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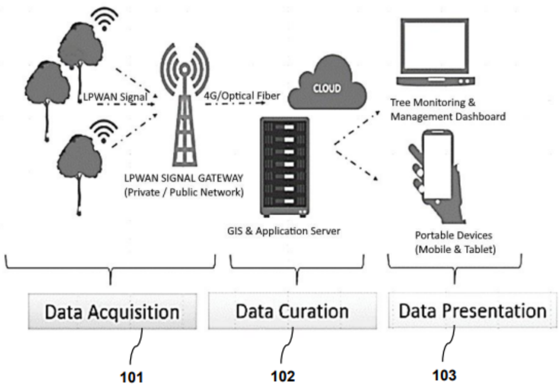
[54] TREE MONITORING SYSTEM FOR URBAN TREE MANAGEMENT
城市樹木管理的樹木監測系統

[57] Provided herein is a tree monitoring system for urban tree management. The monitoring system includes a plurality of sensing devices and a backend system. Each individual sensing device is mountable on a tree for measuring a tilting angle and a direction of tree displacement of the tree. The individual sensing device comprises an IoT communication module and a plurality of detectors. The plurality of detectors includes a gyroscope and/or accelerometer for obtaining a roll angle and a pitch angle; and a vibration sensor configured to measure a vibration amplitude and a sway frequency of the tree. The IoT communication module is communicable with the backend system in real-time. The backend system has a system architecture based on big data analytics and machine learning approaches and is configured to produce models for deeper insights on properties of tree movements.

本發明提供一種城市樹木管理的樹木監測系統。監控系統包括多個感測裝置及後端系統。每個個體感測裝置可安裝在樹上，用於測量樹木的傾斜角度和樹木位移方向。個體感測裝置包括物聯網通信模塊和多個檢測器。多個檢測器包括陀螺儀和/或加速度計，用於獲得滾轉角和俯仰角；動傳感器被配置為測量樹木的振動幅度和搖擺頻率。物聯網通信模塊與後端系統實時通信。後端系統具有基於大數據分析和機器學習方法的系統架構，並配置為生成模型以更深入地了解樹木的擺動特性。


LPWAN Signal
4G/Optical Fiber
CLOUD
Tree Monitoring & Management Dashboard
LPWAN SIGNAL GATEWAY (Private / Public Network)
GIS & Application Server
Portable Devices (Mobile & Tablet)
Data Acquisition
Data Curation
Data Presentation
101
102
103

TREE MONITORING SYSTEM FOR URBAN TREE MANAGEMENT

城市樹木管理的樹木監測系統

TECHNICAL FIELD

[0001] The present disclosure generally relates to a tree monitoring system. More particularly, the present disclosure relates to a tree monitoring system for urban tree management for an early identification of trees in need of follow-up actions.

BACKGROUND

[0002] Urban trees are important for cultivating a sustainable urban ecology in a city. They exhibit a wide range of ecosystem services that benefit our environment and urban inhabitants in multi-faceted dimensions. These include reducing the urban heat island effect, enhancing biodiverse habitat for wildlife, increasing the aesthetic value of the street view, and relieving mental distress. Yet, trees growing in urban and surrounding areas are subject to considerable environmental stress, requiring proper maintenance to avoid potential hazards, no matter to human life or to the property and infrastructures. Some trees may deteriorate without presenting with signs of symptoms or inflection, and results in a higher vulnerability under dynamic conditions. For example, during and after strong windstorms, extreme wind events, typhoon seasons, or severe weather events, accidents relating to urban trees failures may cause personal damages, economic loss, and infrastructural destruction. Therefore, continuous monitoring of the well-being of the urban trees is vital in ensuring a sustainable urban design.

[0003] In Hong Kong, every year before the onset of the wet season, tree management officers and other stakeholders are required to complete tree risk assessments in areas with high pedestrian and traffic flow professionally and systematically and implement appropriate risk mitigation measures. Dangerous trees with untreatable problems need to be removed as soon as possible to safeguard public safety. Tree inspection personnel will have to perform a ground inspection to examine and assess various parts of a tree and may even need to climb up the tree to inspect the hidden parts from different angles. This takes a lot of manpower and time to cover all the urban trees (more than 1,700,000 trees) in Hong Kong.

[0004] To assess and predict tree falling, tree tilt monitoring in association with weather observation is crucial. Apart from tree species, health, and growing conditions, the critical wind speed for tree failure varies with structural attributes of a tree, such as: diameter, age, height, inclination, size, canopy spread, and wood density. Trees with a lesser diameter at breast height (DBH) are more susceptible to strong winds. Thus, the height to diameter ratio of a tree is a critical physical attribute associated with the risk of tree failure. On the other hand, trees behave like a vibrant system, and the tree anchorage holds soil firmly so the root supports the tree trunk and foliage. Weak anchorage in the root system may cause tree falling hazards. This can be detected by measuring the turning momentum or the tilting data of a tree. Long-term data on tree tilt movements and their response to weather observations can provide important information for early detection of tree mortality, which can help to mitigate associated risks with tree failure and protect public life and property.

[0005] The significance and value of a tree in an urban space are determined through its benefits to society, whereas the respective risks are associated with any tree failures due to extreme wind events, tree defects, and health status. With the rising global average temperature, scientific studies indicate that extreme weather events such as tropical cyclones and large storms are likely to become more frequent and more intense in the coming decades. Therefore, it is important to model and monitor the response of trees to windstorms, devise effective measures to stabilize trees in the urban landscape, and minimize damages to human life and infrastructures.

[0006] In view of the deficiencies, there is a need for a tree monitoring system that seeks to address at least some of the above issues for providing continuous monitoring and early identification of trees with potential hazards. Furthermore, other desirable features and characteristics will become apparent from the subsequent detailed description and the appended claims, taken in conjunction with the accompanying drawings and this background of the disclosure.

SUMMARY OF THE INVENTION

[0007] Embodiments of the present disclosure provide a tree monitoring system for urban tree management. Such tree monitoring system can provide continuous monitoring and early identification of trees with potential hazards.

[0008] In accordance with certain aspects of the present invention, a monitoring system for urban tree management is disclosed. The monitoring system includes a plurality of sensing devices and a backend system. Each individual sensing device is mountable on a tree for measuring a tilting angle and a direction of tree displacement of the tree. The individual sensing device comprises an IoT communication module and a plurality of detectors. The plurality of detectors includes a gyroscope and/or accelerometer for obtaining a roll angle and a pitch angle; and a vibration sensor configured to measure a vibration amplitude and a sway frequency of the tree. The IoT communication module is communicable with the backend system in real-time. The backend system has a system architecture based on big data analytics and machine learning approaches and is configured to produce models for deeper insights on tree movements.

[0009] According to certain aspects, the gyroscope and/or accelerometer is configured to measure the acceleration on one to three axes and detect a roll angle and a pitch angle of the individual sensing device.

[0010] According to certain aspects, the gyroscope and/or accelerometer is a triaxial accelerometer configured to measure a longitudinal motion, a lateral motion, and a vertical motion.

[0011] According to certain aspects, the gyroscope and/or accelerometer is controllable by the IoT communication module for adjusting to varying sampling frequency modes, wherein the varying sampling frequency modes comprises a high sampling frequency mode activated in a typhoon season or during an adverse weather condition, and a low sampling frequency mode activated in a normal weather condition for maximizing data capture for an unusual pattern visualization which could in turn save the power consumption.

[0012] According to certain aspects, the individual sensing device comprises a reading logger for keeping a backup record of the roll angle, the pitch angle, the vibration amplitude, and the sway frequency, wherein the reading logger is configured to store the backup record in a removable storage medium or a build-in memory element.

[0013] According to certain aspects, the IoT communication module adopts low-power wide-area network (LPWAN) to provide connectivity, wherein the LPWAN is selected from either LoRaWAN or NB-IoT.

[0014] According to certain aspects, the backend system comprises an access application programming interface (API) for receiving the data from the individual sensing device, wherein the access API is a representational state transfer (REST) API or a simple object access protocol (SOAP).

[0015] According to certain aspects, the backend system comprises a system processor configured to execute an algorithm for determining whether the tree requires a safety inspection and further comprises a triggering function to activate responsive actions when a safety issue is identified.

[0016] Preferably, the algorithm is based on regressive models, descriptive statistics, and spatial big data analysis to perform a tree tilt analysis for determining a tree risk index.

[0017] Preferably, the tree tilt analysis is executed based on seasonal decomposition, a wavelet transform, a seasonal autoregressive integrated moving average (SARIMA) model, an gradient boosting tree model and/or a bagging tree machine learning model.

[0018] Preferably, the SARIMA forecasting model incorporates a seasonal component of time series, and comprises a SARIMA model with roll angle forecasting and pitch angle forecasting respectively. Both short-term and long-term of roll and pitch angles forecasting are converted to tilt angle prediction.

[0019] According to certain aspects, the backend system comprises an application dashboard based on a geographical information system (GIS) platform, wherein the application dashboard is configured to provide color indication for categorizing the tilting angle, information on the individual sensing device, environmental factors, point-of-interests, and an azimuth graph indicating a trajectory of the tree.

[0020] This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used as an aid in determining the scope of the claimed subject matter. Other aspects and advantages of the present invention are disclosed as illustrated by the embodiments hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] The appended drawings contain figures to further illustrate and clarify the above and other aspects, advantages, and features of the present disclosure. It will be appreciated that these drawings depict only certain embodiments of the present disclosure and are not intended to limit its scope. It will also be appreciated that these drawings are illustrated for simplicity and clarity and have not necessarily been depicted to scale. For example, the dimensions of some of the elements in the illustrations, block diagrams or flowcharts may be exaggerated in respect to other elements to help to improve understanding of the present embodiments.

