METHOD AND SYSTEM FOR DETECTING STRUCTURAL CONDITION OF OBJECT

FIELD OF THE INVENTION

[0001] The present disclosure relates to the field of object condition monitoring, and more particularly to a method and a system for detecting a structural condition of an object.

BACKGROUND OF THE INVENTION

[0002] Generally, due to external impact or other reasons, many objects placed in outdoor environments or open spaces may be damaged. For example, protective meshes in high security areas, outdoor farming, etc. may be damaged because of long-term use aging, impact from wild animals or external forces or other reasons. Once a protective mesh is defective or damaged, it will be difficult to separate spaces on both sides of the protective mesh, resulting in the protective mesh being unable to provide effective protection accordingly.

[0003] In order to check whether the objects as described above is damaged, manual visual inspection is used in most cases. If the object is damaged, the damaged object will be subjected to maintenance. However, this manual inspection method requires a lot of labor cost and may cause omissions due to human error. Moreover, if the object is placed in outdoor environment and the area of the object that needs to be inspected is relatively large, the disadvantages of the manual inspection become more obvious.

[0004] In order to overcome the drawbacks of the conventional technologies, it is important to provide a method and a system for detecting a structural condition of an object (hereinafter also referred to as “object structural condition”) and thereby monitoring the structural condition or physical damages of the object.

SUMMARY OF THE INVENTION

[0005] An object of the present disclosure provides a detection method and a detection system for detecting a structural condition of an object, which can automatically monitor the object structural condition and detect whether the object is damaged, and can enhance the detection precision by minimizing noise interference. In this way, the drawbacks of manual inspection methods in the conventional technologies can be overcome, and the labor cost can be saved.

[0006] In accordance with an aspect of the present disclosure, a detection method is provided. The detection method is used in a detection system for detecting a structural condition of an object. The detection system includes a signal generation device, at least one sensor and a processor. The signal generation device and the at least one sensor are disposed on the object. The signal generation device is configured to issue a trigger signal. The at least one sensor receives the trigger signal through the object and outputs a sensing result to the processor. The detection method includes the following steps. In a step (S1), the detection system enters an initial state, and the sensing result from each of the at least one sensor is processed into an initial time domain data and an initial frequency domain data by the processor. In a step (S2), the detection system enters a detection state, and the trigger signal is detected by the at least one sensor for at least one time within a predetermined time interval. In a step (S3), the sensing result from the at least one sensor is processed into a detection time domain data and a detection frequency domain data by the processor when the detection system is in the detection sate. In a step (S4), at least one first difference score of the at least one sensor is obtained by the processor according to a result of comparing the detection time domain data with the corresponding initial time domain data, and at least one second

difference score of the at least one sensor is obtained by the processor according to a result of comparing the detection frequency domain data with the corresponding initial frequency domain data. In a step (S5), the processor respectively determines whether at least one first comparing result between the at least one first difference score and a first predetermined value satisfies a first condition and whether at least one second comparing result between the at least one second difference score and a second predetermined value satisfies a second condition. When the at least one first comparing result corresponding to a specified sensor of the at least one sensor satisfies the first condition and the at least one second comparing result corresponding to the specified sensor of the at least one sensor satisfies the second condition, the processor issues a warning signal corresponding to the sensing result from the specified sensor.

[0007] In accordance with another aspect of the present disclosure, a detection system is provided for detecting a structural condition of an object. The detection system includes a signal generation device, at least one sensor and a processor. The signal generation device is disposed on the object and configured to issue a trigger signal. The at least one sensor is disposed on the object, receives the trigger signal through the object and outputs a sensing result. The processor receives the sensing result, and analyzes and processes the sensing result. In an initial state, the sensing result from the at least one sensor is processed into an initial time domain data and an initial frequency domain data by the processor. In a detection state posterior to the initial state, the trigger signal is detected by the at least one sensor for at least one time within a predetermined time interval, and the sensing result from the at least one sensor is processed into a detection time domain data and a detection frequency domain data by the processor. The processor obtains at least one first difference score of the at least one sensor according

to a result of comparing the detection time domain data with the corresponding initial time domain data. In addition, the processor obtains at least one second difference score of the at least one sensor according to a result of comparing the detection frequency domain data with the corresponding initial frequency domain data. The processor respectively determines whether at least one first comparing result between the at least one first difference score and a first predetermined value satisfies a first condition and whether at least one second comparing result between the at least one second difference score and a second predetermined value satisfies a second condition. When the at least one first comparing result corresponding to a specified sensor of the at least one sensor satisfies the first condition and the at least one second comparing result corresponding to the specified sensor satisfies the second condition, the processor issues a warning signal corresponding to the sensing result from the specified sensor.

