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(54) **SYSTEMS AND METHODS FOR DETECTING PHYSIOLOGICAL INFORMATION USING MULTI-MODAL SENSORS**

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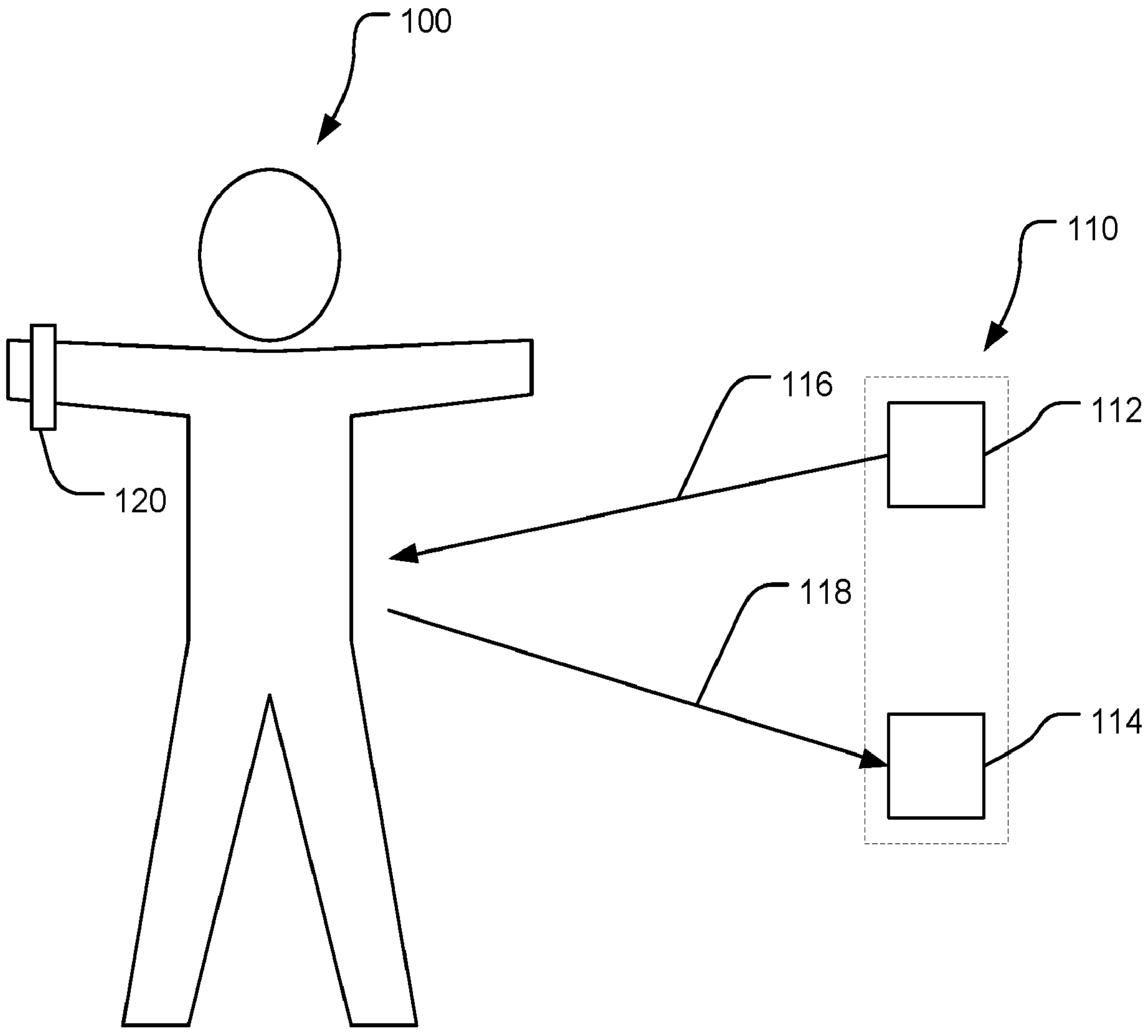
(57) **ABSTRACT**

A micro impulse radar (MIR) system includes a first sensor, a second sensor, and a control circuit. The first sensor includes a micro impulse radar (MIR) sensor configured to receive a plurality of radar returns corresponding to an MIR radar signal transmitted towards a subject. The second sensor is configured to detect sensor data regarding the subject. The control circuit is configured to calculate a physiological parameter of the subject based on the plurality of radar returns and the sensor data.



