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IN-VEHICLE MOTION IDENTIFICATION WITH ULTRAWIDEBAND RADAR

Abstract

A computer includes a processor and a memory, the memory storing instructions executable by the processor to receive radar data from an ultrawideband radar in a passenger compartment of a vehicle, determine a starting-time for a time-window based on a second derivative of the radar data, identify a motion inside the passenger compartment based on the radar data received during the time-window, and actuate a component of the vehicle based on the identification of the motion.

Publication Classification

Background/Summary

BACKGROUND

[0001] Some radars use an ultrawideband signal, e.g., a signal with a low energy level spread over a large range of the radio spectrum. The Federal Communications Commission and the International Telecommunications Union Radiocommunication Sector define "ultrawideband" as an antenna transmission for which emitted signal bandwidth exceeds the lesser of 500 MHz or 20% of the arithmetic center frequency.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0002] FIG. **1** is a top diagrammatic view of an example vehicle with a passenger compartment exposed for illustration.

[0003] FIG. **2**A shows example plots of signal strength and fast time versus slow time for example radar data before and after applying a first filter.

[0004] FIG. **2**B shows example plots of signal strength and fast time versus slow time for example radar data before and after applying a second filter.

[0005] FIG. **3** shows example plots of amplitude versus frequency for example radar data.

[0006] FIG. **4** is a flowchart of an example process for identifying motion in the passenger compartment based on the radar data.

DETAILED DESCRIPTION

[0007] This disclosure describes techniques for controlling a vehicle based on identifying motions inside a passenger compartment of the vehicle, e.g., respiration by an occupant, a person entering or exiting the passenger compartment, etc. The identification is performed on radar data from an ultrawideband (UWB) radar in the passenger compartment. Using a UWB radar is beneficial because UWB radars may be installed on board the vehicle for other uses, e.g., phone-as-a-key (PaaK). A computer of the vehicle is programmed to receive radar data from the UWB radar, determine a starting-time for a time-window based on a second derivative of the radar data, identify a motion inside the passenger compartment based on the radar data received during the time-window, and actuate a component of the vehicle based on the identification of the motion. The dynamic setting of the time-window permits the computer to perform the identification with the radar data from a single time-window. A fixed window, by contrast, may have too little radar data for the identification or may have more radar data than needed for the identification, thereby adding latency. With the motion identified, the computer can, e.g., output an alert to the occupant in response to the motion satisfying a condition.

[0008] A computer includes a processor and a memory, the memory storing instructions executable by the processor to receive radar data from an ultrawideband radar in a passenger compartment of a vehicle, determine a starting-time for a time-window based on a second derivative of the radar data, identify a motion inside the passenger compartment based on the radar data received during the time-window, and actuate a component of the vehicle based on the identification of the motion.

[0009] In an example, the second derivative of the radar data may be a second derivative of fast time with respect to slow time.

[0010] In an example, the instructions may further include instructions to refrain from using the radar data received before the starting-time to identify the motion inside the passenger compartment.

[0011] In an example, the instructions may further include instructions to convert the radar data received during the time-window to a frequency domain, and identify the motion in the passenger compartment based on the radar data in the frequency domain. In a further example, the instructions may further include instructions to convert the radar data received during the time-

window to the frequency domain by applying a fast Fourier transform.

[0012] In an example, the time-window may have a preset duration.

[0013] In an example, the instructions may further include instructions to apply a filter to the radar data, and the second derivative may be of the radar data after the application of the filter. In a further example, the filter may be a smoothing filter.

[0014] In another further example, the filter may be a bandpass filter isolating frequencies for human respiration.

[0015] In an example, the time-window may be a first time-window, the starting-time may be a first starting-time, and the instructions may further include instructions to identify the motion in the passenger compartment based on the radar data received during a second time-window, the second time-window starting at an ending time of the first time-window. In a further example, the instructions may further include instructions to, in response to the second derivative being below a threshold amount for at least a threshold duration, refrain from using the radar data received after a current time-window to identify the motion inside the passenger compartment.

[0016] In an example, the instructions may further include instructions to classify the motion as a type of animate bulk motion based on the radar data received during the time-window. In a further example, the instructions may further include instructions to classify the motion as a type of animate bulk motion by executing a neural network classifier with the radar data received during the time-window as an input.

