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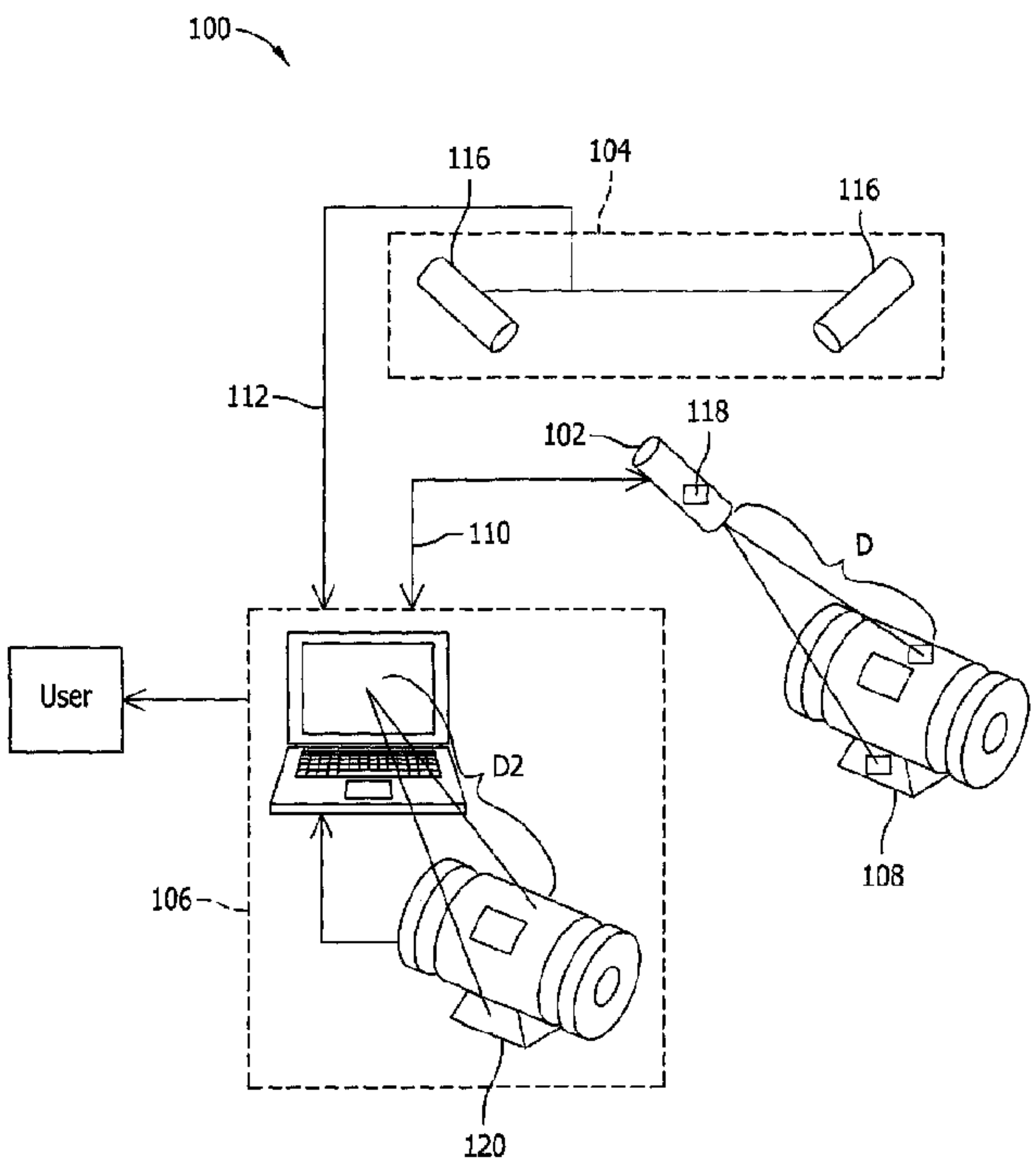
(72) **Inventeurs/Inventors:**
DOYLE, JOSEPH D., US;
DAVIES, PAUL R., US

(73) **Propriétaire/Owner:**
THE BOEING COMPANY, US

(74) **Agent:** SMART & BIGGAR

(54) **Titre : METHODES ET SYSTEMES D'INSPECTION D'UNE PIECE DE TRAVAIL**
(54) **Title: METHODS AND SYSTEMS FOR INSPECTING A WORKPIECE**



(57) **Abrégé/Abstract:**
Methods and systems for inspecting a workpiece are provided. The method includes inputting model data associated with the workpiece in an inspection system, determining a relative position of a depth sensing device relative to the workpiece, and calibrating a pose view for the inspection system relative to the model based on the position of the depth sensing device relative to the workpiece. The method further includes measuring actual depth distance data of at least one pixel of the depth sensing device relative to the workpiece and determining, based on the actual depth distance data, if the workpiece satisfies predetermined inspection criteria.

METHODS AND SYSTEMS FOR INSPECTING A WORKPIECE

ABSTRACT OF THE DISCLOSURE

Methods and systems for inspecting a workpiece are provided. The method includes inputting model data associated with the workpiece in an inspection system, determining a relative position of a depth sensing device relative to the workpiece, and calibrating a pose view for the inspection system relative to the model based on the position of the depth sensing device relative to the workpiece. The method further includes measuring actual depth distance data of at least one pixel of the depth sensing device relative to the workpiece and determining, based on the actual depth distance data, if the workpiece satisfies predetermined inspection criteria.

METHODS AND SYSTEMS FOR INSPECTING A WORKPIECE

BACKGROUND

The present disclosure relates generally to non-destructive workpiece inspection and, more particularly, to methods and systems for automated inspection of a workpiece.

Production of a workpiece or assembly may require using multiple parts and tools. It is desirable to perform an accurate and reliable inspection of the assembly during and after construction to ensure production quality by identifying possible issues such as assembly errors, damage of a component in the assembly, and/or foreign object debris (FOD).

At least some known inspections of assemblies are performed manually. In such inspections, inspectors typically use visual and tactile inspections, in combination with personal knowledge, to compare the workpiece against a design model or chart. However, manual inspections generally require inspectors to visually inspect, touch, and feel the workpiece to detect differences between the assembly and the model. As such, manual inspections introduce possibilities of human error. For example, large assemblies such as aircraft, trains, automobile, and ships may include small objects in areas having limited accessibility and thus such areas may be difficult for inspectors to inspect. Moreover, manual inspections may be time-consuming and/or require costly, skilled labor. In some instances, inspectors may use a small optical inspection tool, such as a boroscope or X-ray technology, but such inspection methods still introduce a potential for human error as they require the inspectors to visually recognize differences between the workpiece and the model. Moreover, X-ray technology can only be used on a limited group of materials, as some materials are not visible using X-ray technology.

