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(54) **Title**: DISTANCE ESTIMATION

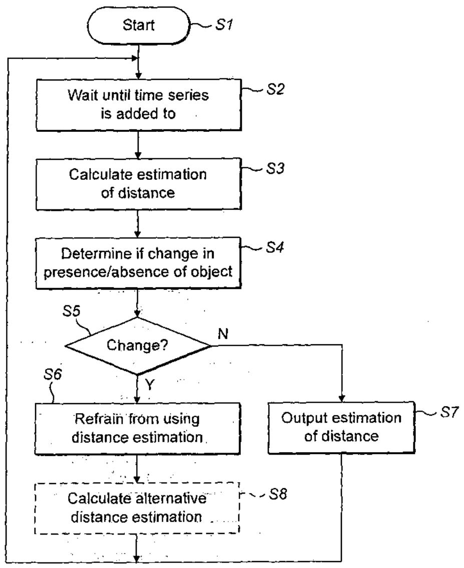

FIG. 4

(57) **Abstract**: Apparatus is configured to perform a method comprising: using a time series of received signal strength measurements to provide a time series of attenuation estimates, each estimate relating to the attenuation of radio waves propagating through a channel between a transmitter and a receiver at a different instance of time; calculating a first estimation of distance between the transmitter and the receiver using at least one of the attenuation estimates of the time series of attenuation estimates (S3); determining whether there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver, said determining using at least two attenuation estimates from the time series of attenuation estimates (S4); determining that the first estimation of distance is unreliable in response to determining that there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver (S5); and refraining from using the first estimation of distance in response to determining that the first estimation of distance is unreliable (S6).

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Distance Estimation

Field of the Invention

This specification relates generally to distance estimation.

Background to the Invention

Bluetooth Low Energy (BLE) is a new wireless communication technology published by the Bluetooth SIG as a component of Bluetooth Core Specification Version 4.0. BLE is a lower power, lower complexity, and lower cost wireless communication protocol, designed for applications requiring lower data rates and shorter duty cycles. Inheriting the protocol stack and star topology of classical Bluetooth, BLE redefines the physical layer specification, and involves many new features such as a very-low power idle mode, a simple device discovery, and short data packets, etc. BLE is also known as BTLE or Bluetooth Smart.

BLE technology is aimed at devices requiring a low power consumption, for example devices that may operate with one or more button cell batteries such as sensors, key fobs, and/or the like. BLE can also be incorporated into devices such as mobile phones, smart phones, tablet computers, laptop computers, desktop computers etc.

BLE includes a 'proximity profile' feature that enables monitoring between two devices. The principles involved are such that similar proximity features could be implemented using other technologies.

Summary of Embodiments of the Invention

A first aspect of the invention provides apparatus comprising:

means for using a time series of received signal strength measurements to provide a time series of attenuation estimates, each estimate relating to the attenuation of radio waves propagating through a channel between a transmitter and a receiver at a different instance of time;

means for calculating a first estimation of distance between the transmitter and the receiver using at least one of the attenuation estimates of the time series of attenuation estimates;

means for determining whether there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver, said determining using at least two attenuation estimates from the time series of attenuation estimates;

means for determining that the first estimation of distance is unreliable in response to determining that there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver; and

means for refraining from using the first estimation of distance in response to determining that the first estimation of distance is unreliable.

The apparatus may comprise:

means for determining a rate of change of estimated attenuation using the at least two attenuation estimates from the time series of attenuation estimates,

wherein the means for determining that there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver is configured to determine that there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver in response to detecting that the rate of change of estimated attenuation exceeds a threshold.

The apparatus may comprise:

means for calculating a second estimation of distance between the transmitter and the receiver for a time instance corresponding to the first estimation of distance by low pass filtering the time series of attenuation estimates.

The apparatus may comprise:

means for determining whether there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver using the at least two attenuation estimates from the time series of attenuation estimates and using sensor information indicating whether the transmitter is moving.

The apparatus may comprise:

means for determining whether there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver using the at least two attenuation estimates from the time series of attenuation estimates and using sensor information indicating whether the receiver is moving.

The apparatus may comprise: means for determining whether there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver using the at least two attenuation estimates from the time series of attenuation estimates and using sensor information indicating an amount of movement of the transmitter and/or the receiver between the time instances relating to the at least two attenuation estimates. Here, the means for determining whether there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver using the at least two attenuation estimates from the time series of attenuation estimates and using sensor information indicating an amount of movement of the transmitter and/or the receiver between the time instances relating to the at least two attenuation estimates may comprise means for determining whether the first estimation of distance is consistent with a previous estimation of distance having regard to an amount of relative movement between the transmitter and the receiver that is consistent with the sensor information.

The apparatus may be the transmitter, and wherein the apparatus may be configured to receive the time series of signal strength measurements from the receiver. The apparatus may comprise a sensor arrangement comprising one or more sensors selected from the group comprising: a gyroscope, an accelerometer and a magnetometer.

The apparatus may be configured to receive movement information or sensor information indicative of movement from the receiver.

The apparatus may be the receiver.

The apparatus may comprise a sensor arrangement comprising one or more sensors selected from the group comprising: a gyroscope, an accelerometer and a magnetometer.

The apparatus may be configured to receive movement information or sensor information indicative of movement from the transmitter.

A second aspect of the invention provides a method comprising:

using a time series of received signal strength measurements to provide a time series of attenuation estimates, each estimate relating to the attenuation of radio waves propagating through a channel between a transmitter and a receiver at a different instance of time;

calculating a first estimation of distance between the transmitter and the receiver using at least one of the attenuation estimates of the time series of attenuation estimates;

determining whether there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver, said determining using at least two attenuation estimates from the time series of attenuation estimates;

determining that the first estimation of distance is unreliable in response to determining that there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver; and

refraining from using the first estimation of distance in response to determining that the first estimation of distance is unreliable.

The method may comprise:

determining a rate of change of estimated attenuation using the at least two attenuation estimates from the time series of attenuation estimates,

wherein determining that there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver may comprise determining that there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver in response to detecting that the rate of change of estimated attenuation exceeds a threshold.

The method may comprise:

calculating a second estimation of distance between the transmitter and the receiver for a time instance corresponding to the first estimation of distance by low pass filtering the time series of attenuation estimates.

The method may comprise:

determining whether there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver using the at least two attenuation estimates from the time series of attenuation estimates and using sensor information indicating whether the transmitter is moving.

The method may comprise:

determining whether there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver using the at least two attenuation estimates from the time series of attenuation estimates and using sensor information indicating whether the receiver is moving.

The method may comprise:

determining whether there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver using the at least two attenuation estimates from the time series of attenuation estimates and using sensor information indicating an amount of movement of the transmitter and/or the receiver between the time instances relating to the at least two attenuation estimates. The method may comprise: determining whether there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver using the at least two attenuation estimates from the time series of attenuation estimates and using sensor information indicating an amount of movement of the transmitter and/or the receiver between the time instances relating to the at least two attenuation estimates by determining whether the first estimation of distance is consistent with a previous estimation of distance having regard to an amount of relative movement between the transmitter and the receiver that is consistent with the sensor information.

The method may be performed by the transmitter, and the method may comprise the transmitter receiving the time series of signal strength measurements from the receiver.

The transmitter may comprise a sensor arrangement comprising one or more sensors selected from the group comprising: a gyroscope, an accelerometer and a magnetometer.

The method may comprise: the transmitter receiving movement information or sensor information indicative of movement from the receiver.

The method may be performed by the receiver.

