

CLAIMS

WHAT IS CLAIMED IS:

1. A computer-implemented method of determining a historical state of a system, the method comprising:

obtaining data about the system from a plurality of different data sources;

constructing a full history dynamic network (FHDN) ~~of the system~~ using the data, wherein the FHDN comprises a graph representing the system, wherein the graph comprises:

(1) a plurality of nodes that represent elements of the system, wherein the plurality of nodes are capable of dynamically changing;_;

(2) a plurality of edges connecting the nodes, wherein each edge of the plurality of edges represents a relationship between a pair of nodes of the plurality of nodes, and wherein the plurality of edges are capable of dynamically changing;_; ~~and~~

(3) first time series associated with each of the plurality of nodes; and

(4) second time series associated with the plurality of edges;

wherein the first time series indicate changes in a state of the plurality of nodes over time and the second time series indicate changes in a state of the plurality of edges over time; and

providing a graphical representation of an operational state of the system ~~for at~~ a historical time instance in response to a query of the FHDN ~~for said historical time instance~~.

2. The method of claim 1, wherein the operational state of the system comprises an exact graphical state of the system, in an as-operated state, at the historical time instance.

3. The method of claim 1, wherein the operational state of the system comprises an exact graphical state for a subset of the system at the historical time instance.

4. The method of claim 1, ~~wherein further comprising determining~~ a historical dynamic behavior of the FHDN based on the first time series and the second time series ~~is determined without analyzing a sequence of snapshots of the network captured at different points in time~~.

5. The method of claim 1, further comprising searching, based on the query of the FHDN for the historical time instance, a subset of the first time series, a subset of the second time series, or a subset of both the first time series and the second time series ~~where the~~

~~FHDN permits the query for the historical time instance to be answered without requiring full network instantiation at said historical time instance.~~

6. The method of claim 1, wherein the plurality of nodes and edges comprises (1) all nodes and edges that had previously existed in the network beginning at a given time instance, and (2) all nodes and edges that presently exist in the network.

7. The method of claim 1, wherein the first time series for a selected node or the second time series for a selected edge comprises times of additions or removals of the selected node or the selected edge in the network.

8. The method of claim 1, wherein the first time series or the second time series are based on events or changes occurring at a selected node or edge.

9. The method of claim 1, wherein the state of the system at the historical time instance is obtained by using a search algorithm that iterates over the plurality of nodes and searches through the first time series.

10. The method of claim 9, wherein the search algorithm comprises an iterative graph search algorithm that is configured to only check ~~the a~~ status of selected nodes or edges on an as-needed basis.

11. The method of claim 9, wherein the query comprises an information request about a subset of nodes at a given time instance, and wherein the search algorithm is configured to query the subset of nodes only and directly, without querying other ~~unnecessary~~ nodes.

12. The method of claim 1, further comprising: utilizing a blocking technique to cache entire connected graphical regions of the FHDN in memory for any given instance in time.

13. The method of claim 12, wherein the connected graphical regions of the FHDN contain no unreachable nodes.

14. The method of claim 13, wherein the blocking technique comprises standard blocking, token blocking, or attribute-clustering blocking.

15. The method of claim 13, wherein the caching of the entire connected graphical regions in memory allows searches to be carried out more quickly compared to conventional network graphing techniques.

~~16. The method of claim 1, wherein the use of the FHDN allows memory/storage savings of several orders of magnitude compared to conventional network graphing techniques.~~

~~17. The method of claim 16, wherein the storage requirements can be reduced by at least three orders of magnitude compared to conventional network graphing techniques.~~

~~18.16.~~ The method of claim 1, wherein the system comprises an electrical distribution system.

~~19.17.~~ The method of claim ~~18.16~~, wherein the electrical distribution system comprises a plurality of distribution feeders.

~~20.18.~~ The method of claim ~~19.17~~, wherein the state of the electrical distribution system comprises exact graphical states of the plurality of distribution feeders at the historical time instance.

~~21.19.~~ The method of claim ~~19.17~~, wherein the state of the electrical distribution system comprises exact graphical states of a subset of the distribution feeders at the historical time instance.

~~22.20.~~ The method of claim ~~18.16~~, where the FHDN permits the query for the historical time instance to be determined based on a subset of the first time series, a subset of the second time series, or a subset of both the first time series and the second time series~~answered without requiring full network instantiation of the electrical distribution system at said historical time instance.~~

~~23.21.~~ The method of claim ~~19.17~~, wherein (1) the plurality of nodes and edges and (2) the time series are associated with the plurality of distribution feeders and the connected nodes and branches within each feeder.

~~24.22.~~ The method of claim ~~23.21~~, wherein the time series for a selected node or edge comprises times of additions or removals of the selected node or edge within the network.

~~25.23.~~ The method of claim ~~24.22~~, wherein the additions or removals of the selected node or edge corresponds to the opening or closing of a breaker switch within the electrical distribution system, wherein said breaker switch is associated with the selected edge.

~~26.24.~~ The method of claim ~~23.21~~, wherein the query comprises a query of an electrical configuration of one or more selected distribution feeders at any given time instance.

~~27.25.~~ The method of claim ~~26.24~~, wherein a graph search algorithm is utilized to query the exact states of the one or more selected distribution feeders at any given time instance, by only searching the nodes and edges that are contained in the one or more selected distribution feeders.

~~28.26.~~ The method of claim ~~2725~~, wherein the graph search algorithm is configured to only query ~~the a~~ status of nodes and edges that are contained in the selected distribution feeders ~~on an as-needed basis~~.