Other known inspection methods use automated image processing to perform inspections. During inspections, images of a workpiece are captured and analyzed using image processing, such that features within the images are compared to a library of standard features. Features may be identified using border fitting, color matching, and re-sizing of flexible objects. However, such inspection methods may still introduce inaccuracies when identifying small parts, and when inspecting objects of the same color. Moreover, the areas that may be inspected using such technologies may be limited.

BRIEF DESCRIPTION

In accordance with one disclosed aspect there is provided a method for inspecting a workpiece. The method involves inputting model data associated with the workpiece in an inspection system, determining a relative position of a depth sensing device relative to the workpiece, and calibrating a position and orientation (pose) view for the inspection system relative to the model based on the position of the depth sensing device relative to the workpiece. The method also involves measuring actual depth distance data of at least one pixel in a field of view of the depth sensing device relative to the workpiece, and determining, based on the actual depth distance data, if the workpiece satisfies predetermined inspection criteria. Determining if the workpiece satisfies predetermined criteria involves calculating model depth distance data for the pose view of the inspection system, model depth distance data representing a model depth distance from the pose view of the inspection system to the model workpiece, determining whether the actual depth distance differs from the model depth distance, and determining whether the difference satisfies the inspection criteria when the actual depth distance differs from the model depth distance. Compliance with a threshold indicates the workpiece is in acceptable condition.

Inputting the model data may involve inputting computer aided design model data associated with the workpiece.

Inputting the model data may involve inputting a previously scanned model of the workpiece.

Determining the relative position of the depth sensing device may involve defining a coordinate system origin at a designated position of the workpiece, and determining a location of the depth sensing device relative to the workpiece using a plurality of position-detecting cameras.

The method may involve transmitting the location of the depth sensing device to the inspection system.

Measuring actual depth distance may involve moving the depth sensing device about the workpiece to capture a plurality of actual depth distances, and the method may further involve comparing the plurality of actual depth distances to a plurality of associated model depth distances to identify non-equivalent portions.

The method in accordance may involve displaying a portion of the workpiece that is not present in the model workpiece using an overlay applied to a view of the depth sensing device.

The overlay may be configured to illustrate a presence of at least one of foreign object debris, a missing component, an assembly error, and a damaged component.

Measuring the actual depth distance data may further involve generating a three-dimensional point cloud.

In accordance with another disclosed aspect there is provided a system for inspecting a workpiece. The system includes a depth sensing device configured to measure actual depth distance data of at least one pixel in a field of view of the depth sensing device relative to the workpiece, a position and orientation (pose) detection system configured to determine a relative position of the depth sensing device relative to the workpiece, and an inspection computer system in communication with the depth sensing device and the pose detection system. The inspection computer system is programmed to input model data associated with the workpiece, calibrate a pose view for the inspection computer system relative to the model based on the position of the depth sensing device relative to the workpiece, and determine, based on the actual depth distance data, if the workpiece satisfies predetermined inspection criteria. The inspection computer system is further programmed to calculate model depth distance data for the pose view of the inspection computer system, the model depth distance data representing a model depth distance from the pose view of the inspection computer system to the model workpiece, determine whether the actual depth distance differs from the model depth distance, and determine whether the difference satisfies the inspection criteria when the actual depth distance differs from the model depth distance. Compliance with a threshold indicates the workpiece is in acceptable condition.

To input model data, the inspection computer system may be further programmed to input a previously scanned model of the workpiece.

The inspection computer system may be configured to display a portion of the workpiece that is not present in the model workpiece using an overlay applied to a view of the depth sensing device.

The overlay may be displayed in one of real-time and near real-time.

In accordance with another disclosed aspect there is provided a computer system for inspecting a workpiece, the computer system including a processor, and a computer-readable storage device having encoded thereon computer readable instructions that are executable by the processor to perform functions including storing model data associated with the workpiece in the storage device, determining a relative position of a depth sensing device relative to the workpiece, calibrating a position and orientation (pose) view for the computer system relative to the model based on the position of the depth sensing device relative to the workpiece, measuring actual depth distance data of at least one pixel in a field of view of the depth sensing device relative to the workpiece, and determining, based on the actual depth distance data, if the workpiece satisfies predetermined inspection criteria. The functions also include determining if the workpiece satisfies predetermined inspection criteria and further include calculating model depth distance data for the pose view of the computer system, the model depth distance data representing a model depth distance from the pose view of the computer system to the model workpiece, determining whether the actual depth distance differs from the model depth distance, and determining whether the difference satisfies the inspection criteria when the actual depth distance differs from the model depth distance. Compliance with a threshold indicates the workpiece is in acceptable condition.

Storing model data, the functions performed by the processor may further include storing at least one of computer aided design model data associated with the workpiece and a previously scanned model of the workpiece.

The functions performed by the processor may further include displaying a portion of the workpiece that may be not present in the model workpiece using an overlay applied to a view of the depth sensing device.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic illustration of an exemplary inspection system.

FIG. **2** is a schematic illustration of an exemplary inspection computer system that may be used with the inspection system shown in FIG. **1**.

FIG. **3** is a flowchart of an exemplary method that may be implemented by the inspection system shown in FIG. **1**.

DETAILED DESCRIPTION

The present disclosure relates generally to workpiece inspection and, more particularly, to methods and systems that enable automated inspection of a workpiece. In one embodiment, an inspection system includes a depth-sensing device that measures actual depth distance data for at least one pixel of the depth sensing device, a position and orientation (pose) detection system that determines pose data of the depth sensing device relative to the workpiece, and an inspection computer system that is coupled to the depth sensing device and to the pose detection system. Embodiments of the methods and systems described herein enable the computing system to (i) input model data associated with the workpiece,

(ii) determine a relative position of the depth sensing device relative to the workpiece, (iii) calibrate a pose view for the inspection computer system relative to the model based on the position of the depth sensing device relative to the workpiece, (iv) measure actual depth distance data of at least one pixel of the depth sensing device relative to the workpiece, and (v) determine, based on the actual depth distance data, if a predetermined threshold with respect to the workpiece has been exceeded.

