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Internet of Things Construction Monitors

Thomas A. Stern

INTERNET OF THINGS CONSTRUCTION MONITORS

Introduction

The present disclosure is directed to a system that can be used to more effectively determine when a structural failure is apt to occur through use of sensors and computing devices that can predict structural failures based on the state of the structure. Existing methodologies and systems provide a variety of ways to detect failure in structures, however, such methodologies and systems do not offer an effective way of determining the state of internal portions of a structure that may be inaccessible after the initial construction of the structure. Furthermore, many existing methodologies and systems are limited with respect to the prediction of structural failure based on the occurrence of small changes in the current state of the structure. It is often the case that construction collapses (e.g., failures in bridges, pedestrian walkways, and buildings) occur with little or no warning. In such cases, the determination that a structural failure is about to occur can happen moments before the structural failure, providing minimal time to take action (e.g., prevent pedestrians from walking on a bridge that exhibits signs of structural failure).

In the present disclosure, the state of internal portions of a structure (e.g., internal portions of concrete and/or steel structural elements of a bridge) may be determined via sensors placed in the structure at the time of construction. These sensors can provide information that is used to determine structural changes and when a structural failure is imminent. The system can then generate messages to service providers with information (e.g., the location of the structure) that can be used to take appropriate action (e.g., close a bridge that may soon suffer a structural failure).

Additionally, the sensors can provide sensor data that can be used as an input for machine-learning systems that train machine-learned models to detect structural states that correspond to eventual structural failure. Furthermore, intelligent targeted warnings can be issued using various communications technologies (e.g., text alerts) to alert emergency services providers and people in the vicinity of a structure that may experience structural failure.

Summary

The present disclosure proposes to solve the challenges described above by using sensors to gather information about the state of a structure, process the information from the sensors, and make a determination of when a structural failure is likely to occur. In particular, the monitoring system in the present disclosure can use a local computing system to determine changes in a structure that may result in a structural failure. In some embodiments, the state data can be sent via a communication channel (e.g., a communications network) to a remote computing device which may include machine-learned models trained to determine when a structural failure may occur. When a structural failure is determined to be likely, the monitoring system can provide alerts that can be used to address the structural failure (e.g., alert emergency service providers and warn passersby via text message).

In some embodiments, the present disclosure describes Internet of Things (IoT) sensors embedded in a structure. The sensors can include small devices (e.g., devices the size of a golf ball) that contain sensors and radio frequency elements that can be used to determine their respective locations. Such sensors can be powered in various ways including an independent power source (e.g., an internal radioactive power source), an external power source (e.g., power provided via current passed through wires or conductive construction elements including rebar), or passive power such as a temperature-differential generator. Further, the sensors can be used to form low powered, adjacencies with other sensors embedded in a structure and can use the

Doppler effect of periodic beaconing messages to determine relative distances between the adjacencies.

In some embodiments, the sensors can be used to provide information that can be used to forward messages to the local computing device that can collect, aggregate, and report the state of the structure to a remote cloud device. The local computing device can preserve the individual identity of each sensor and act as a protocol and network proxy for the sensors. Analysis of the data collected from the sensors can indicate changes that reveal the impact on the structure of temperature changes, weather changes, or lunar cycles. Such periodic and seasonal changes can be identified and treated accordingly in the determination of structural changes.

In this way, changes that are out of the ordinary, sudden, or that occur very slowly over long periods of time can be determined. As the structure changes, alerts can be issued to indicate that the structure is no longer meeting its original specifications. Further, such alerts can trigger human construction safety evaluation and engineering inspection. Additionally, any sudden or rapid changes in the state of the structure may trigger alerts that may prioritize people closer to the structure. For example, nearby cell towers could be identified in advance and an alert notification system could be kept in a ready state through keepalive messages. An expedited notification could then alert people near. Furthermore, emergency services could also be alerted in order to expedite the process of limiting access to the structure (e.g., placing barriers around a bridge to prevent pedestrians and vehicles from traversing a bridge that is structurally unsound).