[0022] The present disclosure will now be described and explained with additional specificity and detail through the use of the accompanying drawings in which:

[0023] FIG. **1** shows an overview of the system architecture of the tree monitoring system, in accordance with embodiments of the invention;

[0024] FIG. **2** shows a conceptual diagram illustrating a sensing device mounted on a tree, in accordance with embodiments of the invention;

[0025] FIG. **3** shows a circuit block diagram of a sensing device, in accordance with embodiments of the invention;

[0026] FIG. **4** shows the gyroscope and/or accelerometer of the sensing device of FIG. **3**;

[0027] FIG. **5** shows a block diagram of the system architecture of the tree monitoring system, in accordance with embodiments of the invention;

[0028] FIG. **6** shows a block diagram of the tree tilt analysis, in accordance with embodiments of the invention; and

[0029] FIG. **7** shows an exemplary application dashboard of the backend system, in accordance with embodiments of the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0030] The following detailed description is merely exemplary in nature and is not intended to limit the disclosure or its application and/or uses. It should be appreciated that a vast number of variations exist. The detailed description will enable those of ordinary skilled in the art to implement an exemplary embodiment of the present disclosure without undue experimentation, and it is understood that various changes or modifications may be made in the function and structure described in the exemplary embodiment without departing from the scope of the present disclosure as set forth in the appended claims.

[0031] Some portions of the description which follows are explicitly or implicitly presented in terms of algorithms and functional or symbolic representations of operations on data within a computer memory. These algorithmic descriptions and functional or symbolic representations are the means used by those skilled in the data processing arts to convey most effectively the substance of their work to others skilled in the art. An algorithm is here, and generally, conceived to be a self-consistent sequence of steps leading to a desired result. The steps are those requiring physical manipulations of physical quantities, such as electrical, magnetic, or optical signals capable of being stored, transferred, combined, compared, and otherwise manipulated.

[0032] The present specification also discloses apparatus for performing the operations of the methods. Such apparatus may be specially constructed for the required purposes or may include a computer or other computing devices selectively activated or reconfigured by a computer program stored therein. The algorithms and displays presented herein are not inherently related to any particular computer or other apparatus. Various machines may be used with programs in accordance with the teachings herein. Alternatively, the construction of a more specialized apparatus to perform the required method steps may be appropriate. The structure of a computer will appear from the description below.

[0033] In addition, the present specification also implicitly discloses a computer program, in that it would be apparent to one skilled in the art that the steps of the method described herein may be put into effect by computer code. The computer program is not intended to be limited to any particular programming language and implementation thereof. It will be appreciated that a variety of programming languages and coding thereof may be used to implement the teachings of the disclosure contained herein. Moreover, the computer program is not intended to be limited to any particular control flow. There are many other variants of the computer program, which can use different control flows without departing from the spirit or scope of the present disclosure.

[0034] Furthermore, one or more of the steps of the computer program may be performed in parallel rather than sequentially. Such a computer program may be stored on any computer readable medium. The computer readable medium may include storage devices such as magnetic or optical disks, memory chips, or other storage devices suitable for interfacing with a computer. The computer readable medium may also include a hard-wired medium such as exemplified in the Internet system or wireless medium. The computer program when loaded and executed on a computer effectively results in an apparatus that implements the steps of the preferred method.

[0035] As used herein, the term “server” may refer to a single computing device or a network of interconnected computing devices which operate together to perform a particular function. In other words, the server may be contained within a single hardware unit or be distributed among several or many different hardware units. The term “cloud” is construed and interpreted in the sense of cloud computing or, synonymously, distributed computing over a network unless otherwise specified.

[0036] The term “Internet of Things (IoT) device” is used to refer to any device that has an addressable interface (e.g., an Internet protocol (IP) address, a Bluetooth identifier (ID), a near-field communication (NFC) ID, etc.) and can transmit information to one or more other devices over a wired or wireless connection. An IoT device may have an active communication interface, such as a modem, a transceiver, or the like. An IoT device may be controlled or monitored by a central processing unit (CPU), microprocessor, ASIC, or the like, and configured for connection to an IoT network or the Internet. The IoT device for the present invention is a sensing device. It is apparent that the sensing device may not have direct Internet-connectivity, in which the sensing device may be connected to one or more communication devices, such as cell phones, desktop computers, laptop computers, or tablet computers, etc., to form a connected system, such that the connected system can be IoT device.

[0037] The term “Big Data” is generally used to describe collections of data of a relatively large size and complexity, such that the data becomes difficult to analyze and process within a reasonable time, given computational capacity (e.g., available database management tools and processing power). Thus, the term “Big Data” can refer to data collections measured in gigabytes, terabytes, or larger, depending on the processing entity's ability to handle the data. “Big Data” is intended to refer to collections of electronic data stored in one or more storage locations, and it is not intended to limit the applicability of the inventive subject matter to a particular data size range or a particular amount of data complexity.

[0038] The use of the terms “a” and “an” and “the” and “at least one” and similar referents in the context of describing the invention (especially in the context of the following claims) are to be construed to cover both the singular and the plural, unless otherwise indicated herein or clearly contradicted by context. The terms “comprising,” “having,” “including,” and “containing” are to be construed as open-ended terms (i.e., meaning “including, but not limited to,”) unless otherwise noted. The use of any and all examples, or exemplary language (e.g., “such as”) provided herein, is intended merely to illuminate the invention better and does not pose a limitation on the scope of the invention unless otherwise claimed. No language in the specification should be construed as indicating any non-claimed element as essential to the practice of the invention.

[0039] The benefits, advantages, solutions to problems, and any element(s) that may cause any benefit, advantage, or solution to occur or become more pronounced are not to be construed as a critical, required, or essential features or elements of any or all of the claims. The invention is defined solely by the appended claims including any amendments made during the pendency of this application and all equivalents of those claims as issued.

[0040] Using the disclosed embodiments of a tree monitoring system **100**, a long-term monitoring of tree tilt angles can be achieved. The monitoring system **100** uses plural sensing devices **200**, each installed on an urban tree, to monitor and analyze the conditions of the trees across a city.

[0041] FIG. **1** is an overview of the monitoring system architecture of the tree monitoring system **100**. The monitoring system **100** tracks the physical response of urban trees under different wind loading for whole tree swaying conditions using sensing devices **200**. Applying the concept of the Internet of Things (IoT), a seamless and massive interconnection of the sensing devices **200** with the cloud server and end user can be achieved. Coupled with the Big Data Infrastructure and using a machine learning approach, the smart intelligent layer is essential for smart resources to be able to process information. The ubiquitous framework of the monitoring system **100** can be summarized in three main operations: comprising data acquisition **101**, data curation **102**, and data presentation **103**, where this architecture of the monitoring system **100** has been proven to be able to make positive impacts and provide useful solutions for outdoor monitoring and management.

[0042] The data acquisition **101** adopts a new generation of low-power wide-area network (LPWAN), such as LoRaWAN and/or NB-IoT, to provide pervasive connectivity between the sensing device **200** and the cloud database. The LoRaWAN may be a private or a public network that has a typical range of 5-10 km. The maximum power consumption is as low as 0.025W, which offers an extremely low power solution. On the other hand, the NB-IoT may be provided by the mobile operator with a typical range of 2-10 km, which is similar to the mobile network coverage. The maximum power consumption is around 0.2W. Despite the applications for both communication systems are diverse, LoRaWAN is considered the better choice on the low-cost applications front, whereas NB-IoT is preferred for areas without LoRaWAN coverage and mobile network coverages is available. Preferably, the monitoring system **100** of the present invention adopts dual-mode networks with both LoRaWAN and NB-IoT, which provide complementary resolution in solving the problem of deteriorated network performance in some high-density terrains in urban areas. It is apparent that the monitoring system **100** may adopt either one of the networks or other low-power networks without departing from the scope and spirit of the present invention. The LPWAN signal gateway, either private or public network, receives the signals from the sensing devices **200** and transmits the signals through 4G or LoRaWAN to the cloud server.

[0043] The data curation **102** is a backend system developed using big data analytics and machine learning approaches to provide predictive analysis on the conditions of the urban trees. The application server comprises a data processing backend, which is configured to handle streams of geographical information system (GIS) from each tree, and produce models for deeper insights on the tree movement mechanism, and generate a specific time-frame, reliable predictions for forecasting future failure-related incidents of a single or a cluster of trees. The data processing backend not only handles streams of geographical data from individual trees within the whole territory, but it also produces models for deeper insights on the tree movement mechanism, and generates within a specific timeframe, reliable predictions for forecasting future failure-related incidents of a single, or clusters of trees. The development of the daily monitoring platform is based on the functional requirements provided by the tree managers working closely on urban trees.

[0044] The data presentation **103** is a frontend system configured to collect analysis results from the cloud database and present the results on a computer or a portable device. The results may be presented as a summary of the measurements from multiple sensing devices **200** for a quick review of the tree conditions in an area. A tailor-made application dashboard with a control console is preferably designed to visualize the real-time information to the users, and is also conveniently accessible by the user using a portable device. The application dashboard can support users in obtaining quick review of tree conditions, and identifying high-risk trees through dynamically data fetching, from data curation to the multi-model data presentation. This is done by overlaying interactive maps and azimuth-like data plots to exhibit relevant data features, powered by a tailor-made application dashboard to extract insights through visualizing knowledge for the users, which is based on space-time environmental data and tilting data of trees.

[0045] For performing data acquisition **101**, as illustrated in FIG. **2**, the sensing device **200** is installed and mounted on an urban tree. Preferably, the sensing device **200** is a device mountable on a tree, particularly on the tree trunk, for measuring the tilting angles and directions of the tree displacement. The sensing device **200** can be installed at the lower tree trunk of selected trees. Due to concerns of public safety, higher priority was given to roadside trees with heavy vehicle or pedestrian traffic, as well as trees in public facilities (parks and promenades). The emergence of the IoT paradigm is the key to enabling a seamless and massive interconnection of smart devices.