The methods and systems described herein may be implemented using computer programming or engineering techniques including computer software, firmware, hardware or any combination or subset thereof, wherein the technical effects may include at least one of: a) loading model data for the workpiece onto the inspection computer system; b) determining pose data of a depth sensing device relative to the workpiece being inspected; c) calibrating a pose view for the inspection computer system relative to the model and the pose of the depth sensing device relative to the workpiece being inspected; d) measuring actual depth distance data for at least one pixel, wherein the actual depth distance data represents an actual depth distance between the depth sensing device and the workpiece being inspected; e) calculating model depth distance data for the pose view of the inspection computer system, wherein the model depth distance data represents a model depth distance from the pose view of the inspection computer system to the model workpiece; f) comparing the actual depth distance data to the model depth distance data; g) determining whether the actual depth distance differs from the model depth distance and determining whether the difference exceeds a predetermined threshold; and h) displaying a portion of the workpiece that is not present in the model workpiece using an overlay applied to a view of the depth sensing device.

As used herein, an element or step recited in the singular and proceeded with the word “a” or “an” should be understood as not excluding plural elements or steps unless such exclusion is explicitly recited. Moreover, references to “one embodiment” and/or the “exemplary embodiment” are not intended to be interpreted as excluding the existence of additional embodiments that also incorporate the recited features.

FIG. **1** is a schematic illustration of an exemplary inspection system **100** that may be used to inspect an assembly or workpiece **108**. Generally the workpiece is the product of an engineered environment in which the elements of the structure are assembled in a predefined manner such that the constituent elements are positioned and oriented in a predefined manner with respect to one another and to the workpiece as a whole. Inspection system **100** may be used in a wide variety of applications. For example, inspection system **100** may be used to inspect large assemblies, such as aircraft, trains, ships, or any other large assembly having numerous elements. Alternatively, inspection system **100** may also be used to inspect small assemblies, such as tools or gas/fluid tubes and the like.

As shown in FIG. **1**, inspection system **100** includes a depth sensing device **102**, a pose detection system **104**, and an inspection computer system **106**. As used herein, the term "pose" is defined as a position and an orientation of one object relative to another. Inspection system **100** is used to inspect a workpiece, for example, workpiece **108**, as described in more detail below, and depth sensing device **102** communicates with inspection computer system **106**. Specifically, depth sensing device **102** transmits a signal **110** indicative of a distance D between depth sensing device **102** and workpiece **108** for each pixel in a field of view of depth sensing device **102**. Pose detection system **104** communicates with inspection computer system **106** and transmits a signal **112** indicative of a pose of depth sensing device **102** relative to workpiece **108**. Alternatively, or in addition, depth sensing device **102** and pose detection system **104** may include a transmitter, a transceiver, and/or any other signal transmission device that enables inspection system **100** to function as described herein.

Depth sensing device **102** may be any suitable depth sensing device or camera capable of measuring an actual distance between depth sensing device **102** and workpiece **108**. In some embodiments, depth sensing device **102** is a laser or 3D light depth sensing device. In one embodiment, depth sensing device **102** determines actual distance data by calculating the two-way travel time of a laser beam transmitted towards workpiece **108** and reflected from workpiece **108**. In another embodiment, depth sensing device **102** projects an infrared (IR) pattern towards workpiece **108**. Depth sensing device **102** includes an infrared camera (not shown) that captures an image of the IR pattern. The depth data is then determined by comparing the expected IR pattern to the actual IR pattern seen by depth sensing device **102**. Alternatively, to calculate the distance, depth sensing device **102** may determine a phase difference of the laser beam. Depth sensing device **102** determines the distance based on the travel time or the phase difference using 3D coordinate components (i.e., points on an X, Y, Z axis) in a point cloud where multiple points are grouped.

In the exemplary embodiment, depth sensing device **102** communicates with inspection computer system **106** via a wired connection or via wireless transmissions, and transmits the actual depth distance data to inspection computer system **106**. In the exemplary embodiment, depth sensing device **102** includes an image processor that enables a real-time, or substantially real-time, video image of any object within its field of view to be generated. In an alternative embodiment, depth sensing device **102** may capture and store images of any object within its field of view. During use, in the exemplary embodiment, a user manually positions depth sensing device **102** at a desired location relative to workpiece **108**. Because depth sensing device **102** generates a video image, the user may move depth sensing device **102** relative to workpiece **108** without causing error or inaccuracy in the inspection. In alternative embodiments, depth sensing device **102** may be positioned using automated controlling devices, or depth sensing device **102** may remain stationary while workpiece **108** is moved relative to depth sensing device **102**.

In the exemplary embodiment, pose detection system **104** determines a pose of depth sensing device **102** relative to workpiece **108**. More specifically, in the exemplary embodiment, pose detection system **104** includes a processor that enables pose detection system **104** to determine pose of depth sensing device **102** in real-time, or near real-time. Pose detection system **104** communicates with inspection computer system **106** via a wired connection or via wireless transmissions.

Pose detection system **104** may determine the pose of depth sensing device **102** using different methods. In the exemplary embodiment, pose detection system **104** is a motion capture system that includes a plurality of cameras **116** positioned about workpiece **108**. A plurality of small reflective markers **118** are coupled to each object being tracked (i.e., to depth sensing device **102** and to workpiece **108**). Such markers **118** facilitate the calibration of the pose of depth sensing device **102** relative to workpiece **108**. Cameras **116** emit a near infra-red light about workpiece **108**, which is reflected back from markers **118**. In the exemplary embodiment, workpiece **108** remains stationary during the inspection process and is calibrated at an origin (**0**, **0**, **0**) with respect to the coordinate system because workpiece **108** remains stationary during the inspection process. When multiple cameras **116** observe a reflective marker **118**, pose detection system **104** can determine, i.e., essentially triangulate, a position of that marker **118** in 3D space. Moreover, when multiple markers **118** are attached to the same object, pose detection system **104** can also determine a relative orientation of that object. Other systems and methods of determining the pose of depth sensing device **102** may include, but are not limited to, marker-based tracking, two-dimensional (2D) planar-natural feature tracking, 3D model-based tracking, 3D depth-sensor training, 3D tracking using an iterative closest point, mechanical tracking devices that physically connect depth sensing device **102** to a reference location (i.e., the marker on workpiece **108**), magnetic-tracking devices that determine a strength and location of a pulsed magnetic field, sourceless non-inertial tracking devices that use passive magnetic sensors referenced to the earth's magnetic field, optical tracking devices, acoustic tracking devices, and/or any other tracking device, combination of devices, or method that enables the pose to be determined.

