

CLAIMS

1. A method (200) for detecting anomalies in a water distribution system composed of a network of nodes, said method comprising:
 - A) parametrizing (220) a hydraulic model (211) of the water distribution system by initializing a set of values of control variables (210) characterizing the network and its output at the nodes;
 - B) using sensors on the network to acquire observations (230) of a subset of state variables, said observations having time references;
 - C) changing the set of values of the control variables (310);
 - D) using the hydraulic model to calculate (320) predicted values of a set of state variables characterizing at least water velocity and pressure at the nodes at the time references;
 - E) computing residue values (330) of the set of state variables as a difference between predicted values and observations at the time references;
 - F) if said differences satisfy a break criterion (340) meaning that the residue value are small enough for considering that values of control variables accurately describe the network, going to step H);
 - G) if not, changing the set of values of the control variables (350) and going back to step D);
 - H) if said differences satisfy a refinement criterion (360) comprising the calculation of values of one of a least square and a Bayesian objective function, going to step J);
 - I) if not, selecting an subset of the network where to calculate predicted values, going back to step D)
 - J) classifying (270) an entity of the network, according to the set of control variables, to a class in a set of class comprising at least one class representative of a normal state, and at least one class representative of an abnormal state using a supervised machine learning engine previously trained using historical labelled feature vectors corresponding to said at least one class.

2. The method of claim 1, wherein steps C) to J) are performed for at least one event type, and changing the state of control variables is performed according to said at least one event type.
3. The method of claim 2, wherein a plurality of event types is tested, and one instance of steps C) to J) is performed for each event type.
4. The method of one of claims 1 to 3, wherein the selection and modification of control variables is determined by a Levenberg-Marquardt algorithm.
5. The method of one of claims 1 to 4, wherein the control variables comprise scalar variables characterizing the topology and the topography of the network, and time-based variables characterizing the inputs and outputs of the network having at least one value at each time reference.
6. The method of claim 5, wherein changing the set of values of the control variables comprises modifying at least one of:
 - the values of a subset of the time-based control variables;
 - the values of a subset of the scalar control variables calculated during a phase of modeling of the network.
7. The method of claim 6, wherein modifying the values of a subset of the time-based control variables comprises modifying the values of the time-based control variables representative of water consumption.
8. The method of one of claims 1 to 7, wherein state variables further characterize pressure.
9. A method of detecting anomalies in a water distribution system, said method comprising:
 - A) parametrizing (220) a hydraulic model (211) of the water distribution system with a set of values (210) of control variables characterizing the network and its output at the nodes;

- B) using sensors on the network to acquire (230) observations of a subset of state variables at time references;
- D) using the hydraulic model to calculate (320) predicted values of a set of state variables characterizing at least a water velocity at the nodes, said values having time references;
- E) computing (330) residue values of the subset of the state variables as a difference between predicted values and observations at the time references;
- performing (410) a statistical analysis of residue values at an entity of the network at a selection of the time references;
- F) if said differences satisfy a break criterion (340) meaning that the residue value are small enough for considering that values of control variables accurately describe the network, going to step H);
- G) if not, changing the set of values of the control variables (350) and going back to step D);
- H) if said differences satisfy a refinement criterion (360) comprising the calculation of values of one of a least square and a Bayesian objective function, going to step J);
- I) if not, selecting a subset of the network where to calculate predicted values, going back to step D); and
- classifying the network in a state at the output of:
 - o J) using a previously trained supervised machine learning algorithm to classify (270) an entity of the network, according to the set of control variables, to a class in a set of class comprising at least one class representative of a normal state, and at least one class representative of an abnormal state using a supervised machine learning engine previously trained using historical labelled feature vectors corresponding to said at least one class;
 - o classifying (420) the at least one of a node and an arc of the network to a class in a set of class comprising at least one class representative of a normal state, and at least one class representative of an abnormal

state, by applying to said statistical analysis a classification previously trained using a historical dataset of residue values.

10. The method of claim 9, wherein the statistical analysis comprises the calculation of one of a mean, a standard deviation, an absolute mean or median deviation, an auto-regressive model, boxplot, Support Vector Machine, a Principal Component Analysis, PCA, K-nearest neighbor and results of statistical tests, computing P-values.
11. The method of one of claims 9 and 10, wherein an entity of the network is classified in a class representative of an abnormal state if the residue values at the at least a node exceeds a threshold based on statistical analysis of historical data and operational risk level a predefined number of successive time references.
12. A system for detecting anomalies in a water distribution system composed of a network of nodes, said system comprising:
 - sensors of at least water velocity and pressure at a subset of nodes of the network;
 - a computing device comprising a processor;
 - communication links between sensors and the computing device;
 - a storage media;wherein the computing device is configured for:
 - retrieving an initial set of values of control variables characterizing the network and its output at the nodes from the storage media and using it to parametrize a hydraulic model of the water distribution system;
 - using communication links between sensors on the network to acquire observations of a subset of the state variables, said observations having time references;
 - executing a method according to any one of claims 1 to 11.
13. A computer program product, stored on a non-transitory computer-readable medium, for detecting anomalies in a water distribution system composed of a network of nodes, said computer program product comprising code instructions for executing a method according to any one of claims 1 to 11.