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### Noncontact thermometry systems and methods

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#### Abstract

A method of determining a temperature of a patient includes determining that a temperature measurement device is located within at least one of a distance range and an alignment range of a portion of a measurement site of the patient, providing an indication to a user of the device that the device is located within the at least one of the distance range and the alignment range, and determining, with the device, a first temperature of a first location on the portion of the measurement site without contacting the patient with the device. Such a method also includes determining, with the device, a second temperature of a second location on the portion of the measurement site without contacting the patient with the device, wherein the second location is different from the first location. Such a method further includes determining a third temperature of the patient based on the first and second temperatures.

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## Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS (1) This application is a continuation of U.S. application Ser. No. 15/692,222, filed Aug. 31, 2017, which is a continuation of U.S.

application Ser. No. 15/162,078, filed May 23, 2016, now U.S. Pat. No. 9,750,414, which is a continuation of U.S. application Ser. No. 14/218,710, filed Mar. 18, 2014, now U.S. Pat. No. 9,375,149. The entire disclosures of each of the above applications are incorporated herein by reference.

## FIELD OF THE INVENTION

(1) The present disclosure relates to systems and methods for temperature determination and, in particular, to systems and methods for determining a patient's core temperature.

## BACKGROUND OF THE INVENTION

(2) Temperature is an important vital sign in patient evaluation. Physicians commonly use a variety of methods for determining patient temperature including, for example, obtaining temperature measurements with a thermometer. While thermometers utilizing mercury have been in existence for many years, modern thermometers typically employ one or more electronic sensors configured to measure patient temperature. Such sensors may take one or more measurements over a relatively short period of time. Based on these measurements, the thermometer may generate an estimated internal and/or core temperature of the patient.

(3) Existing non-contact thermometers typically employ a sensing element configured to measure the temperature of, for example, the patient's forehead, temple, and/or other external body surfaces without contacting these surfaces, and to estimate the patient's core temperature based on such measurements. Such non-contact thermometers are described in co-owned U.S. patent application Ser. No. 13/450,446, the entire disclosure of which is incorporated herein by reference. While the accuracy of measurements taken with existing non-contact thermometers is highly dependent upon the distance and alignment of the device relative to the external body surface, such thermometers are typically not configured to assist the user in properly orienting the device prior to measurement. Thus, measurements taken with such devices are prone to significant error, and existing non-contact thermometers are not highly reliable as a means of patient evaluation.

(4) The example embodiments of the present disclosure are directed toward overcoming at least the deficiencies described above.

## SUMMARY

(5) In an example embodiment of the present disclosure, a method of determining a temperature of a patient includes determining that a temperature measurement device is located within at least one of a distance range and an alignment range of a first portion of a measurement site of the patient, providing an indication to a user of the device that the device is located within the at least one of the distance range and the alignment range, and determining, with the device, a first temperature of a first location on at least one of the first portion and a second portion of the measurement site, without contacting the patient with the device. Such a method also includes determining, with the device, a second temperature of a second location on at least one of the first portion and the second portion of the measurement site, without contacting the patient with the device, wherein the second location is different from the first location. Such a method further includes determining a third temperature of the patient based on the first and second temperatures.

(6) In another embodiment of the present disclosure, a temperature measurement device includes a first sensor configured to determine that the device is located within at least one of a distance range and an alignment range of a first portion of a measurement site of a patient, and at least one additional sensor configured to determine a first temperature of a first location on at least one of the first portion and a second portion of the measurement site and a second temperature of a second location on at least one of the first portion and the second portion of the measurement site. In such a device, the at least one additional sensor determines the first and second temperatures without contacting the patient, and the first and second temperatures are determined in response to the first sensor determining that the device is located within the at least one of the distance range and the alignment range. Such a device further includes a controller in communication with the first sensor

and the at least one additional sensor. The controller is programmed to determine a third temperature of the patient based on the first and second temperatures.

(7) In still another embodiment of the present disclosure, a method of manufacturing a temperature measurement device includes providing a first sensor configured to determine that the device is located within at least one of a distance range and an alignment range of a first portion of a measurement site of a patient, and providing at least one additional sensor configured to determine a first temperature of a first location on at least one of the first portion and a second portion of the measurement site and a second temperature of a second location on at least one of the first portion and the second portion of the measurement site. In such device the at least one additional sensor determines the first and second temperatures without contacting the patient, and the first and second temperatures are determined in response to the first sensor determining that the device is located within the at least one of the distance range and the alignment range. Such a method also includes providing a controller in communication with the first sensor and the at least one additional sensor, and programming the controller to determine a third temperature of the patient based on the first and second temperatures.

(8) In yet another example embodiment, a method of determining a temperature of a patient includes determining that a temperature measurement device is located within at least one of a distance range and an alignment range of a portion of a measurement site of the patient, providing an indication to a user of the device that the device is located within the at least one of the distance range and the alignment range, and determining, with the device, a temperature from an inner-canthal region of the patient, without contacting the patient with the device. The method also includes determining a core temperature of the patient based on the temperature.

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## Description

### BRIEF DESCRIPTION OF THE DRAWINGS

(1) FIG. 1 illustrates a temperature measurement system according to an example embodiment of the present disclosure.

(2) FIG. 2 illustrates a first view of an example temperature measurement device associated with the system shown in FIG. 1.

(3) FIG. 3 illustrates a second view of the temperature measurement device shown in FIG. 2.

(4) FIG. 4 illustrates a third view of the temperature measurement device shown in FIG. 2.

(5) FIG. 5 is a schematic diagram illustrating various positions of an example temperature measurement device relative to a plane.

(6) FIG. 6 is another schematic diagram illustrating various positions of an example temperature measurement device relative to a plane.

(7) FIG. 7 illustrates a flowchart outlining an example method of use associated with the present disclosure.

### DETAILED DESCRIPTION

(8) FIG. 1 illustrates an example temperature measurement system **100** of the present disclosure including a temperature measurement device **10**. The temperature measurement device **10** of the system **100** may include a first sensor **12** configured to determine that the device **10** is located within a predetermined and/or desired distance range of a patient **14**. Such a distance range may be characterized by a distance  $D$ , and the distance range and/or the distance  $D$  may extend from a plane A substantially defined by the device **10** to a plane B substantially defined by the patient **14**. For example, as will be described in greater detail below, such a distance range may extend from the plane A to a plane B substantially defined by at least a portion **34** of the face of the patient **14**. In still further examples, such a distance range may extend from the plane A to a plane B substantially defined by any other portion and/or “measurement site” formed by an external surface

of the patient's skin, such as the face, forehead, temple, ears (such as the outer or inner ear), eyes, nose, lips, neck, wrist, chin, open mouth, and/or other like skin surfaces. Such measurement sites may also include the oral cavity, rectal cavity, axilla area, ear drum, groin, sub-clavian, and/or other known body cavities or areas. In example embodiments, the plane B may comprise and/or be substantially parallel to a coronal plane of the patient **14**. Additionally, the plane B may extend substantially parallel to a spinal axis E of the patient **14**.

(9) As shown in FIG. **1**, the temperature measurement device **10** may also include an imaging device **16** configured to assist in forming an image of the patient **14**, and at least one additional sensor **18a . . . 18n** (collectively, “sensors **18**”) separate from the first sensor **12** and the imaging device **16**. In example embodiments, the sensors **18** may be configured to determine respective temperatures of locations **36a . . . 36n** (collectively, “locations **36**”) on the portion **34** of the face and/or any of the other measurement sites described herein. In some embodiments, the sensors **18** may comprise non-contact temperature sensors configured to determine the respective temperatures without contacting the patient **14**, the locations **36**, and/or other measurement sites. For ease of description, and without limiting the extent of the present disclosure, such temperature determinations will be described herein with respect to the face of the patient **14** unless otherwise specified.

(10) Additionally, the temperature measurement device **10** may include one or more displays **20**, signal devices **22**, user interfaces **24**, and/or communication devices **26**. Further, one or more components of the temperature measurement device **10** may be in communication with and/or otherwise connected to a controller **30** of the device **10** and/or memory **32** associated with the controller **30**. One or more components of the temperature measurement device **10** may also be in communication with and/or otherwise connected to one or more remote components **28** of the system **100**, and such remote components **28** may include one or more controllers, additional temperature measurement devices, servers, computers, databases, displays, hand-held devices, tablet devices, cellular phones, and the like. In such embodiments, the one or more components of the temperature measurement device **10** may communicate with such remote components **28** via the communication device **26**.