FIG. **2** is a schematic illustration of an exemplary inspection computer system **106** (shown in FIG. **1**) that may be used with the inspection system **100** (shown in FIG. **1**). In the exemplary embodiment, inspection computer system **106** includes a memory device **200**, and a processor **202** coupled to memory device **200** for use in executing instructions. More specifically, in the exemplary embodiment, inspection computer system **106** is configurable to perform one or more operations described herein by programming memory device **200** and/or processor **202**. For example, processor **202** may be programmed by encoding an operation as one or more executable instructions and by providing the executable instructions in memory device **200**.

Processor **202** may include one or more processing units (e.g., in a multi-core configuration). As used herein, the term "processor" is not limited to integrated circuits referred to in the art as a computer, but rather broadly refers to a controller, a microcontroller, a microcomputer, a programmable logic controller (PLC), an application specific integrated circuit, and other programmable circuits. In the exemplary embodiment, processor **202** is configured to load model workpiece **120** (shown in FIG. **1**) data for workpiece **108** (shown in FIG. **1**), receive pose data from pose detection system **104** (shown in FIG. **1**), calibrate a pose view for inspection computer system **106** relative to the model and the pose of depth sensing device **102** (shown in FIG. 1) relative to workpiece **108**, receive the actual depth distance data from depth sensing device **102**, calculate model workpiece **120** depth distance data for the pose view of inspection computer system **106**, wherein the model depth distance data represents a model depth distance from the pose view of inspection computer system **106** to model workpiece **120**, and compare the actual depth distance data to the model depth distance data.

In the exemplary embodiment, memory device **200** includes one or more devices (not shown) that enable information such as executable instructions and/or other data to be selectively stored and retrieved. In the exemplary embodiment, such data may include, but is not limited to, pose data, positional data, directional data, previously scanned model workpiece **120** data, computer aided design (CAD) model data, GPS data, map data, blueprint data, floor plan data, operational data, inspection threshold data, and/or control algorithms. Alternatively, inspection computer system **106** may be configured to use any algorithm and/or method that enable the methods and systems to function as described herein. Memory device **200** may also include one or more computer readable media, such as, without limitation, dynamic random access memory (DRAM), static random access memory (SRAM), a solid state disk, and/or a hard disk. In the exemplary embodiment, memory device **200** stores data related to the inspection process, for example, previously scanned model workpiece **120** data, CAD model data of workpiece **108** and/or inspection threshold data. Point clouds detected by depth sensing device **102** may also be saved on memory device **200** and used as documentation of a built condition or a verified inspection of workpiece **108**.

In the exemplary embodiment, inspection computer system **106** includes a presentation interface **204** that is coupled to processor **202** for use in presenting information to a user. For example, presentation interface **204** may include a display adapter (not shown) that may couple to a display device (not shown), such as, without limitation, a cathode ray tube (CRT), a liquid crystal display (LCD), a light-emitting diode (LED) display, an organic LED (OLED) display, an "electronic ink" display, and/or a printer. In some embodiments, presentation interface **204** includes one or more display devices. In the exemplary embodiment, processor **202** is configured to compare a distance D (shown in FIG. **1**) measured by depth sensing device **102** to a distance D2 (shown in FIG. **1**) calculated for model workpiece **120** by inspection computer system **106**. If there is a difference, processor **202** compares the difference to predetermined threshold data stored on memory device **200**. In the exemplary embodiment, when a difference of distances D and D2 exceeds the predetermined threshold, processor **202** displays to a user a portion of workpiece **108** that is not present in model workpiece **120** using presentation interface **204**. The overlay may be displayed using different methods. In one embodiment, only that portion of workpiece **108** exceeding the predetermined threshold is displayed. In another embodiment, all of workpiece **108** is displayed, and the non-compliant portions of workpiece **108** are displayed in a different color than the remainder of workpiece **108**. Alternatively, any other method of display may be used that enables displaying selected areas of a workpiece determined to have portions that predetermined tolerances.

Inspection computer system **106**, in the exemplary embodiment, includes an input interface **206** for receiving input from the user. For example, in the exemplary embodiment, input interface **206** receives information suitable for use with any of the methods described herein. Input interface **206** is coupled to processor **202** and may include, for example, a joystick, a keyboard, a pointing device, a mouse, a stylus, a touch sensitive panel (e.g., a touch pad or a touch screen), and/or a position detector. It should be noted that a single component, for example, a touch screen, may function as both presentation interface **204** and as input interface **206**.

In the exemplary embodiment, inspection computer system **106** includes a communication interface **208** that is coupled to processor **202**. In the exemplary embodiment, communication interface **208** communicates with at least one remote device, such as depth sensing device **102** and/or pose detection system **104**. For example, communication interface **208** may use, without limitation, a wired network adapter, a wireless network adapter, and/or a mobile telecommunications adapter. A network (not shown) used to couple inspection computer system **106** to the remote device may include, without limitation, the Internet, a local area network (LAN), a wide area network (WAN), a wireless LAN (WLAN), a mesh network, and/or a virtual private network (VPN) or other suitable communication means.

FIG. **3** is a flowchart of an exemplary method **300** that may be implemented to inspect a workpiece, such as workpiece **108** (shown in FIG. **1**) using an inspection system, such as inspection system **100** (shown in FIG. **1**). During operation, in the exemplary embodiment, inspection system **100** is operated by a user using inspection computer system **106** (shown in FIG. **1**). Input interface **206** (shown in FIG. **2**) enables the user to input **302** model workpiece **120** data associated with workpiece **108** into inspection computer system **106**. In one embodiment, the model data is 3D CAD model data that is stored in memory device **200** (shown in FIG. **2**).

After inputting **302** the model data, inspection computer system **106** transmits **304** a signal **112** (shown in FIG. **1**) requesting pose detection system **104** (shown in FIG. **1**) to determine **306** a pose of depth sensing device **102** (shown in FIG. **1**) relative to workpiece **108**.

To determine **306** the pose of depth sensing device **102**, in the exemplary embodiment, the user defines **308** a 3D coordinate system origin at a position of workpiece **108**. Pose detection system **104** determines **306** a pose of depth sensing device **102** relative to workpiece **108** using a plurality of position-detecting cameras, such as cameras **116** (shown in FIG. **1**). Pose detection system **104** transmits **310** the pose data back to inspection computer system **106** as signal **112**.