The receiver may comprise a sensor arrangement comprising one or more sensors selected from the group comprising: a gyroscope, an accelerometer and a magnetometer.

The method may comprise: the receiver receiving movement information or sensor information indicative of movement from the transmitter.

Another aspect of the invention provides a computer program comprising machine readable instructions that when executed by computing apparatus control it to perform any method above.

A third aspect of the invention provides apparatus, comprising at least one processor, at least one memory, and computer-readable code stored on the at least one memory, wherein the computer-readable code when executed controls the at least one processor to perform a method comprising:

using a time series of received signal strength measurements to provide a time series of attenuation estimates, each estimate relating to the attenuation of radio waves propagating through a channel between a transmitter and a receiver at a different instance of time;

calculating a first estimation of distance between the transmitter and the receiver using at least one of the attenuation estimates of the time series of attenuation estimates;

determining whether there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver, said determining using at least two attenuation estimates from the time series of attenuation estimates;

determining that the first estimation of distance is unreliable in response to determining that there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver; and

refraining from using the first estimation of distance in response to determining that the first estimation of distance is unreliable.

The computer-readable code when executed may control the at least one processor to perform:

determining a rate of change of estimated attenuation using the at least two attenuation estimates from the time series of attenuation estimates, and

determining that there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver by determining that there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver in response to detecting that the rate of change of estimated attenuation exceeds a threshold.

The computer-readable code when executed may control the at least one processor to perform:

calculating a second estimation of distance between the transmitter and the receiver for a time instance corresponding to the first estimation of distance by low pass filtering the time series of attenuation estimates.

The computer-readable code when executed may control the at least one processor to perform:

determining whether there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver using the at least two attenuation estimates from the time series of attenuation estimates and using sensor information indicating whether the transmitter is moving.

The computer-readable code when executed may control the at least one processor to perform:

determining whether there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver using the at least two attenuation estimates from the time series of attenuation estimates and using sensor information indicating whether the receiver is moving.

The computer-readable code when executed may control the at least one processor to perform:

determining whether there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver using the at least two attenuation estimates from the time series of attenuation estimates and using sensor information indicating an amount of movement of the transmitter and/or the receiver between the time instances relating to the at least two attenuation estimates.

The computer-readable code when executed may control the at least one processor to perform:

determining whether there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver using the at least two attenuation estimates from the time series of attenuation estimates and using sensor information indicating an amount of movement of the transmitter and/or the receiver between the time instances relating to the at least two attenuation estimates by determining whether the first estimation of distance is consistent with a previous estimation of distance having regard to an amount of relative movement between the transmitter and the receiver that is consistent with the sensor information.

The apparatus may be the transmitter, and the computer-readable code when executed may control the at least one processor to receive the time series of signal strength measurements from the receiver.

The apparatus may comprise a sensor arrangement comprising one or more sensors selected from the group comprising: a gyroscope, an accelerometer and a magnetometer.

The computer-readable code when executed may control the at least one processor to receive movement information or sensor information indicative of movement from the receiver.

The apparatus may be the receiver.

The apparatus may comprise a sensor arrangement comprising one or more sensors selected from the group comprising: a gyroscope, an accelerometer and a magnetometer.

The computer-readable code when executed may control the at least one processor to perform receive movement information or sensor information indicative of movement from the transmitter.

A fourth aspect of the invention provides a storage medium, comprising computing apparatus, at least one memory, and computer-readable code stored on the at least one memory, wherein the computer-readable code when executed by computing apparatus controls the computing apparatus to perform a method comprising:

using a time series of received signal strength measurements to provide a time series of attenuation estimates, each estimate relating to the attenuation of radio waves propagating through a channel between a transmitter and a receiver at a different instance of time;

calculating a first estimation of distance between the transmitter and the receiver using at least one of the attenuation estimates of the time series of attenuation estimates;

determining whether there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver, said determining using at least two attenuation estimates from the time series of attenuation estimates;

determining that the first estimation of distance is unreliable in response to determining that there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver; and

refraining from using the first estimation of distance in response to determining that the first estimation of distance is unreliable.

The computer-readable code when executed may control the computing apparatus to perform:

determining a rate of change of estimated attenuation using the at least two attenuation estimates from the time series of attenuation estimates, and

determining that there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver by determining that there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver in response to detecting that the rate of change of estimated attenuation exceeds a threshold.

The computer-readable code when executed may control the computing apparatus to perform:

calculating a second estimation of distance between the transmitter and the receiver for a time instance corresponding to the first estimation of distance by low pass filtering the time series of attenuation estimates.

The computer-readable code when executed may control the computing apparatus to perform:

determining whether there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver using the at least two attenuation estimates from the time series of attenuation estimates and using sensor information indicating whether the transmitter is moving.

The computer-readable code when executed may control the computing apparatus to perform:

determining whether there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver using the at least two attenuation estimates from the time series of attenuation estimates and using sensor information indicating whether the receiver is moving.

The computer-readable code when executed may control the computing apparatus to perform:

determining whether there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver using the at least two attenuation estimates from the time series of attenuation estimates and using sensor information indicating an amount of movement of the transmitter and/or the receiver between the time instances relating to the at least two attenuation estimates.

The computer-readable code when executed may control the computing apparatus to perform:

determining whether there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver using the at least two attenuation estimates from the time series of attenuation estimates and using sensor information indicating an amount of movement of the transmitter and/or the receiver between the time instances relating to the at least two attenuation estimates by determining whether the first estimation of distance is consistent with a previous estimation of distance having regard to an amount of relative movement between the transmitter and the receiver that is consistent with the sensor information.

The computing apparatus is the transmitter, and wherein the computer-readable code when executed may control the computing apparatus to receive the time series of signal strength measurements from the receiver.

The computing apparatus may comprise a sensor arrangement comprising one or more sensors selected from the group comprising: a gyroscope, an accelerometer and a magnetometer.

The computer-readable code when executed may control the computing apparatus to receive movement information or sensor information indicative of movement from the receiver.

The computing apparatus may be the receiver.

The computing apparatus may comprise a sensor arrangement comprising one or more sensors selected from the group comprising: a gyroscope, an accelerometer and a magnetometer.

The computer-readable code when executed may control the computing apparatus to perform receive movement information or sensor information indicative of movement from the transmitter.

Brief Description of the Drawings

Embodiments will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a schematic diagram illustrating a system including two devices according to embodiments of the invention and illustrating a scenario in which the devices move relative to one another;

Figure 2 is a schematic diagram illustrating components of a first terminal 100 of Figure 1 according to embodiments of the invention;

Figure 3 is a schematic diagram illustrating components of a second terminal 200 of Figure 1 according to embodiments of the invention;

Figure 4 is a flow chart illustrating operation of one of the terminals 100, 200 according to embodiments of the invention;

Figure 5 is a plot of estimated distance versus time, that is useful in understanding operation of the terminals 100, 200; and

Figure 6 is another plot of distance versus time that is useful in understanding operation of the terminals.

Detailed Description of Embodiments of the Invention

Figure 1 shows a system comprising a first terminal 100 in proximity with a second terminal 200. There is a distance D1 between the first and second terminals 100, 200 at a first time t1, a second distance D2 between the first and second terminals 100, 200 at a time t2, which is later than t1, and a third distance D3 between the first and second terminals 100, 200 at a time t3, which is later than t2.

One or both of the terminals 100, 200 is configured to determine proximity to the other terminal by measuring the strength of signals received from the other terminal, estimating attenuation of the channel between the terminals and then using the estimated attenuation to estimate the distance. The transmitted signals may for instance be Bluetooth Low Energy signals, in which case they are transmitted at a predetermined, fixed power level. Alternatively, there may be signals of some other form, in which case they may be transmitted at a fixed power level or at a variable power level. In the case of variable power levels being used at a transmitter, the receiver needs to know the transmit power at the transmitter in order to estimate the attenuation in the channel between the transmitter and receiver 100, 200.