(11) Whenever possible, like item numbers will be used throughout this disclosure to identify like components of the temperature system **100**. Additionally, as will be described herein, the described implementations of the present technology in the temperature measurement device **10** are merely examples. The disclosed technology may be applicable to any other medical device that may use one or more sensors to calculate, estimate, look-up, measure, sense, monitor, and/or otherwise “determine” a temperature of a patient **14**. Such a temperature may include a temperature of a measurement site of the patient **14**, and such temperatures may comprise surface or skin temperatures of the patient **14** at the measurement site. Additionally, such a temperature may include any internal temperature of the patient **14**, such as a sub-skull temperature, a rectal temperature, an oral temperature, an axillary temperature, a “core” temperature, and/or any other like temperature of the patient **14**. Additionally, the device **10** and/or one or more sensors thereof may be configured to determine other indicators of patient health such as vaso-dilation, an emerging fever, a diminishing fever, and the like. Such indicators may be determined, for example, based at least in part on one or more of the temperatures determined by the sensors **18**. Such medical devices may include, for example, probes, scopes, and/or other like contact-based and/or noncontact-based devices.

(12) The temperature measurement device **10** of example system **100** may comprise, for example, a hand-held device having a first side **38** and a second side **40** opposite the first side **38**. Although not shown in FIG. **1**, in some embodiments the device **10** may include a handle or other like component configured to assist the user in holding, manipulating, and/or orienting the device **10** relative to the patient **14**. Alternatively, as shown in FIG. **1**, the device **10** may be substantially rectangular, substantially square, and/or any other known shape. In example embodiments, the

thickness (i.e., the distance between the first side and the second side) and/or the length of the device **10** may be minimized so as to improve the ergonomics of the device **10**. Although not expressly labeled in FIG. **1**, the device **10** may include a one-piece or multi-piece housing and/or other like components, and corners and/or edges of the device **10** may be sufficiently rounded and/or otherwise configured so as not to cause injury to the patient **14** or the user upon contact therewith. Further, the housing and/or other components of the device **10** may be made from any material and/or combinations of materials commonly used in medical and/or examination devices. Such materials may include, for example, plastics, polymers, composites, stainless steel, alloys, and/or any other like materials. Such materials may be suitable for repeated use and/or repeated sanitation. Accordingly, in an example embodiment of the present disclosure, the temperature measurement device **10** and/or its components may be substantially waterproof. One or more waterproof seals may be included and/or otherwise utilized with components of the temperature measurement device **10** to facilitate such repeated sanitation and/or use.

(13) In an example embodiment, the first sensor **12** may comprise a proximity sensor and/or other like device configured to determine a distance between the sensor **12** and one or more objects disposed in the vicinity of the sensor **12** without contacting the object. Such a sensor **12** may also be configured to determine the length, width, height, angular orientation, and/or other dimension or orientation of such objects relative to the sensor **12**. Such dimensions may include, for example, a height H of an ear of the patient **14**, the height and/or width of a nose of the patient **14**, the distance between the eyes of the patient **14**, an inner-canthal distance, and/or any other like dimension. Such dimensions may also include, for example, a distance between various locations **36** on the portion **34** of the patient's face or on an additional measurement site. Such dimensions may be used to determine, for example, the age, gender, ethnicity, and/or other characteristics of the patient **14**.

(14) In example embodiments, the first sensor **12** may be configured to determine whether and/or when the first sensor **12** (and, consequently, the temperature measurement device **10**) is within a desired distance range of the object. Such a distance range may correspond to, for example, a field of view of the first sensor **12**, and as noted above, an example distance range may be characterized by the distance D illustrated in FIG. **1**. Such proximity sensors may include, for example, an inductive sensor, a magnetic sensor, an infrared sensor, a capacitive photoelectric sensor, a sonic distance sensor, and/or any other like proximity sensor known in the art. In such embodiments, the first sensor **12** may emit an electromagnetic field or beam of electromagnetic (such as infrared) radiation. Such a field or beam may impinge upon the object and at least a portion of the field of beam may return to the first sensor **12**. In such embodiments, the first sensor **12** may determine a change in the field or return beam, and may determine the distance D between the first sensor **12** and the object based on the determined change. In such embodiments, the first sensor **12** may comprise a plurality of components including, for example, an emitter, a receiver, and/or other like sensing devices. Such an example first sensor **12** is further illustrated in FIG. **3**.

(15) As shown in at least FIGS. **1** and **3**, in an example embodiment the first sensor **12** may be disposed such that at least one of an emitter, receiver, and/or other component of the first sensor **12** is disposed substantially coplanar with the first side **38**. In such embodiments, the first side **38** may be substantially coplanar with the plane A, and at least a portion of the first sensor **12** may also be substantially coplanar with the plane A. As shown in FIG. **1**, the distance range may extend from the plane A to the plane B. As noted above, the plane B may be substantially defined by the portion **34** of the face of the patient **14**, and the portion **34** of the face may comprise an inner-canthal region, a sinus region, a temple region, a cheek region, and/or other region of the face. As shown in at least FIG. **1**, portion **34** of the face defining the inner-canthal region may comprise a region of the face including the tear ducts. For example, such a region of the face may extend from approximately the nose of the patient **14** to at least a portion of each eye (such as a corner of each eye), and may include at least a portion of the sinus region and/or upper cheek. The locations **36** on the portion **34** may comprise particular points, areas, and/or other identifiable locations within the

specified region. In further example embodiments, however, the plane B may be substantially defined by any of the alternative measurement sites described herein. In example embodiments, the distance range described herein with respect to the first sensor **12** may be less than approximately 24 inches. For example, the distance range characterized by the distance D may be between approximately 0.01 inches and approximately 24 inches, or alternatively between approximately 6 inches and approximately 14 inches. It is understood that the first sensor may be tuned, focused, and/or otherwise configured to employ a distance range that is not overly intrusive to the patient **14** while the device **10** is being used to determine a temperature of the patient **14**. Further, minimizing the distance range may result in an increase in the accuracy of the patient temperature determined by the device **10**.

(16) The imaging device **16** may comprise, for example, one or more digital cameras, infrared sensors, and/or other like devices configured to assist in generating an image of the patient **14**. For example, the imaging device **16** may comprise a digital camera operably connected to the controller **30** and/or the display **20**, and the imaging device **16** may be configured to capture an image of the measurement site and/or other portions of the patient **14**. Alternatively or in addition, the imaging device **16** may be configured to collect thermal, infrared, and/or other radiation emitted by the patient **14**, and to assist in forming a thermal image of the patient **14** using and/or based on the collected radiation. In such example embodiments, the imaging device **16** may be configured to send information and/or signals to the controller **30** and/or the display **20**, and the display **20** may display an image of the patient **14** using and/or based on such signals.

(17) In example embodiments, the controller **30** may include components such as an image processor and/or image processing software configured to receive information and/or signals from the imaging device **16**. The image processor may be configured to assist in forming the image of the patient **14** based on such inputs. For example, in embodiments in which the imaging device **16** comprises a digital camera, the image processor may receive information and/or signals from the imaging device **16**, and may assist in forming a visual image of the patient **14** based on such inputs. As shown in FIG. 2, such a visual image **42** may be illustrated on the display **20** of the temperature measurement device **10**.

(18) Alternatively, in embodiments in which the imaging device **16** is configured to collect thermal, infrared, and/or other radiation emitted by the patient, the image processor may receive information and/or signals from the imaging device **16** indicative of such collected radiation. In such embodiments, the image processor may assist in forming a thermal image (not shown) of the patient **14** based on such inputs. Similar to the visual image **42** described above, the thermal image may be illustrated on the display **20**, and such a thermal image may comprise a two or three-dimensional image, temperature gradient, and/or temperature profile of the patient **14**.