Using the pose data of depth sensing device **102** and the model data for workpiece **108** stored in memory device **200**, inspection computer system **106** generates **312** a pose view for inspection computer system **106** relative to the model workpiece. Inspection computer system **106** calibrates **314** the pose view of model workpiece **120** and the pose of depth sensing device **102**, enabling the pose view of model workpiece **120** to be displayed by inspection computer system **106** such that it remains in sync with a view of depth sensing device **102** relative to workpiece **108** as depth sensing device **102** is repositioned about workpiece **108**.

The user positions **316** depth sensing device **102** for inspection of a desired portion of workpiece **108**. In the exemplary embodiment, depth sensing device **102** is positioned **316** manually by the user. In alternative embodiments, depth sensing device **102** may be positioned **316** by an automated positioning system or it may remain stationary while workpiece **108** is moved for inspection.

After calibration **314** and positioning **316**, depth sensing device **102** measures **318** depth distance data to determine an actual depth distance between depth sensing device **102** and workpiece **108** for each pixel of depth sensing device **102**. In one embodiment, the user may continuously move or sweep depth sensing device **102** about workpiece **108** to capture a plurality of actual depth distances and to enable comparisons **320** to a plurality of associated model depth distances to identify **322** non-equivalent portions that may represent assembly error and/or damage to workpiece **108**. Depth sensing device **102** transmits **324** the actual depth distance data as a signal **110** (shown in FIG. **1**) to inspection computer system **106**.

Inspection computer system **106** then calculates **326** model workpiece **120** depth distance data representing a model depth distance between the pose view generated **312** by inspection computer system **106** and model workpiece **120**. Inspection computer system **106** compares **328** the actual depth distance data to the model depth distance data to determine **330** whether the actual depth distance differs from the model depth distance. If the actual depth distance differs from the model depth distance, inspection computer system **106** determines **332** whether the difference exceeds predetermined thresholds. Compliance with the thresholds is an indication that workpiece **108** is in acceptable condition. If the thresholds are exceeded, inspection computer system **106** generates **334** an alert or event to indicate a potential assembly error, existence of foreign object debris, and/or damage to workpiece **108**. Moreover, inspection computer system **106** displays **336** a portion of workpiece **108** that is not present in model workpiece **120** using an overlay applied to a view of depth sensing device **102**.

The embodiments described herein relate generally to workpiece inspection and, more particularly, to methods and systems for automated inspection of a workpiece. The embodiments described herein coordinate accurate and reliable systems and methods for workpiece inspection. More specifically, the embodiments described herein provide an automated method that facilitates reducing the human error component during workpiece inspection. A depth sensing device measures a distance for each pixel in its field of view and transmits the distance data to an inspection computer system. A pose detection system tracks the position and orientation of the depth sensing device with respect to the workpiece and transmits the positioning to the inspection computer system. Using a model of the workpiece stored on the inspection computer system, the system generates a model view of the model workpiece, wherein the model view tracks the actual view seen by the depth sensing device in real-time or near real-time. The inspection computer system then compares the actual distance seen by the depth sensing device with the model distance calculated on the inspection computer system, and creates an alert if the difference in distances exceeds a predetermined threshold. The inspection computer system may also generate a display to illustrate to a user which section of the workpiece caused the alert. Human error is substantially reduced by the embodiments described herein. Moreover, the inspection system enables measurement of both large and small workpieces, as well as a workpiece with limited physical accessibility. The embodiments described herein also facilitate reducing inspection times of costly manual inspections.

Exemplary embodiments of methods and systems for workpiece inspection systems are described above in detail. The methods and systems are not limited to the specific embodiments described herein, but rather, components of systems and/or steps of the method may be utilized independently and separately from other components and/or steps described herein. Each method step and each component may also be used in combination with other method steps and/or components. Although specific features of various embodiments may be shown in some drawings and not in others, this is for convenience only. Any feature of a drawing may be referenced and/or claimed in combination with any feature of any other drawing.

This written description uses examples to disclose the embodiments, including the best mode, and also to enable any person skilled in the art to practice the embodiments, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the disclosure is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal language of the claims.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A method for inspecting a workpiece, said method comprising:

inputting model data associated with the workpiece in an inspection system;

determining a relative position of a depth sensing device relative to the workpiece;

calibrating a position and orientation (pose) view for the inspection system relative to the model based on the position of the depth sensing device relative to the workpiece;

measuring actual depth distance data of at least one pixel in a field of view of the depth sensing device relative to the workpiece; and

determining, based on the actual depth distance data, if the workpiece satisfies predetermined inspection criteria, wherein determining if the workpiece satisfies predetermined criteria comprises:

calculating model depth distance data for the pose view of the inspection system, wherein model depth distance data represents a model depth distance from the pose view of the inspection system to the model workpiece;

determining whether the actual depth distance differs from the model depth distance; and

determining whether the difference satisfies the inspection criteria when the actual depth distance differs from the model depth distance, wherein compliance with a threshold indicates the workpiece is in acceptable condition.

2. A method in accordance with Claim **1**, wherein inputting the model data comprises inputting computer aided design model data associated with the workpiece.

3. A method in accordance with Claim **1**, wherein inputting the model data comprises inputting a previously scanned model of the workpiece.

4. A method in accordance with Claim **1**, wherein determining the relative position of the depth sensing device comprises:

defining a coordinate system origin at a designated position of the workpiece; and

determining a location of the depth sensing device relative to the workpiece using a plurality of position-detecting cameras.

5. A method in accordance with Claim **1**, further comprising transmitting the location of the depth sensing device to the inspection system.

6. A method in accordance with Claim **1**, wherein measuring actual depth distance includes moving the depth sensing device about the workpiece to capture a plurality of actual depth distances, said method further comprising:

comparing the plurality of actual depth distances to a plurality of associated model depth distances to identify non-equivalent portions.

7. A method in accordance with Claim **1**, further comprising displaying a portion of the workpiece that is not present in the model workpiece using an overlay applied to a view of the depth sensing device.

8. A method in accordance with Claim **7**, wherein the overlay is configured to illustrate a presence of at least one of foreign object debris, a missing component, an assembly error, and a damaged component.

9. A method in accordance with Claim **1**, wherein measuring the actual depth distance data further comprises generating a three-dimensional point cloud.