[0017] In an example, the instructions may further include instructions to identify a number of respirating individuals based on the radar data received during the time-window.

[0018] In an example, the instructions may further include instructions to command a user interface to output an alert to an occupant of the passenger compartment based on the identification of the motion.

[0019] A method includes receiving radar data from an ultrawideband radar in a passenger compartment of a vehicle, determining a starting-time for a time-window based on a second derivative of the radar data, identifying a motion inside the passenger compartment based on the radar data received during the time-window, and actuating a component of the vehicle based on the identification of the motion.

[0020] In an example, the second derivative of the radar data may be a second derivative of fast time with respect to slow time.

[0021] In an example, the method may further include refraining from using the radar data received before the starting-time to identify the motion inside the passenger compartment.

[0022] In an example, the method may further include converting the radar data received during the time-window to a frequency domain, and identifying the motion in the passenger compartment based on the radar data in the frequency domain.

[0023] In an example, the method may further include commanding a user interface to output an alert to an occupant of the passenger compartment based on the identification of the motion.

[0024] With reference to the Figures, wherein like numerals indicate like parts throughout the several views, a computer **105** includes a processor and a memory, the memory storing instructions executable by the processor to receive radar data from an ultrawideband (UWB) radar **110** in a passenger compartment **115** of a vehicle **100**, determine a starting-time for a time-window based on a second derivative of the radar data, identify a motion inside the passenger compartment **115** based on the radar data received during the time-window, and actuate a component **120** of the vehicle **100** based on the identification of the motion.

[0025] With reference to FIG. **1**, the vehicle **100** may be any passenger or commercial automobile such as a car, a truck, a sport utility vehicle, a crossover, a van, a minivan, a taxi, a bus, etc. The vehicle **100** includes the passenger compartment **115**, the computer **105**, a communications network **130**, a plurality of UWB radars **110**, and other components **120** such as a user interface.

[0026] The vehicle **100** includes the passenger compartment **115** to house occupants **140**, if any, of

the vehicle **100**. The passenger compartment **115** includes one or more seats **125**, e.g., one or more of the seats **125** disposed in a front row of the passenger compartment **115** and one or more of the seats **125** disposed in a second row behind the front row. The passenger compartment **115** may also include seats **125** in a third row (not shown) at a rear of the passenger compartment **115**. The seats **125** are shown to be bucket seats in the front row and bench seats in the second row, but the seats **125** may be other types. The position and orientation of the seats **125** and components thereof may be adjustable by an occupant **140**.

[0027] The computer **105** is a microprocessor-based computing device, e.g., a generic computing device including a processor and a memory, an electronic controller or the like, a field-programmable gate array (FPGA), an application-specific integrated circuit (ASIC), a combination of the foregoing, etc. Typically, a hardware description language such as VHDL (VHSIC (Very High Speed Integrated Circuit) Hardware Description Language) is used in electronic design automation to describe digital and mixed-signal systems such as FPGA and ASIC. For example, an ASIC is manufactured based on VHDL programming provided pre-manufacturing, whereas logical components inside an FPGA may be configured based on VHDL programming, e.g., stored in a memory electrically connected to the FPGA circuit. The computer **105** can thus include a processor, a memory, etc. The memory of the computer **105** can include media for storing instructions executable by the processor as well as for electronically storing data and/or databases, and/or the computer **105** can include structures such as the foregoing by which programming is provided. The computer **105** can be multiple computers coupled together.

[0028] The computer **105** may transmit and receive data through the communications network **130**. The communications network **130** may be, e.g., a controller area network (CAN) bus, Ethernet, WiFi, Local Interconnect Network (LIN), onboard diagnostics connector (OBD-II), and/or any other wired or wireless communications network. The computer **105** may be communicatively coupled to the UWB radars **110** and the other components **120** via the communications network **130**.

[0029] The UWB radars **110** transmit and receive radio waves. The UWB radars **110** use an ultrawideband signal, e.g., a signal with a low energy level spread over a large range of the radio spectrum. The Federal Communications Commission and the International Telecommunications Union Radiocommunication Sector define "ultrawideband" as an antenna transmission for which emitted signal bandwidth exceeds the lesser of 500 MHz or 20% of the arithmetic center frequency. The UWB radars **110** may use any suitable modulation method, e.g., orthogonal frequency-division multiplexing (OFDM), phase-shift keying (PSK), pulse-position modulation (PPM), etc. The UWB radars **110** are configured to transmit UWB waves and receive reflections of those UWB waves to detect physical objects in the environment. The UWB radars **110** may also be configured to communicate wirelessly with mobile devices using UWB waves, e.g., for PaaK functionality. This can be a benefit of using the UWB radars **110** rather than another type of ranging sensor.