(19) In example embodiments, the temperature measurement device **10** may be configured to determine one or more physical attributes of the patient **14**, and the controller **30** may be configured to automatically select an operating mode of the device **10** based on the determined attribute. For example, the imaging device **16**, the first sensor **12**, and/or one or more of the images described herein may be used by the image processor and/or other components of the controller **30** to determine a distance between a first location **36a** on the portion **34** of the face of the patient **14** and a second location **36b** on the portion **34**, a distance between at least one of the first and second locations **36a**, **36b** and a third location **36c** on the face of the patient **14**, a length, width, height, and/or other dimension related to an ear (such as the height H shown in FIG. 1), nose, eye, cheek, chin, and/or other body part of the patient **14**, and/or other like attributes. One or more such attributes may be used to determine, for example, the age, gender, ethnicity, and/or other characteristics of the patient **14**, and the controller **30** may automatically select one or more temperature algorithms, lookup tables, neural networks, and/or other like temperature determination components or protocols for use based on such a determination.

(20) For example, upon initial screening of the patient **14**, the imaging device **16** may assist in



generating a digital image **42** of the patient **14**. Additionally, the first sensor **12** may determine one or more distances associated with the patient **14**, such as a distance from the center of the pupil of the left eye of the patient **14** to the center of the pupil of the right eye of the patient **14**. Alternatively, the distance from the corner of the left eye to the corner of the right eye may be determined. In still further embodiments, the height H (e.g., top to bottom) of the patient's ear may be determined. The imaging device **16** and/or the first sensor **12** may send corresponding information and/or signals to the image processor and/or other components of the controller **30**, and such components may determine an age range of the patient **14** based on such inputs. For instance, based on one or more such inputs, the components may determine whether the patient **14** is an infant, an adolescent youth, or an adult. Upon making such a determination, the controller **30** may select a corresponding operating mode of the device **10** based on the determination. In such embodiments, selecting such an operating mode may comprise selecting a set of temperature determination algorithms for use in core temperature determinations associated with the patient **14**. It is also understood that the controller **30** may select such an operating mode based at least partially on the determined distance and/or other attributes of the patient **14** without making further determinations as to, for example, the age, gender, ethnicity, and/or other characteristics of the patient **14**. Additionally, one or more of the determined attributes and/or characteristics may be illustrated on the display **20** separately and/or as part of the image **42**. Further, as will be described in more detail below, the controller **30** may select an output type (e.g., providing a temperature based on an axillary reference for pediatric patients, etc.) based at least in part on the determined distance and/or any of the above characteristics of the patient **14**.

(21) The sensors **18** may comprise any devices configured to sense one or more vital signs or physical characteristics of a patient such as, for example, temperature, blood pressure, blood oxygen saturation (hereinafter “SpO<sub>2</sub>”), heart rate, and the like. In an example embodiment, at least one of the sensors **18** may comprise a temperature sensor, such as a thermopile, thermocouple, and/or thermistor, configured to determine a temperature associated with the patient **14**. For example, each of the sensors **18** may be configured to determine a temperature of respective locations **36** on the portion **34** of the face of the patient **14**. Alternatively, each of the sensors **18** may be configured to determine a temperature of other respective measurement sites of the patient **14**. It is understood that in some example embodiments, determining a temperature of the patient **14** with the temperature measurement device **10** may include contacting one or more patient measurement sites with the temperature measurement device **10** and/or with at least a portion of one or more of the sensors **18**. Alternatively, in other example embodiments, a temperature of the patient **14**, such as a core temperature of the patient **14**, may be determined without contacting the measurement site and/or other portions of the patient **14** with the device **10** or with the sensors **18** associated therewith. For the duration of the disclosure, such noncontact temperature determination methods will be described in greater detail unless otherwise specified.

(22) In example embodiments, one or more of the sensors **18** may comprise an infrared temperature sensor such as, for example, a thermopile and/or other like infrared-based temperature sensing devices. In still further embodiments, one or more of the sensors **18** may comprise an array of pixels and/or other like sensing elements configured to determine a temperature of the various measurement sites described herein. Such sensors **18** may be configured to convert thermal energy into electrical energy, and may comprise two or more thermocouples connected in series or in parallel. Such components may be configured to generate an output voltage proportional to a local temperature difference and/or temperature gradient. In an example embodiment in which one or more of the sensors **18** comprises at least one thermopile, the temperature measurement device **10** may comprise, for example, an infrared thermometer. In such embodiments, the sensors **18** may be configured to receive and/or emit radiation, such as thermal and/or infrared radiation. For example, the sensors **18** may be configured to sense, detect, collect, and/or otherwise receive radiation emitted by the measurement site, such as, by respective locations **36** on the portion **34** of the face of

the patient **14**. In such embodiments, the sensors **18** may be configured to collect the radiation, and to send a signal to the controller **30** indicative of the collected radiation. For example, a first sensor **18a** may be configured to collect radiation from a first location **36a**, and a second sensor **18b** may be configured to collect radiation from a second location **36b**. In this way, the first sensor **18a** may be configured to determine a temperature of the first location **18a** while the second sensor **18b** may be configured to determine a temperature of the second location **36b**. The controller **30** may utilize the information received from the sensors **18** for any number of known functions. For example, the controller **30** may be configured to determine a core temperature of the patient **14** based on such information and/or on one or more additional inputs.

(23) As shown in at least FIGS. **1** and **3**, one or more of the sensors **18** may be embedded substantially within and/or formed integrally with the device **10**, and at least a portion of at least one of the sensors **18** may be disposed substantially coplanar with the first side **38** and/or with the plane A. Additionally, each of the sensors **18** may have a respective field of view **19a** . . . **19n** (collectively referred to as “fields of view **19**”) that is characterized by a respective angle  $\Theta$ , . . .  $\Theta_{\text{sub}.n}$  (collectively referred to as “angles  $\Theta$ ”). For example, such fields of view **19** may be substantially conical, substantially cylindrical, and/or any other three-dimensional shape, and may extend from each respective sensor **18a** . . . **18n** to the measurement site. Such fields of view **19** may be characterized by any desirable angles  $\Theta$  commonly associated with the sensors **18**. For example, such fields of view **19** may be characterized by angles  $\Theta$  less than approximately 20 degrees, and in some embodiments, by angles  $\Theta$  between approximately 5 degrees and approximately 15 degrees. In such embodiments, the fields of view **19** may define the range and/or area of sensitivity for the corresponding sensors **18**. For example, objects disposed within the field of view **19a** of the first sensor **18a** may be detected and/or sensed by the sensor **18a**, and the sensor **18a** may not be capable of sensing objects disposed outside of the field of view **19a**. Similarly, objects disposed within the field of view **19b** of the second sensor **18b** may be detected and/or sensed by the second sensor **18b**, and the sensor **18b** may not be capable of sensing objects disposed outside of the field of view **19b**.

(24) Additionally, such fields of view **19** may have any length commensurate with the noncontact sensors **18** described herein, and the length of such fields of view **19** may extend to and/or otherwise be characterized by the distance D illustrated in at least FIGS. **1** and **4**. In such embodiments, objects located at a distance less than or substantially equal to the distance D (i.e., within the fields of view **19a**, **19b** of the sensors **18a**, **18b**) may be detected and/or sensed by the sensors **18a**, **18b**, while objects located at a distance greater than the distance D (i.e., outside of the fields of view **19a**, **19b** of the sensors **18a**, **18b**) may not be detected and/or sensed by the sensors **18a**, **18b**. Accordingly, in example embodiments the first sensor **12** may be configured to determine that at least one of the first location **36a** is within the field of view **19a** of the sensor **18a** and the second location **36b** is within the field of view **19b** of the sensor **18b**. In example embodiments, determining that the temperature measurement device **10** is located within a desired distance range of the portion **34** of the face of the patient **14** may include determining at least one of the first location **36a** is within the field of view **19a** of the sensor **18a** and the second location **36b** is within the field of view **19b** of the sensor **18b**. In such embodiments, the first sensor **12** may be tuned such that the field of view thereof (i.e., the desired distance range characterized by the distance D) corresponds to and/or otherwise has a length substantially equal to the lengths of the fields of view **19** of the sensors **18**. It is understood that in further embodiments, more than one distance may be determined by the first sensor **12** in order to determine whether, for example, the temperature measurement device **10** is located within a desired distance range of the portion **34**. In such embodiments, the first sensor **12** may determine a respective distance between the locations **36a**, **36b** and each of the respective sensors **18a**, **18b** to whether at least one of the first location **36a** is within the field of view **19a** of the sensor **18a** and the second location **36b** is within the field of view **19b** of the sensor **18b**. In still further embodiments, the device **10** may include two or more

first sensors **12** to facilitate determining multiple distances. In such embodiments, one sensor **12** may be configured to determine a distance between the location **36a** and the sensor **18a**, while an additional sensor **12** may be configured to determine a distance between the location **36b** and the sensor **18b**.