10. A system for inspecting a workpiece, said system comprising:

a depth sensing device configured to measure actual depth distance data of at least one pixel in a field of view of the depth sensing device relative to the workpiece;

a position and orientation (pose) detection system configured to determine a relative position of the depth sensing device relative to the workpiece; and

an inspection computer system in communication with the depth sensing device and the pose detection system, the inspection computer system programmed to:

input model data associated with the workpiece;

calibrate a pose view for the inspection computer system relative to the model based on the position of the depth sensing device relative to the workpiece; and

determine, based on the actual depth distance data, if the workpiece satisfies predetermined inspection criteria, wherein the inspection computer system is further programmed to:

calculate model depth distance data for the pose view of the inspection computer system, wherein the model depth distance data represents a model depth distance from the pose view of the inspection computer system to the model workpiece;

determine whether the actual depth distance differs from the model depth distance; and

determine whether the difference satisfies the inspection criteria when the actual depth distance differs from the model depth distance, wherein compliance with a threshold indicates the workpiece is in acceptable condition.

11. A system in accordance with Claim **10**, wherein to input model data, the inspection computer system is further programmed to input a previously scanned model of the workpiece.

12. A system in accordance with Claim **10**, wherein the inspection computer system is configured to display a portion of the workpiece that is not present in the model workpiece using an overlay applied to a view of the depth sensing device.

13. A system in accordance with Claim **13,** wherein the overlay is displayed in one of real-time and near real-time.

14. A computer system for inspecting a workpiece, said computer system comprising:

a processor; and

a computer-readable storage device having encoded thereon computer readable instructions that are executable by the processor to perform functions comprising:

storing model data associated with the workpiece in the storage device;

determining a relative position of a depth sensing device relative to the workpiece;

calibrating a position and orientation (pose) view for the computer system relative to the model based on the position of the depth sensing device relative to the workpiece;

measuring actual depth distance data of at least one pixel in a field of view of the depth sensing device relative to the workpiece; and

determining, based on the actual depth distance data, if the workpiece satisfies predetermined inspection criteria, wherein determining if the workpiece satisfies predetermined inspection criteria further comprises:

calculating model depth distance data for the pose view of the computer system, wherein the model depth distance data represents a model depth distance from the pose view of the computer system to the model workpiece;

determining whether the actual depth distance differs from the model depth distance; and

determining whether the difference satisfies the inspection criteria when the actual depth distance differs from the model depth distance, wherein compliance with a threshold indicates the workpiece is in acceptable condition.

15. A computer system in accordance with claim **14**, wherein storing model data, the functions performed by the processor further comprise storing at least one of computer aided design model data associated with the workpiece and a previously scanned model of the workpiece.

16. A computer system in accordance with claim **14**, wherein the functions performed by the processor further comprise displaying a portion of the workpiece that is not present in the model workpiece using an overlay applied to a view of the depth sensing device.