[0030] The UWB radars **110** are fixedly mounted to a body **135** of the vehicle **100** in the passenger compartment **115**. The UWB radars **110** may be spaced apart from each other, e.g., spread over the passenger compartment **115**, which may help an ability to distinguish a location when used for trilateration. For example, the UWB radars **110** may include six UWB radars **110**, four located at corners of the passenger compartment **115** and two toward a longitudinal centerline of the passenger compartment **115**.

[0031] The vehicle **100** includes other components **120** that may be actuated by the computer **105**, e.g., ignition, brake system, user interface, etc. A user interface presents information to and receives information from an occupant **140** (e.g., the operator) of the vehicle **100**. The user interface may be located, e.g., on an instrument panel in the passenger compartment **115** of the vehicle **100**, or wherever may be readily seen by the occupant **140**. The user interface may include dials, digital readouts, screens, speakers, and so on for providing information to the occupant **140**, e.g., human-machine interface (HMI) elements such as are known. The user interface may include buttons,

knobs, keypads, microphone, and so on for receiving information from the occupant **140**.

[0032] With reference to FIGS. **2**A-B, the computer **105** is programmed to receive the radar data from the UWB radars **110**, e.g., via the communications network **130**. The radar data may include return times for UWB pulses and the strength of those pulses. For example, the radar data may be represented as a plot **205**, **215** of slow time versus fast time and signal strength, i.e., slow time is an independent variable and fast time and signal strength are dependent variables, as shown in FIGS. **2**A-B. The dimension of slow time is measured in the increments of time at which the UWB pulses are transmitted by the UWB radars **110**. The dimension of fast time measures the return time for the pulses and may be measured in increments of time at least an order of magnitude more frequent than slow time. A value of fast time indicates the length of time since the most recent pulse was transmitted. The fast time indicates the distance that a pulse traveled before reflecting back to the UWB radar **110**. The signal strength indicates the strength of the pulse, which can be correlated to the distance to the object and the reflectivity of the object.

[0033] The radar data may include multiple signals **225**, **230** enduring over the slow time dimension. The different signals **225**, **230** can indicate different objects in the passenger compartment **115**, e.g., the seats **125**, the occupants **140**, etc. The computer **105** may identify a set of fast time measurements as a signal **225**, **230** based on the fast times being sufficiently close together from one unit of slow time to the next unit of slow time, e.g., each consecutive pair of fast time measurements in the set is within a fast-time threshold of each other. The fast-time threshold may be chosen to indicate that the fast time measurements are likely of the same object.

[0034] The computer **105** may be programmed to select one or a subset of the signals **225**, **230**, referred to as the selected signal(s) **225**, for the processing that is described below. The computer **105** may select one of the signals **225**, **230** based on the signal **225**, **230** corresponding to an object that is moving relative to the vehicle **100**, e.g., an occupant **140** but not a seat **125**. For example, the computer **105** may select the selected signal **225** from the signals **225**, **230** based on one or more values characterizing the selected signal **225**, e.g., contrast in fast times, variance of fast time over slow time, and/or derivative of fast time with respect to slow time. The contrast of a signal **225**, **230** may be a difference between a greatest value of fast time and a smallest value of fast time. The computer **105** may select the selected signal **225** in response to one or more of the values characterizing the signal **225**, **230** exceeding a threshold, e.g., peak contrast, variance, contrast normalized by variance, or derivative of fast time with respect to slow time. Alternatively, or additionally, the computer **105** may select the selected signal **225** in response to one or more of the values characterizing the signal **225**, **230** being greater for the selected signal **225** than for any of the unselected signals **230**.

[0035] The computer **105** may be programmed to apply one or more filters to the radar data, e.g. to the selected signal **225**. The term "filter" is used herein in its signal processing sense, as a process that removes components or features from a signal (here, the radar data). The filters may be applied to the dimensions of fast time versus slow time in the radar data, i.e., to the radar data indicating distance. The filters may be chosen to isolate data relevant to identifying different types of motion. Multiple filters may be used for different types of motion.

