine or the production volume over a specific period may be considered as an output variable. Such digital twin models may be illustrated in FIG. **1**.

[0045] FIG. **1** is a schematic block configuration diagram of a digital twin system to which an embodiment is applied.

[0046] Referring to FIG. **1**, a digital twin system **100** to which the embodiment is applied may include one or more complex digital objects **110-1**, . . . , **110**-M and a single digital object **120**.

[0047] The single digital object **120** may be formed by simulating a physical object, and may be simulated based on data by utilizing various sensors, drivers, etc.

[0048] Each of the complex digital objects **110-1**, . . . , **110**-M may be composed of multiple digital objects.

[0049] An example of a complex digital object is a vehicle, which can be composed of combinations of various single physical objects such as an engine, wheels, and windows. Therefore, to simulate a vehicle as a digital object, a combination of various single digital objects is required.

[0050] However, when a complicated actual system needs to be constructed as a digital twin or when a service in which a complicated environment is taken into consideration needs to be provided based on a digital twin, if the digital twin is constructed using only the digital twin system **100**, the number of physical objects, single digital objects, and complex digital objects to be managed by one digital twin system may greatly increase, and thus complexity in actual implementation increases.

[0051] In this case, federating multiple digital twin systems to construct a single large federated digital twin system may be an alternative. When the above-described multiple single digital twin systems are federated, such a method is intended to construct a federated digital twin by guaranteeing operation and management independency for respective single digital twins and federating the output data of the single digital twins.

[0052] FIG. **2** is a schematic block configuration diagram of a federated digital twin system according to an embodiment.

[0053] Referring to FIG. **2**, the federated digital twin system according to an embodiment has a configuration in which at least two digital twin systems **100-1**, **100-2**, . . . , **100**-K are connected through a digital twin federation apparatus **200**.

[0054] The digital twin federation apparatus **200** may configure a federated digital twin by linking at least two digital twin systems **100-1**, **100-2**, . . . , **100**-K.

[0055] The federated digital twin system configured by the digital twin federation apparatus **200** may provide federated digital twin-based services to users through an application service layer **300**.

[0056] Here, the application service may be a service for optimizing complicated systems, a service associated with digital twins in various fields, etc.

[0057] FIG. **3** is a schematic block configuration diagram of a digital twin federation apparatus associated with an application service layer according to an embodiment.

[0058] Referring to FIG. **3**, single twin types for allowing a digital twin federation apparatus **200** according to an embodiment to configure a federated digital twin and output values of the digital twin federation apparatus **200** may be sorted and selected depending on the configuration purpose of the federated digital twin for application services.

[0059] The application service layer **300** functions to provide an application service depending on the requirements of the final user.

[0060] A user GUI **310** takes charge of direct communication between each user and the application service layer. That is, the service user selects a desired service through the user GUI **310** and requests the provision of the service. Such service provision requests are delivered to a service purpose-based federated digital twin selection unit **330**.

[0061] The service purpose-based federated digital twin selection unit **330** selects a single digital twin system type and an output value required for providing a service and delivers the corresponding request to the digital twin federation apparatus.

[0062] Also, a federated digital twin service generation unit **320** functions to generate an application service by federating multiple pieces of single digital twin system data, which are received from the digital twin federation apparatus **100** and which are validated and synchronized.

[0063] The digital twin federation apparatus **200** according to the embodiment may include a single digital twin system registration unit (hereinafter also referred to as a registration unit) **210**, a federation synchronization unit **230**, and a federation management unit **240**. In addition, the digital twin federation apparatus **200** may further include a validation (i.e., validity verification) unit **220**.

[0064] The registration unit **210** may register at least one digital twin system, and may provide the data input/output interface of the registered at least one digital twin system.

[0065] Here, the at least one digital twin system may be registered and managed based on metadata. Detailed description of the registration unit **210** will be made later with reference to FIGS. **4** to **7**.