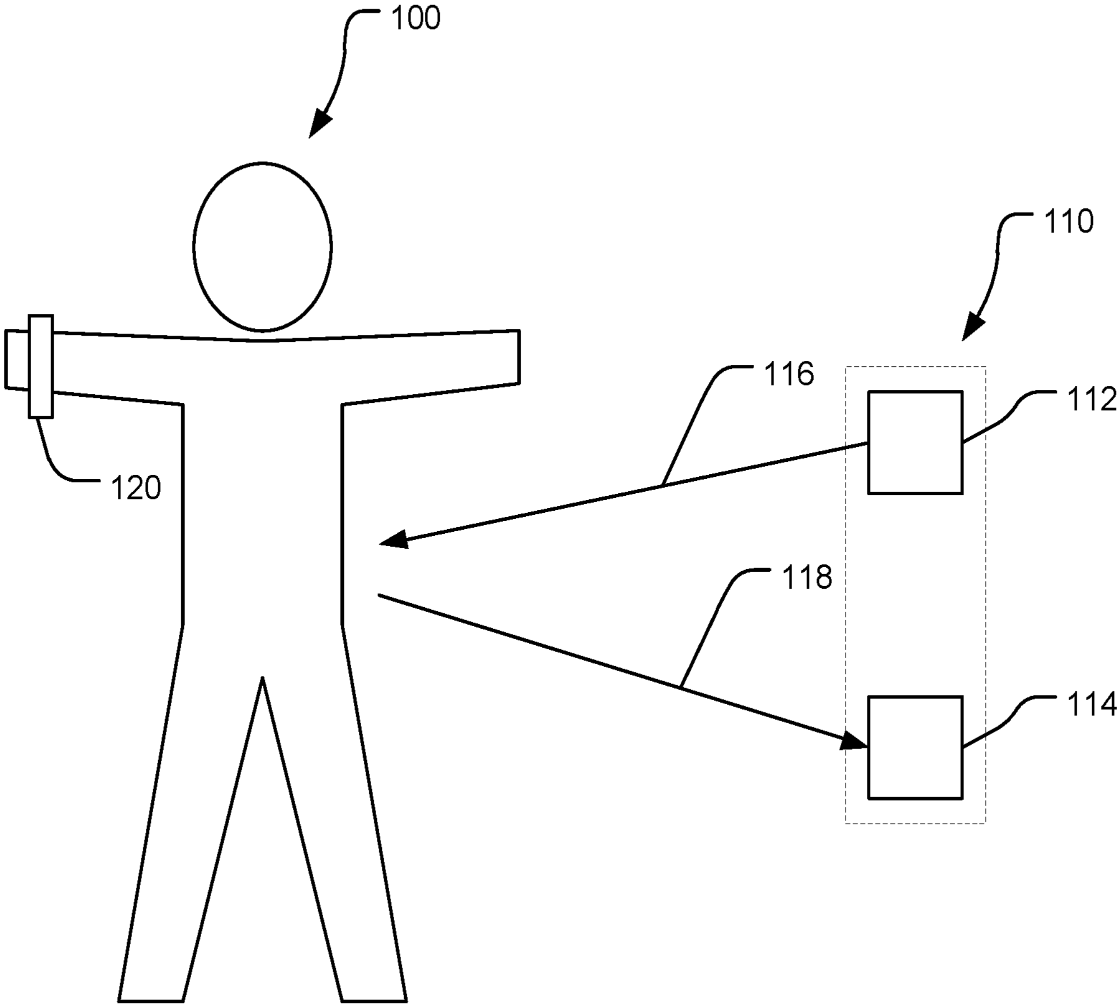

100
110
116
112
120
118
114

FIG. 1

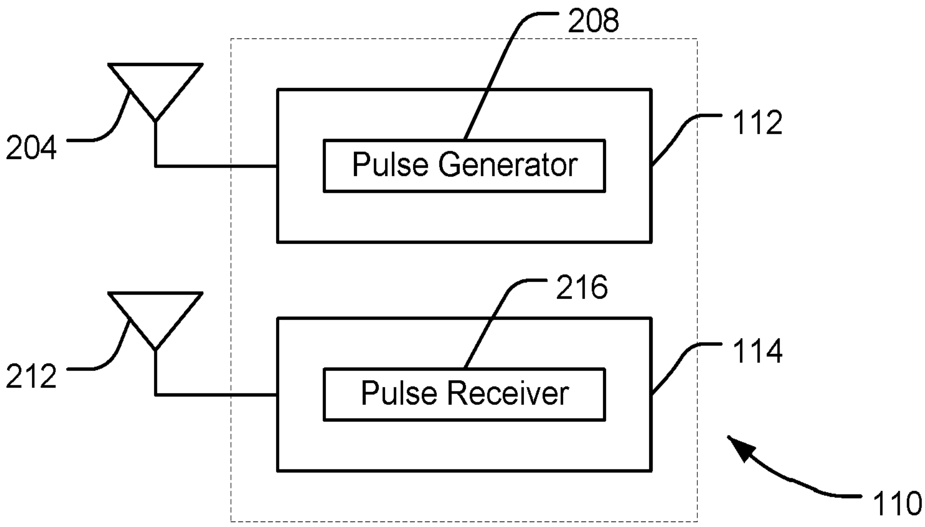

208
204
Pulse Generator
112
216
212
Pulse Receiver
114
110

FIG. 2

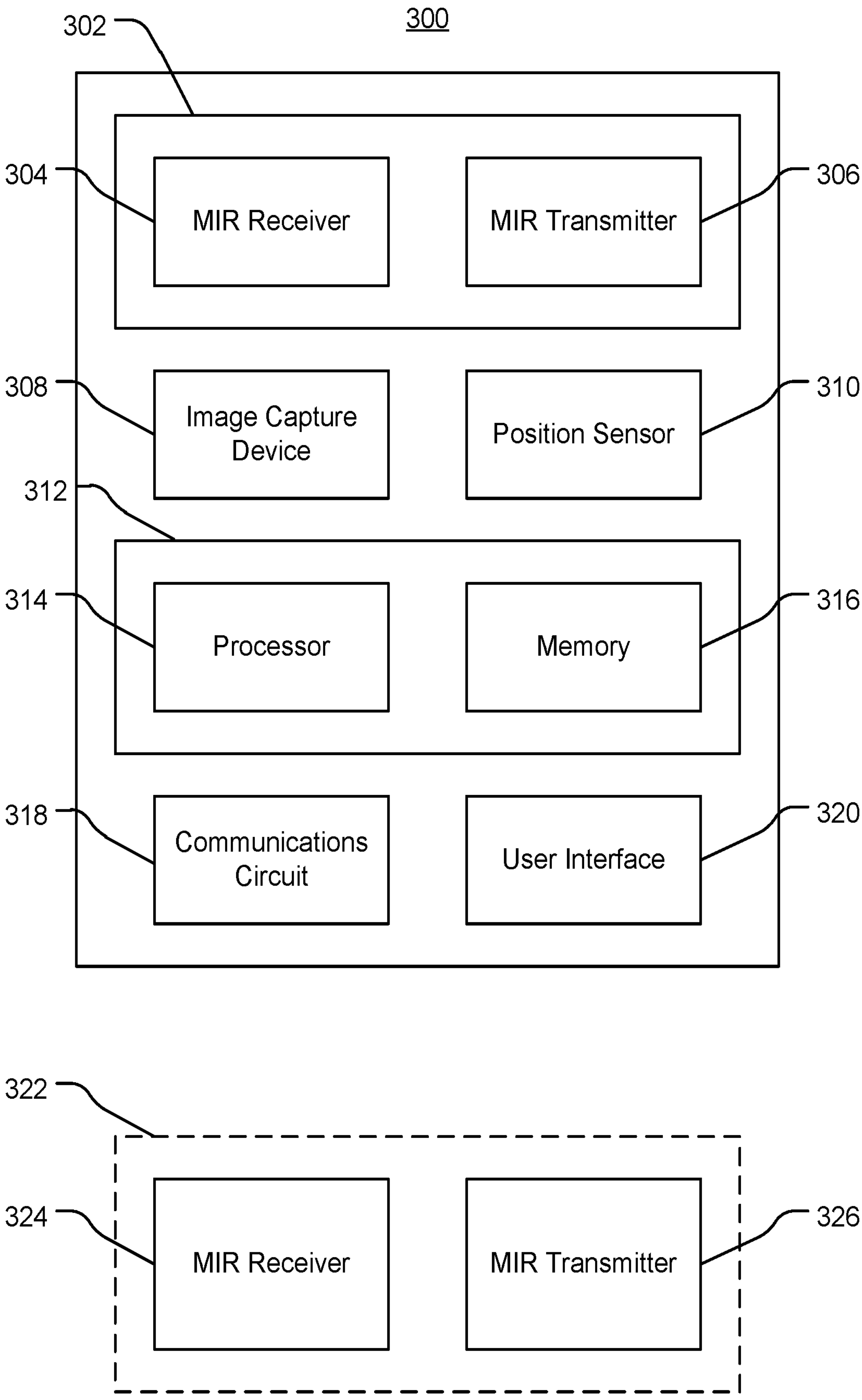

300
302
304
MIR Receiver
MIR Transmitter
306
308
Image Capture Device
Position Sensor
310
312
314
Processor
Memory
316
318
Communications Circuit
User Interface
320
322
324
MIR Receiver
MIR Transmitter
326

FIG. 3

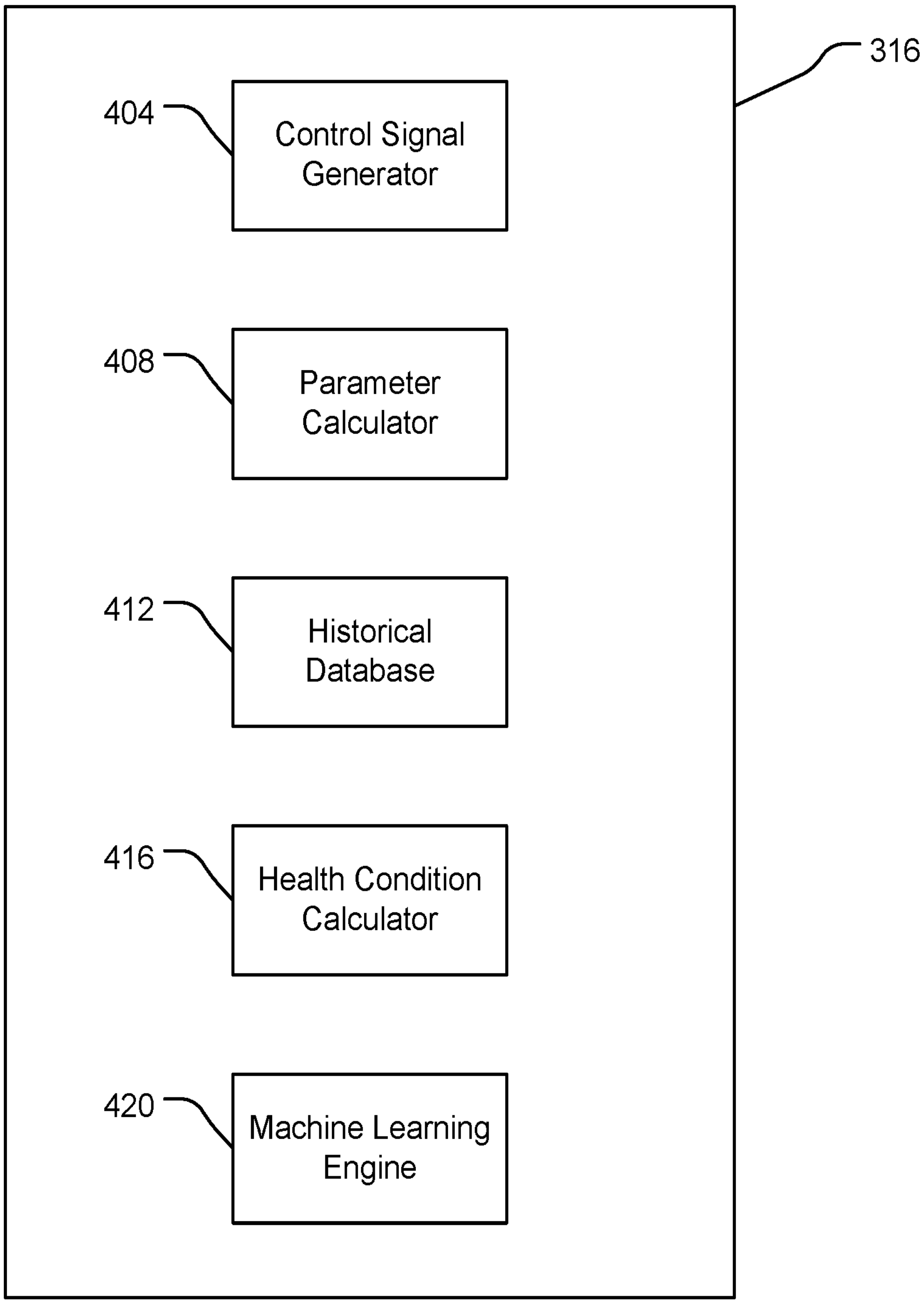

316
404
Control Signal Generator
408
Parameter Calculator
412
Historical Database
416
Health Condition Calculator
420
Machine Learning Engine

FIG. 4

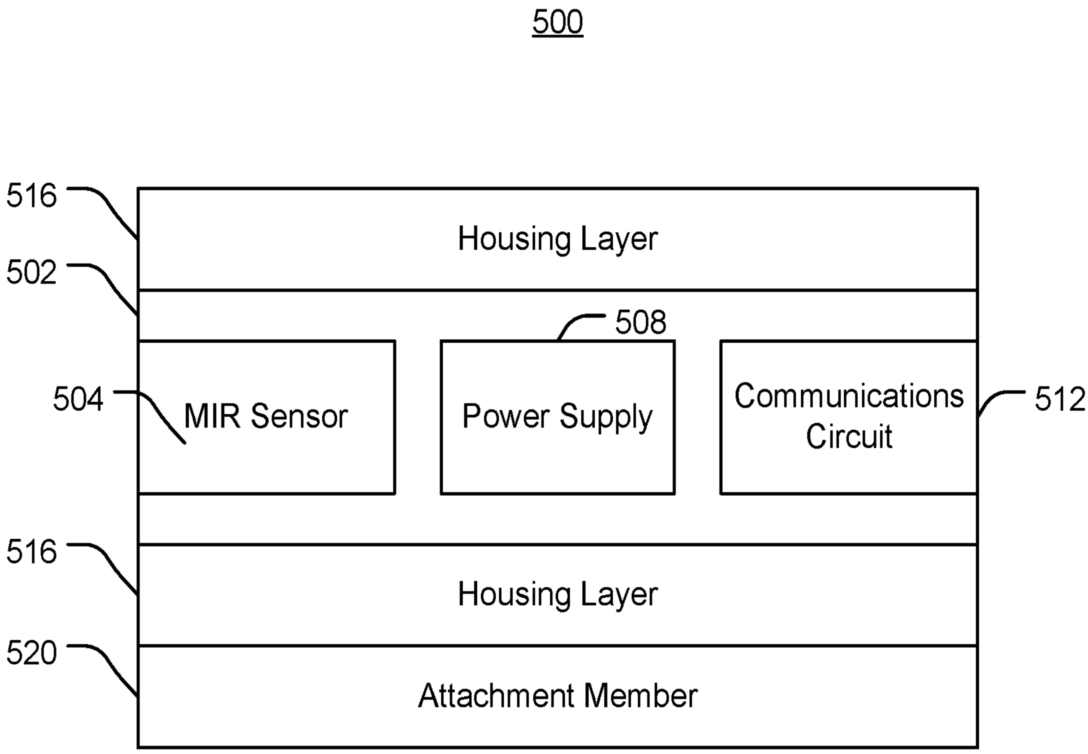

500
516
Housing Layer
502
508
504
MIR Sensor
Power Supply
Communications Circuit
512
516
Housing Layer
520
Attachment Member