A large-scale installation of the sensing devices **200** on a large number of trees in an urban area can enable large-scale remote monitoring of all the urban trees via low-power wireless transmission technologies, either LoRaWAN or NB-IoT. Therefore, extensive coverage of urban trees over the whole territory of an urban city can be achieved. In certain embodiments, the dimension of a sensing device **200** is 125mm(L) x 67mm(W) x 40mm(H) for using LoRaWAN, or 132mm(L) x 67mm(W) x 50mm(H) for using NB-IoT.

[0046] FIG. **3** shows a circuit block diagram of an individual sensing device **200** in accordance with certain embodiments of the present disclosure. The sensing device **200** comprises a plurality of detectors **110**, an IoT communication module **220**, and a reading logger **130**. The plurality of detectors **110** are designed to track the physical response of trees under different wind loading conditions, by measuring rotational angles, tree displacements, and tree tilt angles within a tilt accuracy of 0.05°. In certain embodiments, the plurality of detectors **110** comprises a gyroscope and/or accelerometer **111**, a vibration sensor **112**, and a digital thermometer **113**. The gyroscope and/or accelerometer **111** are configured to detect the roll angle and the pitch angle of the sensing device **200**.

[0047] For categorizing the trees, the physical characteristics include, but be not limited to, the height, the diameter at breast height (DBH), the tree species, the crown spread, and the tree health conditions, such as root and trunk health status. The sensing device **200** is mounted on the tree with a serial number assigned thereto. The serial number, with the extended unique identifier (EUI) of the sensing device **200**, is used to track the information of each tree.

[0048] The gyroscope and/or accelerometer **111** are conceptually shown in FIG. **4**, which can be an electromechanical device for performing tilt measurement. The gyroscope and/or accelerometer **111** may measure the acceleration on one to three axes, which is used to obtain a tilt angle data. In one embodiment, the gyroscope and/or accelerometer **111** is a triaxial accelerometer configured to measure a longitudinal motion (X-axis), a lateral motion (Y-axis), and a vertical motion (Z-axis), which essentially detects the roll angle and the pitch angle of the sensing device **200**. The gyroscope and/or accelerometer **111** have a high angular sensitivity, preferably at 0.01°. The sampling frequency may be as high as 20 Hz, and the response time may be 400 ms. In particular, the gyroscope and/or accelerometer **111** controlled by the communication sensors which could adjust to a varying sampling frequency modes. A high sampling frequency mode is particularly important and activated in a typhoon season or during an adverse weather condition, the gyroscope and/or accelerometer **111** can collect a near-real-time data. In a normal weather condition, the gyroscope and/or accelerometer **111** are changed to activate a low sampling frequency mode in which the sampling frequency is automatically adjusted to approximately 5 minutes for maximizing the data capture for visualizing any unusual pattern that might lead to imminent tree risk hazard.

[0049] The vibration sensor **112** is a device configured to measure the vibration amplitude and sway frequency of the tree. In certain embodiments, the vibration sensor **112** is realized by a piezoelectric accelerometer, velocity sensors, or a laser displacement sensor. The vibration sensor **112** can determine the vibration amplitude and the sway frequency under natural wind loading or extreme wind loading, thereby determines whether the stability of the tree.

[0050] The digital thermometer **113** is provided in the sensing device **200** for determining the temperature of the environment. This information helps for analyzing the relationship between the weather condition and the tilting response of the tree. Statistical models are used to analyze the atmospheric stability and temperature conditions for predicting tree sway.

[0051] The sensing device **200** is characterized in that the reading logger **130** is provided for keeping a backup record of the measurement from the plurality of detectors **110**, particularly the roll angle, the pitch angle, the vibration amplitude, and the sway frequency.

[0052] In certain embodiments, the sensing device **200** has a slot for mounting a removable storage medium **131**. The removable storage medium **131** may be any external memory, such as a USB mass storage device (for example, a USB memory), an SD card, a multimedia card (MMC), a memory stick, and the like. The reading logger **130** is configured to store the backup record in the removable storage medium **131**.

[0053] In an alternative embodiment, the sensing device **200** has a build-in memory element **132** for storing data from the plurality of detectors **110** and any threshold values. In certain embodiments, the build-in memory element **132** is a device-readable storage medium such as a non-transitory storage device, such as digital memory, a magnetic storage medium, optical readable digital data storage medium, semiconductor device, or any suitable combination of the foregoing. More specific examples of the build-in memory element **132** would include the following: a portable computer diskette, a hard disk, a random-access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or Flash memory), an optical storage device, a magnetic storage device, or any suitable combination of the foregoing. The reading logger **130** is configured to store the backup record in the build-in memory element **132**.

[0054] Depending on actual design requirements and preferences, the sensing device **200** may also include other electronic components (not shown in the illustrations), such as on/off switch or button, power converters, controllers, interconnecting wiring and cables, lighting elements, battery, and among others, which are not shown in the illustrated embodiments. Preferably, the battery is a rechargeable battery, such as a lithium-ion battery, a nickel-metal hydride battery, a lithium polymer battery, or the like. In one embodiment, the battery has a capacity of 8,500mAh for using LoRaWAN, and has a capacity of 19,000mAh for using NB-IoT.

[0055] The processor **210** may be a microcontroller unit (MCU), a custom integrated circuit, a digital signal processor (DSP), a field-programmable gate array (FPGA), an application-specific integrated circuits (ASIC), a programmable I/O device, other semiconductor devices, or any suitable combination of the foregoing. The processor **210** is configured to execute a method to receive the data from the plurality of detectors **110** and transmits the data to the reading logger **130** and IoT communication module **220** for communicating with the backend system **300**. The processor **210** may further comprise other circuitry or connect to other filtering devices for performing noise cancellation.

[0056] The monitoring system **100** applies the concept of IoT, a seamless interconnection between the sensing device **200** and the backend system **300**. The IoT communication module **220** is communicable with the backend system **300** in real-time by transmitting a signal from the antenna **221**. The signal includes the roll angle and the pitch angle of the tree, the vibration amplitude, the sway frequency, the temperature condition, and other measurement or control signals. In certain embodiments, the signal may also include system metadata, GIS data, timestamp data, and global positioning system (GPS) data. The IoT communication module **220** adopts LPWAN to provide connectivity to the backend system **300**. In certain embodiments, the LPWAN is selected from either LoRaWAN or NB-IoT. Comparing to 3G, 4G, Bluetooth, or WiFi, the speed of NB-IoT and LoRaWAN is much faster, and the amount of information that can be shared is higher. The latency for the data to be communicated between backend system **300** and the sensing device **200** can be very low. The overall power consumption is also minimized, therefore, the battery of the sensing device **200** can last for 2 to 3 years. This advantageously solved the battery problem in the art by providing consistent performance in an outdoor environment.

[0057] The backend system **300** has a system architecture based on big data analytics and machine learning approaches. The backend system **300** is configured not to only handle streams of geographical data from individual trees in a territory, but also to produce models for deeper insights on tree movements, and to generate reliable predictions for forecasting future failure-related incidents of a single or a cluster of trees.

[0058] FIG. **5** provides a block diagram of the system architecture of the tree monitoring system **100**. The monitoring system **100** may include a plurality of sensing devices **200**, comprising sensing devices supporting NB-IoT **111** and sensing devices supporting LoRaWAN **112**. The plurality of sensing devices **200** are communicable with a backend system **300** for big data analytics and machine learning. The backend system **300** is configured to receive the data from the sensing devices **200** and identify meaningful data. Depending on the type of IoT communication module **220** used in the sensing device **200**, the data package is transmitted via a gateway to an access API **140** of the backend system **300** for further processing.

[0059] In particular, the sensing device **200** supporting NB-IoT **111** has a NB-IoT module **231** to realize the connection to the backend system **300**. By the NB-IoT communication protocol **232**, the signal is transmitted through the NB-IoT platform **241** and received by the NB-IoT Gateway application programming interface (API) **141**. Similarly, the sensing device **200** supporting LoRaWAN **112** has a LoRaWAN module **221** to realize the connection to the backend system **300**. By the LoRaWAN communication protocol **222**, the signal is transmitted through the LoRaWAN platform **242** and received by the LoRaWAN Gateway API **142**.

[0060] Both the NB-IoT Gateway API **141** and the LoRaWAN Gateway API **142** are connected to the access API **140**, wherein the access API **140** is preferably a representational state transfer (REST) API, as is known in the art. The REST API is a lightweight service interface based on hypertext transfer protocol (HTTP), optionally secured with authentication and authorization. In certain embodiments, the access API **140** may alternatively be a simple object access protocol (SOAP), or any other suitable client-server communication protocols.

[0061] The data received by the access API **140** is then transmitted as a data stream to a system processor **170** over an internet connection, which may further be stored in a TMS database **150**. The TMS database **150** is configured to keep a complete record of the data received in the cloud for the system processor **170** to analyze. For each tree in the TMS database **150**, data on a range of tree attributes are stored under five major categories, including the physical characteristics, environment, point-of-interest (POI), data from the sensing device **200**, and the tree trajectory.

[0062] The physical characteristics include, but be not limited to, the height, the DBH, the tree species, the crown spread, and the tree health conditions, such as root and trunk health status. The EUI and the serial number of each sensing device **200** mounted to each individual tree were also stored. For the environment, information about the surrounding environment, including air quality and wind speed, as well as other demographic information such as population density in the district, is stored. The POI denotes the proximity of an individual or cluster of trees to the nearest residential and commercial areas. The POI can be used to calculate the dynamic correlation which analyzes the tree failure pattern in the urban landscape heterogeneity. The tree trajectory is a moving pathway visualized as an azimuth visualization, which interpolates the tree moving trajectory in terms of tilting angles and the movement direction, thereby the track record of the movement pattern of a tree can be clearly illustrated.