[0036] With reference to FIG. **2**A, the computer **105** may apply a bandpass filter to the radar data. The term "bandpass filter" is used herein in its signal processing sense, as a filter that passes frequencies within a predefined range and rejects or attenuates frequencies outside the predefined range. The predefined range is stored in the memory of the computer **105**, e.g., as a fixed upper bound and fixed lower bound. The bandpass filter may isolate frequencies for human respiration. FIG. **2**A shows a first plot **205** of the radar data before applying the bandpass filter on the left and a second plot **210** of the radar data after applying the bandpass filter on the right. For example, the predefined range, e.g., the upper bound and lower bound, may be chosen to cover typical breathing frequencies, e.g., 0.2 to 0.4 Hz. The computer **105** may also apply a gain to the radar data within the predefined range, which can compensate for the small magnitude of movement involved in

breathing.

[0037] With reference to FIG. **2**B, the computer **105** may apply a smoothing filter to the radar data. The smoothing filter may remove noise from the radar data uncorrelated to frequency. FIG. **2**B shows a first plot **215** of the radar data before applying the smoothing filter on the left and a second plot **220** of the radar data after applying the smoothing filter on the right. The computer **105** may use any suitable algorithm for smoothing data, e.g., moving average, Savitsky-Golay smoothing filter, local regression, etc.

[0038] The computer **105** may use the radar data collected during a data collection period for identifying motion in the passenger compartment **115**, as described below. The data collection period may consist of a plurality of consecutive time-windows, as will be described below. The computer **105** may refrain from using the radar data received before the beginning of the data collection period, i.e., before a starting-time of the first time-window of the data collection period, to identify the motion inside the passenger compartment **115**. The computer **105** may refrain from using the radar data received after a last time-window of the data collection period to identify the motion inside the passenger compartment **115**.

[0039] When performing the identification of motion described below, the computer **105** uses the radar data collected during a time-window. The computer **105** may use the radar data collected during a single time-window at a time, i.e., use the radar data collected during one time-window in isolation, before moving on to use the radar data collected during the next time-window. Each time-window extends from a starting-time to an ending time. The starting-time and ending time are points in slow time. The time-window may have a preset duration, i.e., a preset length of time from the starting-time to the ending time. The preset duration may be stored in the memory of the computer **105**. The preset duration may be chosen to provide sufficient data for the processes described below for identifying the motion. The computer **105** may store the radar data collected during each time-window in a buffer in the memory of the computer **105**, and the computer **105** may clear the buffer upon the next time-window beginning. As described below, the starting-time is variable and thus not preset. The computer **105** may, upon determining the starting-time for a time-window, determine the ending time for the time-window by adding the preset duration to the starting-time.

[0040] The computer **105** may be programmed to determine a starting-time for a time-window based on a second derivative of the radar data. For example, the computer **105** may determine the starting-time for the first time-window of the data collection period, and thereby the beginning of the data collection period, based on the second derivative of the radar data. The second derivative of the radar data may be a second derivative of the fast time with respect to slow time of the selected signal **225** from the radar data. The computer **105** may perform the second derivative on the radar data, e.g., on the selected signal **225**, after the application of one of the filters. The computer **105** may determine the starting-time as a slow time at which the second derivative first exceeds a threshold amount, e.g., as in the least value for x such that the following expression is satisfied:

[00001] $\frac{d^2y}{dx^2} > K$

in which y represents the fast time of the selected signal **225**, x represents slow time, and K represents the threshold amount. The threshold amount K may be chosen to indicate movement of an object. The inventors have determined that the second derivative performs well at indicating a change of state of an object.

[0041] The computer **105** may be programmed to determine starting-times of time-windows in a data collection period after the first time-window of that data collection period. For example, the starting-time for a time-window may be the ending time of the immediately previous time-window. In other words, the time-windows in a data collection period may be consecutive, with each time-window starting when the previous time-window ends.