(25) The first sensor **12** may provide one or more signals to the controller **30** indicating that at least one of the locations **36a**, **36b** is within a corresponding field of view **19a**, **19b** of a respective sensor **18a**, **18b**, and the controller **30** may assist in providing one or more indications **44a**, **44b**, **44c** (collectively referred to herein as “indications **44**”) to the user of the device in response to such signals from the first sensor **12**. Such indications **44** may include audible, visible, and/or tactile indications, and example indications **44** are shown in at least FIG. 2 as being illustrated in the image **42** of the patient **14** shown on the display **20**. For instance, a first indication **44a** may comprise a visible box, circle, window, and/or other marker overlaying the first location **36a** in the image **42** of the patient **14**, and a second indication **44b** may comprise a visible box, circle, window, and/or other marker overlaying the second location **36b** in the image **42**. In such embodiments, the first indication **44a** may be indicative of the first location **36a** being disposed within the field of view **19a** of the first sensor **18a** and the second indication **44b** may be indicative of the second location **36b** being disposed within the field of view **19b** of the second sensor **18b**. Example embodiments may also include additional indications **44c** comprising one or more visible boxes, circles, windows, and/or other markers generally overlaying at least part of the face of the patient **14** in the image **42**. In still further embodiments, such indications **44** may include text, symbols, graphics, and/or other like notations in the image **42** indicating that the device **10** is oriented and/or located such that the locations **36** are disposed within the respective fields of view **19**. In example embodiments, such indications **44** may not be shown in the image **42** until the device **10** is oriented and/or located as described above.

(26) It is understood that such indications **44** may be useful in prompting input from a user of the device **10**. For example, upon hearing, feeling, and/or viewing such indications **44**, the user may provide one or more inputs via the display **20** and/or one or more of the user interfaces **24**. For example, upon viewing one or more of the indications **44a**, **44b** indicative of the locations **36a**, **36b** being disposed within the fields of view **19a**, **19b** of the respective sensors **18a**, **18b**, a user of the temperature measurement device **10** may actuate one of the user interfaces **24** to activate one or more of the sensors **18**. Alternatively, in exemplary embodiments in which the display **20** comprises a touch screen or other like device configured to accept input, the user may touch and/or otherwise interact with the display **20** to activate one or more of the sensors **18**. In any of the embodiments described herein, the temperature measurement device **10** may determine the temperature of the first location **36a**, the temperature of the second location **36b**, and/or the core temperature of the patient **14** in response to input received by the user. Alternatively, the temperature measurement device **10** may determine one or more of the above temperatures automatically (i.e., without receiving input from the user) upon determining that the device **10** is located within the distance range of the portion **34** of the face. The temperature measurement device **10** may also determine one or more of the above temperatures automatically (i.e., without receiving input from the user) upon determining that one or more of the locations **36** is disposed within or more of the fields of view **19** described above. In example embodiments, the controller **30**, image processor, and/or the image processing software associated therewith may automatically activate one or more of the sensors **18** to determine respective temperatures in response to, for example, determining that the device **10** is located within the distance range of the portion **34** of the face. In still further embodiments, the remote component **28** of the system **100** may employ such image processing software and may be operable to automatically activate one or more of the sensors **18** to determine respective temperatures in a similar fashion.

(27) It is also understood that such indications **44** may be indicative of one or more additional alignment parameters associated with the device **10** and/or one or more of the sensors **12**, **18**, and

such alignment parameters are illustrated in at least FIGS. 1 and 4-6. For example, such alignment parameters may include the distance range described above with respect to the distance D.

Additionally, the first sensor 12 may comprise one or more gyroscopes, accelerometers, and/or other components configured to determine an angular position of the temperature measurement device 10 relative to another object. For example, the sensor 12 may be configured to determine the magnitude of one or more angles formed between the temperature measurement device 10 and the plane B substantially defined by the portion 34 of the face and/or other measurement sites of the patient 14. In example embodiments, such angles may be formed between the plane B and at least one of the sensor 12, the plane A, and the first surface 38, and any of the angles described herein may comprise additional alignment parameters determined by the sensor 12.

(28) With respect to the embodiment shown in the top view of FIG. 5, such angles  $\alpha_{\text{sub.a}}-\alpha_{\text{sub.c}}$  may be formed by, for example, rotating and/or otherwise moving the temperature measurement device 10 from side to side about an axis C. In such embodiments, the axis C may be substantially parallel to the spinal axis E, and may extend along and/or within the plane B. In example embodiments, the sensors 18 may have a preferred angular alignment range F within which the accuracy of temperature determinations made by the sensors 18 may be optimized. Such a preferred angular alignment range F may comprise an additional alignment parameter of the present disclosure, and the first sensor 12 may be configured to determine when the sensors 18, and the temperature measurement device 10 generally, are located within the preferred angular alignment range F relative to the portion 34 of the face and/or relative to respective locations 36 on the portion 34. Additionally, one or more of the indications 44 described above may be provided to the user of the device 10 in response to determining that the temperature measurement device 10 is located within the preferred angular alignment range F.

(29) Such angles  $\alpha_{\text{sub.a}}-\alpha_{\text{sub.c}}$  may be formed between the plane B and a normal line extending substantially perpendicularly from the plane A, the first side 38, and/or the sensor 12 through the axis C. When, for example, the sensor 12 and/or the temperature measurement device 10 is disposed substantially parallel to the plane B, an angle  $\alpha_{\text{sub.a}}$  equal to approximately 90 degrees may be formed between the plane B and the normal line. Alternatively, rotating the temperature measurement device 10 about the axis C, such as by rotating the temperature measurement device 10 about the face of the patient 14, may increase (angle  $\alpha_{\text{sub.c}}$ ) or decrease (angle  $\alpha_{\text{cm}}$ ) the magnitude of the angle  $\alpha$  formed between the normal line and the plane B. In example embodiments, the sensors 18 may determine temperatures of the respective locations 36 when the temperature measurement device 10 is disposed substantially parallel to the portion 34 of the face (i.e., when the angle  $\alpha_{\text{sub.a}}$  formed between the plane B and the normal line is equal to approximately 90 degrees). It is understood, however, that temperature determinations made by the sensors 18 may also have an acceptable accuracy for some applications when the angle  $\alpha$  is within the preferred angular alignment range F. Such a preferred angular alignment range F for the angle  $\alpha$  may be between approximately 75 degrees and approximately 105 degrees. The accuracy of such temperature determinations may be considered “acceptable” when the temperature measured using the sensors 18 is within approximately 10 percent of a corresponding temperature measured using one or more additional sensors (not shown) via patient contact.

(30) As shown in the side view of FIG. 6, rotating the temperature measurement device 10 about an axis I may result in angles  $\mu_{\text{sub.a}}-\mu_{\text{sub.c}}$  formed between the plane B and the normal line extending substantially perpendicularly from the first side 38, plane A, and/or the first sensor 12 through the axis I. In such embodiments, the axis I may extend substantially perpendicular to the axis C described above, and may extend along and/or substantially within the plane B. When the sensor 12 and/or the temperature measurement device 10 is disposed substantially parallel to the plane B, an angle  $\mu_{\text{sub.a}}$  equal to approximately 90 degrees may be formed between the plane B and the normal line. Alternatively, rotating the temperature measurement device 10 about the axis I, such as by rotating the temperature measurement device 10 from the forehead to the chin of the

patient **14**, may increase (angle  $\mu$ .sub.c) or decrease (angle  $\mu$ .sub.b) the magnitude of the angle  $\mu$  formed between the normal line and the plane B. In additional example embodiments, the angle  $\mu$  described herein may comprise a further alignment parameter associated with the temperature measurement device **10**.