FIG. 5

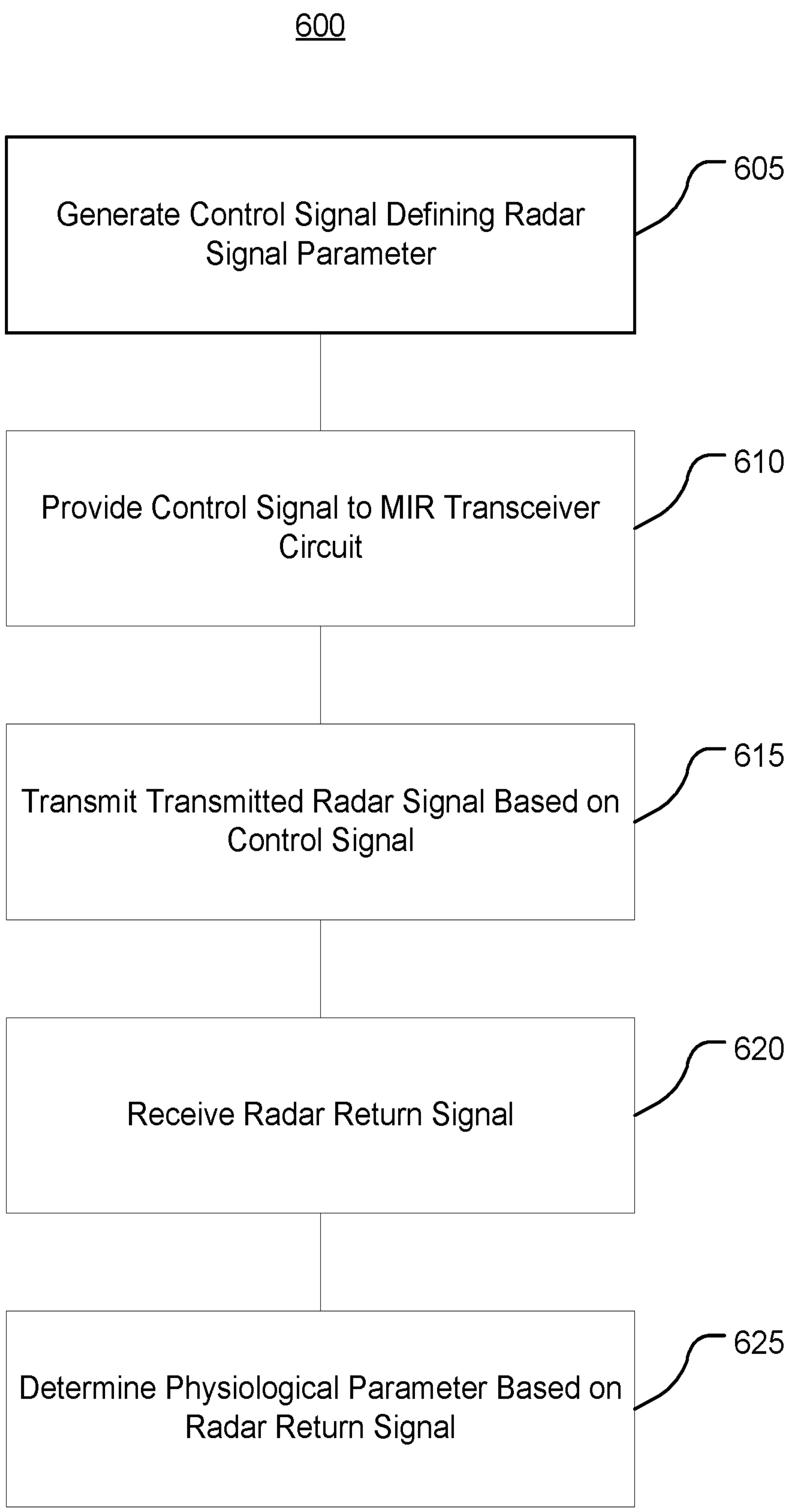

600
Generate Control Signal Defining Radar Signal Parameter
605
Provide Control Signal to MIR Transceiver Circuit
610
Transmit Transmitted Radar Signal Based on Control Signal
615
Receive Radar Return Signal
620
Determine Physiological Parameter Based on Radar Return Signal
625

FIG. 6

SYSTEMS AND METHODS FOR DETECTING PHYSIOLOGICAL INFORMATION USING MULTI-MODAL SENSORS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present disclosure claims the benefit of and priority to U.S. Provisional Application No. 62/747,617, titled "SYSTEMS AND METHODS OF MICRO IMPULSE RADAR DETECTION OF PHYSIOLOGICAL INFORMATION," filed Oct. 18, 2018, the disclosure of which is incorporated herein by reference in its entirety.

BACKGROUND

[0002] The present disclosure relates generally to the field of micro impulse radar (MIR). More particularly, the present disclosure relates to systems and methods for micro impulse radar detection of physiological information.

[0003] MIR systems can output wideband signals that have relatively low power requirements. MIR systems can be relatively inexpensive to manufacture, as compared to existing radar systems.

SUMMARY

[0004] At least one embodiment relates to a micro impulse radar (MIR) system. The system includes an MIR transceiver circuit configured to transmit, towards a subject, at least one transmitted radar signal; and receive at least one radar return signal. The system includes a control circuit configured to generate a control signal defining a radar signal parameter of the at least one transmitted radar signal; provide the control signal to the MIR transceiver circuit to cause the MIR transceiver circuit to transmit the at least one transmitted signal based on the radar signal parameter; and determine, based on the at least one radar return signal, a physiological parameter of the subject.

[0005] Another embodiment relates to a method. The method includes generating, by a control circuit, a control signal defining a radar signal parameter of a transmitted radar signal; providing, by the control circuit, the control signal to an MIR transceiver circuit; transmitting, by the MIR transceiver circuit, the transmitted radar signal based on the radar signal parameter; receiving, by the MIR transceiver circuit, a radar return signal; and determining, by the control circuit based on the radar return signal, a physiological parameter of a subject.

[0006] Another embodiment relates to a method. The method includes receiving, by a first sensor comprising a micro impulse radar (MIR) sensor, a plurality of radar returns corresponding to an MIR radar signal transmitted towards a subject. The method includes receiving, by a second sensor, sensor data. The method includes calculating, by a control circuit, a physiological parameter of the subject based on the plurality of radar returns and the sensor data.

[0007] Another embodiment relates to a system. The system includes a micro impulse radar (MIR) sensor configured to receive a plurality of radar returns corresponding to an MIR radar signal transmitted towards a subject; and a control circuit configured to calculate a physiological parameter of the subject based on the plurality of radar returns.

[0008] Another embodiment relates to a method. The method includes receiving, by a micro impulse radar (MIR) sensor, a plurality of radar returns corresponding to an MIR radar signal transmitted towards a subject; and calculating, by a control circuit, a physiological parameter of the subject based on the plurality of radar returns.

[0009] Another embodiment relates to a system. The system includes a first sensor, a second sensor, and a control circuit. The first sensor includes a micro impulse radar (MIR) sensor configured to receive a plurality of radar returns corresponding to an MIR radar signal transmitted towards a subject. The second sensor is configured to detect sensor data regarding the subject. The control circuit is configured to calculate a physiological parameter of the subject based on the plurality of radar returns and the sensor data.

[0010] Another embodiment relates to a system. The system includes a housing configured to be coupled to a subject; a sensor mounted in the housing, the sensor configured to detect information regarding the subject; and a control circuit coupled to the sensor, the control circuit configured to calculate a physiological parameter regarding the subject based on the information detected by the sensor.

[0011] Another embodiment relates to a method. The method includes detecting, by a sensor mounted in a housing coupled to a subject, information regarding the subject; and calculating, by a control circuit coupled to the sensor, a physiological parameter regarding the subject based on the information detected by the sensor.

[0012] This summary is illustrative only and is not intended to be in any way limiting.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] The disclosure will become more fully understood from the following detailed description, taken in conjunction with the accompanying figures, wherein like reference numerals refer to like elements, in which:

[0014] FIG. **1** is a schematic diagram of an MIR system in accordance with an embodiment of the present disclosure.

[0015] FIG. **2** is a schematic diagram of a transceiver of the MIR system of FIG. **1**.

[0016] FIG. **3** is a block diagram of an MIR system in accordance with an embodiment of the present disclosure.

[0017] FIG. **4** is a block diagram of processing modules of the MIR system of FIG. **3**.

[0018] FIG. **5** is a schematic diagram of a portable MIR system in accordance with an embodiment of the present disclosure.

[0019] FIG. **6** is a flow diagram of a method of operating an MIR system in accordance with an embodiment of the present disclosure.

DETAILED DESCRIPTION

[0020] Before turning to the figures, which illustrate certain exemplary embodiments in detail, it should be understood that the present disclosure is not limited to the details or methodology set forth in the description or illustrated in the figures. It should also be understood that the terminology used herein is for the purpose of description only and should not be regarded as limiting.

A. Systems and Methods of Micro Impulse Radar Detection of Physiological Information

[0021] Referring now to FIGS. **1-2**, an MIR system **110** is shown according to an embodiment of the present disclosure. The MIR system **110** is used to detect physiological information regarding a subject **100**. The subject **100** may be a living subject, such as a mammalian (e.g., human) subject.

[0022] The MIR system **110** includes a transmitter circuit **112** and a receiver circuit **114**. The transmitter circuit **112** can transmit a first radar signal **116**, such as in a direction towards the subject **100**. The transmitter circuit **112** can generate the first radar signal **116** to be an MIR signal. For example, the transmitter circuit **112** can include a pulse generator **208** that applies a voltage to a transmit antenna **204** to cause the transmit antenna **204** to output the first radar signal **116**. The pulse generator **208** can apply the voltage in short pulses to generate MIR signals. For example, the pulses may have rise times on the order of picoseconds, and the pulse generator can generate the pulses on the order of millions of pulses per second. In some embodiments, a pulse width of the pulse outputted by the pulse generator is between approximately two hundred picoseconds and five nanoseconds. The pulse can be a relatively wideband pulse in terms of frequency, as compared to typical radar systems.