[0066] The validation unit **220** may determine whether errors occur in data obtained from the digital twin system and validate the operation of the corresponding digital twin system. That is, the validation unit **220** may receive multiple pieces of single digital twin data extracted by the federation management unit **240**, determine whether errors/anomalies are present in the data, and validate the operation of the single digital twin system.

[0067] Here, the validation unit **220** may determine whether to operate depending on the importance of data. Detailed description of the registration unit **210** will be made later with reference to FIG. **8**.

[0068] The federation synchronization unit **230** may synchronize pieces of data obtained from at least two digital twin systems so that the pieces of data are linked in the same time slot and the same unit.

[0069] That is, in order to provide the federated digital twin service, multiple pieces of single digital twin data extracted by the federation management unit are received, and synchronization between the pieces of data is performed.

[0070] The individual digital twin system operates and outputs data based on each operation and management policy. Therefore, data output times may be different from each other, or data output intervals may be different from each other. In this case, the federation synchronization unit **230** functions to align data output times, or correct and unify data output intervals for the purpose of smoothly linking and

operating respective pieces of data. Detailed description of the federation synchronization unit **230** will be made later with reference to FIG. **8**.

[0071] The federation management **240** links and manages single digital twins required in order to provide a federated digital twin service. Here, the federation management unit **240** functions to link and manage pieces of single digital twin data depending on a service purpose-based single digital twin list. Detailed description of the federation management unit **240** will be made later with reference to FIG. **9**.

[0072] FIG. **4** is an operation flowchart between detailed components of a registration unit according to an embodiment, and FIGS. **5** to **7** illustrate examples of a metadata standard system according to an embodiment.

[0073] Referring to FIG. **4**, the registration unit **210** according to the embodiment may include a type identification unit **211**, a metadata standard system provision unit **212**, and a metadata acquisition unit **213**.

[0074] As the digital twin system **100** applies for new registration in the registration unit **210** at step S**410**, the type identification unit **211** identifies the type of the digital twin system **100** requested to be newly registered at step S**420**.

[0075] The type identification unit **211** identifies the type of the digital twin system **100** desired to be newly registered, determines whether to register the digital twin system **100** at step S**420**, and delivers the result of identification to the metadata standard system registration unit **212** at step S**430**.

[0076] Here, the type identification unit **211** may determine whether the identified type of the digital twin system **100** is included in the types of previously held digital twin systems.

[0077] Here, the types of the digital twin system may include, for example, transportation digital twin, a weather digital twin, a river digital twin, etc.

[0078] Here, when the identified type of the digital twin system **100** is a previously held type, the type of the new digital twin system may be delivered to the metadata standard system provision unit **212** at step S**430**.

[0079] On the other hand, when the identified type of the digital twin system **100** is not a previously held type, the type identification unit **211** notifies the metadata standard system provision unit **212** of the new type of digital twin at step S**430**.

[0080] The metadata standard system provision unit **212** detects a metadata system corresponding to the identified type of the digital twin system **100** at step S**440**, and delivers the metadata system to the corresponding digital twin system **100** at step S**450**.

[0081] FIGS. **5** to **7** illustrate examples of metadata standard systems provided for respective single digital twins.

[0082] Here, when the identified type of the digital twin system **100** is a previously held type, the metadata standard system provision unit **212** may deliver the previously held metadata system to the digital twin system **100** at step S**450**.

[0083] On the other hand, when the identified type of the digital twin system **100** is not a previously held type, the metadata system of the corresponding type is not held, and thus the metadata standard system provision unit **212** may deliver the metadata standard system of the digital twin system having a type, which is similar to that of the corresponding digital twin system, to the digital twin system **100** at step S**450**.

[0084] Then, the digital twin system **100** generates metadata by utilizing the metadata standard system received from the metadata standard system provision unit **212** at step S**460**, and thereafter delivers the generated metadata to the metadata acquisition unit **213** at step S**470**.