(31) In example embodiments, the sensors **18** may determine respective temperatures of the locations **36** when the temperature measurement device **10** is disposed substantially parallel to the portion **34** (i.e., when the angle  $\mu$ .sub.a formed between the plane B and the normal line is equal to approximately 90 degrees). It is understood, however, that temperature determinations made by the sensors **18** may also have an acceptable accuracy for some applications when the angle  $\mu$  is within a preferred angular alignment range G. Such a preferred angular alignment range G for the angle  $\mu$  may be between approximately 75 degrees and approximately 105 degrees. As described above, the accuracy of such temperature determinations may be considered “acceptable” when the temperature measured using the sensors **18** is within approximately 10 percent of a corresponding temperature measured using one or more additional sensors (not shown) via patient contact.

(32) The temperature measurement device **10** may additionally include at least one window, lens, filter, and/or other like optical component (not shown) positioned proximate one or more of the sensors **12**, **18**, and/or the imaging device **16**. For example, such an optical component may be disposed substantially flush and/or coplanar with the first side **38** of the device **10**. Such optical components may be configured to assist in, for example, focusing, directing, and/or otherwise transmitting radiation to the sensors **12**, **18**, and/or the imaging device **16** for collection. In additional example embodiments, such optical components may assist in focusing, directing, and/or otherwise transmitting radiation emitted by one or more of sensors **12**, **18**. Such optical components may also assist in protecting the thermopile, thermocouple, thermistor, photo sensors, and/or other components of the sensors **12**, **18**, and/or the imaging device **16** during use of the temperature measurement device **10**, and may assist in forming a substantially fluid-tight compartment (not shown) within the device **10** to protect such components from contact with bodily fluids, cleaning solutions, and/or other liquids. It is understood that such optical components may be substantially transparent to assist in the transmission of infrared and/or other types of radiation. In example embodiments, the optical components may comprise one or more convergent, collimating, and/or divergent lenses. Additionally, in such embodiments at least a component of at least one of the sensors **12**, **18** and/or at least a component of the controller **30** may be disposed within the substantially fluid-tight compartment.

(33) In further example embodiments, the temperature measurement device **10** may include one or more actuation devices (not shown) associated with one or more of the sensors **12**, **18**, and/or the imaging device **16**. Such actuation devices may be operably connected to the controller **30** and may be configured to move the sensors **12**, **18**, and/or the imaging device **16** relative to the temperature measurement device **10**. For example, in the embodiment shown in FIG. 1 such actuation devices may be configured to pivot the sensors **12**, **18**, and/or the imaging device **16** relative to the first side **38** and/or any other portion of the temperature measurement device **10**. In such an example embodiment, the one or more actuation devices may be configured to pivot the sensors **12**, **18**, and/or the imaging device **16** about a longitudinal axis L of the temperature measurement device **10** extending substantially parallel to the plane A from a top of the device **10** to a bottom thereof. In further example embodiments, such actuation devices may be configured to move the sensors **12**, **18**, and/or the imaging device **16** longitudinally (i.e., along the longitudinal axis L) and/or laterally (i.e., transverse to the longitudinal axis L) along the first side **38** of the temperature measurement device **10**.

(34) The example actuation devices described above may comprise any electric motor, servo motor, and/or other known device configured to assist in moving one or more components of the sensors **12**, **18**, and/or the imaging device **16** relative to the device **10**. Accordingly, it may be possible to form any of the angles  $\alpha$ ,  $\mu$  described herein with respect to FIGS. 5 and 6 through activation of

one or more such actuation devices while maintaining the position of the temperature measurement device **10** substantially stationary with respect to the plane B and/or the patient **14**. Additionally and/or alternatively, in further embodiments at least one of the sensors **12**, **18** and/or the imaging device may be positioned at an angle relative to, for example, the first side **38**. For example, at least one of the sensors **18** may be angled toward an axis X extending substantially perpendicular from the longitudinal axis L and/or the first side **38**. Such an example axis X is shown in FIGS. **1** and **4**. In such examples, at least one of the sensors **18** may be angled inward and/or otherwise aimed toward the eyes and/or the inner-canthal region of the face of the patient **14**. Additionally, in any of the examples described herein, one or more of the sensors **12**, **18** and/or the imaging device **16** may be moveable in order to maintain focus on the respective locations **36** as, for example, the patient **14** and/or the temperature measurement device **10** is moved. One or more of the sensors **12**, **18** and/or the imaging device **16** may also be moveable in response to and/or based on the determination of one or more physical attributes of the patient **14**. Such physical attributes will be described in greater detail below.

(35) As discussed above, and as illustrated in at least FIGS. **1** and **2**, the temperature measurement device **10** may include one or more displays **20**. An example display **20** may be operably connected to the controller **30** and/or to the image processor thereof. The display **20** may comprise, for example, a liquid crystal display (LCD) screen, a light emitting diode (LED) display, a digital read-out, an interactive touch-screen, and/or any other like components configured to communicate information to the user or to control the temperature measurement device **10**. In addition to the various indications **44** described herein, as shown in FIG. **2**, such displays **20** may be configured to indicate, for example, one or more distances **46a**, such as the distance D associated with the distance range and/or fields of view **19** described herein. Such displays **20** may also be configured to indicate temperatures **46b** determined by the sensors **18**, and one or more temperatures **46c**, such as a core temperature of the patient **14**, determined based on signals received from one or more of the sensors **18**. Although FIG. **2** illustrates the temperatures **46b**, **46c** being shown in separate respective windows on the display **20**, in further example embodiments, one or more of the temperatures **46b**, **46c**, such as the temperatures determined by the sensors **18**, may be shown on the display **20** within corresponding respective indications **44a**, **44b**, or elsewhere on a corresponding location **36** of the face. Additionally, such displays **20** may be configured to indicate an ambient temperature **46d** associated with the environment in which the device **10** is being used, the name, age, gender, and/or any other information **46e** that may be useful during operation of the temperature measurement device **10**. For example, the display **20** may also be configured to communicate information indicative of the angles  $\alpha$ ,  $\mu$ , fields of view **19**, and/or other alignment parameters described herein. The display **20** may also be configured to communicate information indicative of additional physical characteristics of the patient **14** including but not limited to disease state, injury, and emotional state. The display **20** may be configured to communicate such information substantially simultaneously and/or substantially continuously depending on the mode of operation of the temperature measurement device **10**.

(36) With continued reference to FIGS. **1** and **2**, example signal devices **22** of the temperature measurement device **10** may include, for example, one or more lights, LEDs, speakers, and/or other like devices configured to emit an audible and/or visible alarm or signal in response to a command or signal from the controller **30**. Such an alarm or other signal may be initiated by, for example, the controller **30** when a temperature determined by the temperature measurement device **10** meets or exceeds a threshold temperature. In additional example embodiments, such an alarm or signal may be initiated during a substantially continuous temperature determination operation where the rate of patient temperature change meets or exceeds a predetermined temperature change rate threshold.

(37) In further example embodiments, such an alarm or signal may be initiated and/or otherwise communicated to a user of the temperature measurement device **10** based on one or more of the alignment parameters described herein. For example, the signal device **22** may be configured to

output information indicative of one or more such alignment parameters to assist the user in positioning the temperature measurement device **10** and/or the sensors **18** relative to the patient **14**. In example embodiments, the signal device **22** may output an audible alarm, signal, and/or other indication indicating that the temperature measurement device **10** and/or the sensors **18** are disposed outside of the angular alignment ranges F, G and/or the fields of view **19** described herein. Alternatively, the signal device **22** may be configured to output an audible alarm, signal, and/or other indication indicating when the temperature measurement device **10** and/or the sensors **18** have been positioned within the angular alignment ranges F, G and/or the fields of view **19** described herein.

(38) In each of the example embodiments described herein, one or more of the signal device **22** and the display **20** may be configured to request and/or direct movement of the patient **14** relative to the temperature measurement device **10**, or vice versa. In such embodiments, for example, the signal device **22** and/or the display **20** may output one or more audible and/or visual signals or requests informing the user where to position the patient **14** or the device **10**. Such requests may comprise, for example, one or more visual alignment beams, visual images, and/or audible communications/instructions indicating a desired movement of the device **10** relative to a substantially stationary patient **14**. In still further embodiments, such requests may comprise visual instructions including one or more of the indications **44** described above.