[0023] The receiver circuit **114** can include a receive antenna **212** (which may be co-located with/the same as the transmit antenna **204** of the transmitter circuit **112**, or may be separate from the transmit antenna **204**) and a pulse receiver **216**. The receiver circuit **114** can receive a second radar signal **118** at the receive antenna **212**, which can correspond to the first radar signal **116**. For example, the second radar signal **118** (e.g., return signal) can be a radar return signal corresponding to the first radar signal **116**. The second radar signal **118** can result from interaction of the first radar signal **116** and the subject **100**. For example, the second radar signal **118** can result from transmission, reflection, refraction, absorption (and later emission), shadowing, or otherwise scattering of the first radar signal **116** by the subject **100**, or various combinations, such as multi-path combinations, thereof. Various signals may be described herein as first, second, third, or further numbered signals, which may refer to aspects of one or more signals at various points in space, time, output, or reception. In some embodiments, the receiver circuit **114** controls timing of reception of the second radar signal **118** so that a detection range of the receiver circuit **114** is relatively small. For example, the receiver circuit **114** can use an expected round-trip time of flight of the first radar signal **116** and the second radar signal **118** to maintain the detection range below a threshold detection range. In some embodiments, the threshold detection range is on the order of feet. In some embodiments, the threshold detection range is on the order of inches or less (e.g., for portable MIR system **120**). As such, the MIR system **110** can maintain a relatively high signal to noise ratio by focusing on second radar signals **118** for which the MIR system **110** can have a high confidence of corresponding to interaction of the first radar signals **116** with the subject **100**. The pulse receiver **216** can receive the second radar signal **118** via the receive antenna **212** and generate an electronic signal (e.g., analog signal, radio frequency signal) corresponding to the second radar signal **118** for further analysis. The MIR system **110** can receive and transmit the signals **116**, **118** to detect a physiological parameter regarding the subject **100**.

[0024] As shown in FIG. **1**, a portable MIR system **120** may be provided. The portable MIR system **120** may be similar to the MIR system **110**, such as to output radar signals and receive return radar signals corresponding to the outputted radar signals. The portable MIR system **120** may include straps, adhesives, or other attachment members to enable the portable MIR system **120** to be worn by the subject **100**.

[0025] Referring now to FIGS. **3-4**, an MIR system **300** is shown according to an embodiment of the present disclosure. The MIR system **300** can incorporate features of the MIR system **110**, **120** described with reference to FIGS. **1-2**.

[0026] The MIR system **300** includes an MIR transceiver circuit **302** including an MIR transmitter **306** and an MIR receiver **304**, and a processing circuit **312**. The MIR transmitter **306** can incorporate features of the transmitter circuit **112** described with reference to FIGS. **1-2**, and the MIR receiver **304** can incorporate features of the receiver circuit **114** described with reference to FIGS. **1-2**. For example, the MIR transmitter **306** can transmit a first radar signal towards a subject, and the MIR receiver **304** can receive a second radar signal corresponding to the first radar signal.

[0027] The processing circuit **312** includes a processor **314** and memory **316**. The processor **314** may be implemented as a specific purpose processor, an application specific integrated circuit (ASIC), one or more field programmable gate arrays (FPGAs), a system on a chip (SoC), a group of processing components (e.g., multicore processor), or other suitable electronic processing components. The memory **316** is one or more devices (e.g., RAM, ROM, flash memory, hard disk storage) for storing data and computer code for completing and facilitating the various user or client processes, layers, and modules described in the present disclosure. The memory **316** may be or include volatile memory or non-volatile memory and may include database components, object code components, script components, or any other type of information structure for supporting the various activities and information structures of the inventive concepts disclosed herein. The memory **316** is communicably connected to the processor **314** and includes computer code or instruction modules for executing one or more processes described herein. The memory **316** includes various circuits, software engines, and/or modules that cause the processor **314** to execute the systems and methods described herein.

[0028] As shown in FIG. **4**, the memory **316** can include a control signal generator **404**, a parameter calculator **408**, a historical database **412**, each of which the processor **314** can execute to perform the systems and methods described herein. The processing circuit **312** may be distributed across multiple devices. For example, a first portion of the processing circuit **312** that includes and executes the control signal generator **404** may be mechanically coupled to the MIR transceiver circuit **302**, while a second portion of the processing circuit **312** that includes an executes the parameter calculator **408**, historical database **412**, health condition calculator **416**, and/or machine learning engine **420** may be remote from the first portion and communicably coupled to the first portion (e.g., using communications circuit **318**).

[0029] The MIR system **300** can include an image capture device **308**. The image capture device **308** can capture images regarding the subject **100**, and provide the images to the processing circuit **312** (e.g., to historical database **412**).

[0030] The processing circuit **312** can execute object recognition and/or location estimation using the images captured by the image capture device **308**. For example, the processing circuit **312** can extract, from a received image, features such as shapes, colors, edges, and/or spatial relationships between pixels of the received images. The processing circuit **312** can compare the extracted features to template features (e.g., a template of a human subject), and recognize objects of the images based on the comparison, such as by determining a result of the comparison to satisfy a match condition. The template can include an expected shape of the subject **100**. In some embodiments, the processing circuit **312** can estimate the location of anatomical features of the subject **100** based on the receive image, such as by estimating a location of a heart, lungs, or womb of the subject **100** based on having detected the subject **100**.

[0031] The MIR system **300** can include a position sensor **310**. The position sensor **310** can detect a pose (e.g., at least one of a position or an orientation) of one or more components of the MIR system **300**. For example, the position sensor **310** can detect a pose of the MIR receiver **304** and detect a pose of the MIR transmitter **306**. The position sensor **310** can include various sensors, such as accelerometers,

[0032] The MIR system **300** can include a communications circuit **318**. The communications circuit **318** can include wired or wireless interfaces (e.g., jacks, antennas, transmitters, receivers, transceivers, wire terminals, etc.) for conducting data communications with various systems, devices, or networks. For example, the communications circuit **318** can include an Ethernet card and port for sending and receiving data via an Ethernet-based communications network. The communications circuit **318** can include a WiFi transceiver for communicating via a wireless communications network. The communications circuit **318** can communicate via local area networks (e.g., a building LAN), wide area networks (e.g., the Internet, a cellular network), and/or conduct direct communications (e.g., NFC, Bluetooth). In some embodiments, the communications circuit **318** can conduct wired and/or wireless communications. For example, the communications circuit **318** can include one or more wireless transceivers (e.g., a Wi-Fi transceiver, a Bluetooth transceiver, a NFC transceiver, a cellular transceiver).

[0033] In some embodiments, the MIR system **300** includes a user interface **320**. The user interface **320** can receive user input and present information regarding operation of the MIR system **300**. The user interface **320** may include one or more user input devices, such as buttons, dials, sliders, or keys, to receive input from a user. The user interface **320** may include one or more display devices (e.g., OLED, LED, LCD, CRT displays), speakers, tactile feedback devices, or other output devices to provide information to a user.

Control Signal Generator

[0034] The control signal generator **404** controls operation of the MIR transceiver circuit **302**. The control signal generator **404** can generate a control signal defining a radar signal parameter of the first radar signal to be transmitted by the MIR transmitter **306**. The control signal generator **404** can define the radar signal parameter to include at least one of a frequency, an amplitude, a pulse width, or a pulse repetition frequency of the first radar signal.

[0035] In some embodiments, the control signal generator **404** defines the radar signal parameter based on an expected response of the subject to the first radar signal and/or an expected response of the first radar signal to the subject. For example, the control signal generator **404** can define the radar signal parameter based on an expected physical response that causes the second radar signal to have an expected signal to have an expected signal to noise ratio for a physiological parameter that the control signal generator **404** determines based on the second radar signal. The expected responses can correspond to factors such as whether the first radar signal will be reflected by an outer surface of the subject **100** (e.g., including clothing worn by the subject), will penetrate the subject **100** before being absorbed or reflected, or a distance the first radar signal is expected to penetrate the subject **100**. In some embodiments, the control signal generator **404** estimates the expected physical response based on biological and/or anatomical features of the subject **100**, such as regions that the MIR transceiver circuit **302** targets that may be primarily composed of water molecules as compared to bone structures. For example, the control signal generator **404** can define the radar signal parameter so that the outputted first radar signals have a particular frequency, amplitude, pulse width, and/or pulse repetition frequency.

[0036] The control signal generator **404** can define the radar signal parameter by determining the expected response based on an actual signal to noise ratio of a prior received radar signal. For example, the control signal generator **404** can retrieve from the historical database **412** the actual signal to noise ratio of the prior received radar signal, a historical radar signal parameter corresponding to the prior received radar signal, and a parameter of the subject **100** corresponding to the prior received radar signal, and determine the expected response by comparing the data retrieved from the historical database **412** to corresponding data regarding operation of the MIR system **300** to probe the subject **100**. The parameter of the subject **100** may include a distance from the MIR system **300** to the subject **100**, or a location of a particular anatomical feature of the subject **100**.

[0037] The control signal generator **404** can apply noise to the control signal, such as to randomize a pulse rate of the control signal. By applying noise to the control signal, the control signal generator **404** can uniquely encode the control signal, and thus the transmitted radar signal transmitted by the MIR transceiver circuit **302**. In addition, applying noise can reduce the effect of interference from other electromagnetic radiation sources.

[0038] In some embodiments, the control signal generator **404** controls operation of the MIR receiver **304**. For example, the control signal generator **404** can control a range gate of the MIR receiver **304**. The range gate can correspond to an expected round trip time of the transmitted radar signal transmitted by the MIR transmitter **306** and the corresponding radar return signal received by the MIR receiver **304** based on interaction with the subject **100**. For example, the control signal generator **404** can use a distance to the subject **100** to control the range gate. In some embodiments, the control signal generator **404** uses a location of a particular anatomical feature of the subject **100**, such as the heart or lungs, to control the range gate.