[0085] Here, when the received digital twin metadata standard system is identical to that of the digital twin system **100**, the digital twin system **100** may generate metadata using the corresponding system, and may generate and add a new parameter as needed.

[0086] On the other hand, when the received digital twin metadata standard system is of a new type, the digital twin system **100** generates its own metadata by utilizing the received example metadata system.

[0087] The metadata acquisition unit **213** receives the metadata generated by the digital twin system **100** based on the metadata system, and stores the metadata as the registration information of the digital twin system **100** at step S**480**.

[0088] Through the above-described process, the digital twin system **100** may be registered and utilized in the digital twin federation apparatus **200**.

[0089] FIG. **8** is a block diagram illustrating the internal configuration of a validation unit according to an embodiment.

[0090] Referring to FIG. **8**, the validation unit **220** according to the embodiment may include a validation adjustment unit **221**, a data validation unit **222**, and an operation validation unit **223**.

[0091] The validation unit **220** determines data validation accuracy of the requested digital twin system and time required for data validation.

[0092] Here, for data requiring near real-time processing, the data validation unit **220** simply determines whether errors or anomalies are present, and quickly delivers the validated data to the federation management unit **240**.

[0093] On the other hand, when the data has high importance and requires a procedure such as accurate determination, error correction, or noise removal, the validation unit **220** forwards the corresponding situation to the data validation unit **222** or the operation validation unit **223** to enable a more precise validation process.

[0094] Therefore, when the data has high importance, the data validation unit **222** validates pieces of data of at least two digital twin systems using individual units, or may validate the pieces of data by linking the pieces of data based on correlation.

[0095] Furthermore, the operation validation unit **223** validates the operation of the single digital twin.

[0096] FIG. **9** is a block diagram illustrating the internal configuration of the federation synchronization unit according to an embodiment.

[0097] Referring to FIG. **9**, the federation synchronization unit **230** according to the embodiment may include a time/timestamp synchronization unit **231**, a unit synchronization unit **232**, and a data link unit **233**.

[0098] The time/timestamp synchronization unit **231** synchronizes times or output timestamps between pieces of data.

[0099] The unit synchronization unit **232** may unify the units of pieces of metadata when data units between pieces of metadata are different from each other (e.g., cm, inch, meter, feet, or the like).

[0100] The data link unit **233** may link pieces of data to each other so that pieces of data that are time synchronized and have a unified unit can be federated and used.

[0101] FIG. **10** is a flowchart for explaining a digital twin federation method according to an embodiment.

[0102] Referring to FIG. **10**, in the digital twin federation method according to an embodiment, as service provision request item information is received from the application service layer **300** at step S**510**, the digital twin federation method may be initiated.

[0103] Next, the federation management unit **240** of the digital twin federation apparatus **200** extracts at least two digital twin systems corresponding to digital twin types matching a service purpose, received from the application service layer **300**, from a pre-registered digital twin system list at step S**520**.

[0104] Thereafter, the federation management unit **240** obtains pieces of data from the extracted at least two digital twin systems, respectively, at step S**530**.

[0105] Here, the at least two digital twin systems may be those registered in the digital twin federation apparatus **200**.

[0106] That is, the digital twin federation method according to an embodiment may further include the step of registering at least one digital twin system and the step of providing a data input/output interface of the registered at least one digital twin system.

[0107] Here, the registering step may include the step of identifying the type of digital twin system requested to be newly registered, the step of delivering a metadata system corresponding to the identified type of the digital twin system to the corresponding digital twin system, and the step of receiving metadata generated by the digital twin system based on the metadata system.

[0108] Here, the identifying step may include the step of determining whether the identified type of the digital twin system is included in the types of previously held digital twin systems.

[0109] Here, the delivering step may include the step of, when the identified type of the digital twin system is previously held type, delivering a previously held metadata system to the digital twin system.

[0110] Here, the delivering step may include the step of, when the identified type of the digital twin system is not previously held type, delivering the metadata standard system of a digital twin system having a type similar to that of the corresponding digital twin system to the digital twin system.