Detailed Description

FIG. 1 illustrates a schematic diagram of one embodiment of a computing system **100** in accordance with aspects of the present disclosure. In the embodiment shown in **FIG. 1**, the computing system **100** includes a sensor **102**, a sensor **104**, a network **106**, one or more remote computing devices **110**, and a computing system **120**.

The sensor **102** and/or the sensor **104** can include one or more sensors and/or one or more communications devices. For example, the sensors **102/104** can include radio transceivers, thermometers, pressure sensors, and/or moisture sensors, which can be used to detect one or more states of a structure (e.g., a bridge or portion of road). The sensors **102/104** can transmit data (e.g., sensor data) and/or information associated with the state of the detected structure to a device including the one or more computing devices **110**. Further, the sensors **102/104** can include a power source that can provide power to perform operations including the sensing and/or transmitting operations.

The network **106** can include any type of communications network, including a local area network (e.g., intranet), wide area network (e.g., Internet), or some combination thereof and can further include any number of wired or wireless links. Communication over the network **106** can occur via any type of wired and/or wireless connection, using a variety of communication protocols (e.g., TCP/IP, HTTP, SMTP, or FTP), encodings or formats (e.g., HTML, XML), and/or protection schemes (e.g., VPN, secure HTTP, SSL). The network **106** can for example be used to exchange signals or data between the sensor **102**, the sensor **104**, the one or more remote computing devices **110**, and the computing system **120**.

As shown in **FIG. 1**, the one or more remote computing devices **110** can include a controller **112** that includes one or more processors **114** and one or more memory devices **116** associated with the one or more processors **114**. The one or more processors **114** can include any suitable processing device, including as a microprocessor, microcontroller, integrated circuit, logic device, or other suitable processing device. Similarly, the one or more memory devices

116 can include one or more computer-readable media, including, but not limited to, non-transitory computer-readable media, RAM, ROM, hard drives, flash drives, and/or other memory devices. Furthermore, the one or more remote computing devices **110** can generate one or more outputs including signals and/or data (e.g., sensor data and/or state data) including information associated with the state of a structure as indicated by the sensor **102** and/or the sensor **104**.

The communications interface **118** can be used to communicate (e.g., send and/or receive) signals or data to one or more systems (e.g., the computing system **120**). By way of example, the one or more remote computing devices **110** can receive sensor data from the sensor **102** and use the sensor data to generate state data including information associated with the state of a structure that is then sent to the computing system **120** via the network **106** using the communications interface **118**. In general, the communications interface **118** can include one or more transmitters, receivers, ports, circuits, and other interfaces for communicating digital information over a wired communication link, wireless communication link, or combination of wired and wireless communication links. As an example, the communications interface **118** can communicate data via a wired and/or wireless protocol including Bluetooth, IEEE 802.11, and/or WiMAX.

As shown in **FIG. 1**, the computing system **100** includes the computing system **120** that can include a controller **122** that includes one or more processors **124** and one or more memory devices **126** associated with the one or more processors **124**. The one or more processors **124** can include one or more features of the one or more processors **114**. Further, the one or more memory devices **126** can include one or more features of the one or more memory devices **116**.

In some embodiments, the one or more memory devices **126** can store information accessible by the one or more processors **124**, including computer-readable instructions that can be executed by the one or more processors **124**. The instructions can be any set of instructions that when executed by the one or more processors **124**, cause the one or more processors **124** to perform operations. For instance, the instructions can be executed by the one or more processors **124** to determine the content of data (e.g., state data including information associated with the state of a structure) sent from the one or more remote computing devices **110**. Further, the one or more processors **124** can include one or more features of the one or more processors **114**. The one or more memory devices **126** can also store data for manipulation by the one or more processors **124**. Furthermore, the computing system **120** can generate one or more outputs based in part on one or more signals or data received by the communication interface **128**. For example, the computing system **120** can generate output including one or more notifications of a weakness or potential failure associated with a structure.

Further as shown in **FIG. 1** the computing system **120** can also include the communications interface **128** that can be used to communicate (e.g., send and/or receive) one or more signals or data with one or more computing devices including the one or more remote devices **110**. Further, the communications interface **128** can include one or more features of the communications interface **118** of the one or more remote computing devices **110**.