[0063] The system processor **170** is configured to execute an algorithm **171** based on regressive models, descriptive statistics, and spatial big data analysis for determining whether the trees require a safety inspection, and further comprises a triggering function **172** to activate responsive actions in an event when a safety issue is identified. The monitoring system **100** goes beyond simple identification of which trees require a safety inspection. The triggering function **172** is configured to timely inform the tree personnel to take action for minimizing the risk. Currently, ground inspection on the highly concerned trees is conducted once or twice a year. With the monitoring system **100** of the present invention, the trees can be assessed and monitored on the roll angle and the pitch angle, the vibration amplitude, and the sway frequency every day. When a tree is detected with unusual tree movement under the normal weather and in the storms, the monitoring system **100** can detect potential falling trees in a short period during extreme weather events, thereby tree personnel and other relevant parties could be informed of such tree hazard location, and faster emergency and remedial response can be made to the falling tree event. For other monitoring trees with the tendency of tree lean, the monitoring system **100** can bring early attention to tree personnel so that they can react to moderate the potential tree risk through proper tree preservation mechanism with timely and appropriate mitigation measures to be taken in advance.

[0064] The algorithm **171** receives the numerical values of the roll angle and the pitch angle of the trees and determines whether the numerical values are accurate and reliable, thereby the triggering function **172** can activate the alarm when exceeding the threshold values. The algorithm **171** includes predictive analysis by applying artificial intelligence (AI) algorithms onto a spatial big data analysis to forecast a chance of tree falling. The algorithm **171** computes a tree risk index of uprooting failure based on a tree tilt analysis **400**. A territory-wide urban tree management is also realized using the tree risk index.

[0065] The trees were assumed to be stable after the day of installation, and the reading of the roll and pitch angles after the first day of installation was considered to be the initial values. For measurements taken after initialization, the current measurement was subtracted by the initial values:

[0066] $Roll = Roll_{current} - Roll_{initial}$ Eq. (1)

[0067] $Roll$ is the corrected roll angle, $Roll_{current}$ is the instant roll angle, and the $Roll_{initial}$ is the initial roll angle during installation.

[0068] $Pitch = Pitch_{current} - Pitch_{initial}$ Eq. (2)

[0069] $Pitch$ is the corrected pitch angle, $Pitch_{current}$ is the instant pitch angle, and the $Pitch_{initial}$ is the initial pitch angle during installation.

[0070] The roll and pitch angles present rotational angles along the x-axis and y-axis respectively; the resulting tilting angle can be calculated by applying the trigonometric formula (Eq. (3)) with an assumption of no self-rotating movement along the tree trunk at z-axis.

[0071] $Tilt = \arctan(\sqrt{(\tan(Roll))^2 + (\tan(Pitch))^2})$ Eq. (3)

[0072] $Tilt$ is the tilting angle of the tree.

[0073] The real-time data of the tilting angle of a territory-wide of urban trees can be captured continuously and recorded in the TMS database **150** for big data analysis. The system processor **170** monitors and forecasts the state of the tree condition by performing tree tilt analysis **400**.

[0074] FIG. **6** shows the details of the tree tilt analysis **400**, which is executed based on a seasonal decomposition **410**, a wavelet transformation **420**, a seasonal autoregressive integrated moving average (SARIMA) model **430**, and an gradient boosting tree model **440**.

[0075] Seasonal decomposition **410** aims to examine the trend and seasonal or periodic patterns of a signal. The time series of the tilting angle from the trees are analyzed by applying an additive model with seasonal decomposition **410**, as shown in Eq. (4) below.

[0076] Signal (t) = AV (t) + Trend (t) + Seasonal (t) + Residual (t) Eq. (4)

[0077] Wherein, Signal (t) is the input signal, AV (t) is the average value in the time series, Trend (t) is the increasing or decreasing value in the series, Seasonal (t) is the repeating cycle in the time series, and Residual (t) is the random variation in the time series.

[0078] Since the raw data were not corrected at equally spaced points of frequencies, time series of tilt angles were pre-processed to the regular sampling frequency, by resampling the time series and setting of the seasonal decomposition **410**. In the pre-processed time series, the tilt angle was resampled to 5-minute intervals using linear interpolation. The default length of the cycles was set to 24 hours and the trend was extrapolated for forecasting.

[0079] The wavelet transformation **420** is utilized to transform a signal into multiple lower resolution levels by applying a combination of scaling and controlling factors of a single wavelet function. The wavelet transformation **420** filters out the high frequency or low-frequency part of a signal, by changing the resolution of the signal. For each wavelet transformation, half of the signal components with higher frequency are discarded according to Nyquist's rules, while the points of the filtered signal are reduced by half. For the purpose of the present disclosure, discrete wavelet transform (DWT) was used. The tilt angle was resampled to 1-hour intervals using interpolation. If the original signal were sampled at 1-hour intervals and the first detail coefficients generated from the wavelet analysis **420** were removed, then the signal components with a period of less than 1-hour would be eliminated.

[0080] SARIMA forecasting model **430** is an advanced form of autoregressive integrated moving average (ARIMA) model. SARIMA forecasting model **430** incorporates a seasonal component of time series for roll and pitch angles in the data analysis. All tilt angle readings from the gyroscope and/or accelerometer **111** were resampled to 1-hour intervals. The order of the hyperparameters is limited from 0 to 2, while the number of time steps (m) was set to 0 (no seasonal component) or 24 hours. A first SARIMA model **431** which forecast roll angle and a second SARIMA model **432** which forecast pitch angle were adopted. The forecasting period for the first SARIMA model **431** and the second SARIMA model **432** could be set from 1 hour to 14 days concurrently. The first and second SARIMA models **431**, **432** will be integrated and the forecasted tilt angle will be generated **433**, which can effectively detect sudden and potential changes of trees, such as falling, sensor interference, and malfunction.

[0081] Gradient boosting tree model **440** is an optimized, supervised machine learning technique based on the principle of gradient boosted decision tree algorithm (GBDT) such as Extreme Gradient Boosting (xGBoost), or Catboost, and/or a bagging decision tree algorithm such as Random Forest for predicting tree tilting and analysis. In this example, xGBoost and Random Forest forecasting models are applied, they use multiple decision trees to solve classification or regression learning problems. The independent variables (features) are manually decided, and the quality of selected features is one of the key factors affecting the performance of the machine learning model. Extra features were created for the Gradient boosting tree model **440**, which comprises lag/backshift operation and exponential moving average of tilt angle, and weather observations data. The weather observations data are obtainable from the observatory or other online resources. the Gradient boosting tree model **440** supports GPU (pipeline) computing to speed up the model training and evaluation process. The time series (tilt angle) are also resampled with a 1-hour interval before model training and evaluation. In the Gradient boosting tree model **440**, an hourly forward chaining method in xGBoost and Random Forest forecasting model is used for model performance evaluation, which means the value of last tilt angle was predicted successively while all previous data were assigned into the training set, until the required length of the testing set is generated. To optimize the model performance for forecasting models, hyperparameters are fine-tuned as they largely affect the model performance. The key hyperparameters used for the xGBoost forecasting model are ‘eta’: model learning rate (step size per each boost training), ‘max_depth’: maximum depth of a tree, and ‘gamma’: minimum loss reduction required for making a partition of a leaf node; subsample: ‘Ratio of the sample (rows)’ used for model training, and ‘colsample_bytree’: ratio of features (columns) used for model training. While the key hyperparameters used for the Random Forest is ‘max_depth’: maximum depth of a tree, in certain embodiments, the number of boosting round of xGBoost is set to range from 200-400, while 500-1000 is used for Random Forest model, and a GPU is used to speed up the training process.

[0082] The present disclosure also provides an interactive, web-based application dashboard **160**, as illustrated in FIG. **7**. The application dashboard **160** is based on a GIS platform, by incorporating the attributes, data, and analysis. With the coordinates of each individual sensing device **200**, each individual tree can be displayed on the map and a user could identify respective tree locations. The application dashboard **160** is optimized to have an update every second for obtaining the real-time information indicating the tree risk index. Color indications for the tree icons, for example, green, yellow, red, and blue, are assigned for categorizing the tree tilting angles. In certain embodiments, a green icon denotes a normal tree with a tilt angle smaller than one degree; and a blue icon denotes a tree having a high possibility of a tree falling with a large tilt angle. A user can locate the trees with potential problems from the map interface, based on the colors of the tree icons and take appropriate actions. When a user clicks on a tree icon, the corresponding graphs of tilting angle, trend of tilting angle, periodic pattern, the remainder of tilting angle, wavelet analysis, and prediction of tree tilting trend, are plotted for visualization and analysis.

[0083] Apart from the tilt angle data, the basic information of trees, the sensor information, the environmental factors, the POIs, and an azimuth graph, are available. When the user clicks on the tree icon for further information, the other information can be presented. The tree attributes collected in the tree risk assessment exercise, for example, species, tree height, crown size, and the DBH, are also included in the basic information for the identification of trees. Information based on the sensing device **200** installed on the trees, including device ID, sensor ID, sampling interval, and other status, provides general information for the control of the sensing device **220**. The “Environment” tab lists the big data, which includes the static data of historical weather data, air quality, and the information of nearby population, buildings, and roads. Further big data analysis can be conducted by considering these parameters. The ‘POI’ tab shows the number of nearby facilities, for evaluating the impact to the public if a tree failure were to occur. The ‘azimuth graph’ indicates the trajectory of a tree, which is useful for understanding the tree movement direction, since a healthy tree would bounce back to the original location after a strong wind load.