[0111] Thereafter, the federation management unit **240** delivers the obtained data to the validation unit **220** to perform steps S**540** to S**560** of determining whether errors are present in the obtained data and validating the operation of the corresponding digital twin system. However, whether to perform validating steps S**540** to S**560** may be selectively determined. That is, validating steps S**540** to S**560** may be skipped depending on the importance or the like of data.

[0112] Here, at validating step S**550**, the validation unit **220** may simply determine only whether errors are present and whether anomalies are present for data requiring near-real time processing.

[0113] Here, validating step S**550** may be performed such that, when the importance of data is high, the validation unit **220** may validate pieces of data of at least two digital twin systems using individual units, or may validate the pieces of data by linking the pieces of data based on correlation.

[0114] Next, the federation management unit **240** may deliver the obtained data to the federation synchronization unit **230** to perform steps S**570** to S**590** of synchronizing pieces of data obtained from the extracted two or more digital twin systems so that the pieces of data are linked in the same time slot and in the same unit.

[0115] Here, at synchronization step S**580**, the federation synchronization unit **230** may check the metadata, unify the units of pieces of data when the units between pieces of data are different from each other, and synchronize times or timestamps with each other between the pieces of data to link the pieces of data so that the pieces of data are federated and used.

[0116] Finally, the federation management unit **240** delivers the linked data to the application service layer at step S**600**.

[0117] FIG. **11** is a diagram illustrating the configuration of a computer system according to an embodiment.

[0118] A digital twin federation apparatus **200** according to an embodiment may be implemented in a computer system **1000** such as a computer-readable storage medium.

[0119] The computer system **1000** may include one or more processors **1010**, memory **1030**, a user interface input device **1040**, a user interface output device **1050**, and storage **1060**, which communicate with each other through a bus **1020**. The computer system **1000** may further include a network interface **1070** connected to a network **1080**. Each processor **1010** may be a Central Processing Unit (CPU) or a semiconductor device for executing programs or processing instructions stored in the memory **1030** or the storage **1060**. Each of the memory **1030** and the storage **1060** may be a storage medium including at least one of a volatile medium, a nonvolatile medium, a removable medium, a non-removable medium, a communication medium or an information delivery medium, or a combination thereof. For example, the memory **1030** may include Read-Only Memory (ROM) **1031** or Random Access Memory (RAM) **1032**.

[0120] According to embodiments, a digital twin may be easily constructed to target a large-scale physical world at the city or national level.

[0121] That is, the effect of implementing a large-scale digital twin may be obtained by linking previously constructed diverse digital twins without having to configure a large-scale significantly complicated digital twin. Therefore, the time and cost required in order to construct and operate a large-scale digital twin may be greatly reduced.

[0122] Although the embodiment of the present disclosure has been disclosed, those skilled in the art will appreciate that the present disclosure can be implemented as other concrete forms, without departing from the scope and spirit of the disclosure as disclosed in the accompanying claims. Therefore, it should be understood that the exemplary embodiment is only for illustrative purpose and do not limit the scope of the present disclosure.

What is claimed is:

1. A digital twin federation apparatus, comprising:

a memory configured to store at least one program; and

a processor configured to execute the program,

wherein the program performs:

extracting at least two digital twin systems corresponding to digital twin types matching a service purpose, received from an application service layer, from a pre-registered digital twin system list;

obtaining pieces of data from the extracted at least two digital twin systems, respectively;

synchronizing the pieces of data obtained from the extracted at least two digital twin systems, respectively, so that the pieces of data are linked in an identical time slot and in an identical unit; and

delivering the linked data to the application service layer.

2. The digital twin federation apparatus of claim **1**, wherein the program further performs:

registering at least one digital twin system; and

providing a data input/output interface of the registered at least one digital twin system.