Parameter Calculator

[0039] The parameter calculator **408** can determine, based on the second radar signal, a physiological parameter of the subject. For example, the parameter calculator **408** can calculate, based on the second radar signal, parameters such as locations of anatomical features, movement of anatomical features, sizes of anatomical features, movement of fluids (e.g., blood flow), or velocity data. The parameter calculator **408** can execute a Doppler algorithm to calculate velocity data. The parameter calculator **408** can calculate information such as an amplitude or power of the radar return signals at various frequencies, such as to generate a spectral analysis of the radar return signal. The parameter calculator **408** can calculate the physiological parameter to include at least one of a cardiac parameter, a pulmonary parameter, a blood flow parameter, or a fetal parameter based on the radar return signals. The radar return signal can include any of a variety of return signals including reflected, absorbed, refracted, or scattered signals, or combinations thereof, including multi-path signals.

[0040] In some embodiments, the parameter calculator **408** calculates the physiological parameter using at least one of a predetermined template or a parameter function. The predetermined template may include features such as expected signal amplitudes at certain frequencies, or pulse shapes of the radar return signal. The predetermined template may include anatomical features, such as shapes of vessel walls or cavity walls, such that the parameter calculator **408** can identify the movement of anatomical features (as well as blood flow and other fluid flow). The parameter function may be configured to convert data of the radar return signal (e.g., amplitude as a function of time at various frequencies) into various other variables, such as velocity or periodicity.

[0041] In some embodiments, the parameter calculator **408** calculates the physiological parameter based on an indication of a type of the physiological parameter. For example, the parameter calculator **408** can receive the indication based on user input. The parameter calculator **408** can determine the indication, such as by determining an expected anatomical feature of the subject **100** that the MIR system **300** is probing using the transmitted radar signal. For example, the parameter calculator **408** can use image data from image capture device **308** to determine that the MIR system **300** is probing a heart of the subject **100**, and determine the type of the physiological parameter to be a cardiac parameter. The parameter calculator **408** may use the determined type of the physiological parameter to select a particular predetermined template or parameter function to execute, or to increase a confidence that the radar return signal represents the type of physiological parameter (which may be useful for calculating the physiological parameter based on comparing the radar return signal to predetermined template(s) and searching for a match accordingly).

[0042] In some embodiments, the parameter calculator **408** calculates the cardiac parameter to include at least one of a heart rate, a heart volume, a heart stroke volume, a blood volume, a heart rate variation, a pulse shape, a heart pumping efficiency, or a cycle-to-cycle variation. For example, the parameter calculator **408** can extract a periodicity from the radar return signal to calculate the heart rate, and can monitor the periodicity across various cycles to calculate the heart rate variation. The parameter calculator **408** can use one or more pulse shape templates to calculate the pulse shape represented by the radar return signal. The parameter calculator **408** can monitor for changes in amplitude of the radar return signal at various frequencies to calculate the cycle-to-cycle variation.

[0043] The parameter calculator **408** can calculate the pulmonary parameter to include at least one of a breathing rate, a breathing rate variation, a volume in a chest of the subject **100**, a volume change in the chest of the subject, or an air exchange efficiency. The parameter calculator **408** can determine the breathing rate based on a periodicity extracted from the radar return signal, including a periodic movement of walls of the lungs (e.g., determined using a shape template corresponding to the walls of the lungs). The parameter calculator **408** can determine the breathing rate variation by monitoring the breathing rate over several cycles. The parameter calculator **408** can determine the volume in the chest by determining the locations and/or shapes of walls of the lungs, and the volume change in the chest based on the volume and the periodic movement of the walls of the lungs. The parameter calculator **408** can calculate the air exchange efficiency (e.g., gas exchange efficiency) by monitoring parameters that may be associated with gas exchange, such as ventilation and/or perfusion parameters. The parameter calculator **408** can calculate the physiological parameter to include a subject performance parameter. The subject performance parameter can include health parameters, athletic parameters, and other parameters associated with performance parameters of the subject. For example, the subject performance parameter can include muscle content information, fat content information, breathing capacity, blood oxygen content, and other such information. The parameter calculator **408** can compare the subject performance parameter to a previous value to determine a change in performance.

[0044] In some embodiments, the parameter calculator **408** calculates the fetal parameter to include similar parameters as the cardiac and/or pulmonary parameters. The parameter calculator **408** can use predetermined templates and/or parameter functions that have different characteristics specific to the fetal parameters (e.g., based on an expectation that a fetal heart rate is faster than an adult heart rate). The parameter calculator **408** can calculate the fetal parameter to include similar parameters as used for fetal ultrasound, such as a volume of amniotic fluid, fetal position, gestational age, or birth defects.

Historical Database

[0045] The historical database **412** can maintain historical data regarding a plurality of subjects, radar signals received for each subject, physiological parameters calculated for each subject, and MIR system operations—for example, radar signal parameters—corresponding to the physiological parameters calculated for each subject. For example, the historical database **412** can assign, to each subject, a plurality of data structures each including a radar signal parameter of a first radar signal transmitted to probe the subject, a second radar signal received in return, and a physiological parameter calculated based on the second radar signal. The historical database **412** can maintain indications of intended physiological features to be probed using the radar signals (e.g., heart, lungs) and/or types of the calculated physiological parameters (e.g., cardiac, pulmonary). The historical database **412** can assign to each subject various demographic data (e.g., age, sex, height, weight).

[0046] The historical database **412** can maintain various parameters calculated based on radar return signals. For example, the historical database **412** can maintain physiological parameters, signal to noise ratios, health conditions, and other parameters described herein that the processing circuit **312** calculates using the radar return signals. The processing circuit **312** can update the historical database **412** when additional radar return signals are received and analyzed.

Health Condition Calculator

[0047] In some embodiments, the MIR system **300** includes the health condition calculator **416**. The health condition calculator **416** can use the physiological parameters calculated by the parameter calculator **408** and/or the historical data maintained by the historical database **412** to calculate a likelihood of the subject **100** having a particular health condition. The health condition calculator **416** can calculate likelihoods associated with medical conditions, emotion conditions, physiological conditions, or other health conditions.

[0048] In some embodiments, the health condition calculator **416** predicts a likelihood of the subject **100** having the health condition by comparing the physiological parameter to at least one of (i) historical values of the physiological parameter associated with the subject (e.g., as maintained in the historical database **412**) or (ii) a predetermined value of the physiological parameter associated with the medical condition (e.g., a predetermined value corresponding to a match condition as described below). For example, the health condition calculator **416** can calculate an average value over time of the physiological parameter to determine a normal value or range of values for the subject **100**, and determine the likelihood of the subject **100** having the medical condition based on a difference between the physiological parameter and the average value.

[0049] The health condition calculator **416** can maintain a match condition associated with each health condition. The match condition can include one or more thresholds indicative of radar return data and/or physiological parameters that match the health condition. As an example, the health condition calculator **416** can determine a likelihood of the subject **100** having arrhythmia by comparing a heart rate of the subject **100** to at least one of a minimum heart rate threshold (e.g., a threshold below which the subject **100** is likely to have arrhythmia) or a maximum heart rate threshold (e.g., a threshold above which the subject **100** is likely to have arrhythmia), and output the likelihood of the subject having arrhythmia based on the comparison. The health condition calculator **416** can store the outputted likelihoods in the historical database **412**.

[0050] In some embodiments, the health condition calculator **416** updates the match conditions based on external input. For example, the health condition calculator **416** can receive a user input indicating a health condition that the subject **100** has; the user input may also include an indication of a confidence level regarding the health condition. The health condition calculator **416** can adjust the match condition, such as by adjusting the one or more thresholds of the match condition, so that the match condition more accurately represents the information of the external input. In some embodiments, the health condition calculator **416** updates the match condition by providing the external input as training data to the machine learning engine **420**.

[0051] The health condition calculator **416** can determine the likelihood of the subject **100** having the medical condition based on data regarding a plurality of subjects. For example, the historical database **412** can maintain radar return data, physiological parameter data, and medical conditional data regarding a plurality of subjects (which the machine learning engine **420** can use to generate richer and more accurate parameter models). The health condition calculator **416** can calculate a statistical measure of a physiological parameter (e.g., average value, median value) for the plurality of subjects, and calculate an indication of the physiological parameter of the subject **100** being abnormal and/or calculate a likelihood of the subject **100** having the medical condition based on the statistical measure.

Machine Learning Engine

[0052] In some embodiments, the MIR system **300** includes a machine learning engine **420**. The machine learning engine **420** can be used to calculate various parameters described herein, including where relatively large amounts of data may need to be analyzed to calculate parameters as well as the thresholds used to evaluate those parameters. For example, the parameter calculator **408** can execute the machine learning engine **420** to determine [the thresholds used to recognize physiological parameters]. The health condition calculator **416** can execute the machine learning engine **420** to determine [the thresholds used to determine whether physiological parameters indicate that the subject **100** has a particular medical condition].

[0053] In some embodiments, the machine learning engine **420** includes a parameter model. The machine learning engine **420** can use training data including input data and corresponding output parameters to train the parameter model by providing the input data as an input to the parameter model, causing the parameter model to calculate a model output based on the input data, comparing the model output to the output parameters of the training data, and modifying the parameter model to reduce a difference between the model output and the output parameters of the training data (e.g., until the difference is less than a nominal threshold). For example, the machine learning engine **420** can execute an objective function (e.g., cost function) based on the model output and the output parameters of the training data.

[0054] The parameter model can include various machine learning models that the machine learning engine **420** can train using training data and/or the historical database **412**. The machine learning engine **420** can execute supervised learning to train the parameter model. In some embodiments, the parameter model includes a classification model. In some embodiments, the parameter model includes a regression model. In some embodiments, the parameter model includes a support vector machine (SVM). In some embodiments, the parameter model includes a Markov decision process engine.