(39) The one or more user interfaces **24** of the temperature measurement device **10** may be configured to assist in initiating, performing, and/or controlling one or more functions of the temperature measurement device **10**. For example, the user interfaces **24** may comprise any combination of switches, buttons, levers, knobs, dials, keys, and/or other like components configured to activate, deactivate, manipulate, and/or otherwise control components of the temperature measurement device **10**. Such user interfaces **24** may, for example, assist the user in toggling through and/or selecting one or more modes of operation of the temperature measurement device **10**, enabling and/or disabling one or more sensors **12**, **18**, imaging devices **16**, alarms, and/or signal devices **22** associated with the device **10**, initiating a single substantially instantaneous temperature determination, initiating a substantially continuous and/or repeating temperature determination, and/or other like modes, functions, or operations. Accordingly, one or more user interfaces **24** may be operably connected to at least one of the sensors **12**, **18**, the imaging device **16**, the display, **20**, and/or other components of the temperature measurement device **10**. In an example embodiment, at least one of the user interfaces **24** may be embedded substantially within and/or otherwise formed integrally with the device **10** and/or a housing thereof. Additionally, in embodiments in which the display **20** comprises a touch screen, one or more of the user interfaces **24** may be omitted.

(40) The communication device **26** of the temperature measurement device **10** may include one or more transmitters, receivers, transceivers and/or other like communication components configured to send information to and/or receive information from the remote component **28**. In such example embodiments, the temperature measurement device **10** may be configured to send and/or receive any of the information described herein with regard to the display **20**, sensors **12**, **18**, imaging device **16**, and/or other components of the temperature measurement device **10** via such communication devices **26**. In such embodiments, a communication device **26** of the temperature measurement device **10** may be configured to send and/or receive such information to the remote component **28** of the system **100** wirelessly via BLUETOOTH®, WIFI®, cellular networks, internet networks, or other like means. Such a communication device **26** may be disposed at any convenient location on the temperature measurement device **10**, and in additional embodiments, such a communication device **26** may be disposed partially and/or completely internal to the temperature measurement device **10**. Such remote components **28** may be disposed at a different location in the same examination room as the device **10**, in a different examination room and/or other location within the same healthcare facility as the device **10**, or in an entirely different

healthcare facility than the device **10**. Accordingly, the communication device **26** may facilitate communication between a local temperature measurement device **10** and a remote component **28** via any of the means described above depending on the relative locations of the device **10** and the remote component **28**.

(41) The controller **30** may be operably connected to the user interfaces **24**, display **20**, sensors **12**, **18**, imaging device **16**, communication device **26**, and/or other components of the temperature measurement device **10**, and the controller **30** may be configured to control the operation of such components. In an example embodiment, the controller **30** may be configured to receive signals, information, measurements, and/or other data from the sensors **12**, **18** and/or the imaging device **16**, and to determine a temperature value indicative of a core temperature of the patient **14** based on the information received. The controller **30** may also be configured to execute one or more commands and/or control programs. In addition to the image processor described above, the controller **30** may comprise memory **32**, additional processors, and/or other known controller components to facilitate the functionality described herein. In an example embodiment, the controller **30** may be disposed within, for example, the housing of the temperature measurement device **10**. In such an embodiment, the housing may form one or more substantially water-tight and/or substantially hermetically sealed compartments for storing the various components of the controller **30**.

(42) The example temperature measurement system **100** described herein may be utilized by physicians, nurses, health care professionals, and/or other users in a variety of different environments. For example, the temperature measurement device **10** may be employed in any of a number of examination facilities to determine one or more temperatures associated with a patient **14** such as, for example, an estimated core temperature of the patient **14**. Such an estimated core temperature may be utilized by the health care professional to assist in treating the patient **14**, and may have a variety of uses that are well known in the medical field.

(43) In example embodiments, the temperature measurement devices **10** disclosed herein may be configured to determine patient temperature and/or other physical characteristics of the patient **14** using one or more contact-based and/or noncontact-based methods of patient evaluation. For ease of description, a noncontact-based method of temperature determination will be described with respect to the flowchart **200** shown in FIG. 7.

(44) In an example method of determining a temperature of a patient **14**, the controller **30** and/or the first sensor **12** of the temperature measurement device **10** may, at step: **202** determine whether the device **10** is located within the distance range described above with respect to the portion **34** of the face of the patient **14**. As shown in at least FIG. 1, such a distance range may be characterized by the distance **D** extending from the plane **B** substantially defined by the portion **34** of the face, or any of the other measurement sites described herein, to the plane **A** substantially defined by the temperature measurement device **10**. Such a determination may comprise a proximity determination. In particular, the distance range characterized by the distance **D** may correspond to and/or may be substantially equivalent to the length of the fields of view **19** associated with the sensors **18**. Accordingly, determining at step: **202** that the temperature measurement device **10** is located within such a distance range may comprise determining that the portion **34** of the face and/or locations **36** on the portion **34** of the face are disposed within a field of view **19a . . . 19n** of at least one of the sensors **18**.

(45) In example embodiments, determining that the temperature measurement device **10** is located within such a distance range at step: **202** may include the first sensor **12** emitting a beam and/or a field of infrared radiation, at least a portion of which impinges on the portion **34** of the face. The first sensor **12** may also collect at least a portion of such emitted radiation, and may determine the distance **D** between, for example, the first sensor **12** and the plane **B** based on the collected radiation. The first sensor **12** may also provide one or more signals to the controller **30** indicative of the collected radiation and/or of the corresponding distance **D**. Alternatively and/or in addition, at



step: **202** any other metric or process may be used by the controller **30** to determine whether the device **10** is within an acceptable sensing range and/or field of view of the sensors **18**. For example, instead of determining the distance  $D$  between the first sensor **12** and the plane **B** at step: **202**, the imaging device **16** may be utilized to capture one or more images of the face of the patient. The imaging device **16** may send one or more signals to the controller **30** containing information indicative of the image, and the controller **30** and/or the image processors associated therewith may determine whether the device **10** is within a field of view of the sensors **18** based on such information. For instance, if the image processors are able to identify one or more portions of the face, such as one or more of the locations **36**, the controller **30** may determine that the device **10** has been properly positioned relative to the patient **14** to determine surface temperatures of the locations **36**.

(46) At step: **204**, the controller **30** and/or the first sensor **12** may determine whether the temperature measurement device **10** is disposed within one or more alignment ranges relative to the plane **B**, and such alignment ranges may include one or more of the preferred angular alignment ranges  $F$ ,  $G$  described above. For example, the first sensor **12** may determine whether the device **10** is disposed between a minimum angle  $\alpha_{\text{sub.b}}$  and a maximum angle  $\alpha_{\text{sub.c}}$  defined by the plane **B** and a line normal to the plane **A**. Such angles  $\alpha_{\text{sub.a}}$ ,  $\alpha_{\text{sub.c}}$  are described above with respect to the top view shown in FIG. **5**. Additionally, the first sensor **12** may determine whether the device **10** is disposed between a minimum angle  $\mu_{\text{sub.b}}$  and a maximum angle  $\mu_{\text{sub.c}}$  defined by the plane **B** and a line normal to the plane **A**. Such angles  $\mu_{\text{sub.a}}$ ,  $\mu_{\text{sub.c}}$  are described above with respect to the side view shown in FIG. **6**. Further, as noted above, such angles  $\alpha$ ,  $\mu$  may further define the fields of view **19** of the sensors **18**, and the plane **B** may be substantially defined by any of the measurement sites described herein. Thus, determining that the temperature measurement device **10** is within one or more of the alignment ranges  $F$ ,  $G$  at step: **204** may comprise a further confirmation that at least one of the first location **36a** is disposed within the field of view **19a** of the sensor **18a**, and that the second location **36b** is disposed within the field of view **19b** of the sensor **18b**. It is understood that the determinations made at step: **204** may be made by the first sensor **12** and/or the controller **30** substantially simultaneously with the determinations made at step: **202**.

(47) In example embodiments, the imaging device **16** and/or the controller **30** may assist in generating a visual and/or thermal image of the patient **14**, and such an image **42** may be displayed by the display **20** of the temperature measurement device **10**. Such an image **42** may be displayed on the display **20** before, during, and/or after the determinations described above with respect to steps: **202**, **204** have been made. Additionally, such an image **42** may comprise a real time image and/or video of the patient **14**, and the image **42** may be displayed on the display **20** throughout the various temperature determination methods described herein.