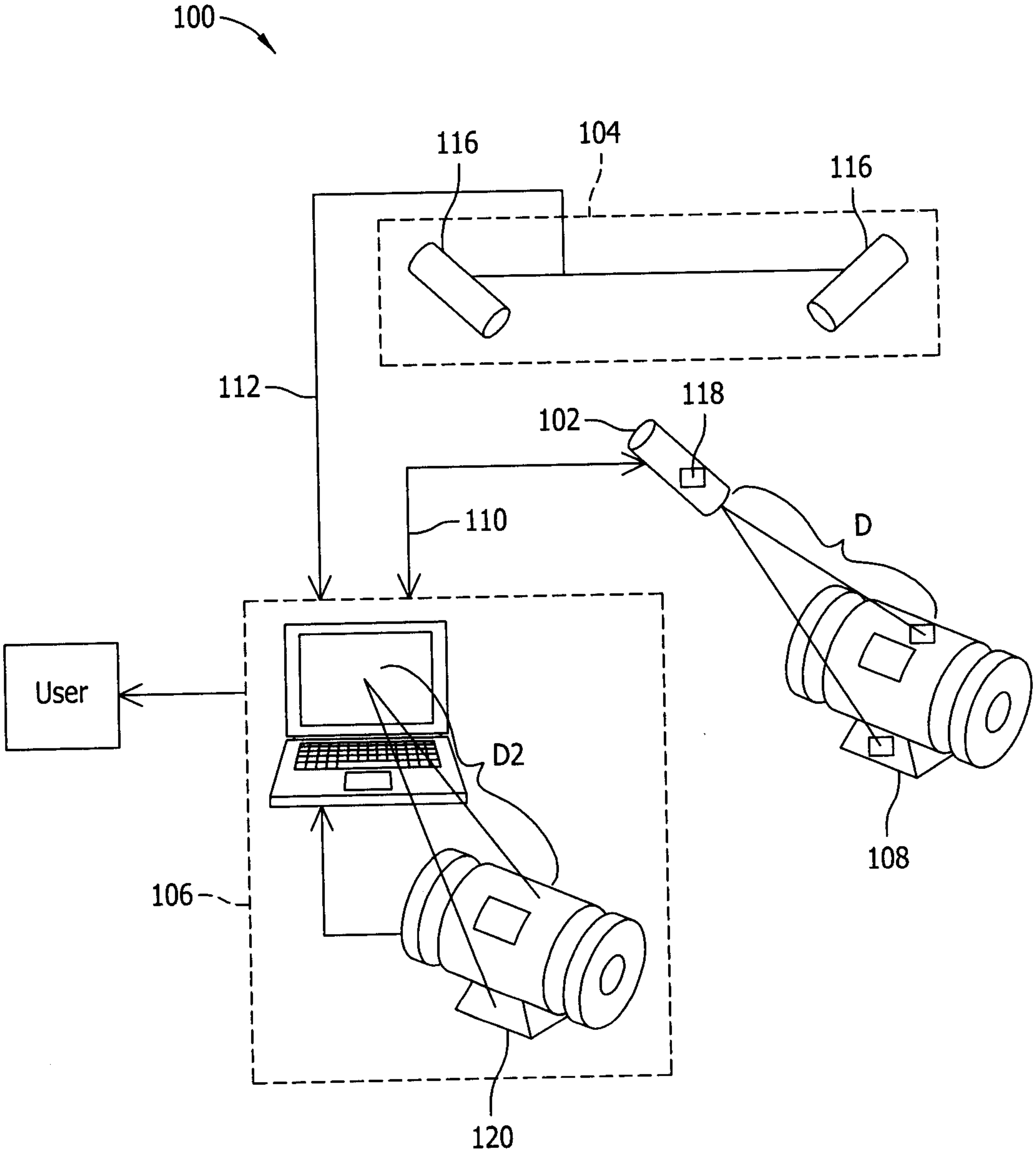


FIG. 1

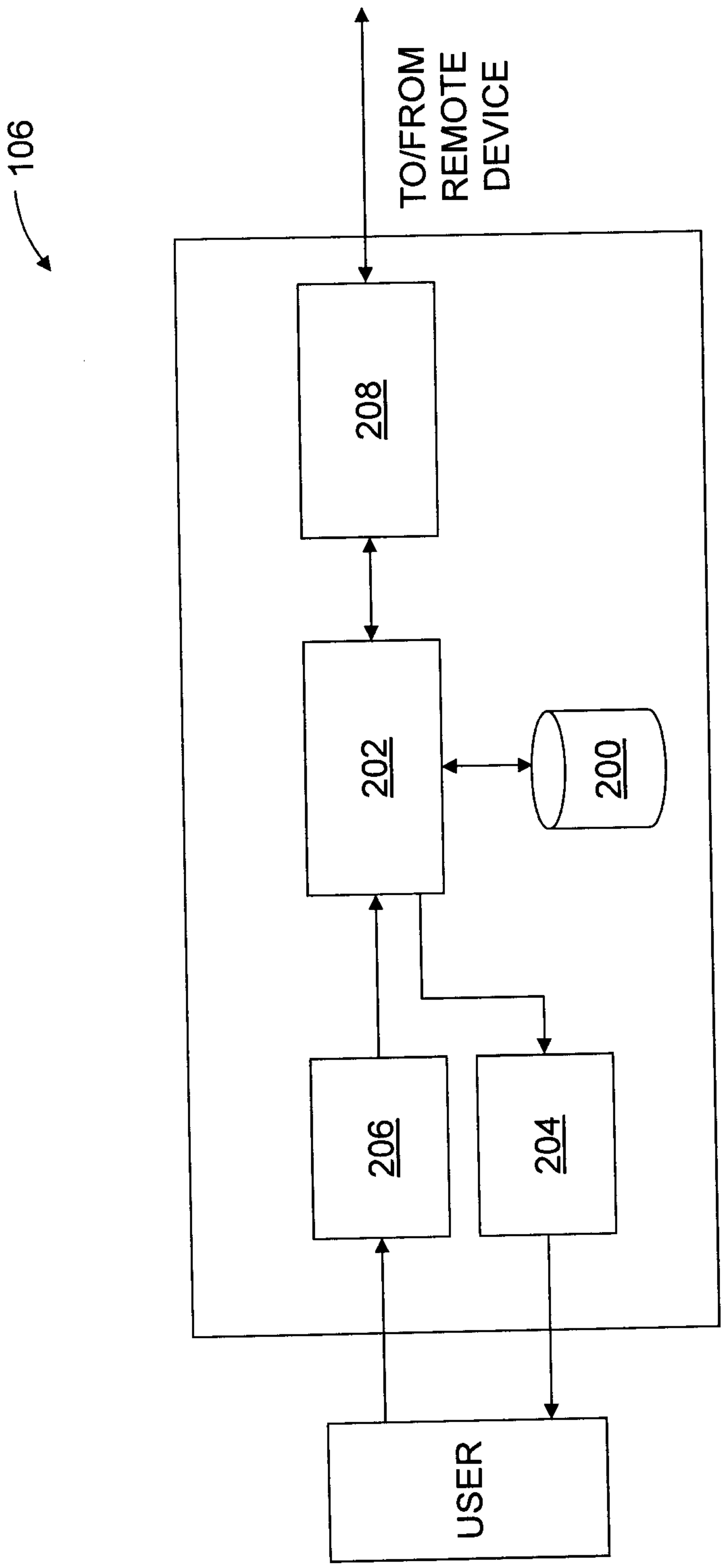
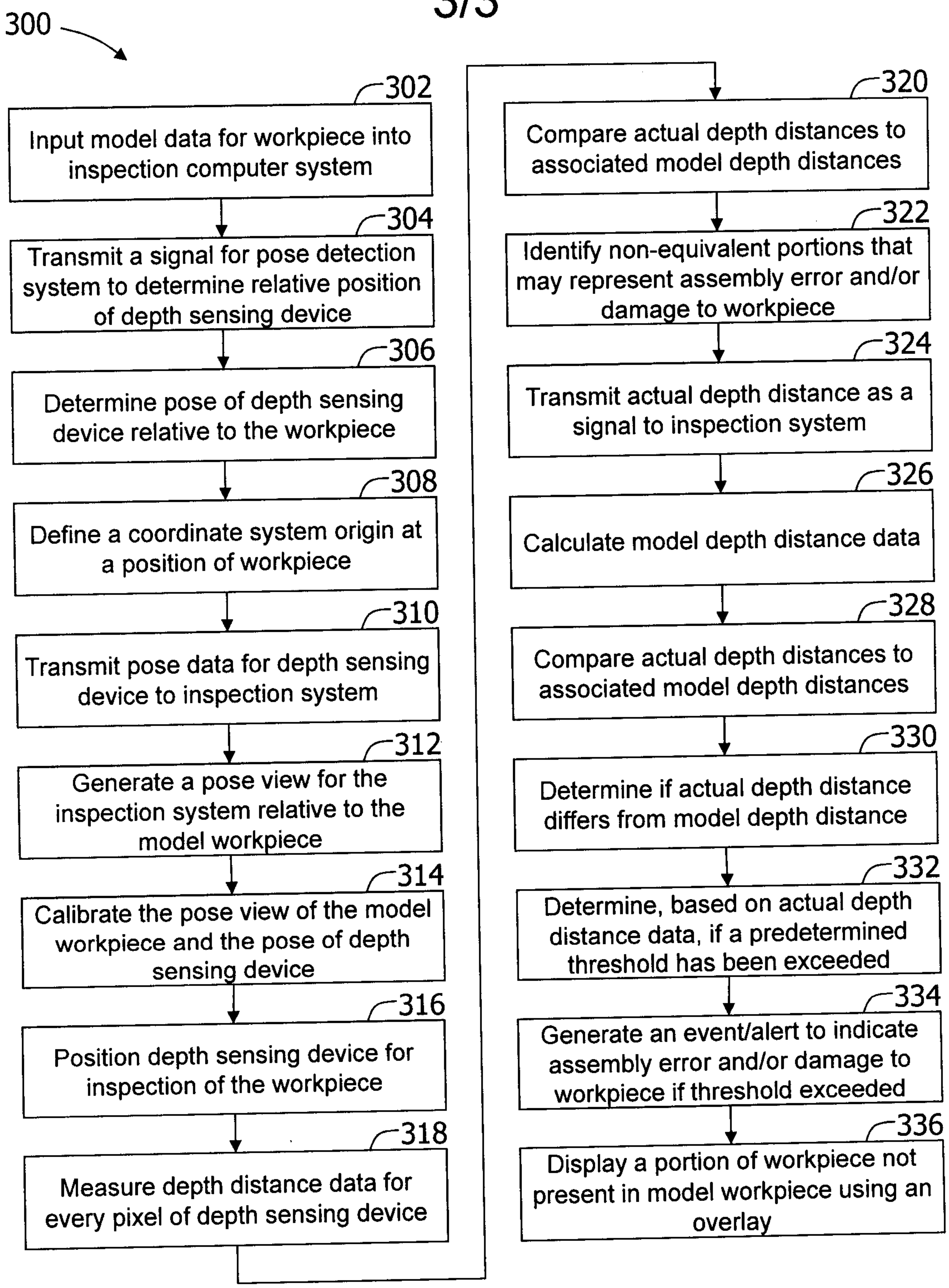