[0055] In some embodiments, the parameter model includes a neural network. The neural network can include a plurality of layers each including one or more nodes (e.g., neurons, perceptrons), such as a first layer (e.g., an input layer), a second layer (e.g., an output layer), and one or more hidden layers. The neural network can include characteristics such weights and biases associated with computations that can be performed between nodes of layers, which the machine learning engine **420** can modify to train the neural network. In some embodiments, the neural network includes a convolutional neural network (CNN). The machine learning engine **420** can provide the input from the training data and/or historical database **412** in an image-based format (e.g., computed radar values mapped in spatial dimensions), which can improve performance of the CNN as compared to existing systems, such as by reducing computational requirements for achieving desired accuracy in calculating health conditions. The CNN can include one or more convolution layers, which can execute a convolution on values received from nodes of a preceding layer, such as to locally filter the values received from the nodes of the preceding layer. The CNN can include one or more pooling layers, which can be used to reduce a spatial size of the values received from the nodes of the preceding layer, such as by implementing a max pooling function, an average pooling function, or other pooling functions. The CNN can include one or more pooling layers between convolution layers. The CNN can include one or more fully connected layers, which may be similar to layers of neural networks by connecting every node in fully connected layer to every node in the preceding layer (as compared to nodes of the convolution layer(s), which are connected to less than all of the nodes of the preceding layer).

[0056] The machine learning engine **420** can train the parameter model by providing input from the training data and/or historical database **412** as an input to the parameter model, causing the parameter model to generate model output using the input, modifying a characteristic of the parameter model using an objective function (e.g., loss function), such as to reduce a difference between the model output and the and the corresponding output of the training data. In some embodiments, the machine learning engine **420** executes an optimization algorithm that can modify characteristics of the parameter model, such as weights or biases of the parameter model, to reduce the difference. The machine learning engine **420** can execute the optimization algorithm until a convergence condition is achieved (e.g., a number of optimization iterations is completed; the difference is reduced to be less than a threshold difference).

[0057] As described further below, the machine learning engine **420** can train the parameter model using input from multiple sensor modalities. By using input from multiple sensor modalities, such as MIR and electrocardiography to analyze cardiac parameters, the machine learning engine **420** can more accurately train the parameter model and improve operation of the MIR system **300**, as the input from multiple sensor modalities represents multiple, independent sets of correlated data. For example, both the MIR data and electrocardiography data can be independently determined to represent cycle-to-cycle variation, increasing the accuracy of the parameter model when these independent data sets are correlated in training the parameter model.

Pose Control

[0058] In some embodiments, the MIR system **300** generates instructions regarding adjusting the pose of at least one of the MIR receiver **304** or the MIR transmitter **306**. The processing circuit **312** can receive an initial pose of the at least one of the MIR receiver **304** or the MIR transmitter **306** from the position sensor **310**. The processing circuit **312** can receive, from the image capture device **308**, an image of the subject **100**, and as described above, execute object recognition to detect the subject **100** in the image and estimate the location of anatomical features of the subject **100** (e.g., estimate the heart to be in a particular location). As such, the processing circuit **312** can generate instructions for adjusting the initial pose of the at least one of the MIR receiver **304** or the MIR transmitter **306** using the detection of the subject **100**, such as to move the MIR receiver **304** and/or the MIR transmitter **306** closer to or further from the subject **100**, or to adjust an angle at which the MIR transmitter **306** transmits the transmitted radar signals towards the subject **100** or the MIR receiver **304** receives the radar return signals from the subject **100**. For example, the processing circuit **312** can generate instructions to orient the MIR receiver **304** to be pointed directly at the estimated location of the heart of the subject **100** to enable the processing circuit **312** to more effectively calculate cardiac parameters.

[0059] In some embodiments, the processing circuit **312** presents the instructions using the user interface **320**. As such, a user can use the instructions to determine how to adjust the pose of the at least one of the MIR receiver **304** or the MIR transmitter **306** based on the instructions. The processing circuit **312** can iteratively evaluate the pose of the at least one of the MIR receiver **304** or the MIR transmitter **306**, and update the presented instructions as the pose is adjusted. In some embodiments, the MIR system **300** includes an actuator coupled to the at least one of the MIR receiver **304** or the MIR transmitter **306**, and the processing circuit **312** can cause the actuator to automatically adjust the pose.

[0060] In some embodiments, the MIR transceiver circuit **302** includes an electronically scanned array (ESA), such as to selectively direct the transmitted radar signals in particular directions. The processing circuit **312** can generate instructions, in a similar manner as for adjusting the pose, to control operation of the ESA to steer the transmitted radar signals transmitted by the ESA.

Tomography

[0061] The processing circuit **312** can control operation of the MIR transceiver circuit **302** to execute MIR tomography. For example, the control signal generator **404** can generate instructions so that the MIR transmitter **306** can scan a plurality of sections of the subject **100**, such as particular two-dimensional slices of interest. As described above, the processing circuit **312** can generate the instructions to indicate a desired change in pose of the MIR receiver **304** and/or the MIR transmitter **306**, or to electronically steer the MIR transmitter **306**, enabling the MIR transceiver circuit **302** to selectively scan particular sections of the subject **100**.

Multiple MIR Transmitters and/or Receivers

[0062] Referring further to FIG. **3**, in some embodiments, the MIR system **300** includes one or more remote MIR receivers **324** and/or one or more remote MIR transmitters **326**. For example, the MIR system **300** may include multiple transmitters (MIR transmitter **306** and one or more MIR transmitters **326**); the MIR system **300** may include multiple receivers (MIR receiver **304** and one or more MIR transmitters **326**). The remote MIR receivers **324** may be similar to the MIR receiver **304**, and the remote MIR transmitters **326** may be similar to the MIR transmitter **306**. The MIR transmitter **306** or the remote MIR transmitter **326** may be used to transmit the first radar signal, and multiple receivers **304**, **324** may receive second radar signals corresponding to the first radar signal. For example, the MIR transmitters **306**, **326** can transmit a first radar signal, the receiver **304** can receive a second radar signal corresponding to the first radar signal (which may include components from any of transmission, reflection, refraction, absorption (and later emission), shadowing, or otherwise scattering of the first radar signal by the subject **100**), and the receiver **324** can receive a third radar signal (which may include components from any of transmission, reflection, refraction, absorption (and later emission), shadowing, or otherwise scattering of the first radar signal by the subject **100**. The MIR transmitter **306** and the remote MIR transmitter **326** may be used to each transmit first radar signals (or respective first and second radar signals), and one or more of the receivers **304**, **324** may receive second or third radar signal(s) corresponding to the first radar signals.

[0063] In some embodiments, the remote MIR receiver **324** and remote MIR transmitter **326** may be provided in a same transceiver **322**, or may be remotely located from one another. The processing circuit **312** may receive pose data regarding each remote MIR receiver **324** and each remote MIR transmitter **326**.

[0064] The processing circuit **312** can generate radar signal parameters for the one or more remote MIR transmitters **326** based on the radar signal parameter generated for the MIR transmitter **306**. For example, the processing circuit **312** can generate the radar signal parameter for the remote MIR transmitter **326** to have a different pulse width or pulse repetition frequency than the radar signal parameter for the MIR transmitter **306**. The processing circuit **312** can encode a different noise on the control signal provided to the remote MIR transmitter **326** than to the MIR transmitter **306**, to enable the MIR receivers **304**, **324** to more effectively distinguish respective radar return signals.

[0065] The processing circuit **312** can combine radar return signals received from the MIR receiver **304** and the one or more MIR receivers **324** to generate a composite impression of the subject **100**. In some embodiments, the processing circuit **312** uses the pose data regarding the MIR receivers **304**, **324** and/or the MIR transmitters **306**, **326** to combine the radar return signals. For example, the pose data, and a relationship of the pose data to the subject **100**, can indicate different regions of the subject **100** that are probed using the transmitted radar return signals; similarly, the pose data can indicate expected regions of the subject **100** that would be represented by the radar return signals.

Multimodal Analysis

[0066] In some embodiments, the processing circuit **312** receives sensor data from systems that use different modalities than MIR. For example, the processing circuit **312** can receive ultrasound data, magnetic resonance imaging (MRI) data, X-ray data, computed tomography (CT) data, electrocardiography (ECG) data, or other such sensor data. The processing circuit **312** may receive sensor data (or cause remote devices to detect sensor data) of multiple modalities concurrently or asynchronously. For example, MRI data may be detected using an MRI machine, and ECG data and MIR data may be subsequently detected after the subject **100** is moved away from the MRI machine. ECG data and MIR data may be detected concurrently. Various such data from multiple modalities may be maintained in memory by the processing circuit **312** until used to perform various functions described herein such as detecting health conditions using data from multiple modalities. Various such procedures described herein can be performed for a variety of modalities, including X-ray, CT, and PET.

[0067] For example, a procedure can be performed in which a wearable MIR device (e.g., portable MIR system **500**) is provided to a subject **100** at least partially positioned in an MRI machine. The MRI machine can be used to detect MRI data, which may be provided to the processing circuit **312**. The MIR device may detect MIR data (e.g., output radar signals and receive return radar signals) while located in the MRI machine (e.g., within a region bounded by extents of the MRI machine or defined by a magnetic field strength outputted by the MRI machine being greater than a nominal threshold strength), as the MIR device can be made from materials and output and receive signals that do not interfere with operation of the MRI machine. As such, the MIR device and MRI machine can perform simultaneous data detection regarding the subject **100** that may not be possible with combinations of MRI and sensor modalities other than MIR.

[0068] In some embodiments, the MRI machine can be operated based on data detected by the MIR device. For example, the MIR data can be used to detect a location of specific anatomical features of the subject **100** (e.g., heart location), and the MRI machine can be controlled to target field outputs based on the location detected using the MIR data (e.g., based on processing by the processing circuit **312**).

[0069] In some embodiments, sensor data from the MRI machine can be used to operate the MIR device. For example, the processing circuit **312** can receive the MRI sensor data, identify a signature of the subject **100** (e.g., a baseline value of a physiological parameter specific to the subject **100**) regarding the subject using the MRI sensor data, and control operation of the MIR transmitter **306** based on the signature, such as to adjust frequencies of the outputted radar signal based on the signature.

[0070] The processing circuit **312** can use the sensor data from other modalities to validate how the processing circuit **312** evaluates MIR data, and vice versa. For example, the processing circuit **312** can generate training data including the sensor data from other modalities and an indication of an anatomical feature, a physiological parameter, and/or a health condition that the sensor data corresponds to the machine learning engine **420**. The machine learning engine **420** can train the parameter model or other models further based on this training data. As such, the processing circuit **312** can generate more accurate thresholds for calculating parameters and medical conditions by combining data across different modalities.