[0008] The above contents of the present disclosure will become more readily apparent to those ordinarily skilled in the art after reviewing the following detailed description and accompanying drawings, in which:

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. 1 is a flowchart of a detection method for detecting a structural condition of an object according to a first embodiment of the present disclosure;

[0010] FIG. 2 schematically illustrates a detection system according to an embodiment of the present disclosure;

[0011] FIG. 3 schematically illustrates the detection system of FIG. 2 using a first exemplary detection method shown in FIG. 1;

[0012] FIG. 4 is a flowchart of a detection method for detecting a structural condition of an object according to a second embodiment of the present disclosure;

[0013] FIG. 5 schematically illustrates a detection system using a second exemplary detection method shown in FIG. 4;

[0014] FIG. 6A is a schematic timing waveform diagram illustrating a sensing result outputted from any sensor of the detection system shown in FIG. 5 when the physical structure of the object is normal;

[0015] FIG. 6B is a schematic timing waveform diagram illustrating a sensing result outputted from any sensor of the detection system shown in FIG. 5 when the physical structure of the object is damaged;

[0016] FIG. 6C is a schematic timing waveform diagram illustrating a sensing result outputted from a specified sensor of the detection system shown in FIG. 5 when the structural condition of the object is changed from normal status to damaged status;

[0017] FIG. 6D is a schematic timing waveform diagram illustrating a sensing result outputted from a specified sensor of the detection system shown in FIG. 5 when the physical structure of the object blown by the wind is normal;

[0018] FIG. 6E is a schematic timing waveform diagram illustrating three sensing results outputted from a specified sensor of the detection system shown in FIG. 5 in case that the physical structure of the object not blown by the wind is normal, the physical structure of the object blown by the wind is normal, and the physical structure of the object blown by the wind is damaged, respectively;

[0019] FIG. 6F is a schematic timing waveform diagram illustrating a sensing result outputted from a specified sensor of the detection system shown in FIG. 5 when the physical structure of the object caught in the rain is normal; and

[0020] FIG. 6G is a schematic timing waveform diagram illustrating three sensing results outputted from a specified sensor of the detection

system shown in FIG. 5 in case that the physical structure of the object not exposed to rain is normal, the physical structure of the object exposed to rain is normal, and the physical structure of the object exposed to rain is damaged, respectively.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0021] The present disclosure will now be described more specifically with reference to the following embodiments. It is to be noted that the following descriptions of preferred embodiments of this disclosure are presented herein for purpose of illustration and description only. It is not intended to be exhaustive or to be limited to the precise form disclosed.

[0022] Please refer to FIG. 1, FIG. 2 and FIG. 3. FIG. 1 is a flowchart of a detection method for detecting a structural condition of an object according to a first embodiment of the present disclosure. FIG. 2 schematically illustrates a detection system according to an embodiment of the present disclosure. FIG. 3 schematically illustrates the detection system of FIG. 2 using a first exemplary detection method shown in FIG. 1.

[0023] As shown in FIGS. 1, 2, and 3, the detection method can be applied to the detection system 1. The detection method is used for detecting a structural condition of an object 9. Preferably but not exclusively, the object 9 may be protective meshes, a net, a fence or a grid fence, which is used in high security areas, outdoor farming, pasture, protected area fence or zoo. In the embodiment of FIG. 3, the object 9 has a triangular shape. It is noted that the shape of the object 9 is not restricted. For example, in some other embodiments, the object 9 has a rectangular shape, a circular shape or any other appropriate shape. Further, the detection method of the present disclosure can be applicable to the object 9 whether the object 9 is planar or non-planar. In this embodiment, the detection system 1 includes a signal generation device 2, at least one sensor

3 and a processor 4. The detection system 1 can automatically and instantly detect the state or condition of the physical structure (i.e., the structural condition) of the object 9. For example, the detection system 1 is used to detect whether the object 9 has a damage site or a broken site.