(48) At step: **206**, the display **20**, the signal device **22**, and/or the controller **30** may provide one or more indications to a user of the temperature measurement device **10** that the device **10** is located within the distance range described above with respect to step: **202**. At step: **206**, the display **20**, the signal device **22**, and/or the controller **30** may also provide one or more indications indicating that the temperature measurement device **10** is located within one or more of the alignment ranges  $F$ ,  $G$  described above with respect to step: **204**. As described above with respect to FIG. **3**, such indications may include, for example, a first visual indication **44a** substantially overlaying the first location **36a** on the portion **34** of the face shown in the image **42**, and a second visual indication **44b** substantially overlaying the second location **36b** on the portion **34**. In such embodiments, the image **42** may be displayed on the display **20** throughout the temperature determination methods described herein, and at least one of the indications **44** may be displayed in the image **42** in response to at least one of the determinations described above with respect to steps: **202**, **204**.

(49) One or more of the indications **44** described above may prompt the user of the device **10** to provide one or more inputs. For example, in embodiments in which one or more of the indications **44** is indicative of the device **10** being disposed at an acceptable distance  $D$  and/or within an

acceptable alignment range F, G relative to the patient **14** (i.e., relative to the plane B), the user may actuate one or more of the user interfaces **24** or the display **22** direct one or more of the sensors **18** to determine the temperatures of respective locations **36** on the portion **34** of the face. It is understood that such inputs may be provided via the display **20** in embodiments in which the display **20** comprises a touch screen. Alternatively, in further embodiments the sensors **18** may automatically determine the temperature of respective locations **36** on the portion **34** of the face in response to the determinations made at one or more of steps: **202**, **204**. In such embodiments, step: **208** may be omitted.

(50) At step: **210**, the first sensor **12** and/or the controller **30** may determine one or more physical attributes of the patient **14**. For example, at step: **210** the first sensor **12** may determine at least one of a distance between the first location **36a** and the second location **36b**, a distance between at least one of the first and second locations **36a**, **36b** and a third location **36c** on the face of the patient **14**, and one or more dimensions of the ear of the patient **14**, such as a height H of the ear. The first sensor **12** may provide one or more signals to the controller **30** indicative of one or more such distances and/or dimensions, and the controller **30** may determine one or more of the physical attributes of the patient **14** described above based on such signals. Additionally, the imaging device **16** may assist in generating the image **42** described above, and the controller **30** and/or the image processor thereof may utilize the image **42** to determine the physical attributes at step: **210**. It is understood that such physical attributes may be indicative of, for example, the age, gender, ethnicity, and/or other characteristics of the patient **14**. Further, the controller **30** may automatically select one or more operating modes of the temperature measurement device **10** based on the physical attribute determined at step: **210**. Selecting such an operating mode may include, for example, selecting one or more algorithms, neural networks, lookup tables, and/or other like components or protocols for use in determining a temperature of the patient **14**.

(51) For example, if the controller **30** determines, at step: **210**, that the patient **14** is an adult, the controller **30** may, in response to the determination, automatically utilize one or more temperature determination algorithms tailored toward treatment and/or diagnosis of adult patients. Alternatively, if the controller **30** determines that the patient **14** is a pediatric patient, the controller **30** may, in response to the determination, automatically utilize one or more temperature determination algorithms tailored toward treatment and/or diagnosis of pediatric patients. A similar “tailored” algorithm and/or process may be employed by the temperature measurement device **10** in response to the determination of patient gender and/or ethnicity. Accordingly, one or more temperatures of the patient **14**, such as a core temperature of the patient **14**, may be determined based on the operating mode selected by the controller **30**. Further, in such embodiments the controller **30** may automatically select an output type based on the one or more physical attributes determined at step: **210**. For example, upon determining that the patient **14** is a pediatric patient, the controller **30** may, in response, select one or more algorithms, neural networks, look-up tables, and/or other like protocols having an output comprising a temperature corresponding to an axillary temperature output. It is understood that the controller **30** may select such an output type (i.e., an axillary temperature) since axillary temperatures are standard when treating and/or monitoring pediatric patients. Further, in such embodiments the physical attribute of the patient **14** may be entered, selected, and/or otherwise provided by the user of the device **10** at step: **210**.

(52) At step: **212** at least one of the sensors **18**, such as the sensor **18a**, and/or the controller **30** may determine a first temperature corresponding to the first location **36a** on the portion **34** of the face of the patient **14**. Additionally, at step: **212** at least one of the sensors **18**, such as the sensor **18b**, and/or the controller **30** may determine a second temperature corresponding to the second location **36b** on the portion **34** of the face of the patient **14**. In an example embodiment, the first location **36a** may comprise a point or an area on the left inner-canthal region of the patient **14**, and the second location was **36b** may comprise a point or an area on the right inner-canthal region of the patient **14**. In example embodiments, the portion **34** of the face used to obtain the first and second

temperatures described herein may comprise a different measurement site than that used to determine at least one of the distance range and the angular alignment ranges F, G described above with respect to steps: **202** and **204**. For example, while the forehead of the patient **14** may be used for the distance range determination at step: **202**, locations **36** on the inner-canthal region and/or other like portions **34** of the face may be used for the temperature determinations at step: **212**. Additionally, in embodiments in which at least one of the sensors **18** comprises an infrared sensor, the sensors **18** may collect radiation emitted by the respective locations **36**, and may determine corresponding first and second temperatures based on such collected radiation. In such embodiments, the sensors **18** may determine the first and second temperatures at step: **212** without contacting the patient **14**. The sensors **18** may also provide one or more signals to the controller **30** indicative of the first and second temperatures determined at step: **212**.

(53) At step: **214**, the controller **30** may determine a third temperature of the patient **14** based on at least, for example, the first and second temperatures determined at step: **212**. Such a third temperature may comprise any of the temperatures described herein, and in some embodiments, the third temperature determined at step: **214** may comprise a core temperature. In some embodiments, the third temperature may also be determined based at least partially on, for example, one or more of the physical attributes determined at step: **210**. For example, at step: **214** at least one of the first and second temperatures may be utilized as inputs to one or more of the algorithms, neural networks, lookup tables, and/or other components selected based on the one or more physical attributes determined at step: **210**. At least one of the sensors **18** may also determine, for example, an ambient temperature of the environment in which the temperature measurement device **10** is being used. In such embodiments, the ambient temperature may also be utilized as an input to such components at step: **214**. In such embodiments, the third temperature determined at step: **214** may comprise an output of such components.

(54) In example embodiments, the controller **30** may assign an arithmetic bias and/or other like weight factor to one or both of the first and second temperatures and/or the ambient temperature. Such a weight factor may be indicative of, for example, a priority of one of the determined temperatures relative to the other determined temperature, and such a relative priority may be useful when determining the core temperature of the patient **14** at step: **214**. Such a weight factor may comprise, for example, a constant and/or other like coefficient associated with the one or more determined temperatures, and such coefficients may be part of a core temperature determination algorithm employed by the controller **30**. The controller **30** may determine and/or associate such a weight factor with one or more of the determined temperatures described herein by using one or more weight factor look-up tables and/or weight factor data maps stored in the memory **32** of the controller **30**. Moreover, the controller **30** may be configured to modify one of the determined temperatures based on the other determined temperature and the weight factor assigned and/or otherwise associated with at least one of the determined temperatures. Such a modification may be based on the weight factor associated with one or both of the determined temperatures, and such weight factors may be indicative of the relative correlation between such temperatures and the actual core temperature of the patient **14**. Moreover, such a modification may be performed by nature of the one or more algorithms employed to determine the core temperature of the patient **14**.