[0071] The processing circuit **312** can also control operation of other sensor systems using the information gathered using the MIR system **300**. For example, the processing circuit **312** can identify a location of interest of the subject **100** (e.g., location of the heart) using the radar return signals received by the MIR receiver **304**, and provide the location to the other sensor system to enable the other sensor system to more accurately target the location of interest for scanning.

[0072] In some embodiments, the processing circuit **312** combines information determined based on radar return signals received by the MIR system **300** with information from other sensor modalities. For example, the processing circuit **312** can execute a weighted average of the physiological parameter determined using the received radar return signals and the corresponding physiological parameter calculated using the other sensor modality(ies). The processing circuit **312** can determine the weights of the weighted average based on a known or expected level of confidence associated with using the respective sensor modalities to determine the physiological parameter.

[0073] The processing circuit **312** can use the user interface **320** to present information based on radar return signals received by the MIR system **300** together with information from other sensor modalities. For example, the processing circuit **312** can cause the user interface **320** to overlay blood flow data determined using the radar return signals with blood flow data determined using ultrasound.

Portable MIR Systems

[0074] Referring now to FIG. **5**, a portable MIR system **500** is shown according to an embodiment of the present disclosure. The portable MIR system **500** can incorporate features of the portable MIR system **120** described with reference to FIG. **1**. The portable MIR system **500** can be a wearable device.

[0075] As shown in FIG. **5**, the portable MIR system **500** includes a sensor layer **502** including an MIR sensor **504** coupled to a power supply **508** and a communications circuit **512**. The MIR sensor **504** can incorporate features of the MIR transceiver circuit **302** to transmit transmitted radar signals and receive radar return signals. The communications circuit **512** can incorporate features of the communications circuit **318** described with reference to FIG. **3**. In some embodiments, the communications circuit **318** uses a relatively low power communications protocol, such as Bluetooth low energy.

[0076] The power supply **508** can have a relatively low capacity, given the relatively low power requirements of the MIR sensor **504** (e.g., less than 0.1 Watt). Similarly, the portable MIR system **500** can be safe for continuous wear and usage, due to the relatively low power of the transmitted pulses (e.g., on the order of tens of microWatts).

[0077] The MIR sensor **504** can transmit sensor data using the communications circuit **512** to a remote device. In some embodiments, the MIR sensor **504** transmits the sensor data to a portable electronic device (e.g., cell phone), which can perform functions of the MIR system **300**, such as calculating physiological parameters based on the sensor data. As such, the portable MIR system **500** can have relatively low size, weight, power, and/or cost.

[0078] The portable MIR system **500** includes a housing layer **516**. The housing layer **516** can be shaped and configured to be worn by the subject **100**. In some embodiments, the housing layer **516** forms part of clothing or worn equipment (e.g., sports equipment), such as shoulder pads, helmets, or shoes. In some embodiments, the housing layer **516** is transparent to MIR signals.

[0079] The portable MIR system **500** can include an attachment member **520**. The attachment member **520** can enable the portable MIR system **500** to be attached to a wearer or a body of the wearer (e.g., body of the subject **100**). For example, the attachment member **520** can include an adhesive, a strap, or other attachment components. By attaching the portable MIR system **500** to the wearer, the portable MIR system **500** can enable longitudinal evaluation of physiological parameters in a medically safe manner (due to the low power output of the MIR signals).

[0080] Referring now to FIG. **6**, a method **600** of operating an MIR is shown according to an embodiment of the present disclosure. The method **600** can be performed using various systems described herein, including the MIR system **110**, the MIR system **300**, and the portable MIR system **500**.

[0081] At **605**, a control signal defining a radar signal parameter of a transmitted (e.g., to be transmitted) radar signal by a control circuit. The control circuit can define the radar signal parameter based on an expected physical response of the subject to the transmitted radar signal that causes the radar return signal to have an expected signal to noise ratio for the physiological parameter. The control circuit can define the radar signal parameter to include at least one of a frequency, an amplitude, a pulse width, or a pulse repetition frequency of the transmitted radar signal. At **610**, the control circuit provides the control signal to an MIR transceiver circuit.

[0082] At **615**, the MIR transceiver circuit transmits the transmitted radar signal based on the control signal. For example, the MIR transceiver circuit can use an antenna to output the transmitted radar signal. The MIR transceiver circuit can transmit the transmitted radar signal towards a subject.

[0083] At **620**, the MIR transceiver circuit receives a radar return signal. The radar return signal can correspond to the transmitted radar signal. For example, the radar return signal can be based on a reflection, refraction, absorption (and later emission), or other scattering of the transmitted radar signal because of interaction with the subject.

[0084] At **625**, the control circuit determines a physiological parameter based on the radar return signal. The physiological parameter can include cardiac parameters, pulmonary parameters, gastrointestinal parameters, and fetal parameters. In some embodiments, the control circuit determines a likelihood of the subject having a medical condition based on the physiological parameter.

[0085] As utilized herein, the terms "approximately," "about," "substantially", and similar terms are intended to have a broad meaning in harmony with the common and accepted usage by those of ordinary skill in the art to which the subject matter of this disclosure pertains. It should be understood by those of skill in the art who review this disclosure that these terms are intended to allow a description of certain features described and claimed without restricting the scope of these features to the precise numerical ranges provided. Accordingly, these terms should be interpreted as indicating that insubstantial or inconsequential modifications or alterations of the subject matter described and claimed are considered to be within the scope of the disclosure as recited in the appended claims.

[0086] It should be noted that the term "exemplary" and variations thereof, as used herein to describe various embodiments, are intended to indicate that such embodiments are possible examples, representations, or illustrations of possible embodiments (and such terms are not intended to connote that such embodiments are necessarily extraordinary or superlative examples).

[0087] The term "coupled" and variations thereof, as used herein, means the joining of two members directly or indirectly to one another. Such joining may be stationary (e.g., permanent or fixed) or moveable (e.g., removable or releasable). Such joining may be achieved with the two members coupled directly to each other, with the two members coupled to each other using a separate intervening member and any additional intermediate members coupled with one another, or with the two members coupled to each other using an intervening member that is integrally formed as a single unitary body with one of the two members. If "coupled" or variations thereof are modified by an additional term (e.g., directly coupled), the generic definition of "coupled" provided above is modified by the plain language meaning of the additional term (e.g., "directly coupled" means the joining of two members without any separate intervening member), resulting in a narrower definition than the generic definition of "coupled" provided above. Such coupling may be mechanical, electrical, or fluidic.

[0088] The term "or," as used herein, is used in its inclusive sense (and not in its exclusive sense) so that when used to connect a list of elements, the term "or" means one, some, or all of the elements in the list. Conjunctive language such as the phrase "at least one of X, Y, and Z," unless specifically stated otherwise, is understood to convey that an element may be either X, Y, Z; X and Y; X and Z; Y and Z; or X, Y, and Z (i.e., any combination of X, Y, and Z). Thus, such conjunctive language is not generally intended to imply that certain embodiments require at least one of X, at least one of Y, and at least one of Z to each be present, unless otherwise indicated.

[0089] References herein to the positions of elements (e.g., "top," "bottom," "above," "below") are merely used to describe the orientation of various elements in the FIGURES. It should be noted that the orientation of various elements may differ according to other exemplary embodiments, and that such variations are intended to be encompassed by the present disclosure.

[0090] The hardware and data processing components used to implement the various processes, operations, illustrative logics, logical blocks, modules and circuits described in connection with the embodiments disclosed herein may be implemented or performed with a general purpose single- or multi-chip processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA), or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general purpose processor may be a microprocessor, or, any conventional processor, controller, microcontroller, or state machine. A processor also may be implemented as a combination of computing devices, such as a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration. In some embodiments, particular processes and methods may be performed by circuitry that is specific to a given function. The memory (e.g., memory, memory unit, storage device) may include one or more devices (e.g., RAM, ROM, Flash memory, hard disk storage) for storing data and/or computer code for completing or facilitating the various processes, layers and modules described in the present disclosure. The memory may be or include volatile memory or non-volatile memory, and may include database components, object code components, script components, or any other type of information structure for supporting the various activities and information structures described in the present disclosure. According to an exemplary embodiment, the memory is communicably connected to the processor via a processing circuit and includes computer code for executing (e.g., by the processing circuit or the processor) the one or more processes described herein.

[0091] The present disclosure contemplates methods, systems and program products on any machine-readable media for accomplishing various operations. The embodiments of the present disclosure may be implemented using existing computer processors, or by a special purpose computer processor for an appropriate system, incorporated for this or another purpose, or by a hardwired system. Embodiments within the scope of the present disclosure include program products comprising machine-readable media for carrying or having machine-executable instructions or data structures stored thereon. Such machine-readable media can be any available media that can be accessed by a general purpose or special purpose computer or other machine with a processor. By way of example, such machine-readable media can comprise RAM, ROM, EPROM, EEPROM, or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium which can be used to carry or store desired program code in the form of machine-executable instructions or data structures and which can be accessed by a general purpose or special purpose computer or other machine with a processor. Combinations of the above are also included within the scope of machine-readable media. Machine-executable instructions include, for example, instructions and data which cause a general purpose computer, special purpose computer, or special purpose processing machines to perform a certain function or group of functions.

[0092] Although the figures and description may illustrate a specific order of method steps, the order of such steps may differ from what is depicted and described, unless specified differently above. Also, two or more steps may be performed concurrently or with partial concurrence, unless specified differently above. Such variation may depend, for example, on the software and hardware systems chosen and on designer choice. All such variations are within the scope of the disclosure. Likewise, software implementations of the described methods could be accomplished with standard programming techniques with rule-based logic and other logic to accomplish the various connection steps, processing steps, comparison steps, and decision steps.

[0093] It is important to note that the construction and arrangement of the MIR and stethoscope devices and systems as shown in the various exemplary embodiments is illustrative only. Additionally, any element disclosed in one embodiment may be incorporated or utilized with any other embodiment disclosed herein. Although only one example of an element from one embodiment that can be incorporated or utilized in another embodiment has been described above, it should be appreciated that other elements of the various embodiments may be incorporated or utilized with any of the other embodiments disclosed herein.