Put another way, the receiver needs to know the transmit power of the transmitter, and if the transmit power is fixed then the receiver can have knowledge of the transmit power without actually receiving information (data) indicating the transmit power.

An algorithm is used to convert calculated attenuation to a distance estimate. The algorithm can be for example the ITU indoor propagation model, or another model, and may be statistical.

In progressing from the first position at time t1 to the third position at time t3, the second terminal 200 moves through a second position at time t2. When in the second position, the second terminal 200 is a distance D2 from the first terminal 100. However, there is an object, in this case a person, in the path between the first and second terminals 100, 200. As such, the attenuation in the path is much greater when the terminal is at the second position than it is when the terminal is at either of the first and third positions. Using the measure of attenuation estimated from the received signal strength at the receiver, an estimated distance between the first and second terminals 100, 200 at the second time t2, would be very different to the actual distance between the terminals 100, 200.

In the scenario where the first terminal 100 is a mobile phone that has been placed on a table and the second terminal 200 is a tag attached to a user's wallet or keys, and is present in the user's pocket, the scenario in Figure 1 gives rise to an interesting situation. In particular, if the estimated distance between the first and second terminals 100, 200 is used to trigger an alarm when it is detected that the distance between the terminals 100, 200 has exceeded a threshold, indicating that the user's wallet or keys has become separated from their mobile phone, an alarm would be generated when the second terminal 200 was at the second position, even though the actual distance D2 between the first and second terminals 100, 200 when the second terminal is in the second position is not sufficiently great that the alarm should be triggered.

One possible solution to this problem is to include a timer in the alarm system such that an alarm is not raised unless the estimated distance between the terminals is determined to have exceeded a threshold for a minimum period of time. In the scenario shown in Figure 1, the inclusion of a timer with a suitable value would prevent the alarm being raised, because the second terminal 200 would be detected as being below the threshold distance when the terminal 200 is at the third position. However, including a timer in the alarm system in this way may prevent an alarm being raised in situations where it would be desirable for an alarm to be raised, for example when the actual distance between the terminals 100, 200 has increased by an amount such that it does exceed the threshold distance.

An alternative solution to the problem is provided in the following embodiments.

Briefly, a time series of received signal strength measurements is used to provide a time series of attenuation estimates, each estimate relating to the attenuation of radio waves propagating through a channel between a transmitter and a receiver at a different instance of time. A first estimation of distance between the transmitter and the receiver is calculated using at least one of the attenuation estimates from the time series. A change in the presence or absence of an attenuating object in the path between the transmitter and the receiver is determined using at least two attenuation estimates from the time series of attenuation estimates, and is used to determine whether the first estimation of distance is unreliable. If the first estimation of distance is unreliable, it is not used.

This solution can avoid the above-stated disadvantage of the alternative solution, whilst providing a useful proximity determination.

Referring now to Figure 2, a block diagram illustrating internal components of the first terminal 100 is shown. The first terminal 100 includes a processor 102. The processor 102 controls operation of the other hardware components of the first terminal 100. The processor 102 and other hardware components may be connected via a system bus (not shown). Each hardware component may be connected to the system bus either directly or via an interface. The terminal comprises working or volatile memory, such as Random Access Memory (RAM), 104 and a non-volatile memory 106, such as read only memory (ROM) or Flash memory. The non-volatile memory 106 stores an operating system 108 and various software applications 110. The non-volatile memory 106 also stores data files and associated metadata. The terminal comprises a display 112. The display may be a touch sensitive display having a display part 113 and a tactile interface part 114. The terminal may comprise one or more examples of user input hardware 116, such as hardware keys. The first terminal 100 also houses a battery 118 to power the first terminal 100.

The processor 102 is configured to send and receive signals to and from the other components in order to control operation of the other components. For example, the processor 102 controls the display of content on display 112 and receives signals as a result of user inputs from tactile interface 114. The display 112 may be a resistive touch screen or capacitive touch screen of any kind. The display may alternatively not be a touch screen. For instance it may be a liquid crystal display (LCD) or organic light emitting diode (OLED) display. It may alternatively be a near-eye display, such as is found in a wearable computer in the form of spectacles or glasses.

The user input hardware 116 may refer to hardware keys and may also include a QWERTY or numeric keypad, etc. The user input hardware 116 may include accessory input hardware such as an input pen, external touchpad, etc. The user input hardware 116 functions in addition to the touch sensitive display 112, which also receives user inputs.

The first terminal 100 includes a number of other hardware features. These include a microphone arrangement 120 and a speaker arrangement 121. Also provided is a gyroscope 122, which may take any suitable form. A haptic transducer 123 is provided. The haptic transducer 123 is for example a transducer that can provide mechanical vibration in response to electrical signal input. An accelerometer arrangement 124 is provided. A magnetometer 125 is provided.

Each of the microphone 120, the speaker 121, gyroscope 122, the haptic transducer 123, the accelerometer 124 and the magnetometer 125 are connected to the processor 102. Connection may be made in any suitable way, and typically involves a hardware interface and driver software.

The first terminal 100 includes a BLE module 111, which may take any suitable form. The BLE module 111 is connected to the processor 102. Generally speaking, the BLE module 111 comprises processing circuitry 131, including one or more processors, and a storage device 132 comprising a single memory unit or a plurality of memory units. The storage device 132 may comprise volatile memory, such as RAM, and non-volatile memory, such as ROM. It may alternatively comprise flash memory. The storage device 132 stores computer program instructions that, when executed by the processing circuitry 131, control the operation of the BLE module 111.

The BLE module 111 includes a communication stack that is implemented at least partly in software using the processor and memory resources 131, 132 of the BLE module 111. The BLE module 111 includes a transmit/receive subsystem 126, which effects transmission and reception through an antenna 128. The BLE module 111 also includes an RSS (received signal strength) measurement subsystem 127, which is configured to measure the strength of received signals.

The applications 110 include a proximity application 110 that causes control of the BLE module 111 to switch between a proximity determining mode in which it determines proximity with another BLE device, for instance the second terminal 200, and a non-proximity determining mode in which it does not determine proximity with the another BLE device.

The first terminal 100 may be a mobile phone, PDA, tablet computer, wearable computer in the form of spectacles or glasses, watch phone, wrist device, smart watch, portable media player, portable camera, etc. Other standard or optional components of the first terminal 100, such as transceivers and cameras, are omitted from Figure 2.

The processor 102 may be an integrated circuit of any kind. The processor 102 may access volatile memory 104 in order to process data and may control the storage of data in memory 106. Memory 106 may be a non-volatile memory of any kind such as a Read Only Memory (ROM), a Flash memory or a magnetic drive memory. Other non-volatile memories may be included, but are omitted from the Figure. The volatile memory 104 may be a RAM of any type, for example Static RAM (SRAM), Dynamic RAM (DRAM), or it may be Flash memory. Multiple volatile memories 104 may be included, but are omitted from the Figure.

The processor 102 may for instance be a general purpose processor. It may be a single core device or a multiple core device. The processor 102 may be a central processing unit (CPU) or a general processing unit (GPU). Alternatively, it may be a more specialist unit, for instance a RISC processor or programmable hardware with embedded firmware. Multiple processors 102 may be included. The processor 102 may be termed processing means.