(55) At step: **214** the third temperature of the patient **14** may also be communicated to the user. For example, as shown in FIG. **3**, one or more of the first and second temperatures **46b**, the ambient temperature **46d**, and/or the core temperature **46c** may be shown on the display **20**. Additionally and/or alternatively, one or more such temperatures may be provided to one or more of the remote components **28** via the communication device **26** of the temperature measurement device **10**. It is understood that in some embodiments, one or more of the steps illustrated in FIG. **7** may be combined and/or performed in a different order. For example, it is understood that data including the first and second temperatures described above with respect to step: **212** and/or information related to the physical attributes discussed with respect to step: **210** may be collected during any of

the steps shown in FIG. 7. In still further embodiments, one or more of the steps illustrated in FIG. 7 may be omitted. For example, in further embodiments at least one of steps: **202** and **204** may be omitted without deviating from the various example temperature determinations described herein. (56) Such noncontact-based methods of temperature determination may be useful in a variety of applications. Such applications may include initial and/or patient intake screening, and situations in which the patient is uncooperative or unconscious. Such applications may also include situations in which temperature determination through traditional contact-based methods is outside of a designed temperature range of operation or may place the user at an elevated risk of contact with, for example, germs, viruses, contagious disease, patient bodily fluids, and/or other like substances or contaminants.

(57) Other embodiments of the present disclosure will be apparent to those skilled in the art from consideration of the specification and practice of the embodiments described herein. For example, in example embodiments the temperature measurement device **10** of the present disclosure may include one or more ports, connectors, terminals, and/or other like connection devices configured to enable communication between the temperature measurement device **10** and one or more separate devices. It is intended that the specification and examples be considered as example only, with a true scope and spirit of the present disclosure being indicated by the following claims.

## Claims

1. A method of manufacturing a medical device programmed to measure patient temperature, comprising: providing a first sensor configured to determine that the device is located within a predetermined alignment range relative to a measurement site of a patient; providing at least one additional sensor configured to determine a first temperature of a first location on the measurement site and a second temperature of a second location on the measurement site, wherein the at least one additional sensor determines the first and second temperatures without contacting the patient; providing a controller in communication with the first sensor and the at least one additional sensor; providing a display in communication with the controller, the display configured to display a visual image of the patient; and programming the controller to: cause the display to display the visual image of the patient, the visual image showing a face of the patient, and the first and second locations; determine, based on one or more signals received from the first sensor, whether the first and second locations are within a field of view of the at least one additional sensor; in response to determining that the first and second locations are within the field of view of the at least one additional sensor: cause the at least one additional sensor to determine the first and second temperatures, and cause the display to display an augmented visual image comprising real-time video of the face of the patient, the real-time video illustrating: a first skin surface of the face at the first location, a second skin surface of the face at the second location, a first indication overlaying the first location, and a second indication overlaying the second location and displayed together with the first indication, wherein: the first indication is displayed in the real-time video to indicate that the first location is within the field of view of the at least one additional sensor, and the second indication is displayed in the real-time video to indicate that the second location is within the field of view of the at least one additional sensor; and determine a third temperature of the patient based on the first and second temperatures.

2. The method of claim 1, wherein providing the at least one additional sensor comprises providing a first infrared sensor in communication with the controller and configured to determine the first temperature, and providing a second infrared sensor in communication with the controller separate from the first infrared sensor, the second infrared sensor configured to determine the second temperature.

3. The method of claim 1, further including providing a user interface in communication with the controller, the user interface configured to receive an input from a user of the device in response to

determining that the device is located within the predetermined alignment range, wherein the at least one additional sensor is configured to determine at least one of the first temperature and the second temperature in response to the input.

4. The method of claim 1, further comprising programming the controller so that the first and second indications are not shown in the visual image until the temperature measurement device is positioned such that the first and second locations are within the field of view of the at least one additional sensor.

5. The method of claim 4, wherein: the at least one additional sensor comprises a second sensor and a third sensor separate from the second sensor, the first indication indicates that the first location is within a first field of view of the second sensor, and the second indication indicates that the second location is within a second field of view of the third sensor.

6. The method of claim 1, wherein the display is configured to receive an input from the user in response to the first and second indications being displayed, and the controller is further programmed to cause the temperature measurement device to provide tactile feedback in response to determining that the first and second locations are within the field of view of the at least one additional sensor.

7. The method of claim 1, further including providing an imaging device in communication with at least one of the controller and the display, the imaging device being configured to assist in generating the visual image of the patient displayed on the display, the method further comprising programming the controller to: cause imaging device to capture a first image of the patient; determine a distance extending from a third location, on the patient, illustrated in the first image to a fourth location, on the patient, illustrated in the first image; and select an operating mode of the temperature measurement device based on the distance extending from the third location on the patient to the fourth location on the patient.

8. The method of claim 7, wherein the imaging device comprises a digital camera, and wherein selecting the operating mode comprises selecting a particular algorithm, from a plurality of algorithms configured to determine the third temperature, based on the distance.

9. The method of claim 7, wherein the third temperature comprises a core temperature of the patient, and selecting the operating mode comprises selecting at least one temperature determination algorithm configured to determine the core temperature, the method further comprising: programming the controller to select an output type based on the distance; programming the controller to determine the core temperature using the at least one temperature determination algorithm; and programming the controller to output the determined core temperature via the display and in accordance with the output type.

10. The method of claim 1, further comprising programming the controller to, in response to determining that the first and second locations are within the field of view of the at least one additional sensor, cause the display to further augment the augmented visual image by displaying a third indication surrounding the first and second indications in the real-time video, wherein: the first, second, and third indications are displayed together in the real-time video to indicate that the device is located within the predetermined alignment ranges, the first indication is displayed outside of the second indication, the second indication is displayed outside of the first indication, and the first, second, and third indications are not shown in the real-time video until the device is located within the predetermined alignment range relative to the measurement site.

11. The method of claim 7, wherein the distance extending from the third location on the patient to the fourth location on the patient comprises a distance from a center of a pupil of a left eye of the patient to a center of a pupil of the right eye of the patient.

12. The method of claim 7, wherein the distance extending from the third location on the patient to the fourth location on the patient comprises a distance from a corner of a left eye of the patient to a corner of the right eye of the patient.

13. The method of claim 7, wherein the distance extending from the third location on the patient to

the fourth location on the patient comprises a height of an ear of the patient.

14. The method of claim 1, the first and second indications maintaining respective fixed sizes and shapes while displayed irrespective of the first, second, and third temperatures.

15. The method of claim 14, wherein, when displayed in the real-time video, the first indication maintains a first fixed location, relative to the first location, irrespective of the first temperature, and the second indication maintains a second fixed location, relative to the second location, irrespective of the second temperature.

16. The method of claim 1, wherein the first indication comprises a first closed geometric shape surrounding the first location and having a first fixed size irrespective of the first temperature, and the second indication comprises a second closed geometric shape surrounding the second location and having a second fixed size irrespective of the second temperature.

17. The method of claim 1, wherein in the real-time video, the first indication is shown within a frame of the real-time video illustrating the face, and overlays the first location within the frame.

18. The method of claim 1, wherein the augmented visual image is displayed by the display as a component of a user interface including, together with the augmented visual image, a first value indicating the first temperature, a second value indicating the second temperature, and a third value indicating the third temperature.

19. The method of claim 18, wherein the user interface further includes, together with the augmented visual image, a fourth value indicating a distance extending from the temperature measurement device to the measurement site of the patient.

20. A method of manufacturing a medical device programmed to measure patient temperature, comprising: providing a first sensor configured to determine that the device is located within a predetermined alignment range relative to a measurement site of a patient; providing at least one additional sensor configured to determine a first temperature of a first location on the measurement site and a second temperature of a second location on the measurement site, wherein the at least one additional sensor determines the first and second temperatures without contacting the patient; providing a controller in communication with the first sensor and the at least one additional sensor; providing a display in communication with the controller, the display configured to display a visual image of the patient; and programming the controller to: cause the display to display the visual image of the patient, the visual image showing a face of the patient, and the first and second locations; determine, based on one or more signals received from the first sensor, whether the first and second locations are within a field of view of the at least one additional sensor; in response to determining that the first and second locations are within the field of view of the at least one additional sensor: cause the at least one additional sensor to determine the first and second temperatures, cause the display to display a first indication overlaying the first location within a frame of the visual image, and cause the display to display a second indication, separate from the first indication, overlaying the second location within the frame of the visual image; and determine a third temperature of the patient based on the first and second temperatures.

21. The method of claim 1, wherein the first indication comprises a visible box, a circle, or a window overlaying the first location.

22. The method of claim 1, wherein the first indication includes at least one of text, symbols, or graphics indicating that the temperature measurement device is oriented such that the first location is disposed within the field of view of the at least one additional sensor.

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