

CLAIMS

~~What is claimed is:~~

- 5 1. A method for updating one or more properties of one or more digital twins comprising:
- receiving a request for one or more digital twins;
 - retrieving the one or more digital twins required to fulfill the request from a digital twin datastore;
 - 10 retrieving one or more dynamic models corresponding to one or more properties that are depicted in the one or more digital twins indicated by the request;
 - selecting data sources from a set of available data sources based on the one or more inputs of the one or more dynamic models;
 - obtaining data from selected data sources;
 - 15 determining one or more outputs using the retrieved data as one or more inputs to the one or more dynamic models; and
 - updating the one or more properties of the one or more digital twins based on the one or more outputs of the one or more dynamic models.
- 20 2. The method of claim 1, wherein the request is received from at least one of:
_____ a client application that corresponds to an industrial environment and/or one or more industrial entities within the industrial environment, and
_____ a client application that supports an Industrial Internet of Things sensor
system.
- 25
- ~~3. — The method of claim 1, wherein the request is received from a client application that supports an Industrial Internet of Things sensor system.~~
43. The method of claim 1, wherein the digital twins are digital twins of at least one of
- 30 industrial entities and industrial environments.

54. The method of claim 1, wherein the one or more dynamic models take data selected from the set of temperature, pressure, humidity, wind, rainfall, tide, storm surge, cloud cover, snowfall, visibility, radiation, audio, video, image, water level, quantum, flow rate, signal power, signal frequency, motion, velocity, acceleration, lighting level, analyte concentration, biological compound concentration, metal concentration, and organic compound concentration data.

65. The method of claim 1, wherein the selected data sources include at least one of:
an Internet of Things connected device, and
a machine vision system.

~~7. The method of claim 1, wherein the selected data sources include a machine vision system.~~

86. The method of claim 1, wherein retrieving the one or more dynamic models includes identifying the one or more dynamic models based on the one or more properties that are depicted in digital twins indicated by the request and a respective type of the one or more digital twins.

97. The method of claim 96, wherein the one or more dynamic models are identified using a lookup table.

~~10. A method comprising:
receiving imported data from one or more data sources, the imported data corresponding to an industrial environment;
generating an environment digital twin representing the industrial environment based on the imported data;
identifying one or more industrial entities within the industrial environment;
generating a set of discrete digital twins representing the one or more industrial entities within the environment;
embedding the set of discrete digital twins within the environment digital twin;
establishing a connection with a sensor system of the industrial environment;
receiving real time sensor data from one or more sensors of the sensor system via the connection; and~~

- updating at least one of the environment digital twin and the set of discrete digital twins based on the real-time sensor data.
11. — The method of claim 10, wherein the connection with the sensor system is established via one of a webhook and an application programming interface (API).
- 5 12. — The method of claim 10, wherein the environmental digital twin and the set of discrete digital twins are visual digital twins that are configured to be rendered in a visual manner.
13. — The method of claim 12, further comprising outputting the visual digital twins to a client application that displays the visual digital twins via a virtual reality headset.
- 10 14. — The method of claim 12, further comprising outputting the visual digital twins to a client application that displays the visual digital twins via a display device of a user device.
15. — The method of claim 12, further comprising outputting the visual digital twins to a client application that displays the visual digital twins via an augmented reality-enabled device.
- 15 16. — The method of claim 10, further comprising:
- receiving user input relating to one or more steps performed in an industrial process relating to the industrial environment; and
- generating a process digital twin that defines the steps of the industrial process with respect to the industrial environment and one or more of the set of industrial entities.
- 20 17. — The method of claim 10, further comprising instantiating a graph database having a set of nodes connected by edges, wherein a first node of the set of nodes contains data defining the environment digital twin and one or more entity nodes respectively contain respective data defining a respective discrete digital twin of the set of discrete digital twins.
18. — The method of claim 17, wherein each edge represents a relationship between two
- 25 respective digital twins.
19. — The method of claim 18, wherein embedding a discrete digital twin includes connecting an entity node corresponding to a respective discrete digital twin to the first node with an edge representing a respective relationship between a respective industrial entity represented by the respective discrete digital twin and the industrial environment.
- 30 20. — The method of claim 18, wherein each edge represents a spatial relationship between two respective digital twins, and an operational relationship between two respective digital twins.