The processor 102 operates under control of the operating system 108. The operating system 108 may comprise code (i.e. drivers) relating to hardware such as the display 112 and user inputs 116, as well as code relating to the basic operation of the first terminal 100. The operating system 108 may also cause activation of other software modules stored in the memory 106, such as the applications 110. Generally speaking, the processor 102 executes one or more applications 110 using the operating system 108, both of which are stored permanently or semi-permanently in the non-volatile memory 106, using the volatile memory 104 temporarily to store software forming a whole or part of the operating system 108 and the applications 110 and also temporarily to store data generated during execution of the software.

Referring now to Figure 3, a block diagram illustrating internal components of the second terminal 200 is shown.

The second terminal 200 includes a processor 202. The processor 202 controls operation of the other hardware components of the second terminal 200. The processor 202 and other hardware components may be connected via a system bus (not shown). Each hardware component may be connected to the system bus either directly or via an interface.

In these examples, the second terminal 200 is a less sophisticated device than the first terminal 100. In these examples, the second terminal 200 is missing some technical features present in the first terminal 100. Also, some features may be smaller (e.g. the volatile and non-volatile memories) or less powerful (e.g. the processor).

The second terminal 200 comprises working or volatile memory, such as Random Access Memory (RAM), 204 and a non-volatile memory 206, such as read only memory (ROM) or Flash memory. The non-volatile memory 206 stores an operating system 208 and may store one or more software applications 210. The non-volatile memory 206 also stores data files and associated metadata. The second terminal 200 also houses a battery 218 to power the second terminal 200.

The processor 202 is configured to send and receive signals to and from the other components in order to control operation of the other components. For example, the processor 202 receives user inputs through the user input hardware 216 and acts upon them to effect desired operation of the terminal 200.

The user input hardware 216 may refer to on or more hardware keys or touch-sensitive or proximity sensors.

The second terminal 200 includes a gyroscope 222, which may take any suitable form. The gyroscope 222 is connected to the processor 202. Connection may be made in any suitable way, and typically involves a hardware interface and driver software.

The second terminal 200 includes a BLE module 211, which may take any suitable form. The BLE module 211 is connected to the processor 202. Generally speaking, the BLE module 211 comprises processing circuitry 231, including one or more processors, and a storage device 232 comprising a single memory unit or a plurality of memory units. The storage device 232 may comprise volatile memory, such as RAM, and non-volatile memory, such as ROM. It may alternatively comprise flash memory. The storage device 232 stores computer program instructions that, when executed by the processing circuitry 231, control the operation of the BLE module 211.

The BLE module 211 includes a communication stack that is implemented at least partly in software using the processor and memory resources 231, 232 of the BLE module 211. The BLE module 211 includes a transmit/receive subsystem 226, which effects transmission and reception through an antenna 228. The BLE module 211 also includes an RSS (received signal strength) measurement subsystem 227, which is configured to measure the strength of received signals.

The applications 210 include a proximity application 210 that causes control of the BLE module 23 to switch between a proximity determining mode in which it determines proximity with another BLE device, for instance the second terminal 200, and a non-proximity determining mode in which it does not determine proximity with the another BLE device.

The second terminal 200 may be a smart lamp, for example. It may alternatively be a tag, for instance for attaching to keys or for including in a wallet or purse. It may take some other form. For instance, it may be a mobile phone, PDA, tablet computer, wearable computer in the form of spectacles or glasses, watch phone, wrist device, smart watch, portable media player, portable camera, etc. In embodiments in which the second terminal 200 is a tag, the second terminal 200 may comprise a BLE module 211 and a battery 228 and may omit the other features shown in Figure 3, including the memory 206, the processor 202, the input hardware 216, and the sensors 222, 224.

The processor 202 may be an integrated circuit of any kind. The processor 202 may access volatile memory 204 in order to process data and may control the storage of data in memory 206. Memory 206 may be a non-volatile memory of any kind such as a Read Only Memory (ROM), a Flash memory or a magnetic drive memory. Other non-volatile memories may be included, but are omitted from the Figure. The volatile memory 204 may be a RAM of any type, for example Static RAM (SRAM), Dynamic RAM (DRAM), or it may be Flash memory. Multiple volatile memories 204 may be included, but are omitted from the Figure.

The processor 202 may for instance be a general purpose processor. It may be a single core device or a multiple core device. The processor 202 may be a central processing unit (CPU) or a general processing unit (GPU). Alternatively, it may be a more specialist unit, for instance a RISC processor or programmable hardware with embedded firmware. Multiple processors 202 may be included. The processor 202 may be termed processing means.

The processor 202 operates under control of the operating system 208. The operating system 208 may comprise code (i.e. drivers) relating to hardware such as the display 212 and user inputs 216, as well as code relating to the basic operation of the second terminal 200. The operating system 208 may also cause activation of other software modules stored in the memory 206, such as the applications 210. Generally speaking, the processor 202 executes one or more applications 210 using the operating system 208, both of which are stored permanently or semi-permanently in the non-volatile memory 206, using the volatile memory 204 temporarily to store software forming a whole or part of the operating system 208 and the applications 210 and also temporarily to store data generated during execution of the software.

Operation of the first terminal 100 will now be described with reference to the flow chart of Figure 3. In the following, actions said to be made by the terminal typically are made by the processor 102 operating according to instructions provided by the software of the applications 110 and/or the operating system 108.

The operation starts at step S1.

The terminal 100 in general receives signals from the second terminal 200, performs a signal strength measurement of those signals and stores the signal strength measurement along with an indication of time to which the measurements relate in memory, for instance the non-volatile memory 106 or the volatile memory 104. In the case of Bluetooth signals, this is performed by the mobile terminal 100 using the Bluetooth Low Energy module 111. In particular, signals are received using the Tx/Rx component 126 and received signal strength measurements are performed using the RSS measurement module 127.

Using the received signal strength measurement, the terminal 100 performs a calculation to estimate the attenuation in the path between the second terminal 200 and the first terminal 100. The estimated attenuation is included in the recorded time series of received signal strength measurements. Alternatively, the estimated attenuation can replace the signal strength measurements in the recorded time series.

The signals that are used to create the time series typically are received at regular intervals. In the case of Bluetooth Low Energy, the signals may be received at intervals of 20 milliseconds or 50 milliseconds, for instance. The interval can take any suitable value and may be of the order of milliseconds or seconds.

At step S2, the first terminal 100 waits until an addition has been made to the time series. This allows the terminal 100 to perform the operation of the steps of Figure 4 subsequent to step S2 only once a new attenuation estimation has been added to the time series.

At step S3, the terminal 100 calculates an estimation of the distance between the first terminal 100 and the second terminal 200. The estimation of distance is calculated using the estimated attenuation in the channel between the first and second terminals 100, 200 and the known transmit power. The estimated distance is then stored in the time series. The distance estimation may replace the signal strength measurements and/or the calculated attenuation values, but advantageously at least one of the signal strength measurements time series and the calculated attenuation values time series is retained.

At step S4, the first terminal 100 determines whether there has been a change in the presence or absence of an attenuating object in the path between the first and second terminals 100, 200. The determination uses at least two attenuation estimates from the time series of attenuation estimates. In particular, the determination uses at least the two most recent attenuation estimates. A number of options for performing this determination exist. One of these will now be described, with other options being described later in this specification.

In the one option, the determination is made based on the rate of change of attenuation estimate. The rate of change of attenuation estimate is obtained by dividing the change in estimated attenuation between two instances in time by the time interval between the instances of time to which the attenuation estimations relate. If the rate of change exceeds a predetermined threshold, it is determined that there has been a change in the presence or absence of an attenuating object in the path between the terminals 100, 200. If the rate of change is below the threshold, it is determined that there has not been a change in the presence or absence of an attenuating object.