[0024] The signal generation device 2 is disposed on the object 9. The signal generation device 2 is configured to issue a trigger signal. The trigger signal is transmitted through the object 9, so that the structural condition of the object 9 is detected by the detection system 1 according to the changes reflected by the trigger signal transmitted through the object 9. In other words, the signal generation device 2 is served as an energy source that provides a detection reference signal when the detection system 1 detects objects 9. In some embodiments, preferably but not exclusively, the signal generation device 2 is an actuator. In an embodiment, the actuator generates a vibration wave to be served as the trigger signal. In addition, the vibration wave is transmitted through the object 9 and has a plurality of characteristics including at least one vibration direction, a vibration frequency and an amplitude. In an embodiment, the at least one vibration direction of the vibration wave includes an X-axis direction, a Y-axis direction and a Z-direction (i.e., the vibration wave can include three wave components in the X-axis direction, Y-axis direction and Z-axis direction). In some other embodiments, the at least one vibration direction of the vibration wave includes one or two of the X-axis direction, the Y-axis direction and the Z-direction (i.e., the vibration wave can merely include one or two wave components in the X-axis direction, Y-axis direction and Z-axis direction).

[0025] In the embodiment, the detection system 1 includes one sensor 3 as shown in FIG. 3. In some other embodiments, the detection system 1 includes a plurality of sensors 3. Each sensor 3 receives and detects the

trigger signal from the signal generation device 2 through the object 9 and outputs a sensing result accordingly. The processor 4 receives the sensing result from each sensor 3. After the sensing result from each sensor 3 is analyzed by the processor 4, the sensing result is processed into a time domain data and a frequency domain data. The time domain data can include the data about the amplitudes of the trigger signal. The frequency domain data can include the data about the components of the trigger signal.

[0026] The detection method of the present disclosure includes the following steps. In an initial state, the sensing result from each sensor 3 is processed into an initial time domain data and an initial frequency domain data by the processor 4 (Step S1). In addition, the time domain data and the frequency domain data are recorded. In the initial state, the object 9 is normal. That is, the physical structure of the object 9 is not damaged. Meanwhile, the sensing result outputted by the sensor 3 indicates that the physical structure of the object 9 is normal. In other words, the initial time domain data and the initial frequency domain data recorded by the processor 4 in the initial state indicates that the physical structure of the object 9 is normal.

[0027] In a detection state posterior to the initial state, the trigger signal is detected by each sensor 3 for at least one time within a predetermined time interval (Step S2). In some embodiments, for example, the predetermined time interval is 5 minutes, and the at least one time is one time or several times.

[0028] In the detection state, the sensing result from each sensor 3 is processed into a detection time domain data and a detection frequency domain data by the processor 4 (Step S3). If the physical structure of the object 9 is damaged in the detection state, the sensing result outputted by the sensor 3 indicates that the physical structure of the object 9 is damaged. In

other words, at least one of the detection time domain data and the detection frequency domain data recorded by the processor 4 in the detection state can indicate that the physical structure of the object 9 is damaged. In some embodiments, both of the detection time domain data and the detection frequency domain data recorded by the processor 4 in the detection state can indicate that the physical structure of the object 9 is damaged.

[0029] In Step S4, the processor 4 obtains a first difference score of each sensor 3 according to a result of comparing the detection time domain data with the corresponding initial time domain data, and obtains a second difference score of each sensor 3 according to a result of comparing the detection frequency domain data with the corresponding initial frequency domain data. The level of the first difference score represents that the difference between the detection time domain data in the detection state and the initial time domain data in the initial state. The level of the second difference score represents that the difference between the detection frequency domain data in the detection state and the initial frequency domain data in the initial state.

[0030] In an embodiment, the greater the first different score is, the greater the difference between the detection time domain data obtained by the sensor 3 in the detection state and the initial time domain data recorded by the corresponding sensor 3 in the initial state is. On the contrary, the smaller the first different score is, the smaller the difference between the detection time domain data obtained by the sensor 3 in the detection state and the initial time domain data recorded by the corresponding sensor 3 in the initial state is. The greater the second different score is, the greater the difference between the detection frequency domain data obtained by the sensor 3 in the detection state and the initial frequency domain data recorded by the corresponding sensor 3 in the initial state is. On the contrary, the

smaller the second different score is, the smaller the difference between the detection frequency domain data obtained by the sensor 3 in the detection state and the initial frequency domain data recorded by the corresponding sensor 3 in the initial state is.