[0084] Real-time meteorological data are also available on the application dashboard **160**, extracted from the website of the observatory. The information covers the current weather warnings and signals, and district-specific information, such as temperature, humidity, rainfall, and wind speed. These data can help users understand the weather condition and the tilting response of trees.

[0085] This illustrates the monitoring system for urban tree management in accordance with the present disclosure. It is apparent that the present disclosure may be embodied in other types of monitoring systems without departing from the spirit or essential characteristics thereof. The present embodiment is, therefore, to be considered in all respects as illustrative and not restrictive. The scope of the disclosure is indicated by the appended claims rather than by the preceding description, and all changes that come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

WHAT IS CLAIMED IS:

1. A monitoring system for urban tree management, the monitoring system comprising:

a plurality of sensing devices, wherein each individual sensing device is mountable on a tree for measuring a tilting angle and a direction of tree displacement of the tree; and

a backend system,

wherein:

the individual sensing device comprises an IoT communication module and a plurality of detectors;

the plurality of detectors comprises a gyroscope and/or accelerometer for obtaining a roll angle and a pitch angle; and a vibration sensor configured to measure a vibration amplitude and a sway frequency of the tree;

the IoT communication module is communicable with the backend system in real-time; and

the backend system has a system architecture based on big data analytics and machine learning approaches and is configured to produce models for deeper insights on tree movements.

2. The monitoring system of claim 1, wherein the gyroscope and/or accelerometer is configured to measure the acceleration on one to three axes and detect a roll angle and a pitch angle of the individual sensing device.

3. The monitoring system of claim 2, wherein the gyroscope and/or accelerometer is a triaxial accelerometer configured to measure a longitudinal motion, a lateral motion, and a vertical motion.

4. The monitoring system of claim 1, wherein the gyroscope and/or accelerometer is controllable by the IoT communication Module for adjusting to varying sampling frequency modes, wherein the varying sampling frequency modes comprises a high sampling frequency mode activated in a typhoon season or during an adverse weather condition, and a low sampling frequency mode activated in a normal weather condition for maximizing data capture for an unusual pattern visualization.

5. The monitoring system of claim 1, wherein the individual sensing device comprises a reading logger for keeping a backup record of the roll angle, the pitch angle, the vibration amplitude, and the sway frequency, wherein the reading logger is configured to store the backup record in a removable storage medium or a build-in memory element.

6. The monitoring system of claim 1, wherein the IoT communication module adopts a low-power wide-area network (LPWAN) to provide connectivity, wherein the LPWAN is selected from either LoRaWAN or NB-IoT.

7. The monitoring system of claim 1, wherein the backend system comprises an access application programming interface (API) for receiving the data from the individual sensing device, wherein the access API is a representational state transfer (REST) API or a simple object access protocol (SOAP).

8. The monitoring system of claim 1, wherein the backend system comprises a system processor configured to execute an algorithm for determining whether the tree requires a safety inspection and further comprises a triggering function to activate responsive actions when a safety issue is identified.

9. The monitoring system of claim 8, wherein the algorithm is based on regressive models, descriptive statistics, and spatial big data analysis to perform a tree tilt analysis for determining a tree risk index.

10. The monitoring system of claim 9, wherein the tree tilt analysis is executed based on a seasonal decomposition, a wavelet transformation.

11. The monitoring system of claim 10, wherein the tilt analysis is executed based on a Seasonal Autoregressive Integrated Moving Average (SARIMA) model, an Extreme Gradient Boosting (xGBoost), and a Random Forest Forecasting model, wherein the SARIMA model incorporates a seasonal component of time series for roll and pitch angles, with a forecasting period of 1 hour to 14 days.

12. The monitoring system of claim 8, wherein the algorithm determines the tilting angle based on:

$$Roll = Roll_{current} - Roll_{initial}$$

$$Pitch = Pitch_{current} - Pitch_{initial}$$

$$Tilt = \arctan(\sqrt{(\tan(Roll))^2 + (\tan(Pitch))^2})$$

wherein:

$Roll$ is a corrected roll angle;

$Roll_{current}$ is the roll angle;

$Roll_{initial}$ is an initial roll angle during installation;

$Pitch$ is a corrected pitch angle;

$Pitch_{current}$ is the pitch angle; and

$Pitch_{initial}$ is an initial pitch angle during installation.

13. The monitoring system of claim 1, wherein the backend system comprises an application dashboard based on a geographical information system (GIS) platform, wherein the application dashboard is configured to provide a color indication for categorizing the tilting angle, information

on the individual sensing device, environmental factors, point-of-interests, and an azimuth graph indicating a trajectory of the tree.

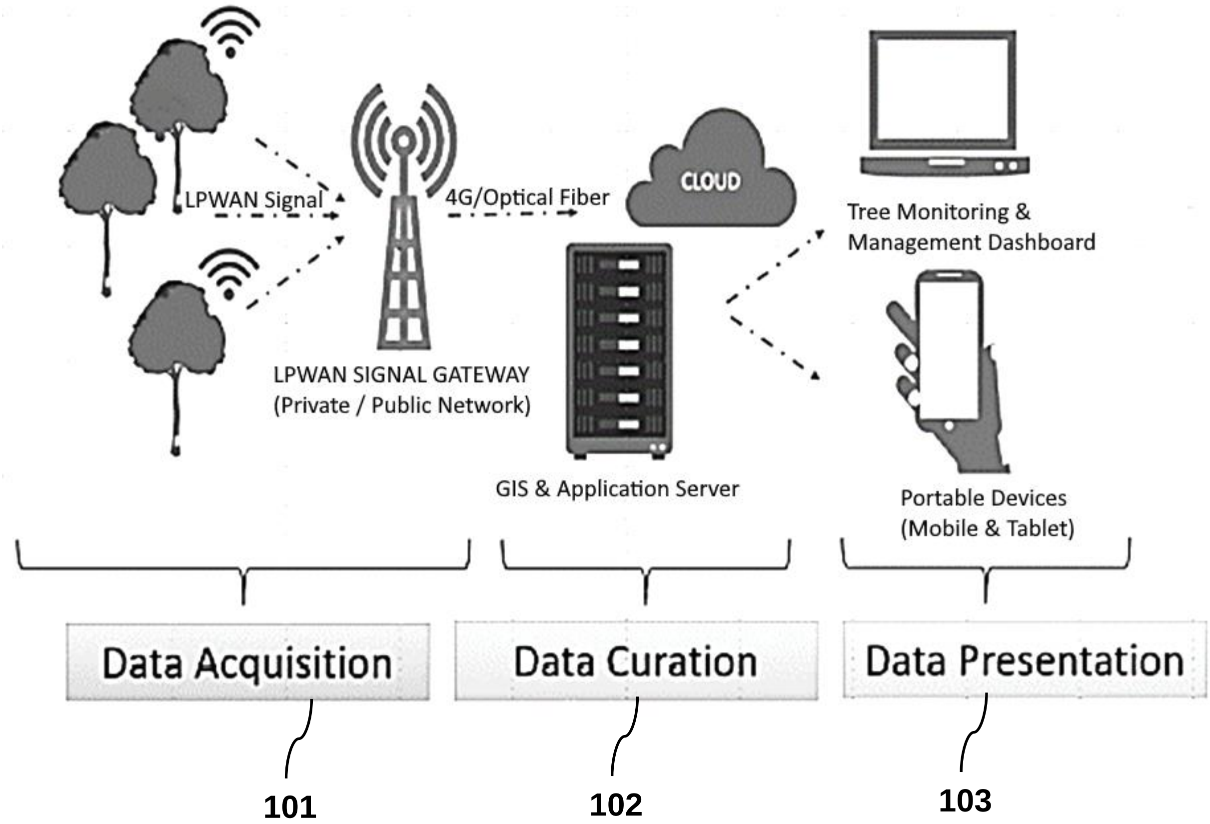

LPWAN Signal
4G/Optical Fiber
CLOUD
Tree Monitoring &
Management Dashboard
LPWAN SIGNAL GATEWAY
(Private / Public Network)
GIS & Application Server
Portable Devices
(Mobile & Tablet)
Data Acquisition
Data Curation
Data Presentation
101
102
103