Referring to Figures 5 and 6, it will be seen that the estimated distance is plotted against time for two different situations. In the situation shown in Figure 5, the estimated distance is relatively constant for a period of time, then increases rapidly to a plateau, before decreasing rapidly again to substantially the same level as before the increase, where again it remains substantially constant. Figure 6 illustrates a similar scenario, although the rate of increase in distance on the initial slope is much lower than in Figure 5, and the rate of change in distance estimation on the downward slope also is much lower.

The scenario illustrated in Figure 5 relates to the scenario shown in Figure 1, in which the second terminal 200 is at the second position such that there is a solid object (a person) in the path between the first and second terminals 100, 200. Here, the plateau in the middle of the chart of Figure 5 relates to the situation when the second terminal is at the second position, with the flat portions before and after the plateau relating to the first and second positions for the second terminal 200 respectively. The relatively steep portions of the charts result from the rapid change in attenuation in the path between the first and second terminals 100, 200 as the second terminal 200 moves behind the object and then moves again from behind the object.

The scenario shown in Figure 6 includes much less steep gradients, corresponding to a lower rate of change of estimated distance over time. The scenario of Figure 6 may result from the distance between the first and second terminals 100, 200 increasing as they move away from one another and then decreasing again as they are again brought closer together.

For instance, the threshold rate of change may be a function of the typical walking speed of a user. For instance, setting the threshold at 3 metres per second (which equates to 10 kilometres per hour), it can reasonably be assumed that a rate of change exceeding the threshold results from an object moving into or out of the path between the terminals 100, 200 resulting in an apparent change of distance that is significantly greater than the actual change in distance. Conversely, a rate of change below the threshold indicates that the change in estimated distance results from an actual change in distance between the terminals 100, 200, rather than the change in the presence or absence of an attenuating object in the path between the terminals 100, 200.

In response to determining that there has been a change in the presence or absence of an attenuating object in the path between the terminals 100, 200, the estimation of distance calculated at step S3 is determined to be unreliable. The terminal 100 takes different action depending on whether or not the calculated distance estimation is unreliable. At step S5, it is determined whether a change was determined at step S4.

On a negative determination from step S5, indicating that no change in the presence or absence of an object in the path between the terminals 100, 200 was detected, at step S7 the distance estimation calculated at step S3 is provided as an output. By providing the estimation of distance as an output, the distance estimation can be used by the terminal 100, for instance to make an assessment as to whether an alarm should be triggered if the distance between the terminals 100, 200 exceeds the threshold.

On a positive determination from step S5, indicating that a change in the presence or absence of an attenuating object in the path between the terminals 100, 200 has been detected, the operation proceeds to step S6. Here, the distance estimation calculated at step S3 is refrained from being used. For instance, the distance estimation may not be used in assessing whether an alarm should be raised because the distance between the terminals 100, 200 has exceeded a threshold. The distance estimation calculated at step S3 may be discarded or deleted without being used.

An optional step S8 may follow step S6. Here, an alternative distance estimation may be calculated, this being an alternative to the estimation of distance calculated at step S3. There are a number of options for step S8, some of which are described in this specification.

In a first option, the alternative distance estimation may be calculated as the last estimated distance that is known to be reliable. This is performed by identifying the estimated distance that was calculated at step S3 in respect of a received signal strength measurement for which it was not determined whether there was a change in the presence or absence of an attenuating object in the path between the terminals 100, 200.

Alternatively, step S8 may involve low-pass filtering the time series of calculated distance estimations. Low-pass filtering the time series excludes changes in distance estimation that result from rapidly changing attenuation in the path between the terminals 100, 200.

Further alternatively, step S8 may involve some other type of signal pre-processing to enhance data quality for estimation. For example, instead of low pass filtering, the time series may be data filtered to smooth statistical nature of measurements, for instance by disregarding a number of the smallest and largest values.

Following step S7 or step S6, or following step S8 if this step is provided, the operation returns to step S2. Here, the first terminal 100 waits until the time series has again been added to before performing steps S3 onwards in respect of the latest addition to the time series.

It will be appreciated that the operation of Figure 4 relates primarily to detecting a change in state from no object being present in the path between the terminals 100, 200, to an object becoming present in the path. This relates to the change from the low value of estimated distance to the high value as shown in Figure 5. The terminal 100 is configured also to determine when the object has ceased to be present in the path between the terminals 100, 200, and subsequently again to provide as outputs estimations of distances resulting from received signal strength measurements obtained following the object ceasing to be in the path between the terminals 100, 200. This can be achieved through the flow chart of Figure 4 with relatively minor modifications, or it may be achieved through a separate operation for which the flow chart is not included in the specification.

A second option for step S4 of Figure 4 will now be described. In this option, the mobile terminal 100 uses information provided by the gyroscope arrangement 122 and/or the accelerometer arrangement 124 and/or the magnetometer 125 in determining whether there has been a change in the presence or absence of an object in the path between the terminals 100, 200.

In particular, the terminal 100 is configured to determine from the sensor arrangements 122, 124, 125 an amount of movement of the first terminal 100 in the interval between the time instances to which the distance estimations relate, and to use this information in the determination. In this option, it is not necessary to determine the rate of change of distance estimation. Instead, the change in distance of the first terminal 100 as determined from the output of the sensors 122, 124 is compared to the change in estimated distance. If the change in estimated distance exceeds the known movement of the first terminal 100 by a predetermined amount or by a predetermined factor, then the first terminal 100 determines that an object has entered the path between the terminals 100, 200.

A third option for step S4 of Figure 4 will now be described. In this option, the mobile terminal 100 uses information provided by sensors in the first terminal and also from sensors in the second terminal 200 in determining whether there has been a change in the presence or absence of an object in the path between the terminals 100, 200. The sensors in the first terminal 100 that are used here are the gyroscope arrangement 122 and/or the accelerometer arrangement 124 and/or the magnetometer 125. The sensors in the second terminal 200 that are used here is the accelerometer arrangement 224 and/or the gyroscope arrangement 222. Of course, other sensors arrangements may be used instead. Here, the second terminal 200 transmits to the first terminal 100 information derived from the accelerometer arrangement 224 and/or the gyroscope arrangement 222 in the form of raw or relatively raw sensor data or in the form of an indication of an amount of movement of the second terminal 200.

In particular, the terminal 100 is configured to determine from the sensor arrangements 122, 124, 125, 222 whether or not both of the terminals 100, 200 are moving. If neither is moving at all and the change in estimated distance exceeds a relatively low threshold, then the first terminal 100 determines that an object has entered the path between the terminals 100, 200. If one or both of the terminals 100, 200 is moving but is moving only slowly and the change in estimated distance exceeds a relatively mid-level threshold, then the first terminal 100 determines that an object has entered the path between the terminals 100, 200. If one or both of the terminals 100, 200 is moving and is moving relatively quickly and the change in estimated distance exceeds a relatively high threshold, then the first terminal 100 determines that an object has entered the path between the terminals 100, 200. Generally speaking, the threshold of change in estimated distance that results in a determination of an object having entered the path between the terminals 100, 200 is set depending on the amount of movement of the terminals 100, 200. This dynamic threshold setting provides improved object detection.

A fourth option for step S4 of Figure 4 will now be described. In this option, the mobile terminal 100 uses information provided by sensors in only one of the terminals 100, 200 in determining whether there has been a change in the presence or absence of an object in the path between the terminals 100, 200. The sensors in the first terminal 100 that may be used here are the gyroscope arrangement 122 and/or the accelerometer arrangement 124 and/or the magnetometer 125. The sensors in the second terminal 200 that may be used here is the gyroscope arrangement 222. If the sensors in the second terminal 200 are used, the second terminal 200 transmits to the first terminal 100 information derived from the gyroscope arrangement 222 in the form of raw or relatively raw sensor data or in the form of an indication of an amount of movement of the second terminal 200. Of course, other sensors arrangements may be used instead.