[0031] In other embodiment, the greater the first different score is, the greater the difference between the detection time domain data obtained by each sensor 3 in the detection state and the initial time domain data recorded by each sensor 3 in the initial state is. On the contrary, the smaller the first different score is, the smaller the difference between the detection time domain data obtained by each sensor 3 in the detection state and the initial time domain data recorded by each sensor 3 in the initial state is. The greater the second different score is, the greater the difference between the detection frequency domain data obtained by each sensor 3 in the detection state and the initial frequency domain data recorded by each sensor 3 in the initial state is. On the contrary, the smaller the second different score is, the smaller the difference between the detection frequency domain data obtained by each sensor 3 in the detection state and the initial frequency domain data recorded by each sensor 3 in the initial state is.

[0032] In Step S5, the processor 4 respectively determines whether a first comparing result between the first difference core of each sensor 3 and a first predetermined value satisfies a first condition and whether a second comparing result between the second difference score of each sensor 3 and a second predetermined value satisfies a second condition. When the first comparing result corresponding to a specified sensor 3 satisfies the first condition and the second comparing result corresponding to the specified sensor 3 satisfies the second condition, the processor 4 issues a warning signal corresponding to the sensing result from the specified sensor 3. Preferably but not exclusively, in the embodiment, the first condition is

expressed as a condition that the first difference score is greater than a first predetermined value, and the second condition is expressed as a condition that the second difference score is greater than a second predetermined value. In an embodiment, when at least one of the first difference score being greater than the first predetermined value and the second difference score being greater than the second predetermined value occurs, it indicates that the physical structure of the object 9 is damaged. In other embodiment, when the first difference score is greater than the first predetermined value and the second difference score is greater than the second predetermined value, it indicates that the physical structure of object 9 is damaged. Preferably but not exclusively, the level of the first predetermined value is predetermined according to a minimum value of the difference between the detection time domain data in the detection state and the initial time domain data in the initial state when the structural condition of the object 9 is in a normal and acceptable state. The level of the second predetermined value is predetermined according to a minimum value of the difference between the detection frequency domain data in the detection state and the initial frequency domain data in the initial state when the structural condition of the object 9 is in a normal and acceptable state.

[0033] Furthermore, in another embodiment, the first condition is expressed as a condition that the first difference score is greater than a first predetermined value, and the second condition is expressed as a condition that the second difference score is less than a second predetermined value. In an embodiment, when the first difference score is greater than the first predetermined value or the second difference score is less than the second predetermined value, the sensing result from the specified sensor 3 indicates that the physical structure of the object 9 is damaged. In another embodiment, when the first difference score is greater than the first

predetermined value and the second difference score is less than the second predetermined value, the sensing result from the specified sensor 3 indicates that the physical structure of object 9 is damaged. Notably, the above two embodiments are merely examples. The first condition and the second condition of the present disclosure can be adjusted according to the design requirements, and the present disclosure is not limited thereto.

[0034] As mentioned above, the detection system 1 includes the signal generation device 2, the at least one sensor 3 and the processor 4. The signal generation device 2, the at least one sensor 3 and the processor 4 cooperate with each other to implement the detection method of the present disclosure. The processor 4 can process the sensing result of the sensor 3 into time domain data and frequency domain data. Consequently, the detection method can be used to detect whether the physical structure of the object 9 is damaged. According to the initial time domain data, the initial frequency domain data, the detection time domain data and the detection frequency domain data, the processor 4 of the detection system 1 can detect whether the physical structure of the object 9 is damaged. Since the interference of noise is minimized, the detection precision is enhanced. Furthermore, the detection method and the detection system 1 of the present disclosure are used to automatically and instantly detect whether the physical structure of the object 9 is damaged. In case that the object is placed in outdoor environment and the area of the object that needs to be inspected is relatively large, the uses of the detection method and the detection system 1 of the present disclosure can largely save the labor cost.

[0035] In some embodiments, the sensing result from the at least one sensor 3 is analyzed and classified by the processor 4 through the fast Fourier transform spectrum and encoded as the frequency domain data. In addition,

the sensing result from the at least one sensor 3 is calculated by the processor 4 according to the standard deviation and encoded as the time domain data.