3. The digital twin federation apparatus of claim **2**, wherein the program performs, in registering:

identifying a type of a digital twin system requested to be newly registered;

delivering a metadata system corresponding to the identified type of the digital twin system to the corresponding digital twin system; and

receiving metadata generated by the digital twin system based on the metadata system.

4. The digital twin federation apparatus of claim **3**, wherein the program performs, in identifying:

determining whether the identified type of the digital twin system is included in types of previously held digital twin systems.

5. The digital twin federation apparatus of claim **4**, wherein the program performs, in delivering:

when the identified type of the digital twin system is a type of a previously held digital twin system, delivering a previously held metadata system to the digital twin system.

6. The digital twin federation apparatus of claim **4**, wherein the program performs, in delivering:

when the identified type of the digital twin system is not a type of a previously held digital twin system,

delivering a metadata standard system of a digital twin system having a type similar to that of the corresponding digital twin system to the digital twin system.

7. The digital twin federation apparatus of claim **1**, wherein the program further performs:

determining whether an error occurs in the obtained data and validating an operation of the corresponding digital twin system.

8. The digital twin federation apparatus of claim **7**, wherein the program performs, in validating:

simply determining only whether an error and an anomaly are present in data requiring near real-time processing.

9. The digital twin federation apparatus of claim **7**, wherein the program performs, in validating:

when data has high importance, validating pieces of data of the two or more digital twin systems using individual units or validating the pieces of data by linking the data based on a correlation.

10. The digital twin federation apparatus of claim **1**, wherein the program performs, in synchronizing:

checking metadata, unifying units of pieces of data when the units of the pieces of data are different from each other, and linking the pieces of data by synchronizing times or output timestamps between the pieces of data so that the pieces of data are federated and used.

11. A digital twin federation method, comprising:

extracting at least two digital twin systems corresponding to digital twin types matching a service purpose, received from an application service layer, from a pre-registered digital twin system list;

obtaining pieces of data from the extracted at least two digital twin systems, respectively;

synchronizing the pieces of data obtained from the extracted at least two digital twin systems, respectively, so that the pieces of data are linked in an identical time slot and in an identical unit; and

delivering the linked data to the application service layer.

12. The digital twin federation method of claim **11**, further comprising:

registering at least one digital twin system; and

providing a data input/output interface of the registered at least one digital twin system.

13. The digital twin federation method of claim **12**, wherein the registering comprises:

identifying a type of a digital twin system requested to be newly registered;

delivering a metadata system corresponding to the identified type of the digital twin system to the corresponding digital twin system; and

receiving metadata generated by the digital twin system based on the metadata system.

14. The digital twin federation method of claim **13**, wherein the identifying comprises:

determining whether the identified type of the digital twin system is included in types of previously held digital twin systems.

15. The digital twin federation method of claim **14**, wherein the delivering comprises;

when the identified type of the digital twin system is a type of a previously held digital twin system, delivering a previously held metadata system to the digital twin system.

16. The digital twin federation method of claim **14**, wherein the delivering comprises:

when the identified type of the digital twin system is not a type of a previously held digital twin system,

delivering a metadata standard system of a digital twin system having a type similar to that of the corresponding digital twin system to the digital twin system.

17. The digital twin federation method of claim **11**, further comprising:

determining whether an error occurs in the obtained data and validating an operation of the corresponding digital twin system.

18. The digital twin federation method of claim **17**, wherein the validating comprises:

simply determining only whether an error and an anomaly are present in data requiring near real-time processing.

19. The digital twin federation method of claim **17**, wherein the validating further comprises:

when data has high importance, validating pieces of data of the two or more digital twin systems using individual units or validating the pieces of data by linking the data based on a correlation.

20. The digital twin federation method of claim **11**, wherein the synchronizing comprises:

checking metadata, unifying units of pieces of data when the units of the pieces of data are different from each other, and linking the pieces of data by synchronizing times or output timestamps between the pieces of data so that the pieces of data are federated and used.

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