~~29.27.~~ The method of claim ~~2826~~, wherein the graph search algorithm is ~~not~~ configured to only query the nodes and edges that are contained in ~~other non-selected~~the selected distribution feeders on an as-needed basis.

~~30.28.~~ The method of claim 1, wherein the FHDN is stored in a two-dimensional matrix comprising a plurality of rows and columns, wherein each row of the plurality of rows represents one of the plurality of nodes, wherein each column of the plurality of columns represents one of the plurality of edges, and wherein an entry at a row and a column in the two-dimensional matrix indicates whether the edge represented by the column is connected to the node represented by the row.

~~31.29.~~ The method of claim ~~3028~~, wherein the plurality of nodes of the graph of the FHDN include nodes that were removed, and wherein the plurality of edges of the FHDN include edges that were removed, deactivated, or disconnected~~the entry is a time series~~.

~~32.30.~~ The method of claim 1, wherein the FHDN is stored in a graph database.

~~33.31.~~ The method of claim ~~3230~~, wherein the graph database comprises a plurality of pointers between the plurality of nodes, wherein each pointer represents one of the plurality of edges.

~~34.32.~~ The method of claim ~~3331~~, wherein the plurality of pointers comprises a pointer that is bidirectional.

~~35.33.~~ The method of claim ~~3331~~, wherein the plurality of pointers comprises a pointer that is unidirectional.

~~36.34.~~ The method of claim 1, wherein the plurality of nodes and the plurality of edges comprise tags or properties.

~~37.35.~~ The method of claim 1, wherein the plurality of edges comprises weights that indicate strength of connections or relationships between nodes.

~~38.36.~~ The method of claim 1, wherein the system comprises ~~the a~~ Bill of Materials for any manufacturing company.

~~39.37.~~ The method of claim 1, wherein the system comprises a supply chain distribution network.

~~40.38.~~ The method of claim 1, wherein the system comprises a social network comprising of a plurality of users.

~~41.39.~~ The method of claim 1, wherein the system is a molecule comprising a plurality of atoms and a plurality of bonds, wherein the plurality of nodes represents the plurality of atoms, and wherein the plurality of edges represents the plurality of bonds.

~~42.40.~~ The method of claim 1, wherein the system is an oil and gas processing pipeline comprising drilling assets, refining assets, and pipeline assets, wherein the plurality of nodes represents the drilling assets and the ~~pipeline-refining~~ assets, and wherein the plurality of edges represents the pipeline assets.

~~43.41.~~ The method of claim 1, wherein the system is a biological neural network comprising neurons and their connections.

~~44.42.~~ The method of claim 1, wherein the system is a road network.

~~45.43.~~ The method of claim 1, further comprising reconstructing snapshots of the FHDN at different historical time instances on demand via queries of the FHDN, wherein the snapshots include graphical representation of the operational state of the system at the different historical time instances~~wherein the FHDN is constructed without requiring periodic capturing and storing of snapshots of the system at different points in time.~~

~~46.44.~~ The method of claim 1, wherein constructing the FHDN of the system comprises generating data objects that represent the plurality of nodes, the plurality of edges, ~~and~~ the first time series, and the second time series.

~~47.45.~~ A system for determining a historical state of a system, the system comprising:

a data aggregation component for continuously obtaining data about a system from a plurality of different data sources; and

a network graphing component configured to:

construct a full history dynamic network (FHDN) of the system using the data, wherein the FHDN comprises a graph representing the system, wherein the graph comprises:

~~the FHDN comprises~~ (1) a plurality of nodes that represent elements of the system, wherein the plurality of nodes are capable of dynamically changing;

(2) a plurality of edges connecting the nodes, wherein each edge of the plurality of edges represents a relationship between a pair of nodes of the plurality of nodes, and wherein the plurality of edges are capable of dynamically changing;~~and~~

(3) first time series associated with each of the plurality of nodes; and

(4) second time series data associated with the plurality of edges, wherein the first time series indicate changes in state of the plurality of nodes over time and the second time series indicate changes in a state of the plurality of edges over time,~~and wherein the FHDN is constructed without requiring periodic capturing and storing of snapshots of the system at different points in time;~~ and

provide a graphical representation of an operational state of the system ~~for at~~ a historical time instance in response to a query of the FHDN ~~for said historical time instance~~.

48.46. A non-transitory computer readable medium storing instructions that, when executed by one or more servers, causes the one or more servers to perform a method, the method comprising:

obtaining data about a system from a plurality of different data sources;

constructing a full history dynamic network (FHDN) of the system using the data, wherein the FHDN comprises a graph representing the system, wherein the graph comprises:

(1) a plurality of nodes that represent elements of the system, wherein the plurality of nodes are capable of dynamically changing;

(2) a plurality of edges connecting the nodes, wherein each edge of the plurality of edges represents a relationship between a pair of nodes of the plurality of nodes, and wherein the plurality of edges are capable of dynamically changing;~~and~~

(3) first time series associated with each of the plurality of nodes; and

(4) second time series associated with the plurality of edges,

wherein the first time series indicate changes in a state of the plurality of nodes over time and the second time series indicate changes in a state of the plurality of edges over time,~~and wherein the FHDN is constructed without requiring periodic capturing and storing of snapshots of the system at different points in time;~~ and

providing a graphical representation of an operational state of the system ~~for~~at a historical time instance in response to a query of the FHDN ~~for said historical time instance~~.