What is claimed is:

1. A system, comprising:

a first sensor comprising a micro impulse radar (MIR) sensor configured to receive a plurality of radar returns corresponding to an MIR radar signal transmitted towards a subject;

a second sensor configured to detect sensor data regarding the subject; and

a control circuit configured to:

calculate a physiological parameter of the subject based on the plurality of radar returns and the sensor data.

2. The system of claim **1**, comprising:

a communications circuit coupled to the MIR sensor, the communications circuit configured to transmit the calculated physiological parameter to a remote device.

3. The system of claim **1**, comprising:

a communications circuit coupled to the MIR sensor, wherein the control circuit is remote from the MIR sensor and the communications circuit is configured to wirelessly transmit the plurality of radar returns to the control circuit.

4. The system of claim **1**, wherein:

the control circuit includes a subject database configured to store the plurality of radar returns and the sensor data and assign a subject identifier of the subject to the plurality of radar returns and the sensor data.

5. The system of claim **4**, wherein:

the subject database is configured to store the calculated physiological parameter and assign the subject identifier to the calculated physiological parameter.

6. The system of claim **1**, wherein:

the control circuit is configured to predict a likelihood of the subject having a medical condition by comparing the calculated physiological parameter to at least one of (i) historical values of the physiological parameter associated with the subject or (ii) a predetermined value of the physiological parameter associated with the medical condition.

7. The system of claim **6**, wherein:

the control circuit is configured to predict the likelihood of the subject having the medical condition further based on a demographic characteristic corresponding to the subject.

8. The system of claim **6**, wherein:

the calculated physiological parameter includes at least one of a cardiac parameter, a pulmonary parameter, or a gastrointestinal parameter of the subject.

9. The system of claim **6**, wherein:

the control circuit is configured to calculate the physiological parameter by extracting a feature from at least one of the plurality of radar returns or the sensor data, compare the extracted feature to a plurality of physiological parameter templates, and determine a match of the extracted feature to one or more of the plurality of physiological parameter templates.

10. The system of claim **6**, wherein:

the control circuit is configured to calculate at least one of an average value of the physiological parameter or a median value of the physiological parameter for a plurality of subjects, and output an indication of the calculated physiological parameter being abnormal based on executing an abnormal parameter identification algorithm.

11. The system of claim **6**, comprising:

a user interface configured to receive the calculated physiological parameter from the control circuit and output an indication of the calculated physiological parameter.

12. The system of claim **11**, wherein:

the user interface is configured to receive a subject identifier of the subject, and the control circuit is configured to assign the subject identifier to the plurality of radar returns and the sensor data.

13. The system of claim **11**, wherein:

the control circuit is configured to generate an audio representation of at least one of the plurality of radar returns or the sensor data; and

the user interface is configured to output an audio signal corresponding to the audio representation.

14. The system of claim **1**, wherein:

the control circuit is configured to generate a control signal indicating at least one of a frequency, an amplitude, or a pulse repetition frequency of the MIR radar signal based on an expected physical response of the subject to the MIR radar signal, and transmit the control signal to an MIR transmitter to cause the MIR transmitter to output the MIR radar signal based on the control signal.

15. The system of claim **14**, wherein:

the control circuit is configured to calculate a signal-to-noise ratio of the plurality of radar returns and generate the control signal further based on the signal-to-noise ratio.

16. The system of claim **1**, wherein:

the control circuit is configured to set a range gate of the MIR sensor based on an expected distance between the MIR sensor and a tissue of the subject.

17. The system of claim **1**, wherein:

the control circuit is configured to filter the plurality of radar returns based on an expected tissue of the subject towards which the MIR radar signal is transmitted.

18. The system of claim **17**, wherein:

the control circuit is configured to filter the plurality of radar returns based on the expected tissue including at least one of a blood vessel wall, a lung wall, or a gastrointestinal wall.

19. The system of claim **1**, comprising:

an image capture device configured to detect an image of the subject, wherein the control circuit is configured to identify a feature of the subject based on the detected image, compare the feature to a desired location for placement of the MIR sensor, and output instructions representative of movement of the MIR sensor to the desired location based on the comparison.

20. The system of claim **1**, wherein the second sensor comprises at least one of a magnetic resonance imaging (MRI) device, an electrocardiogram (ECG) device, an ultrasound device, a microphone, an X-ray device, or a computed tomography (CT) device.

21. The system of claim **1**, wherein the second sensor comprises an MRI device, and the control circuit causes the MIR sensor to detect the at least one radar return during operation of the MRI device.

22. The system of claim **1**, wherein the MIR sensor detects at least one radar return while the second sensor detects the sensor data.

23. The system of claim **1**, wherein the MIR sensor detects at least one radar return subsequent to the second sensor detecting the sensor data and the control circuit storing the sensor data in memory.

24. The system of claim **1**, wherein the control circuit is configured to control operation of the MIR sensor using the sensor data received by the second sensor.

25. The system of claim **1**, wherein the control circuit is configured to control operation of the second sensor using the physiological parameter.

26. A method, comprising:

receiving, by a first sensor comprising a micro impulse radar (MIR) sensor, a plurality of radar returns corresponding to an MIR radar signal transmitted towards a subject;

receiving, by a second sensor, sensor data; and

calculating, by a control circuit, a physiological parameter of the subject based on the plurality of radar returns and the sensor data.

27. The method of claim **26**, comprising:

transmitting, by a communications circuit coupled to the MIR sensor, the calculated physiological parameter to a remote device.

28. The method of claim **26**, comprising:

wirelessly transmitting, by a communications circuit coupled to the MIR sensor, the plurality of radar returns to the control circuit, wherein the control circuit is remote from the MIR sensor.

29. The method of claim **26**, comprising:

storing, by a subject database of the control circuit, the plurality of radar returns and the sensor data; and

assigning, by the subject database, a subject identifier of the subject to the plurality of radar returns and the sensor data.

30. The method of claim **29**, comprising:

storing, by the subject database, the calculated physiological parameter; and

assigning, by the subject database, the subject identifier to the calculated physiological parameter.

31. The method of claim **26**, comprising:

predicting, by the control circuit, a likelihood of the subject having a medical condition by comparing the calculated physiological parameter to at least one of (i) historical values of the physiological parameter associated with the subject or (ii) a predetermined value of the physiological parameter associated with the medical condition.

32. The method of claim **31**, comprising:

predicting, by the control circuit, the likelihood of the subject having the medical condition further based on a demographic characteristic corresponding to the subject.

33. The method of claim **26**, wherein:

the calculated physiological parameter includes at least one of a cardiac parameter, a pulmonary parameter, or a gastrointestinal parameter of the subject.

34. The method of claim **26**, wherein calculating the physiological parameter includes:

extracting, by the control circuit, a feature from at least one of the plurality of radar returns or the sensor data;

comparing, by the control circuit, the extracted feature to a plurality of physiological parameter templates; and

determining, by the control circuit, a match of the extracted feature to one or more of the plurality of physiological parameter templates.

35. The method of claim **26**, comprising:

calculating, by the control circuit, at least one of an average value of the physiological parameter or a median value of the physiological parameter for a plurality of subjects; and

outputting, by the control circuit, an indication of the calculated physiological parameter being abnormal based on a difference between the calculated physiological parameter and the at least one of the average value or the median value.

36. The method of claim **26**, comprising:

receiving, at a user interface from the control circuit, the calculated physiological parameter; and

outputting, by the user interface, an indication of the calculated physiological parameter.

37. The method of claim **36**, comprising:

receiving, by the user interface, a subject identifier of the subject; and

assigning, by the control circuit, the subject identifier to at least one of the plurality of radar returns or the sensor data.

38. The method of claim **37**, comprising:

generating, by the control circuit, an audio representation of at least one of the plurality of radar returns or the sensor data; and

outputting, by the user interface, an audio signal corresponding to the audio representation.

39. The method of claim **26**, comprising:

generating, by the control circuit, a control signal indicating at least one of a frequency, an amplitude, or a pulse repetition frequency of the MIR radar signal based on an expected physical response of the subject to the MIR radar signal; and

transmitting, by the control circuit, the control signal to an MIR transmitter to cause the MIR transmitter to output the MIR radar signal based on the control signal.

40. The method of claim **39**, comprising:

calculating, by the control circuit, a signal-to-noise ratio of the plurality of radar returns; and

generating, by the control circuit, the control signal further based on the signal-to-noise ratio.

41. The method of claim **26**, comprising:

setting, by the control circuit, a range gate of the MIR sensor based on an expected distance between the MIR sensor and a tissue of the subject.

42. The method of claim **26**, comprising:

modifying, by the control circuit, the plurality of radar returns based on an expected tissue of the subject towards which the MIR radar signal is transmitted.

43. The method of claim **26**, comprising:

modifying, by the control circuit, the plurality of radar returns based on the expected tissue including at least one of a blood vessel wall, a lung wall, or a gastrointestinal wall.

44. The method of claim **26**, comprising:

detecting, by an image capture device, an image of the subject;

identifying, by the control circuit, a feature of the subject based on the detected image;

comparing, by the control circuit, the identified feature of the subject to a desired location for placement of the MIR sensor; and

outputting, by the control circuit, instructions representative of movement of the MIR sensor to the desired location based on the comparison.

45. The method of claim **26**, wherein the second sensor comprises at least one of a magnetic resonance imaging (MRI) device, an electrocardiogram (ECG) device, an ultrasound device, a microphone, an X-ray device, or a computed tomography (CT) device.

46. The method of claim **26**, further comprising detecting at least one radar return while detecting the sensor data.

47. The method of claim **26**, further comprising detecting at least one radar return subsequent to detecting the sensor data and storing the sensor data in memory.

48. The method of claim **26**, further comprising controlling operation of the MIR sensor using the sensor data received by the second sensor.

49. The method of claim **26**, further comprising controlling operation of the second sensor using the physiological parameter.

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摘要(译)

微脉冲雷达（MIR）系统包括第一传感器，第二传感器和控制电路。 所述第一传感器包括微脉冲雷达（MIR）传感器，所述微脉冲雷达（MIR）传感器被配置为接收对应于朝着对象传输的MIR雷达信号的多个雷达回波。 第二传感器被配置为检测关于对象的传感器数据。 控制电路被配置为基于多个雷达回波和传感器数据来计算对象的生理参数。