[0036] In an example of Step S2, the trigger signal is received and detected by each sensor 3 for a plurality of times within the predetermined time interval. Correspondingly, in Step S4, the processor 4 obtains a plurality of first difference scores and a plurality of second difference scores. Then, in Step S5, the processor 4 determines whether at least a half of the first comparing results corresponding to the specified sensor 3 satisfies the first condition and at least a half of the second comparing results corresponding to the specified sensor 3 satisfies the second condition. When the determining condition of the step S5 is satisfied, the sensing result from the specified sensor 3 indicates that the physical structure of the object 9 is abnormal, and the processor 4 issues a warning signal corresponding to the abnormality detected by the specified sensor 3.

[0037] FIG. 4 is a flowchart of a detection method for detecting a structural condition of an object according to a second embodiment of the present disclosure. FIG. 5 schematically illustrates a detection system using a second exemplary detection method shown in FIG. 4. In this embodiment, as shown in FIG. 4 and FIG. 5, the structures, elements and functions of the detection system 1a are similar to those of detection system 1 in the first embodiment, and are not redundantly described herein. Different from that of the first embodiment, the detection system 1a includes a plurality of sensors 3a, 3b, 3c, 3c. The plurality of sensors 3a, 3b, 3c, 3d are discretely disposed at different positions of the object 9.

[0038] In the embodiment, since the detection system 1a includes the plurality of sensors 3a, 3b, 3c, 3d, the detection method for the detection system 1a in the second embodiment includes the Steps S1~S5 of the detection method in the first embodiment, and further includes a Step S6.

The Steps S1~S5 of the second embodiment are similar to those of the first embodiment, and are not redundantly described herein. The Step S6 is performed after the Step S5. In the Step S6, the warning signals from all of the plurality of sensors 3a, 3b, 3c, 3d are collected by the processor 4. In addition, the damaged location of the object 9 is analyzed by the processor 4 according to the installation positions of the sensors 3a, 3b, 3c, 3d corresponding to the collected warning signals.

[0039] As shown in FIG. 5, the object 9 is divided into a plurality of areas, such as four areas including the upper left area, the upper right area, the lower left area and the lower right area. Each of the areas is equipped with a corresponding sensor 3a, 3b, 3c, 3d. When the processor 4 determines that the first comparing result and the second comparing result corresponding to the sensor 3a in the upper left area and the sensor 3b in the lower left area satisfy the first condition and the second condition, respectively, the processor 4 outputs the warning signals indicating that the sensor 3a in the upper left area and the sensor 3b in the lower left area have detected abnormalities. The warning signals from the sensors 3 are collected by the processor 4. In addition, the damaged locations of the object 9 are analyzed by the processor 4 according to the installation positions of the sensors 3a, 3b corresponding to the collected warning signals. In other words, for this example, the processor 4 analyzes the damaged positions of the object 9 in the upper left area and the lower left area according to the installation positions of the sensor 3a in the upper left area and the sensor 3b in the lower left area.

[0040] In some embodiments, the sensing result from the at least one sensor 3a、3b、3c、3d is analyzed and classified by the processor 4 through the fast Fourier transform spectrum and encoded as the frequency domain data. In addition, the sensing result from each of the sensors 3a, 3b, 3c, 3d

is calculated by the processor 4 according to the standard deviation and encoded as the time domain data.

[0041] Please refer to FIG. 6A, FIG. 6B, FIG. 6C, FIG. 6D, FIG. 6E, FIG. 6F, and FIG. 6G. FIG. 6A is a schematic timing waveform diagram illustrating a sensing result outputted from any sensor of the detection system shown in FIG. 5 when the physical structure of the object is normal. FIG. 6B is a schematic timing waveform diagram illustrating a sensing result outputted from any sensor of the detection system shown in FIG. 5 when the physical structure of the object is damaged. FIG. 6C is a schematic timing waveform diagram illustrating a sensing result outputted from a specified sensor of the detection system shown in FIG. 5 when the structural condition of the object is changed from normal status to damaged status. FIG. 6D is a schematic timing waveform diagram illustrating a sensing result outputted from a specified sensor of the detection system shown in FIG. 5 when the physical structure of the object blown by the wind is normal. FIG. 6E is a schematic timing waveform diagram illustrating three sensing results outputted from a specified sensor of the detection system shown in FIG. 5 in case that the physical structure of the object not blown by the wind is normal, the physical structure of the object blown by the wind is normal, and the physical structure of the object blown by the wind is damaged, respectively. FIG. 6F is a schematic timing waveform diagram illustrating a sensing result outputted from a specified sensor of the detection system shown in FIG. 5 when the physical structure of the object caught in the rain is normal. FIG. 6G is a schematic timing waveform diagram illustrating three sensing results outputted from a specified sensor of the detection system shown in FIG. 5 in case that the physical structure of the object not exposed to rain is normal, the physical structure of the object exposed to rain is normal, and the physical structure of the object exposed to rain is damaged, respectively. Preferably