In accordance with aspects of the present disclosure, the controller **122** can, in one embodiment, be configured to determine the content of data (e.g., state data received from the one or more remote computing devices **110**). In some embodiments, the computing system **120** can use a machine-learning component **130** to determine when a structural weakness or failure has occurred and/or predict when a structural weakness or failure is likely to occur. For example, the machine-learning component **130** can receive an input including sensor data and/or state data from the one or more remote computing devices **110** and determine when a structural weakness is more likely to occur based on the input. Further, based at least in part on the received sensor data and/or state data, the machine-learning component **130** can include one or more machine-learned models (e.g., a convolutional neural network) trained to determine an output based on inputs including any combination of previously recorded structural data and data from currently monitored structures.

FIG. 2 illustrates a diagram of an exemplary embodiment of a structure monitoring system **200** that monitors the state of a structure in accordance with aspects of the present disclosure. In the embodiment shown in **FIG. 2**, the structure monitoring system **200** includes a structure **202**, a sensor **204**, a sensor **206**, a sensor **208**, and a structure computing device **210**.

In this example, the structure **202** is a bridge that includes the sensors **202/204/206** embedded in the structure of the bridge. The timing of radio signals exchanged between the sensors **202/204/206** can be used to determine the distances between each of the sensors **202/204/206**. Further, changes in the distances between the sensors **202/204/206** can be provided as sensor data to the structure computing device **210**, which can determine the location of the sensors **202/204/206** as well as other data collected by the sensors **202/204/206** and use that data to determine when a structural failure of the structure **202** may be imminent. In some embodiments, the structure computing device **210** can include machine-learned models that have been trained to determine when changes in the location of sensors are more likely to lead to a structural failure.

Referring now to **FIG. 3**, a flow chart illustrating one embodiment of a process **300** for monitoring structural changes is illustrated in accordance with aspects of the present subject matter. The operations of the process **300** can be performed by a computing system including one or more features of the computing system **120** that is depicted in **FIG. 1**. Although the operations of the process **300** are shown and described in a particular order, certain operations can be performed in a different order or at the same time.

As indicated in **FIG. 3**, at **302**, state data (e.g., data including information associated with the state of a structure) is received (e.g., received by the computing system **120** from the one or more remote computing devices **110**). The state data can be received via one or more communications networks (e.g., the communications network **106**) and can include a variety of information associated with the state of a structure including the location and/or position of various portions of the structure, the temperature of portions of the structure, the moisture of an area around a structural component, and/or pressure in the area around a structural component.

At **304**, a structural change in an associated structure can be determined. For example, the computing system **120** can use the state data to determine when a structural failure is likely to occur by using the machine-learning component **130** which can receive location information associated with the state of a structure (e.g., state data indicating the formation of fissures in a road surface) and determine that the changes in the state of the structure may correspond to a structural failure.

At **306**, signals (e.g., radio signals) can be generated when alert criteria are satisfied. The signals can include information associated with the location of the structure (e.g., latitude, longitude, and altitude) as well as the state of the structure. By way of example, upon determining that an alert criteria has been satisfied (e.g., a portion of a walkway has shifted by greater than a distance threshold) and that a structure may be apt to fail, the computing system **120** can transmit signals alerting nearby pedestrians (via text message) and emergency services providers of the location and state of the structure in order that access to the structure can be limited or restricted.