In particular, the terminal 100 is configured to determine from the sensor arrangements 122, 124, 125, 222 in only one of the terminals 100, 200 whether or not the terminal 100, 200 is moving. If the terminal is not moving and the change in estimated distance exceeds a relatively low threshold, then the first terminal 100 determines that an object has entered the path between the terminals 100, 200. If the terminal is moving but is moving only slowly and the change in estimated distance exceeds a relatively mid-level threshold, then the first terminal 100 determines that an object has entered the path between the terminals 100, 200. If the terminal 100, 200 is moving and is moving relatively quickly and the change in estimated distance exceeds a relatively high threshold, then the first terminal 100 determines that an object has entered the path between the terminals 100,

200. Generally speaking, the threshold of change in estimated distance that results in a determination of an object having entered the path between the terminals 100, 200 is set depending on the amount of movement of the terminals 100, 200. This dynamic threshold setting provides improved object detection. The object detection may not be as good as the object detection of the third option described above. However, using sensor data from sensor arrangements in the terminal 100, 200 that is more likely to be the terminal that moves whilst the other remains at one location can provide a significant improvement compared to not using data indicating whether a terminal is moving.

In another option, the second terminal 200 transmits to the first terminal 100 information derived from the gyroscope arrangement 222. The information transmitted from the second terminal 200 to the first terminal 100 may be in the form of raw or relatively raw sensor data. Alternatively, it may be in the form of an indication of distance moved by the second terminal 200 in a relevant period. In this option, the first terminal 100 uses information relating to the amount of movement of the second terminal 200 as well as information relating to the amount of movement of the first terminal 100 in a relevant time period to determine whether an object has entered the path between the terminals 100, 200. In particular, the terminal 100 may be configured to determine whether the sum of the amount of movement of the first and second terminals 100, 200 exceeds the increase in estimated distance by a predetermined amount or a predetermined proportion, and on a positive determination infer that an object has entered the path between the terminals 100, 200. In the event of the distances moved by the first and second terminals 100, 200 being scalar distances, that is not including any indication of direction of movement, simple summing of the scalar distances of movement of the terminals 100, 200 is applied. In the event of vector measurements, in which directions also are known, it is the vectors that are summed in order to determine the relative movement between the first and second terminals 100, 200 to arrive at the value that needs to be compared to the change in estimated distance.

In the case of using information relating to the movement of the first terminal 100 and/or the second terminal 200, the calculation of an alternative distance estimation at step S8 of Figure 4 may involve utilisation of the known movements of the first terminal 100 and/or the second terminal 200.

It will be appreciated from the above explanation that a number of advantages flow from the features of the embodiments. In particular, the features of the embodiments allow distance estimations to be disregarded, or alternatively for alternative distance estimations to be calculated, upon determining that an object has been moved into the path between the terminals 100, 200. Moreover, the features propose particularly effective ways of detecting that an object has moved into the path of terminals 100, 200. Advantageously, all of this can be achieved without requiring additional hardware in the terminals 100, 200. In the case where sensor data is not used in the process, the cost to the terminal 100 may simply be a small number of additional processing steps, thereby having negligible impact on the other aspects of performance of the first terminal 100.

It will be appreciated that the above described embodiments are purely illustrative and are not limiting on the scope of the claims. Other variations and modifications will be apparent to persons skilled in the art upon reading the present application, and some will now be described.

Instead of using gyroscopes and accelerometers to detect movement of a device, any other movement sensor may be used instead. Movement sensors may simply detect movement, or maybe provide a measure of an amount of movement, or may be able to provide an indication of distance moved.

In the above, the first terminal 100 performs distance estimations based on signals transmitted by the second terminal 200. A number of alternative options will now be described.

In a first alternative option, the second terminal 200 is configured to perform distance estimation calculations based on signals received from the first terminal 100.

In a second alternative option, the first terminal 100 is configured to perform received signal strength measurements of signals received from the second terminal 200, and send those signal strength measurements and/or attenuation estimations to the second terminal 200. In this option, the second terminal 200 performs the operation of Figure 4, in calculating the distance between the terminals 100, 200. In this option, the first terminal 100 may transmit to the second terminal 200 information derived from the gyroscope sensor 122 and/or the accelerometer arrangement 124 indicative of the amount of distance travelled by the first terminal 100.

In general, a terminal 100, 200 may perform distance estimation calculations based on signals transmitted by itself or by the other terminal. Also, the determination of the change in a presence or absence of an object in the path between the terminals 100, 200 may involve movement sensors in the terminal itself and/or in the other terminal. Lastly, upon detecting a condition indicating that the distance estimation is unreliable, the terminal may or may not calculate an alternative distance estimation for use in place of the unreliable distance estimation.

Both of the terminals 100, 200 may be mobile or portable, or one of them may be non-mobile or fixed.

Moreover, the disclosure of the present application should be understood to include any novel features or any novel combination of features either explicitly or implicitly disclosed herein or any generalization thereof and during the prosecution of the present application or of any application derived therefrom, new claims may be formulated to cover any such features and/or combination of such features.

Claims

1. Apparatus comprising:

means for using a time series of received signal strength measurements to provide a time series of attenuation estimates, each estimate relating to the attenuation of radio waves propagating through a channel between a transmitter and a receiver at a different instance of time;

means for calculating a first estimation of distance between the transmitter and the receiver using at least one of the attenuation estimates of the time series of attenuation estimates;

means for determining whether there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver, said determining using at least two attenuation estimates from the time series of attenuation estimates;

means for determining that the first estimation of distance is unreliable in response to determining that there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver; and

means for refraining from using the first estimation of distance in response to determining that the first estimation of distance is unreliable.

2. Apparatus as claimed in claim 1, comprising:

means for determining a rate of change of estimated attenuation using the at least two attenuation estimates from the time series of attenuation estimates,

wherein the means for determining that there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver is configured to determine that there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver in response to detecting that the rate of change of estimated attenuation exceeds a threshold.

3. Apparatus as claimed in claim 2, comprising:

means for calculating a second estimation of distance between the transmitter and the receiver for a time instance corresponding to the first estimation of distance by low pass filtering the time series of attenuation estimates.

4. Apparatus as claimed in any preceding claim, comprising:

means for determining whether there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver using the at least two attenuation estimates from the time series of attenuation estimates and using sensor information indicating whether the transmitter is moving.

5. Apparatus as claimed in any preceding claim, comprising:

means for determining whether there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver using the at least two attenuation estimates from the time series of attenuation estimates and using sensor information indicating whether the receiver is moving.

6. Apparatus as claimed in any preceding claim, comprising:

means for determining whether there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver using the at least two attenuation estimates from the time series of attenuation estimates and using sensor information indicating an amount of movement of the transmitter and/or the receiver between the time instances relating to the at least two attenuation estimates.

7. Apparatus as claimed in claim 6, wherein the means for determining whether there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver using the at least two attenuation estimates from the time series of attenuation estimates and using sensor information indicating an amount of movement of the transmitter and/or the receiver between the time instances relating to the at least two attenuation estimates comprises means for determining whether the first estimation of distance is consistent with a previous estimation of distance having regard to an amount of relative movement between the transmitter and the receiver that is consistent with the sensor information.