but not exclusively, in an embodiment, the signal generation device 2 is an actuator that generates a periodic or regular vibration wave to be served as the trigger signal. For example, the detection system 1a is used to detect the structural condition of the object 9. As shown in FIG. 5, the sensing result outputted from each of the sensors 3a, 3b, 3c, 3d can reflect the amplitudes of the trigger signal in each axis (e.g., the amplitude of the vibration wave in the X-axis direction, the amplitude of the vibration wave in the Y-axis direction and the amplitude of the vibration wave in the Z-direction) and reflect the components of the trigger signal in the X-axis direction, the Y-axis direction and the Z-direction after the trigger signal (e.g., the vibration wave generated by the actuator) generated by the signal generation device 2 is transmitted through the object 9. The above-mentioned components are, for example, one or more signals with specific frequencies. In addition to the trigger signals, the signals may also include white noise, and background noise caused by environmental factor such as wind and rain, etc. In the timing waveform diagrams shown in FIG. 6A to FIG. 6G, the horizontal axis represents the number of signal samples changing over time, and the vertical axis represents the normalized amplitude intensity.

[0042] FIG. 6A, FIG. 6B, and FIG. 6C are taken to describe examples. When the physical structure of the object 9 is normal, the timing waveform diagrams corresponding to the plurality of sensors 3a, 3b, 3c, 3d are shown in FIG. 6A, respectively. When the physical structure of the object 9 is damaged, for example, the object 9 is damaged near the sensor 3a, the timing waveform diagrams corresponding to the plurality of sensors 3a, 3b, 3c, 3d are shown in FIG. 6B, respectively. From the captured signal in the Y-axis direction shown in FIG. 6C, it can be seen that when the physical structure of the object 9 is damaged and the damaged position is close to the sensor

3a, the amplitude of the vibration wave in the Y-axis direction can be seen from the timing waveform diagram of the sensor 3a, and the change reflects that the damaged position of object 9 is close to the sensor 3a. Therefore, the sensing result outputted from the sensor 3a in the detection state can reflect that the physical structure of the object 9 is damaged. The detection time domain data and the detection frequency domain data processed by the processor 4 in the detection state can reflect that the physical structure of the object 9 is damaged accurately.

[0043] In addition, when the physical structure of the object 9 is normal and the object 9 is blown by the wind, the timing waveform diagram of the sensing result outputted from the sensor, such as the sensor 3a, is shown in FIG. 6D. Furthermore, as shown in FIG. 6E, in case that the physical structure of object 9 is normal and not blown by the wind, the physical structure of object 9 is normal and blown by the wind, and the physical structure of object 9 is damaged and blown by the wind, the sensing situations are illustrated. In the timing waveform diagram of the sensor 3a, the amplitude of the vibration wave in the Y-axis direction will vary correspondingly. Therefore, the sensing result outputted from the sensor 3a in the detection state can reflect whether the object 9 is blown by the wind and the structural condition of the object 9. In this way, the detection time domain data and the detection frequency domain data processed by the processor 4 in the detection state can reflect the structural condition of the object 9 accurately.

[0044] In addition, when the physical structure of the object 9 is normal and the object 9 is caught in the rain, the timing waveform diagram of the sensing result outputted from the sensor, such as the sensor 3a, is shown in FIG. 6F. Furthermore, as shown in FIG. 6G, in case that the physical structure of object 9 is normal and not caught in the rain, the physical

structure of object 9 is normal and caught in the rain, and the physical structure of object 9 is damaged and caught in the rain, the sensing situations are illustrated. In the timing waveform diagram of the sensor 3a, the amplitude of the vibration wave in the Y-axis direction will vary correspondingly. Therefore, the sensing result outputted from the sensor 3a in the detection state can reflect whether the object 9 is caught in the rain and the structural condition of the object 9. In this way, the detection time domain data and the detection frequency domain data processed by the processor 4 in the detection state can reflect the structural condition of the object 9 accurately.