FIG. 1

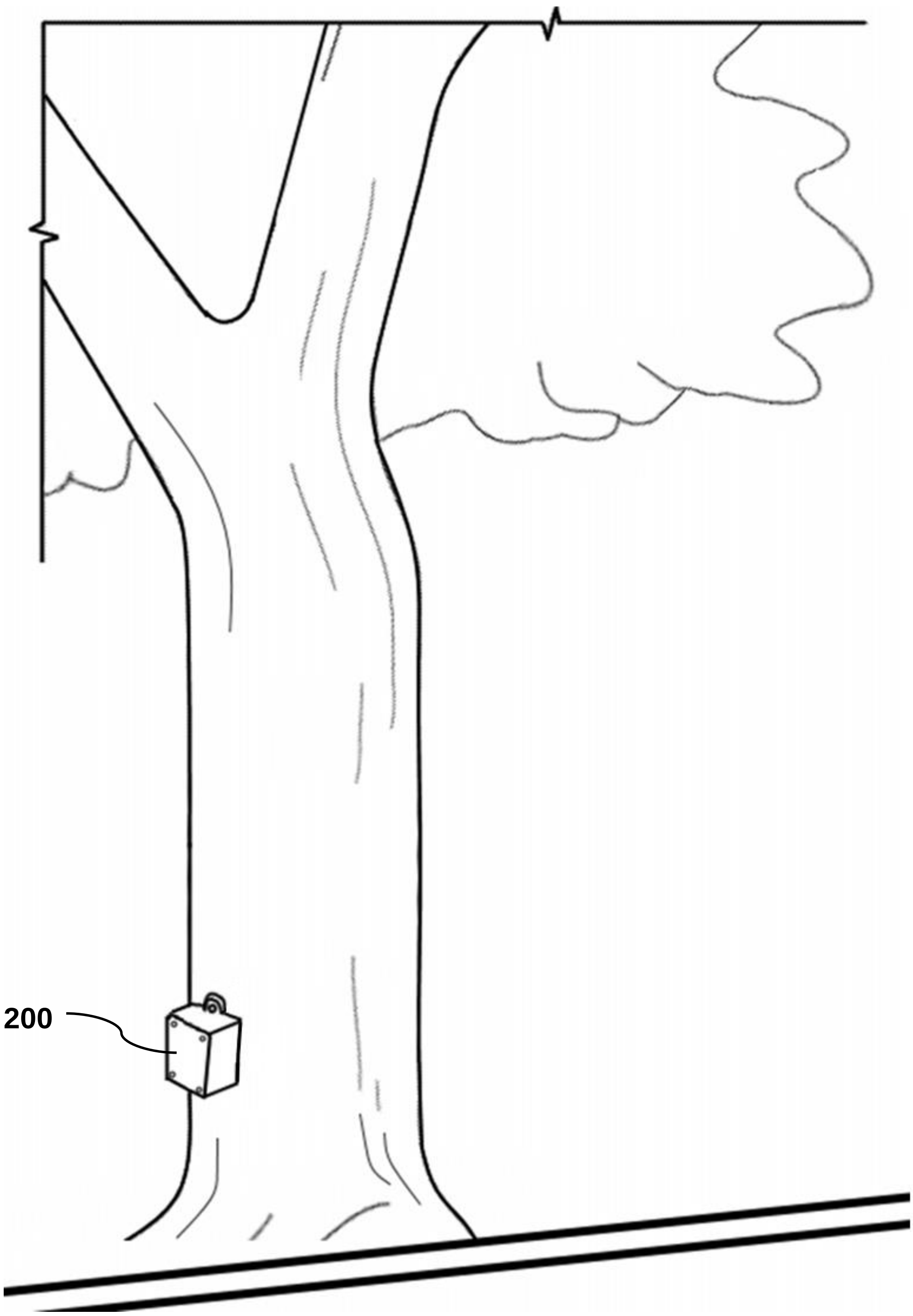


FIG. 2

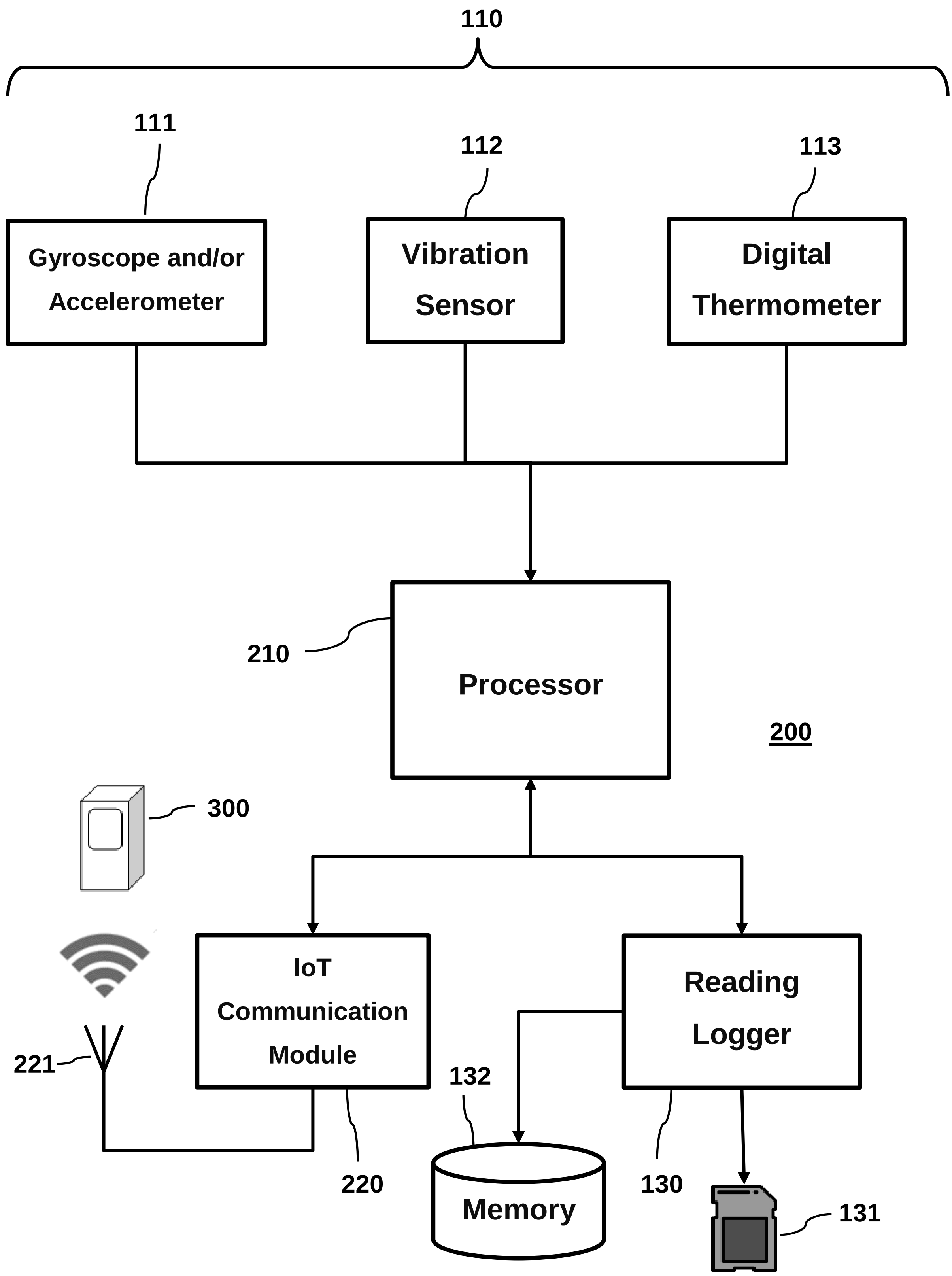

110
111
112
113
Gyroscope and/or Accelerometer
Vibration Sensor
Digital Thermometer
210
Processor
200
300
IoT Communication Module
Reading Logger
221
132
220
Memory
130
131