[0042] The computer **105** may be programmed to determine a final time-window for the data collection period based on the second derivative. For example, the computer **105** may determine that a current time-window is the final time-window in response to the second derivative being below a threshold amount for at least a threshold duration. The second derivative may be the same second derivative as described above, i.e., the second derivative of fast time with respect to slow time for the selected signal **225** after application of one of the filters. The threshold amount may be the same threshold amount K as used for the starting-time of the data collection period. The threshold duration is a length of time and may be chosen to be longer than repetitions of the types of motion that are of interest. Thus, in response to the second derivative being below the threshold amount for at least the threshold duration, the computer **105** may determine that the ending time of the current time-window is the end of the data collection period, and the computer **105** may refrain from using the radar data received after the current time-window to identify the motion inside the passenger compartment **115**.

[0043] With reference to FIG. **3**, the computer **105** may be programmed to convert the radar data received during a time-window to a frequency domain. The conversion to the frequency domain generates a plot of the amplitude of the fast time versus frequency. For example, the computer **105** may convert the radar data received during the time-window to the frequency domain by applying a fast Fourier transform. The computer **105** may perform any suitable algorithm for computing the fast Fourier transform, e.g., Cooley-Tukey, prime-factor, Bruun's, Rader's, Chirp Z-transform, hexagonal, etc.

[0044] The computer **105** is programmed to identify a motion inside the passenger compartment **115** based on the radar data received during the time-window. The computer **105** may separately analyze the radar data filtered with the bandpass filter and the radar data filtered with the smoothing filter. The radar data filtered with the bandpass filter and the radar data filtered with the smoothing filter may be used to identify different types of motion. For example, the radar data filtered with the bandpass filter may be used to identify human respiration, e.g., a number of respirating individuals in the passenger compartment **115**. For another example, the radar data filtered with the smoothing filter may be used to identify animate bulk motion, e.g., classify the motion as a type of animate bulk motion, e.g., a person sitting down into a seat **125**, a person shifting in a seat **125**, a child moving in a car seat installed on a seat **125**, a dog laying down on a seat **125**, etc. The term "animate" indicates that the motion is by a living being, and the term "bulk motion" indicates that the motion is large-scale motion as opposed to physiological processes such as respiration. For one or both of the radar data filtered with the bandpass filter and the radar data filtered with the smoothing filter, the computer **105** may identify the motion in the passenger compartment **115** based on that radar data in the frequency domain.

[0045] For example, the computer **105** may be programmed to identify a number of respirating individuals based on the radar data received during the time-window. The computer **105** may count a number of peaks exceeding a threshold amplitude in the radar data converted to the frequency domain. The threshold amplitude may be chosen to be above a typical noise level of the radar data in the frequency domain and below a typical amplitude of a person respirating. FIG. **3** shows a first plot **305** in which zero peaks exceed the threshold amplitude, indicating zero individuals detected respirating; a second plot **310** in which one peak exceeds the threshold amplitude, indicating one individual detected respirating; and a third plot **315** in which three peaks exceed the threshold amplitude, indicating three individuals detected respirating.

[0046] For another example, the computer **105** may classify the motion as a type of animate bulk motion based on the radar data received during the time-window. The classification of the motion may include a type of living being performing the motion and/or a type of action that the motion is. Types of living beings may include adult human, child, dog, cat, etc. Types of actions may include sitting down, shifting, turning a head, etc. Some actions may be specific to a type of being, e.g., sitting down for a person and laying down for a dog.

[0047] The computer **105** may classify the motion as a type of animate bulk motion by executing a neural network classifier with the radar data received during the time-window as an input. The neural network classifier may receive as an input the radar data received during one of the time-windows and filtered with the smoothing filter. The input radar data may be in the time domain or in the frequency domain. The neural network classifier may provide as an output a classification of the motion as a specific type, e.g., from a prestored list of types. The neural network classifier may be any suitable type of neural network, e.g., a convolutional neural network.

[0048] A convolutional neural network includes a series of layers, with each layer using the previous layer as input. Each layer contains a plurality of neurons that receive as input data generated by a subset of the neurons of the previous layers and generate output that is sent to neurons in the next layer. Types of layers include convolutional layers, which compute a dot product of a weight and a small region of input data; pool layers, which perform a down-sampling operation along spatial dimensions; and fully connected layers, which generate based on the output of all neurons of the previous layer. The final layer of the convolutional neural network generates a score for each potential type of motion, and the final output is the type with the highest score.