Figures

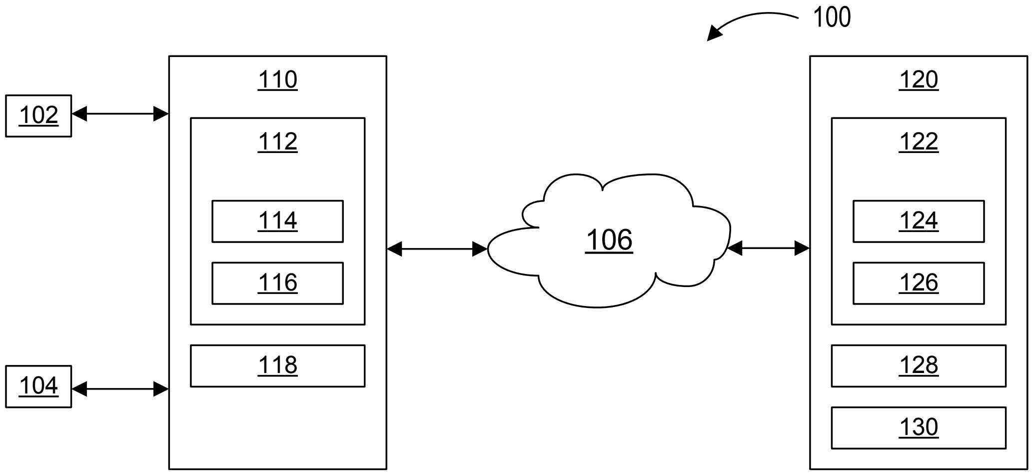

FIG. 1

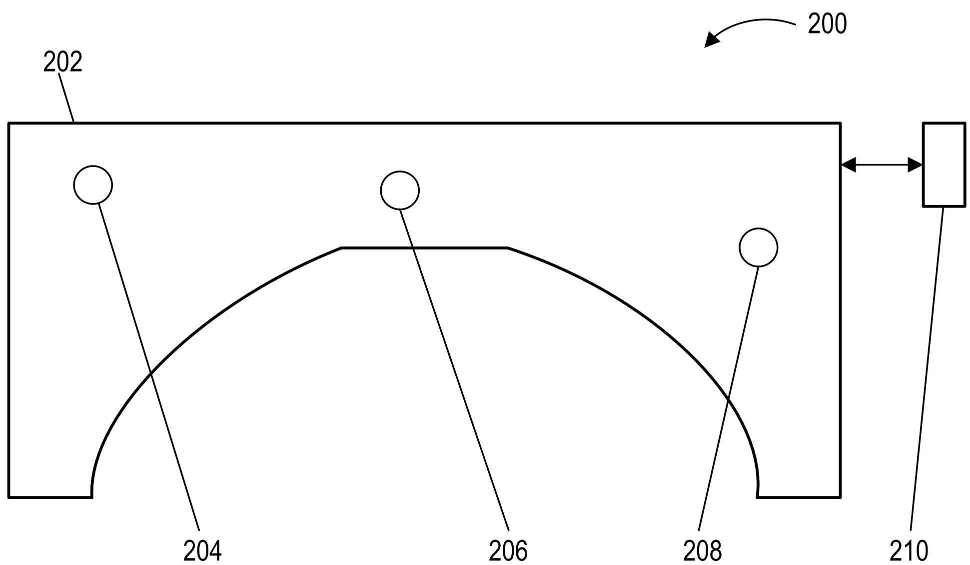

FIG. 2

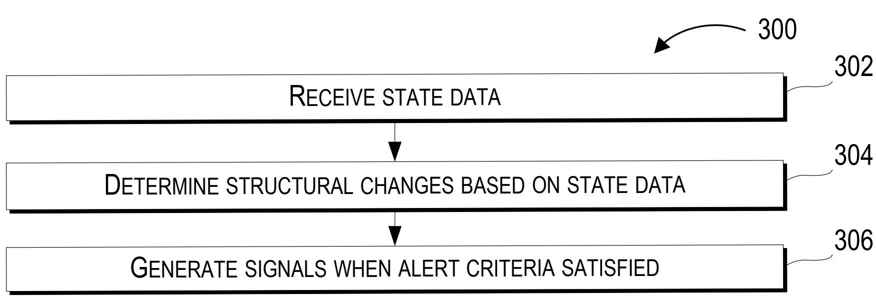

FIG. 3

Abstract

The present disclosure relates to a monitoring system and related method for determining the state of a structure, determining when a structural failure is apt to occur, and sending notifications associated with the state of a structure to external computing devices. The monitoring system can include a computing system that receives state data including information associated with the state of a structure. The state data can be used to determine when the structure is apt to fail. Further, alert notifications can be generated and sent to external computing devices and services when such failures are determined to be likely.