FIG. 3

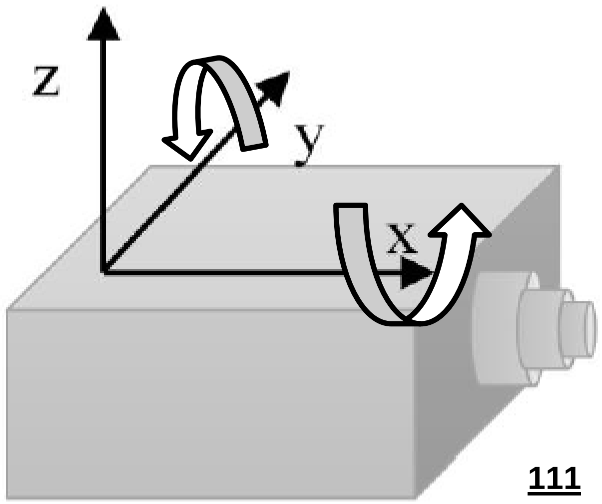


FIG. 4

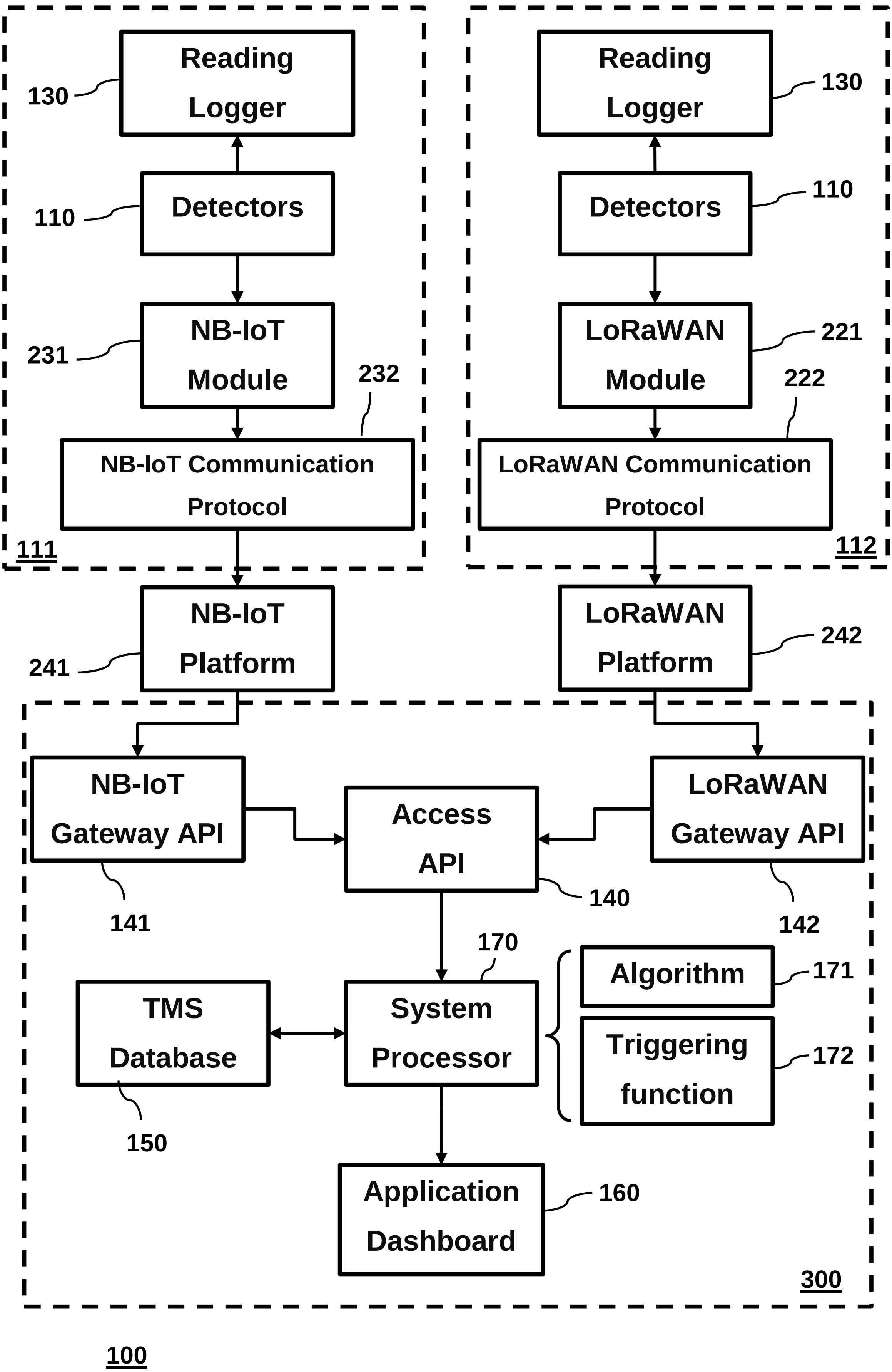

Reading
Logger
130
Detectors
110
NB-IoT
Module
231
232
NB-IoT Communication
Protocol
111
Reading
Logger
130
Detectors
110
LoRaWAN
Module
221
222
LoRaWAN Communication
Protocol
112
NB-IoT
Platform
241
LoRaWAN
Platform
242
NB-IoT
Gateway API
141
Access
API
140
LoRaWAN
Gateway API
142
170
Algorithm
171
Triggering
function
172
TMS
Database
150
System
Processor
Application
Dashboard
160
300
100

FIG. 5

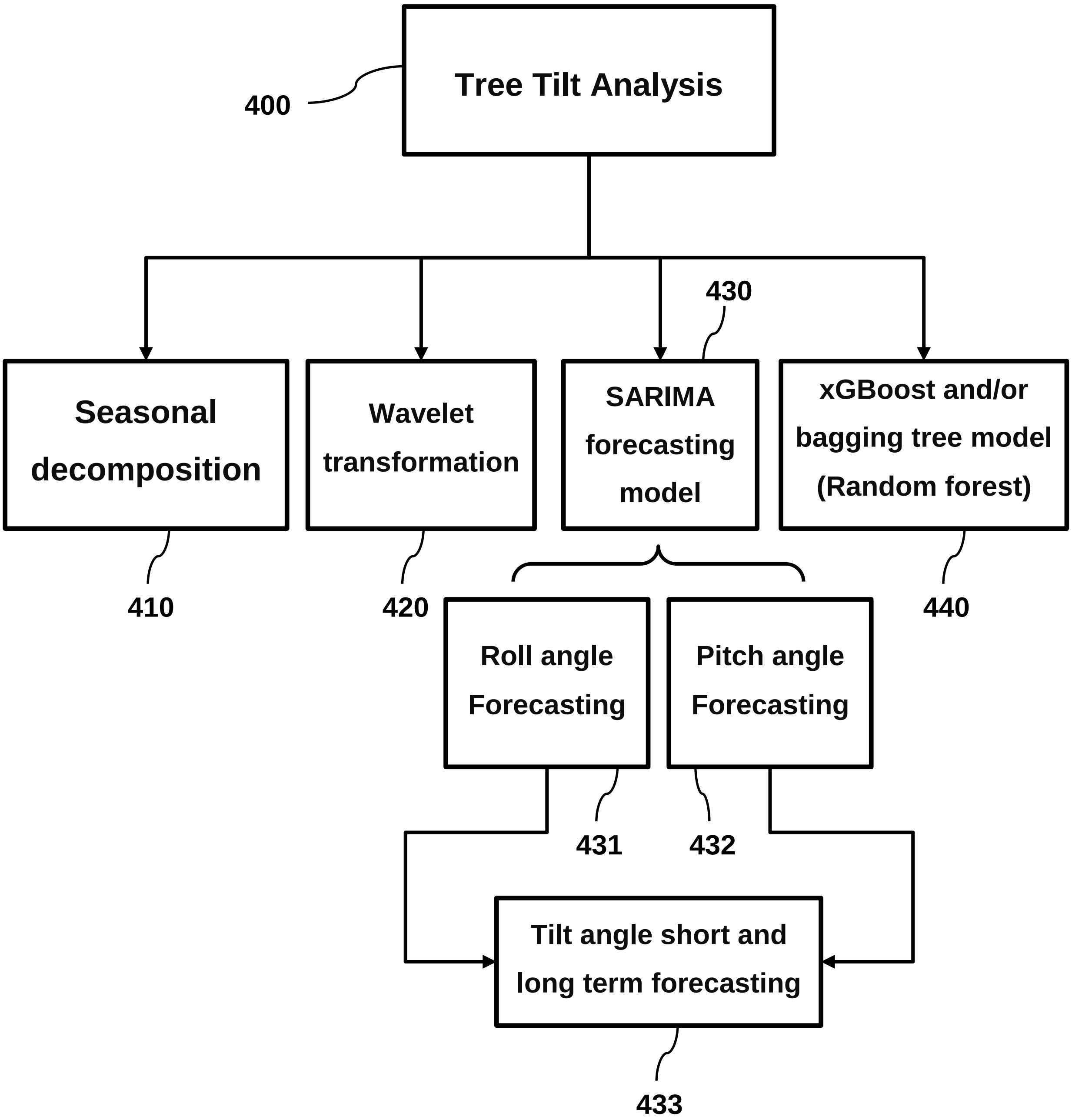

Tree Tilt Analysis
400
Seasonal decomposition
Wavelet transformation
SARIMA forecasting model
430
xGBoost and/or bagging tree model (Random forest)
410
420
440
Roll angle Forecasting
Pitch angle Forecasting
431
432
Tilt angle short and long term forecasting
433