21. — ~~The method of claim 18, wherein each edge stores metadata corresponding to the relationship between the two respective digital twins.~~
22. — ~~The method of claim 17, wherein each entity node of the one or more entity nodes includes one or more properties of a respective properties of the respective industrial entity represented by the entity node.~~
- 5 23. — ~~The method of claim 17, wherein each entity node of the one or more entity nodes includes one or more behaviors of a respective properties of the respective industrial entity represented by the entity node.~~
24. — ~~The method of claim 17, wherein the environment node includes one or more~~
- 10 ~~properties of the environment.~~
25. — ~~The method of claim 17, wherein the environment node includes one or more behaviors of the environment.~~
26. — ~~The method of claim 10, further comprising executing a simulation based on the environment digital twin and the one or more discrete digital twins.~~
- 15 27. — ~~The method of claim 26, wherein the simulation simulates one of an operation of a machine in the industrial environment that produces an output based on a set of inputs and movement of workers in the industrial environment.~~
28. — ~~The method of claim 10, wherein the imported data includes a three-dimensional scan of the environment.~~
- 20 29. — ~~The method of claim 10, wherein the imported data includes a LIDAR scan of industrial the environment.~~
30. — ~~The method of claim 10, wherein generating the digital twin of the industrial environment includes one of generating a set of surfaces of the industrial environment and configuring a set of dimensions of the industrial environment.~~
- 25 31. — ~~The method of claim 10, wherein generating the set of discrete digital twins includes importing a predefined digital twin of an industrial entity from a manufacturer of the industrial entity, wherein the predefined digital twin includes properties and behaviors of the industrial entity.~~
- 30 32. — ~~The method of claim 10, wherein generating the set of discrete digital twins includes classifying an industrial entity within the imported data of the industrial environment and generating a discrete digital twin corresponding to the classified industrial entity.~~

338. ____A system for monitoring interaction within an industrial environment, the system comprising:

a digital twin datastore including data collected by a set of proximity sensors disposed within an industrial environment, the data including location data indicating
5 respective locations of a plurality of elements within the industrial environment; and
one or more processors configured to:

maintain, via the digital twin datastore, an industrial-environment digital twin for the industrial environment;

receive signals indicating actuation of at least one proximity sensor within
10 the set of proximity sensors by a real-world element from the plurality of elements;

collect, in response to actuation of the at least one proximity sensor, updated location data for the real-world element using the at least one proximity sensor; and

update the industrial-environment digital twin within the digital twin
15 datastore to include the updated location data.

349. The system of claim 338, wherein each of the set of proximity sensors is configured to detect a device associated with the user.

20 3510. The system of claim 349, wherein the device is a wearable device and an RFID device.

3611. The system of claim 338, wherein each element of the plurality of elements is at least one of:

25 ____a mobile element, and
____a respective worker.

~~37. — The system of claim 33, wherein each element of the plurality of elements is a respective worker.~~

30 3812. The system of claim 338, wherein the plurality of elements includes mobile equipment elements and workers, mobile-equipment-position data is determined using data transmitted by the respective mobile equipment element, and worker-position data is determined using data obtained by the system.

~~39~~13. The system of claim ~~38~~12, wherein the worker-position data is determined using information transmitted from a device associated with a respective worker.

- 5 ~~40~~14. The system of claim ~~33~~8, wherein the actuation of the at least one proximity sensor occurs in response to interaction between at least one of:
_____ the respective worker and the proximity sensor, and
_____ a worker and a respective at least one proximity-sensor digital twin
corresponding to the at least one proximity sensor.

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~~41. — The system of claim 33, wherein the actuation of the at least one proximity sensor occurs in response to interaction between a worker and a respective at least one proximity-sensor digital twin corresponding to the at least one proximity sensor.~~

- 15 ~~42~~15. The system of claim ~~33~~8, wherein the one or more processors collect updated location data for the plurality of elements using the set of proximity sensors in response to actuation of the at least one proximity sensor.

~~43. — A system for modeling moving elements for an industrial digital twin, the system comprising:~~

- 20 ~~a digital twin datastore storing an industrial-environment digital twin corresponding to an industrial element, the industrial-environment digital twin including real-world-element digital twins embedded therein, wherein each real-world-element digital twin corresponds to a respective real-world element that is disposed within the industrial environment, the real-world-element digital twins including mobile-element digital twins that respectively correspond to a respective mobile element within the industrial environment; and~~
- 25 ~~one or more processors configured to:~~

- ~~for each mobile element:~~
- ~~determine whether the mobile element is in motion; and~~
- ~~obtain path information from the mobile element, and~~
- 30 ~~model, in response to obtaining the path information for each mobile element, traffic within the industrial environment via a digital twin simulation system.~~

~~44. — The system of claim 43, wherein the path information is obtained from a navigation module of the mobile element.~~