[0049] The neural network classifier may be trained to classify motions in training data. The neural network classifier during training may output a classification and a velocity for each motion. The training data may include radar data of different motions paired with ground-truth classifications and ground-truth velocities of the motions. The ground-truth classifications may be derived by performing object recognition on camera data that was recorded simultaneously with the training radar data. The ground-truth velocities may be the first derivative of fast time with respect to slow time for the selected signal **225** of the training radar data. The neural network classifier may be trained to minimize a loss function, e.g., via backpropagation. The loss function may include terms for a classification loss and a physics loss. The classification loss may penalize outputted classifications that do not match the ground-truth classifications. The physics loss may penalize the outputted velocity for a magnitude of the difference with the ground-truth velocity. The use of the physics loss can increase the accuracy of the classification outputted by the neural network classifier, compared with training using only the classification loss.

[0050] The computer **105** is programmed to actuate a component **120** of the vehicle **100** based on the identification of the motion. For example, the computer **105** may command the user interface to output an alert to an occupant **140** of the passenger compartment **115** based on the identification of the motion. The computer **105** may actuate the component **120** in response to the identification of the motion satisfying a condition. For example, the condition may be that the number of respirating individuals exceeds a threshold when the vehicle **100** is turned off. For another example, the condition may be the classification of animate bulk motion as a person moving from one seat **125** to another seat **125**.

[0051] FIG. **4** is a flowchart illustrating an example process **400** for identifying motion in the passenger compartment **115** based on the radar data. The memory of the computer **105** stores executable instructions for performing the steps of the process **400** and/or programming can be implemented in structures such as mentioned above. As a general overview of the process **400**, the computer **105** receives the radar data and selects the selected signal **225** from the radar data and filters the radar data. If data collection is already started or the criteria for starting data collection are met, the computer **105** stores the radar data in a buffer in the memory of the computer **105** until the ending time of the time-window. The computer **105** then converts the radar data in the buffer to the frequency domain, empties the buffer, identifies the motion, and actuates the component **120** if the condition is met. The computer **105** ceases the data collection if the criteria for doing so are met. The process **400** continues for as long as the vehicle **100** remains on.

[0052] The process **400** begins in a block **405**, in which the computer **105** receives the radar data from one of the UWB radars **110** in the passenger compartment **115** of the vehicle **100**, as described above.

[0053] Next, in a block **410**, the computer **105** selects the selected signal **225** from the radar data and applies the filters to the radar data, as described above.

[0054] Next, in a decision block **415**, the computer **105** determines whether the data collection period is currently ongoing, i.e., if the data collection period has already started, as described above. For example, a flag in the memory of the computer **105** may indicate whether the data collection period is ongoing or is not currently being performed. In response to the data collection period not being started yet, the process **400** proceeds to a decision block **420**. In response to the data collection period being ongoing, the process **400** proceeds to a block **425**.

[0055] In the decision block **420**, the computer **105** determines whether to start a first time-window of the data collection period, i.e., whether to designate a current time as the starting-time for the first time-window, based on the second derivative of the radar data, as described above. Upon designating the starting-time, the computer **105** sets the flag in the memory indicating that the data collection period is ongoing, and the process **400** proceeds to the block **425**. In response to the current time not being at the starting-time, the process **400** returns to the block **405** to continue receiving the radar data.

[0056] In the block **425**, the computer **105** stores the radar data in the buffer of the memory of the computer **105**.

[0057] Next, in a decision block **430**, the computer **105** determines whether the current time-window has reached the ending time, i.e., the end of the preset duration of the time-window, as described above, which may correspond to the buffer of the memory being full. In response to the time-window being incomplete, the process **400** returns to the block **405** to continue filling the buffer with the radar data. In response to the current time being at the ending time, the process **400** proceeds to the block **435**.

[0058] In the block **435**, the computer **105** converts the radar data received during the time-window to the frequency domain, as described above, and stores the converted radar data elsewhere in the memory.

[0059] Next, in a block **440**, the computer **105** empties the buffer, i.e., deletes the time-domain radar data stored in the buffer, to make space for continuing to gather the radar data.

[0060] Next, in a block **445**, the computer **105** identifies motions inside the passenger compartment **115** based on the radar data received during the time-window, as described above.

[0061] Next, in a decision block **450**, the computer **105** determines whether any conditions for actuating the component **120** have been satisfied, as described above. In response to one of the conditions being satisfied, the process **400** proceeds to a block **455**. In response to none of the conditions being satisfied, the process **400** proceeds to a decision block **460**.