FIG. 6

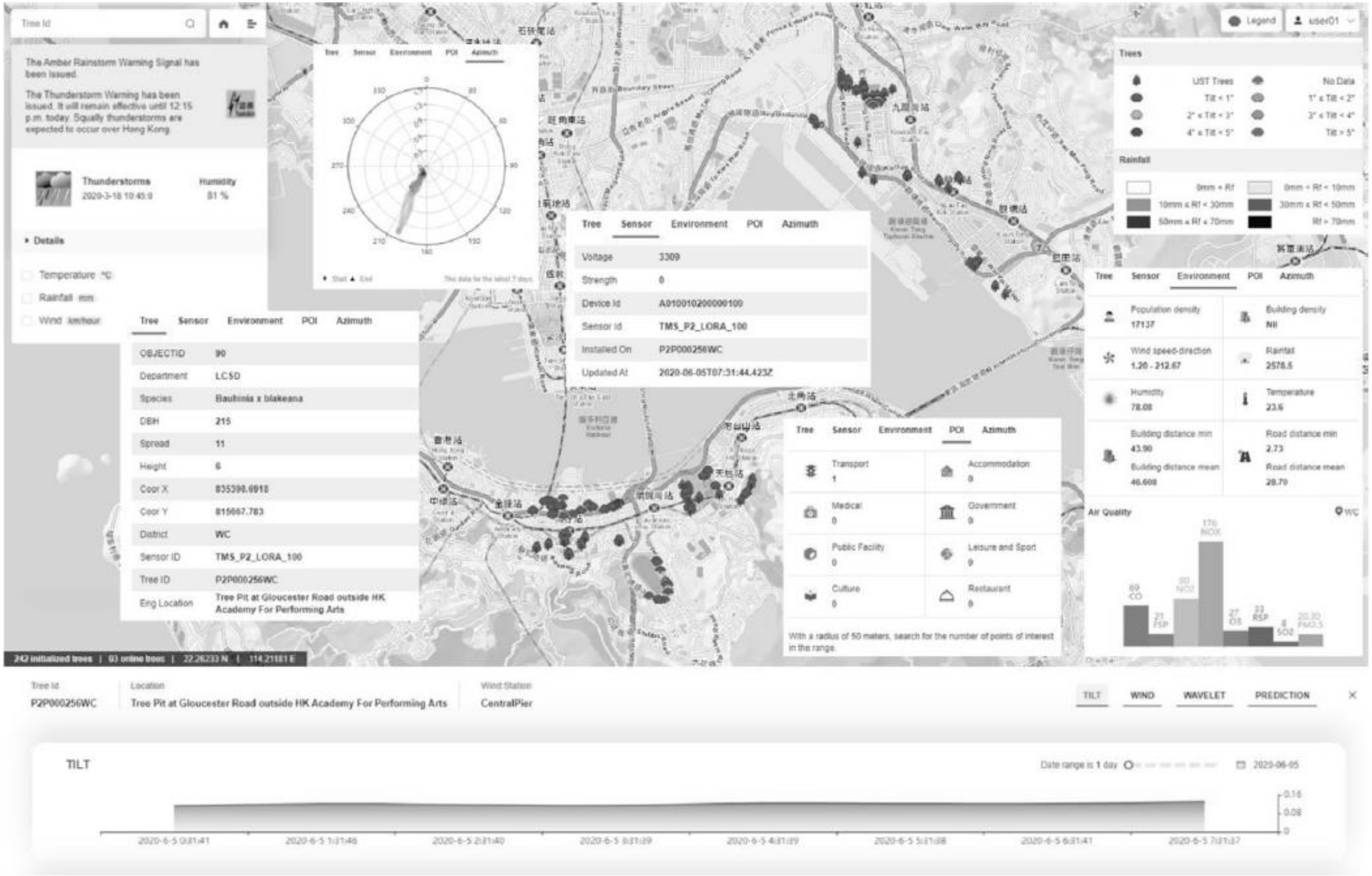

Tree Id
The Amber Rainstorm Warning Signal has been issued.
The Thunderstorm Warning has been issued. It will remain effective until 12:15 p.m. today. Squally thunderstorms are expected to occur over Hong Kong.
Thunderstorms
2020-3-18 10:45:0
Humidity
81 %
Details
Temperature °C
Rainfall mm
Wind km/hour
Tree Sensor Environment POI Azimuth
OBJECTID 90
Department LCSD
Species Bauhinia x blakeana
DBH 215
Spread 11
Height 6
Coor X 835398.6918
Coor Y 815667.783
District WC
Sensor ID TMS_P2_LORA_100
Tree ID P2P000256WC
Eng Location Tree Pit at Gloucester Road outside HK Academy For Performing Arts
Voltage 3309
Strength 0
Device Id A010010200000100
Sensor Id TMS_P2_LORA_100
Installed On P2P000256WC
Updated At 2020-06-05T07:31:44.423Z
Transport 1
Accommodation 0
Medical 0
Government 0
Public Facility 0
Leisure and Sport 0
Culture 0
Restaurant 0
With a radius of 50 meters, search for the number of points of interest in the range
Legend
user01
Trees
UST Trees
Tilt < 1°
2° ≤ Tilt < 3°
4° ≤ Tilt < 5°
No Data
1° ≤ Tilt < 2°
3° ≤ Tilt < 4°
Tilt > 5°
Rainfall
0mm = Rf
10mm ≤ Rf < 30mm
50mm ≤ Rf < 70mm
0mm < Rf < 10mm
30mm ≤ Rf < 50mm
Rf > 70mm
Population density 17137
Building density Nil
Wind speed-direction 1.20 - 212.67
Rainfall 2578.5
Humidity 78.08
Temperature 23.6
Building distance min 43.90
Building distance mean 46.608
Road distance min 2.73
Road distance mean 28.70
Air Quality
WC
69 CO
21 FSP
80 NO2
176 NOX
27 O3
33 RSP
8 SO2
20.30 PM2.5
242 initialized trees | 93 online trees | 22.26233 N | 114.21181 E
Tree Id P2P000256WC
Location Tree Pit at Gloucester Road outside HK Academy For Performing Arts
Wind Station CentralPier
TILT WIND WAVELET PREDICTION
TILT
Date range is 1 day
2020-06-05
0.16
0.08
0
2020-6-5 0:31:41
2020-6-5 1:31:46
2020-6-5 2:31:40
2020-6-5 3:31:39
2020-6-5 4:31:39
2020-6-5 5:31:38
2020-6-5 6:31:41
2020-6-5 7:31:37

FIG. 7

PSCC-QI-8.5-01-05

编号 HK2100328

香港短期专利申请

检 索 报 告

检索名称 TREE MONITORING SYSTEM FOR URBAN TREE MANAGEMENT

申 请 号 32021035715.0

委 托 方 The Hong Kong Polytechnic University

委托日期 2021 年 07 月 29 日

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IPC：G01N 3/12，G05B 19/418

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X	CN111238944A	2020-06-05	G01N3/12	权利要求1-2，说明书第19-29段，图1-3	1-13
A	CN112818668 A	2021-05-18	G06F40/242	全文	1-13
A	CN108363372A	2018-08-03	G05B19/418	全文	1-13
A	CN111652893A	2020-09-11	G06T7/13	全文	1-13
A	KR20130048033A	2013-05-09	G06Q50/02	全文	1-13

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E：在香港短期专利申请的申请日的当天或之后公布的在先申请或专利

P：公布日先于香港短期专利申请的申请日但迟于所要求的优先权日的文件

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关于检索主题是否具有新颖性、创造性的简要说明：

本香港短期检索报告依据《中华人民共和国专利法》（2008 修正）进行说明。

1、权利要求 1 要求一种用于城市树木管理的监控系统，对比文件 1（CN104007728A）公开了一种包括感测装置的数字城市的感测系统，其在树木上安装感测装置（对应于提供一种城市树木管理的树木监测系统）。并具体公开了以下特征（参见说明书第 0022-0036 段，图 1-3）：感测装置（对应于监控系统中的多个感测装置），包括有：无线通信模块，所述无线通信模块为手机通信模块、非标 2.4G 无线模块、Zigbee、蓝牙或者 WIFI 模块（对应于个体感测装置包括物联网通信模块），用于与无线基站通信，接收外部信息和传送内部信息；感测模块（对应于多个检测器），由加速度传感器、陀螺仪（对应于多个检测器包括陀螺仪和/或加速度计）、地磁仪、气压计、红外感应器、温度计、光敏计、风速风向计、雨量计、紫外线计和雾霾感测仪中的一种或多种构成，用于将城市多种环境因素转换为数字信号。中央运算单元，分别与感测模块和无线通信模块相连，所述感测模块将感测到的数据传送给中央运算单元，中央运算单元分别对各种传感器数据进行运算后得到三维空间坐标偏移量、振动或晃动频率振幅（对应于用于测量树木的倾斜角度和树木位移方向，动传感器被配置为测量树木的振动幅度和摇摆频率）、姿态角、高度值、红外轮廓和大小、温度值、光照度值、风速值和风向角、雨量值、紫外线强度值和/或雾霾值。还包括无线基站和云服务器，通过将城市中的多种固定物如树木、电线杆、垃圾桶、路牌、井盖、护栏、建筑物等安装感测装置（对应于每个个体感测装置可安装在树上），通过感测装置采集环境参数数据，并让感测装置通过无线网络(如 Zigbee, BLE4.1, WIFI)实时联网，例如短距无线发送到路由器热点，热点再通过有线或无线手机通讯模块发送到无线基站，或直接通过感测装置内部的手机通讯模块发到基站，再由基站传送到云服务器（对应于后端系统，物联网通信模块与后端系统实时通信）；或将数据存入记忆体内以短程无线数据搜集(data logger)以带有数据搜集器的特定人员或特制车辆进行数据搜集的方式将感测数据集中发送到云服务器。本发明通过云服务器平台的数据收集和大数据分析，可得到异常振动、台风情况（对应于后端系统具有基于大数据分析和机器学习方法的系统架构，并配置为生成模型以更深入地了解树木运动）、火灾感知、求救信号等多种检测，方便迅速采取有效措施，预测容易出现的灾情、控制灾情扩大。

权利要求 1 与对比文件 1 相比，区别在于：检测器获得滚转角和俯仰角。

因此，权利要求 1 具备新颖性，符合中华人民共和国专利法第二十二条第二款的规定。直接或间接引用权利要求 1 的从属权利要求 2-13 也备新颖性，符合中华人民共和国专利法第二十二条第二款的规定。

对于上述区别特征，对比文件 1 已经公开了：中央运算单元分别对各种传感器数据进行运算后得到三维空间坐标偏移量、振动或晃动频率振幅、姿态角、风速值和风向角。在此基础上姿态角为滚转角和俯仰角属于本领域的常用技术手段。

因此，在对比文件 1 的基础上结合本领域常用技术手段得到权利要求 1 的技术方案对本领域技术人员是显而易见的，权利要求 1 不具备突出的实质性特点和显著的进步，权利要求 1 不具备创造性，不符合中华人民共和国专利法第二十二条第三款的规定。

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2、对于权利要求 2-4，其附加特征所限定的测量方式，以及根据天气调整变化的采样频率为本领域的常用技术手段。因此，当其引用的权利要求不具备创造性时，权利要求 2-4 也不具备创造性，不符合中华人民共和国专利法第二十二条第三款的规定。

3、对于权利要求 5-7，其附加特征所限定的数据备份，物联网通信模块采用低功耗广域网提供连接以及后端系统的数据接收 API 接口均是本领域的常用技术手段。因此，当其引用的权利要求不具备创造性时，权利要求 5-7 也不具备创造性，不符合中华人民共和国专利法第二十二条第三款的规定。

4、对于权利要求 8，对比文件 1（出处同上）公开了：本发明通过云服务器平台的数据收集和大数据分析（对应于安全检查的算法），可得到异常振动、台风情况、火灾感知、求救信号等多种检测，方便迅速采取有效措施。所述感测模块侦测到特殊频率或节奏的敲击或振动可以触动警报（对应于激活响应动作的触发功能）。因此，当其引用的权利要求不具备创造性时，权利要求 8 也不具备创造性，不符合中华人民共和国专利法第二十二条第三款的规定。

5、对于权利要求 9-12，其附加特征所限定的内容均为本领域常用的大数据分析算法模型。因此，当其引用的权利要求不具备创造性时，权利要求 9-12 也不具备创造性，不符合中华人民共和国专利法第二十二条第三款的规定。

6、对于权利要求 13，其附加特征所限定的指示方式为本领域常用的较为直观的了解树木情况的方式，为本领域常用技术手段。因此，当其引用的权利要求不具备创造性时，权利要求 13 也不具备创造性，不符合中华人民共和国专利法第二十二条第三款的规定。

检索结论：

权利要求 1-13 具备新颖性，符合中华人民共和国专利法第二十二条第二款的规定；

权利要求 1-13 不具备创造性，不符合中华人民共和国专利法第二十二条第三款的规定。

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