45. — The system of claim 43, wherein the one or more processors are further configured to obtain the path information by:
- detecting, using a plurality of sensors within the industrial environment, movement of the mobile element;
 - 5 obtaining a destination for the mobile element;
 - calculating, using the plurality of sensors within the industrial environment, an optimized path for the mobile element; and
 - instructing the mobile element to navigate the optimized path.
46. — The system of claim 45, wherein the optimized path includes path information for
- 10 other mobile elements within the real-world elements and the optimized path minimizes interactions between mobile elements and humans within the industrial environment.
47. — The system of claim 45, wherein the mobile elements include autonomous vehicles and non-autonomous vehicles and the optimized path reduces interactions of the autonomous vehicles with the non-autonomous vehicles.
48. — The system of claim 43, wherein the traffic modeling includes use of a particle
- 15 traffic model, a trigger-response mobile element following traffic model, a macroscopic traffic model, a microscopic traffic model, a submicroscopic traffic model, a mesoscopic traffic model, or a combination thereof.
49. A method for updating one or more vibration fault level states of one or more digital
- 20 twins comprising:
- receiving a request from a client application to update one or more vibration fault level states of one or more digital twins;
 - retrieving the one or more digital twins required to fulfill the request;
 - retrieving one or more dynamic models required to fulfill the request, wherein the
 - 25 one or more dynamic models include a dynamic model that predicts when a vibration fault level occurs based on an input dataset;
 - selecting data sources from a set of available data sources based on the one or more inputs of the one or more dynamic models;
 - obtaining data from selected data sources;
 - 30 determining one or more outputs using the retrieved data as one or more inputs to the one or more dynamic models; and
 - updating one or more vibration fault level states of the one or more digital twins based on the output of the one or more dynamic models.

50. — The method of claim 49, wherein the request is received from a client application that corresponds to an industrial environment and/or one or more industrial entities within the industrial environment.
51. — The method of claim 49, wherein the request is received from a client application that supports an Industrial Internet of Things sensor system.
52. — The method of claim 49, wherein the digital twins are digital twins of at least one of industrial entities and industrial environments.
53. — The method of claim 49, wherein the dynamic models take data selected from the set of vibration, temperature, pressure, humidity, wind, rainfall, tide, storm surge, cloud cover, snowfall, visibility, radiation, audio, video, image, water level, quantum, flow rate, signal power, signal frequency, motion, displacement, velocity, acceleration, lighting level, financial, cost, stock market, news, social media, revenue, worker, maintenance, productivity, asset performance, worker performance, worker response time, analyte concentration, biological compound concentration, metal concentration, and organic compound concentration data.
54. — The method of claim 49, wherein the data source is selected from the set of an Internet of Things connected device, a machine vision system, an analog vibration sensor, a digital vibration sensor, a fixed digital vibration sensor, a tri-axial vibration sensor, a single axis vibration sensor, an optical vibration sensor, and a cross point switch.
55. — The method of claim 49, wherein retrieving the one or more dynamic models includes identifying the one or more dynamic models based on the one or more properties indicated in the request and a respective type of the one or more digital twins.
56. — The method of claim 49, wherein the one or more dynamic models are identified using a lookup table.
57. — A system for monitoring navigational route data through an industrial environment having real-world elements disposed therein, the system comprising:
- a digital twin datastore including an industrial environment digital twin corresponding to the industrial environment and a worker digital twin corresponding to a respective worker of a set of workers within the industrial environment; and
 - one or more processors configured to:
 - maintain, via the digital twin datastore, the industrial environment digital twin to include contemporaneous positions for the set of workers within the industrial environment;

monitor movement of each worker in the set of workers via a sensor array;
determine, in response to detecting movement of the respective worker,
navigational route data for the respective worker; and
update the industrial environment digital twin to include indicia of the
5 navigational route data for the respective worker and to indicate movement of the worker
digital twin along a route corresponding to the navigational route data.
58.— The system of claim 57, wherein the one or more processors are further configured
to, in response to representing movement of the respective worker, determine navigational
route data for remaining workers in the set of workers.
10 59.— The system of claim 58, wherein the navigational route data is automatically
transmitted to the system by one or more individual associated devices.
60.— The system of claim 59, wherein the individual associated device is one of a mobile
device having cellular data capabilities and a wearable device associated with the worker.
61.— The system of claim 57, wherein the navigational route data is determined via
15 environment associated sensors.
62.— The system of claim 61, wherein the navigational route data is determined using
historical routing data stored in the digital twin datastore.
63.— The system of claim 62, wherein the historical route data is obtained from a device
associated with the respective worker.
20 64.— The system of claim 62, wherein the historical route data is obtained a device
associated with another worker.
65.— The system of claim 64, wherein the historical route data is associated with a
current task of the worker.
66.— The system of claim 57, wherein the digital twin datastore includes an industrial-
25 environment digital twin.
67.— The system of claim 66, wherein the one or more processors are further configured
to:
determine existence of a conflict between the navigational route data and the
industrial environment digital twin;
30 alter, in response to determining accuracy of the industrial environment digital
twin via the sensor array, the navigational route data for the worker; and

~~update, in response to determining inaccuracy of the industrial environment digital twin via the sensor array, the industrial environment digital twin to thereby resolve the conflict.~~

5 ~~68.—The system of claim 67, wherein the industrial environment digital twin is updated using collected data transmitted from the worker.~~

~~69.—The system of claim 68, wherein the collected data includes proximity sensor data, image data, or combinations thereof.~~

~~70.—The system of claim 57, wherein the navigational route includes a route for collecting vibration measurements.~~