[0062] In the block **455**, the computer **105** actuates the component **120** of the vehicle **100** based on the identification of the motion, as described above. After the block **455**, the process **400** proceeds to the decision block **460**.

[0063] In the decision block **460**, the computer **105** determines whether a criteria for ceasing the data collection period has been satisfied, e.g., the second derivative is below the threshold amount for at least the threshold duration, as described above. In response to the criteria not being satisfied, the process **400** proceeds to a block **465**. In response to the criteria being satisfied, the process **400** proceeds to a decision block **470**.

[0064] In the block **465**, the computer **105** sets the flag in the memory to indicate that the data collection period is not ongoing. The computer **105** thus refrains from using the radar data received after the current time-window to identify motions inside the passenger compartment **115**. After the block **465**, the process **400** proceeds to the decision block **470**.

[0065] In the decision block **470**, the computer **105** determines whether the vehicle **100** is still on. In response to the vehicle **100** still being on, the process **400** returns to the block **405** to continue gathering the radar data. In response to the vehicle **100** being turned off, the process **400** ends.

[0066] In general, the computing systems and/or devices described may employ any of a number of

computer operating systems, including, but by no means limited to, versions and/or varieties of the Ford Sync® application, AppLink/Smart Device Link middleware, the Microsoft Automotive® operating system, the Microsoft Windows® operating system, the Unix operating system (e.g., the Solaris® operating system distributed by Oracle Corporation of Redwood Shores, California), the AIX UNIX operating system distributed by International Business Machines of Armonk, New York, the Linux operating system, the Mac OSX and iOS operating systems distributed by Apple Inc. of Cupertino, California, the BlackBerry OS distributed by Blackberry, Ltd. of Waterloo, Canada, and the Android operating system developed by Google, Inc. and the Open Handset Alliance, or the QNX® CAR Platform for Infotainment offered by QNX Software Systems. Examples of computing devices include, without limitation, an on-board vehicle computer, a computer workstation, a server, a desktop, notebook, laptop, or handheld computer, or some other computing system and/or device.

[0067] Computing devices generally include computer-executable instructions, where the instructions may be executable by one or more computing devices such as those listed above. Computer executable instructions may be compiled or interpreted from computer programs created using a variety of programming languages and/or technologies, including, without limitation, and either alone or in combination, Java™, C, C++, Matlab, Simulink, Stateflow, Visual Basic, Java Script, Python, Perl, HTML, etc. Some of these applications may be compiled and executed on a virtual machine, such as the Java Virtual Machine, the Dalvik virtual machine, or the like. In general, a processor (e.g., a microprocessor) receives instructions, e.g., from a memory, a computer readable medium, etc., and executes these instructions, thereby performing one or more processes, including one or more of the processes described herein. Such instructions and other data may be stored and transmitted using a variety of computer readable media. A file in a computing device is generally a collection of data stored on a computer readable medium, such as a storage medium, a random access memory, etc.

[0068] A computer-readable medium (also referred to as a processor-readable medium) includes any non-transitory (e.g., tangible) medium that participates in providing data (e.g., instructions) that may be read by a computer (e.g., by a processor of a computer). Such a medium may take many forms, including, but not limited to, non-volatile media and volatile media. Instructions may be transmitted by one or more transmission media, including fiber optics, wires, wireless communication, including the internals that comprise a system bus coupled to a processor of a computer. Common forms of computer-readable media include, for example, RAM, a PROM, an EPROM, a FLASH-EEPROM, any other memory chip or cartridge, or any other medium from which a computer can read.

[0069] Databases, data repositories or other data stores described herein may include various kinds of mechanisms for storing, accessing, and retrieving various kinds of data, including a hierarchical database, a set of files in a file system, an application database in a proprietary format, a relational database management system (RDBMS), a nonrelational database (NoSQL), a graph database (GDB), etc. Each such data store is generally included within a computing device employing a computer operating system such as one of those mentioned above, and are accessed via a network in any one or more of a variety of manners. A file system may be accessible from a computer operating system and may include files stored in various formats. An RDBMS generally employs the Structured Query Language (SQL) in addition to a language for creating, storing, editing, and executing stored procedures, such as the PL/SQL language mentioned above.

[0070] In some examples, system elements may be implemented as computer-readable instructions (e.g., software) on one or more computing devices (e.g., servers, personal computers, etc.), stored on computer readable media associated therewith (e.g., disks, memories, etc.). A computer program product may comprise such instructions stored on computer readable media for carrying out the functions described herein.