[0045] From the above descriptions, the present disclosure provides the detection method and the detection system. The detection system includes the signal generation device, the at least one sensor, and the processor. The signal generation device, the at least one sensor, and the processor cooperate with each other to implement the detection method of the present disclosure. The processor processes the sensing result outputted by the at least one sensor into time domain data and the frequency domain data to detect the structural condition of the object. Consequently, the detection method can be used to detect whether the physical structure of the object is damaged. According to the initial time domain data, the initial frequency domain data, the detection time domain data, and the detection frequency domain data, the processor can detect whether the physical structure of the object is damaged. Since the interference of noise is minimized, the detection precision is enhanced. Furthermore, in case that the detection system includes a plurality of sensors, the processor collects the warning signals from the plurality of sensors, and the processor analyzes the damaged locations of the object according to the installation positions of the sensors corresponding to the collected warning signals. Since the condition of the physical structure

of the object is determined according to the time domain data and the frequency domain data from many information sources, such as being determined through a multi-tiered or hierarchical decision-making approach, the possibility of misjudgment can be largely reduced. Furthermore, the detection method and the detection system of the present disclosure can be used to automatically and instantly detect whether the physical structure of the object is damaged. In case that the object is placed in outdoor environment and the area of the object that needs to be inspected is relatively large, the uses of the detection method and the detection system of the present disclosure can largely save the labor cost.

[0046] While the disclosure has been described in terms of what is presently considered to be the most practical and preferred embodiments, it is to be understood that the disclosure needs not be limited to the disclosed embodiment. On the contrary, it is intended to cover various modifications and similar arrangements included within the spirit and scope of the appended claims which are to be accorded with the broadest interpretation so as to encompass all such modifications and similar structures.

WHAT IS CLAIMED IS:

1. A detection method used in a detection system for detecting a structural condition of an object, the detection system comprising a signal generation device, at least one sensor, and a processor, wherein the signal generation device and the at least one sensor are disposed on the object, the signal generation device is configured to issue a trigger signal, the at least one sensor is configured to receive the trigger signal through the object and output a sensing result to the processor, the detection method comprising steps of:

(S1) entering an initial state, and processing the sensing result from the at least one sensor into an initial time domain data and an initial frequency domain data by the processor;

(S2) entering a detection state posterior to the initial state, and detecting the trigger signal by the at least one sensor for at least one time within a predetermined time interval;

(S3) processing the sensing result from the at least one sensor into a detection time domain data and a detection frequency domain data by the processor when the detection system is in the detection state;

(S4) obtaining at least one first difference score of the at least one sensor by the processor according to a result of comparing the detection time domain data with the corresponding initial time domain data, and obtaining at least one second difference score of the at least one sensor by the processor according to a result of comparing the detection frequency domain data with the corresponding initial frequency domain data; and

(S5) determining whether at least one first comparing result between the at least one first difference score and a first predetermined value satisfies a first condition and whether at least one second comparing result between the at least one second difference score and a second predetermined value

satisfies a second condition respectively by the processor, wherein when the at least one first comparing result corresponding to a specified sensor of the at least one sensor satisfies the first condition and the at least one second comparing result corresponding to the specified sensor of the at least one sensor satisfies the second condition, the processor issues a warning signal corresponding to the sensing result from the specified sensor.

2. The detection method according to claim 1, wherein the signal generation device comprises an actuator configured to generate a vibration wave to be served as the trigger signal, and the vibration wave is transmitted through the object along at least one vibration direction.

3. The detection method according to claim 2, wherein the at least one vibration direction of the vibration wave comprises an X-axis direction, a Y-axis direction, and a Z-direction, wherein each of the initial time domain data and the detection time domain data includes a data about amplitudes of the trigger signal in the X-axis direction, the Y-axis direction, and the Z-direction, and each of the initial frequency domain data and the detection frequency domain data includes a data about components of the trigger signal in the X-axis direction, the Y-axis direction, and the Z-direction.

4. The detection method according to claim 1, wherein the initial time domain data, the detection time domain data, the initial frequency domain data, and the detection frequency domain data are encoded data.

5. The detection method according to claim 1, wherein the at least one sensor comprises a plurality of sensors, and the plurality of sensors are discretely disposed on the object.

6. The detection method according to claim 5, wherein after the step (S5), the detection method further comprises a step of: (S6) collecting the warning signals from all of the plurality of sensors by the processor, and analyzing at least one damaged location of the object by the processor according to

installation positions of the sensors corresponding to the collected warning signals.