8. Apparatus as claimed in any preceding claim, wherein the apparatus is the transmitter, and wherein the apparatus is configured to receive the time series of signal strength measurements from the receiver.

9. Apparatus as claimed in claim 8, wherein the apparatus comprises a sensor arrangement comprising one or more sensors selected from the group comprising: a gyroscope, an accelerometer and a magnetometer.

10. Apparatus as claimed in claim 8 or claim 9, wherein the apparatus is configured to receive movement information or sensor information indicative of movement from the receiver.

11. Apparatus as claimed in any of claims 1 to 7, wherein the apparatus is the receiver.

12. Apparatus as claimed in claim 11, wherein the apparatus comprises a sensor arrangement comprising one or more sensors selected from the group comprising: a gyroscope, an accelerometer and a magnetometer.

13. Apparatus as claimed in claim 8 or claim 9, wherein the apparatus is configured to receive movement information or sensor information indicative of movement from the transmitter.

14. A method comprising:

using a time series of received signal strength measurements to provide a time series of attenuation estimates, each estimate relating to the attenuation of radio waves propagating through a channel between a transmitter and a receiver at a different instance of time;

calculating a first estimation of distance between the transmitter and the receiver using at least one of the attenuation estimates of the time series of attenuation estimates;

determining whether there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver, said determining using at least two attenuation estimates from the time series of attenuation estimates;

determining that the first estimation of distance is unreliable in response to determining that there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver; and

refraining from using the first estimation of distance in response to determining that the first estimation of distance is unreliable.

15. A method as claimed in claim 14, comprising:

determining a rate of change of estimated attenuation using the at least two attenuation estimates from the time series of attenuation estimates,

wherein determining that there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver comprises determining that there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver in response to detecting that the rate of change of estimated attenuation exceeds a threshold.

16. A method as claimed in claim 14 or claim 15, comprising:

calculating a second estimation of distance between the transmitter and the receiver for a time instance corresponding to the first estimation of distance by low pass filtering the time series of attenuation estimates.

17. A method as claimed in any of claims 14 to 16, comprising:

determining whether there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver using the at least two attenuation estimates from the time series of attenuation estimates and using sensor information indicating whether the transmitter is moving.

18. A method as claimed in any of claims 14 to 17, comprising:

determining whether there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver using the at least two attenuation estimates from the time series of attenuation estimates and using sensor information indicating whether the receiver is moving.

19. A method as claimed in any of claims 14 to 18, comprising:

determining whether there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver using the at least two attenuation estimates from the time series of attenuation estimates and using sensor information indicating an amount of movement of the transmitter and/or the receiver between the time instances relating to the at least two attenuation estimates.

20. A method as claimed in claim 19, comprising determining whether there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver using the at least two attenuation estimates from the time series of attenuation estimates and using sensor information indicating an amount of movement of the transmitter and/or the receiver between the time instances relating to the at least two attenuation estimates by determining whether the first estimation of distance is consistent with a previous estimation of distance having regard to an amount of relative movement between the transmitter and the receiver that is consistent with the sensor information.

21. A method as claimed in any of claims 14 to 20, wherein the method is performed by the transmitter, and wherein the method comprises the transmitter receiving the time series of signal strength measurements from the receiver.

22. A method as claimed in claim 21, wherein the transmitter comprises a sensor arrangement comprising one or more sensors selected from the group comprising: a gyroscope, an accelerometer and a magnetometer.

23. A method as claimed in claim 21 or claim 22, comprising the transmitter receiving movement information or sensor information indicative of movement from the receiver.

24. A method as claimed in any of claims 14 to 20, wherein the method is performed by the receiver.

25. A method as claimed in claim 24, wherein the receiver comprises a sensor arrangement comprising one or more sensors selected from the group comprising: a gyroscope, an accelerometer and a magnetometer.

26. A method as claimed in claim 21 or claim 22, comprising the receiver receiving movement information or sensor information indicative of movement from the transmitter.

27. A computer program comprising machine readable instructions that when executed by computing apparatus control it to perform the method of any of claims 14 to 26.

28. Apparatus, comprising at least one processor, at least one memory, and computer-readable code stored on the at least one memory, wherein the computer-readable code when executed controls the at least one processor to perform a method comprising:

using a time series of received signal strength measurements to provide a time series of attenuation estimates, each estimate relating to the attenuation of radio waves propagating through a channel between a transmitter and a receiver at a different instance of time;

calculating a first estimation of distance between the transmitter and the receiver using at least one of the attenuation estimates of the time series of attenuation estimates;

determining whether there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver, said determining using at least two attenuation estimates from the time series of attenuation estimates;

determining that the first estimation of distance is unreliable in response to determining that there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver; and refraining from using the first estimation of distance in response to determining that the first estimation of distance is unreliable.

29. Apparatus as claimed in claim 28, wherein the computer-readable code when executed controls the at least one processor to perform:

determining a rate of change of estimated attenuation using the at least two attenuation estimates from the time series of attenuation estimates, and

determining that there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver by determining that there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver in response to detecting that the rate of change of estimated attenuation exceeds a threshold.

30. Apparatus as claimed in claim 29, wherein the computer-readable code when executed controls the at least one processor to perform:

calculating a second estimation of distance between the transmitter and the receiver for a time instance corresponding to the first estimation of distance by low pass filtering the time series of attenuation estimates.

31. Apparatus as claimed in claim 28, wherein the computer-readable code when executed controls the at least one processor to perform:

determining whether there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver using the at least two attenuation estimates from the time series of attenuation estimates and using sensor information indicating whether the transmitter is moving.

32. Apparatus as claimed in claim 28, wherein the computer-readable code when executed controls the at least one processor to perform:

determining whether there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver using the at least two attenuation estimates from the time series of attenuation estimates and using sensor information indicating whether the receiver is moving.

33. Apparatus as claimed in claim 28, wherein the computer-readable code when executed controls the at least one processor to perform:

determining whether there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver using the at least two attenuation estimates from the time series of attenuation estimates and using sensor information indicating an amount of movement of the transmitter and/or the receiver between the time instances relating to the at least two attenuation estimates.

34. Apparatus as claimed in claim 33, wherein the computer-readable code when executed controls the at least one processor to perform:

determining whether there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver using the at least two attenuation estimates from the time series of attenuation estimates and using sensor information indicating an amount of movement of the transmitter and/or the receiver between the time instances relating to the at least two attenuation estimates by determining whether the first estimation of distance is consistent with a previous estimation of distance having regard to an amount of relative movement between the transmitter and the receiver that is consistent with the sensor information.

35. Apparatus as claimed in claim 28, wherein the apparatus is the transmitter, and wherein the computer-readable code when executed controls the at least one processor to receive the time series of signal strength measurements from the receiver.

36. Apparatus as claimed in claim 35, wherein the apparatus comprises a sensor arrangement comprising one or more sensors selected from the group comprising: a gyroscope, an accelerometer and a magnetometer.

37. Apparatus as claimed in claim 35, wherein the computer-readable code when executed controls the at least one processor to receive movement information or sensor information indicative of movement from the receiver.

38. Apparatus as claimed in claim 28, wherein the apparatus is the receiver.

39. Apparatus as claimed in claim 38, wherein the apparatus comprises a sensor arrangement comprising one or more sensors selected from the group comprising: a gyroscope, an accelerometer and a magnetometer.

40. Apparatus as claimed in claim 35, wherein the computer-readable code when executed controls the at least one processor to perform receive movement information or sensor information indicative of movement from the transmitter.