FIG. 2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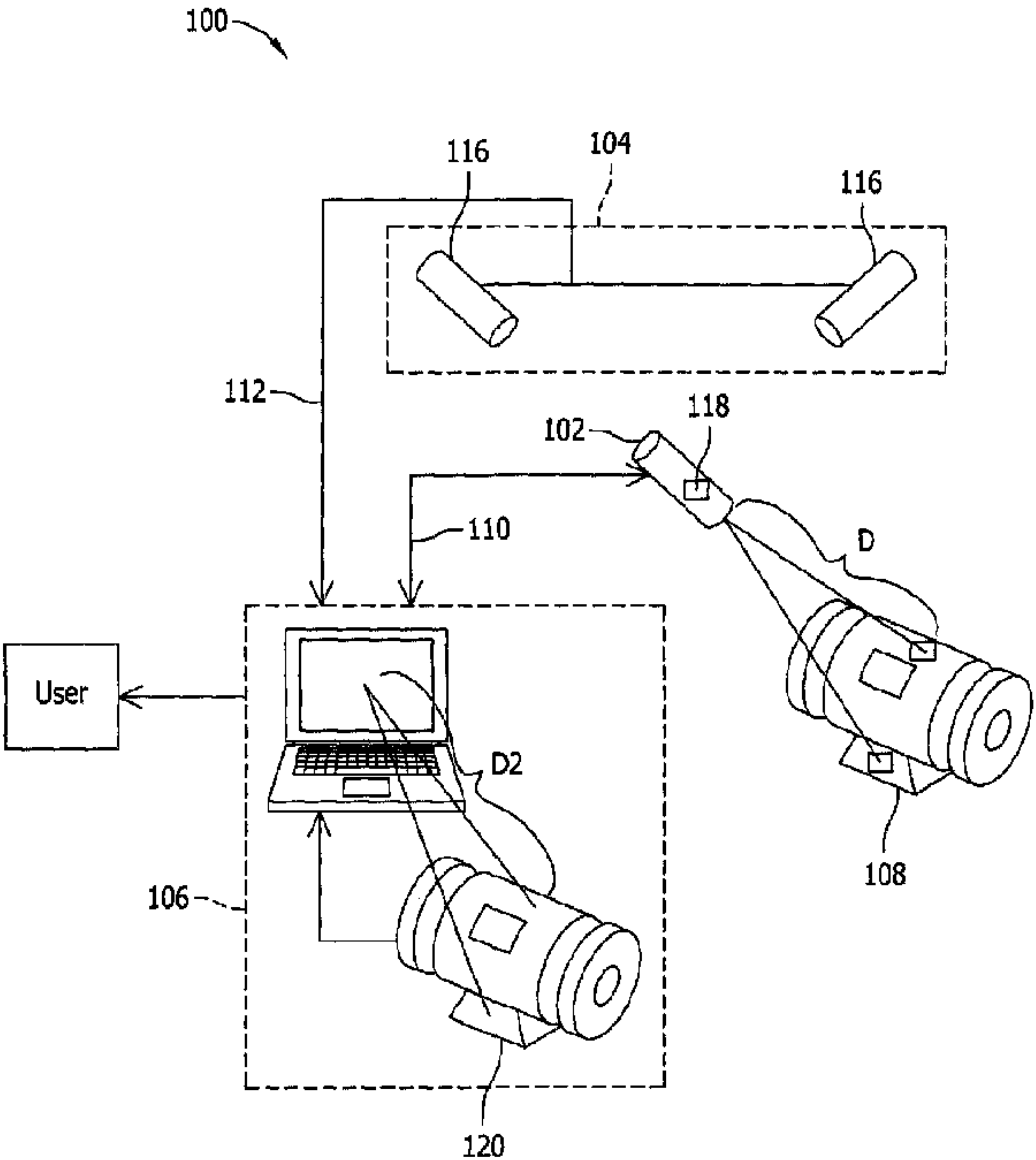
Input model data for workpiece into inspection computer system
304
Transmit a signal for pose detection system to determine relative position of depth sensing device
306
Determine pose of depth sensing device relative to the workpiece
308
Define a coordinate system origin at a position of workpiece
310
Transmit pose data for depth sensing device to inspection system
312
Generate a pose view for the inspection system relative to the model workpiece
314
Calibrate the pose view of the model workpiece and the pose of depth sensing device
316
Position depth sensing device for inspection of the workpiece
318
Measure depth distance data for every pixel of depth sensing device
320
Compare actual depth distances to associated model depth distances
322
Identify non-equivalent portions that may represent assembly error and/or damage to workpiece
324
Transmit actual depth distance as a signal to inspection system
326
Calculate model depth distance data
328
Compare actual depth distances to associated model depth distances
330
Determine if actual depth distance differs from model depth distance
332
Determine, based on actual depth distance data, if a predetermined threshold has been exceeded
334
Generate an event/alert to indicate assembly error and/or damage to workpiece if threshold exceeded
336
Display a portion of workpiece not present in model workpiece using an overlay

FIG. 3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