7. The detection method according to claim 1, wherein in the step (S2), the trigger signal is detected by the at least one sensor for a plurality of times within the predetermined time interval.

8. The detection method according to claim 7, wherein in the step (S4), the at least one first difference score comprises a plurality of first difference scores, and the at least one second difference scores comprises a plurality of second difference scores, wherein in the step (S5), when at least a half of the first comparing results corresponding to the specified sensor satisfy the first condition and at least a half of the second comparing results corresponding to the specified sensor satisfy the second condition, the processor issues the warning signal corresponding to the sensing result from the specified sensor.

9. A detection system for detecting a structural condition of an object, the detection system comprising:

a signal generation device disposed on the object and configured to issue a trigger signal;

at least one sensor disposed on the object, wherein the at least one sensor receives the trigger signal through the object and outputs a sensing result; and

a processor receiving the sensing result and analyzing and processing the sensing result,

wherein in an initial state, the sensing result from the at least one sensor is processed into an initial time domain data and an initial frequency domain data by the processor,

wherein in a detection state posterior to the initial state, the trigger signal is detected by the at least one sensor for at least one time within a predetermined time interval, and the sensing result from the at least one

sensor is processed into a detection time domain data and a detection frequency domain data by the processor,

wherein the processor obtains at least one first difference score of the at least one sensor according to a result of comparing the detection time domain data with the corresponding initial time domain data, and the processor obtains at least one second difference score of each of the at least one sensor according to a result of comparing the detection frequency domain data with the corresponding initial frequency domain data,

wherein the processor respectively determines whether at least one first comparing result between the at least one first difference score and a first predetermined value satisfies a first condition and whether at least one second comparing result between the at least one second difference score and a second predetermined value satisfies a second condition, wherein when the at least one first comparing result corresponding to a specified sensor of the at least one sensor satisfies the first condition and the at least one second comparing result corresponding to the specified sensor satisfies the second condition, the processor issues a warning signal corresponding to the sensing result from the specified sensor.

10. The detection system according to claim 9, wherein the signal generation device is an actuator, wherein the actuator generates a vibration wave to be served as the trigger signal, and the vibration wave is transmitted through the object along at least one vibration direction.

11. The detection system according to claim 10, wherein the at least one vibration direction of the vibration wave includes an X-axis direction, a Y-axis direction and a Z-direction, wherein each of the initial time domain data and the detection time domain data includes a data about amplitudes of the trigger signal in the X-axis direction, the Y-axis direction and the Z-direction, and each of the initial frequency domain data and the detection frequency

domain data includes a data about components of the trigger signal in the X-axis direction, the Y-axis direction and the Z-direction.

12. The detection system according to claim 9, wherein the initial time domain data, the detection time domain data, the initial frequency domain data and the detection frequency domain data are encoded data.

13. The detection system according to claim 9, wherein the at least one sensor comprises a plurality of sensors, and the plurality of sensors are discretely disposed on the object.

14. The detection system according to claim 13, wherein the warning signals from all of the plurality of sensors are collected by the processor, and at least one damaged location of the object is analyzed by the processor according to installation positions of the sensors corresponding to the collected warning signals.

15. The detection system according to claim 13, wherein in the initial state, the sensing result from the at least one sensor is analyzed and classified by the processor through a Fast Fourier Transform Spectrum and encoded as the initial frequency domain data, wherein the sensing result from the at least one sensor is calculated by the processor according to a standard deviation and encoded as the initial time domain data.

16. The detection system according to claim 9, wherein the trigger signal is detected by the at least one sensor for a plurality of times within the predetermined time interval.

17. The detection system according to claim 16, wherein the at least one first difference score comprises a plurality of first difference scores, and the at least one second difference scores comprises a plurality of second difference scores, wherein when at least a half of the first comparing results corresponding to the specified sensor satisfy the first condition and at least a half of the second comparing results corresponding to the specified sensor

satisfy the second condition, the processor issues the warning signal corresponding to the sensing result from the specified sensor.

18. The detection system according to claim 13 or 16, wherein the sensing result from the at least one sensor is analyzed and classified by the processor through a Fast Fourier Transform Spectrum and encoded as the detection frequency domain data, wherein the sensing result from the at least one sensor is calculated by the processor according to a standard deviation and encoded as the detection time domain data.