[0071] In the drawings, the same reference numbers indicate the same elements. Further, some or

all of these elements could be changed. With regard to the media, processes, systems, methods, heuristics, etc. described herein, it should be understood that, although the steps of such processes, etc. have been described as occurring according to a certain ordered sequence, such processes could be practiced with the described steps performed in an order other than the order described herein. It further should be understood that certain steps could be performed simultaneously, that other steps could be added, or that certain steps described herein could be omitted. Operations, systems, and methods described herein should always be implemented and/or performed in accordance with an applicable owner's/user's manual and/or safety guidelines.

[0072] The disclosure has been described in an illustrative manner, and it is to be understood that the terminology which has been used is intended to be in the nature of words of description rather than of limitation. Use of "in response to," "upon determining," etc. indicates a causal relationship, not merely a temporal relationship. The adjectives "first" and "second" are used throughout this document as identifiers and are not intended to signify importance, order, or quantity. Many modifications and variations of the present disclosure are possible in light of the above teachings, and the disclosure may be practiced otherwise than as specifically described.

Claims

1. A computer comprising a processor and a memory, the memory storing instructions executable by the processor to: receive radar data from an ultrawideband radar in a passenger compartment of a vehicle; determine a starting-time for a time-window based on a second derivative of the radar data; identify a motion inside the passenger compartment based on the radar data received during the time-window; and actuate a component of the vehicle based on the identification of the motion.

2. The computer of claim 1, wherein the second derivative of the radar data is a second derivative of fast time with respect to slow time.

3. The computer of claim 1, wherein the instructions further include instructions to refrain from using the radar data received before the starting-time to identify the motion inside the passenger compartment.

4. The computer of claim 1, wherein the instructions further include instructions to convert the radar data received during the time-window to a frequency domain, and identify the motion in the passenger compartment based on the radar data in the frequency domain.

5. The computer of claim 4, wherein the instructions further include instructions to convert the radar data received during the time-window to the frequency domain by applying a fast Fourier transform.

6. The computer of claim 1, wherein the time-window has a preset duration.

7. The computer of claim 1, wherein the instructions further include instructions to apply a filter to the radar data, and the second derivative is of the radar data after the application of the filter.

8. The computer of claim 7, wherein the filter is a smoothing filter.

9. The computer of claim 7, wherein the filter is a bandpass filter isolating frequencies for human respiration.

10. The computer of claim 1, wherein the time-window is a first time-window, the starting-time is a first starting-time, and the instructions further include instructions to identify the motion in the passenger compartment based on the radar data received during a second time-window, the second time-window starting at an ending time of the first time-window.

11. The computer of claim 10, wherein the instructions further include instructions to, in response to the second derivative being below a threshold amount for at least a threshold duration, refrain from using the radar data received after a current time-window to identify the motion inside the passenger compartment.

12. The computer of claim 1, wherein the instructions further include instructions to classify the motion as a type of animate bulk motion based on the radar data received during the time-window.

13. The computer of claim 12, wherein the instructions further include instructions to classify the motion as a type of animate bulk motion by executing a neural network classifier with the radar data received during the time-window as an input.

14. The computer of claim 1, wherein the instructions further include instructions to identify a number of respirating individuals based on the radar data received during the time-window.

15. The computer of claim 1, wherein the instructions further include instructions to command a user interface to output an alert to an occupant of the passenger compartment based on the identification of the motion.

16. A method comprising: receiving radar data from an ultrawideband radar in a passenger compartment of a vehicle; determining a starting-time for a time-window based on a second derivative of the radar data; identifying a motion inside the passenger compartment based on the radar data received during the time-window; and actuating a component of the vehicle based on the identification of the motion.

17. The method of claim 16, wherein the second derivative of the radar data is a second derivative of fast time with respect to slow time.

18. The method of claim 16, further comprising refraining from using the radar data received before the starting-time to identify the motion inside the passenger compartment.

19. The method of claim 16, further comprising converting the radar data received during the time-window to a frequency domain, and identifying the motion in the passenger compartment based on the radar data in the frequency domain.

20. The method of claim 16, further comprising commanding a user interface to output an alert to an occupant of the passenger compartment based on the identification of the motion.