41. A storage medium, comprising computing apparatus, at least one memory, and computer-readable code stored on the at least one memory, wherein the computer-readable code when executed by computing apparatus controls the computing apparatus to perform a method comprising:

using a time series of received signal strength measurements to provide a time series of attenuation estimates, each estimate relating to the attenuation of radio waves propagating through a channel between a transmitter and a receiver at a different instance of time;

calculating a first estimation of distance between the transmitter and the receiver using at least one of the attenuation estimates of the time series of attenuation estimates;

determining whether there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver, said determining using at least two attenuation estimates from the time series of attenuation estimates;

determining that the first estimation of distance is unreliable in response to determining that there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver; and

refraining from using the first estimation of distance in response to determining that the first estimation of distance is unreliable.

42. Apparatus as claimed in claim 41, wherein the computer-readable code when executed controls the computing apparatus to perform:

determining a rate of change of estimated attenuation using the at least two attenuation estimates from the time series of attenuation estimates, and

determining that there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver by determining that there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver in response to detecting that the rate of change of estimated attenuation exceeds a threshold.

43. Apparatus as claimed in claim 42, wherein the computer-readable code when executed controls the computing apparatus to perform:

calculating a second estimation of distance between the transmitter and the receiver for a time instance corresponding to the first estimation of distance by low pass filtering the time series of attenuation estimates.

44. Apparatus as claimed in claim 41, wherein the computer-readable code when executed controls the computing apparatus to perform:

determining whether there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver using the at least two attenuation estimates from the time series of attenuation estimates and using sensor information indicating whether the transmitter is moving.

45. Apparatus as claimed in claim 41, wherein the computer-readable code when executed controls the computing apparatus to perform:

determining whether there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver using the at least two attenuation estimates from the time series of attenuation estimates and using sensor information indicating whether the receiver is moving.

46. Apparatus as claimed in claim 41, wherein the computer-readable code when executed controls the computing apparatus to perform:

determining whether there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver using the at least two attenuation estimates from the time series of attenuation estimates and using sensor information indicating an amount of movement of the transmitter and/or the receiver between the time instances relating to the at least two attenuation estimates.

47. Apparatus as claimed in claim 46, wherein the computer-readable code when executed controls the computing apparatus to perform:

determining whether there has been a change in the presence or absence of an attenuating object in the path between the transmitter and the receiver using the at least two attenuation estimates from the time series of attenuation estimates and using sensor information indicating an amount of movement of the transmitter and/or the receiver between the time instances relating to the at least two attenuation estimates by determining whether the first estimation of distance is consistent with a previous estimation of distance having regard to an amount of relative movement between the transmitter and the receiver that is consistent with the sensor information.

48. Apparatus as claimed in claim 41, wherein the computing apparatus is the transmitter, and wherein the computer-readable code when executed controls the computing apparatus to receive the time series of signal strength measurements from the receiver.

49. Apparatus as claimed in claim 48, wherein the computing apparatus comprises a sensor arrangement comprising one or more sensors selected from the group comprising: a gyroscope, an accelerometer and a magnetometer.

50. Apparatus as claimed in claim 48, wherein the computer-readable code when executed controls the computing apparatus to receive movement information or sensor information indicative of movement from the receiver.

51. Apparatus as claimed in claim 41, wherein the computing apparatus is the receiver.

52. Apparatus as claimed in claim 51, wherein the computing apparatus comprises a sensor arrangement comprising one or more sensors selected from the group comprising: a gyroscope, an accelerometer and a magnetometer.

53. Apparatus as claimed in claim 48, wherein the computer-readable code when executed controls the computing apparatus to perform receive movement information or sensor information indicative of movement from the transmitter.

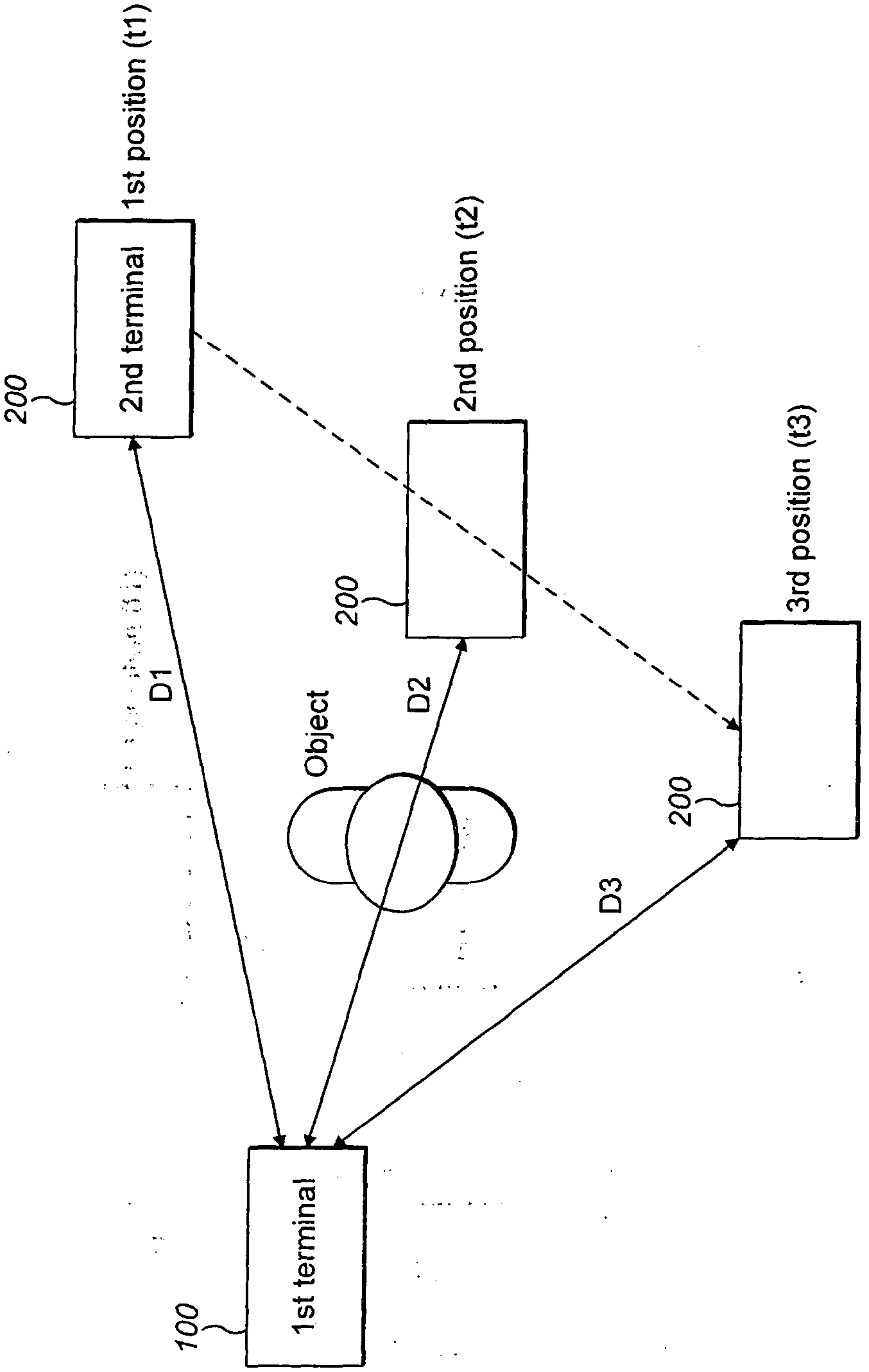
1st position (t1)
200
2nd terminal
2nd position (t2)
200
3rd position (t3)
200
D1
D2
D3
Object
100
1st terminal

FIG. 1

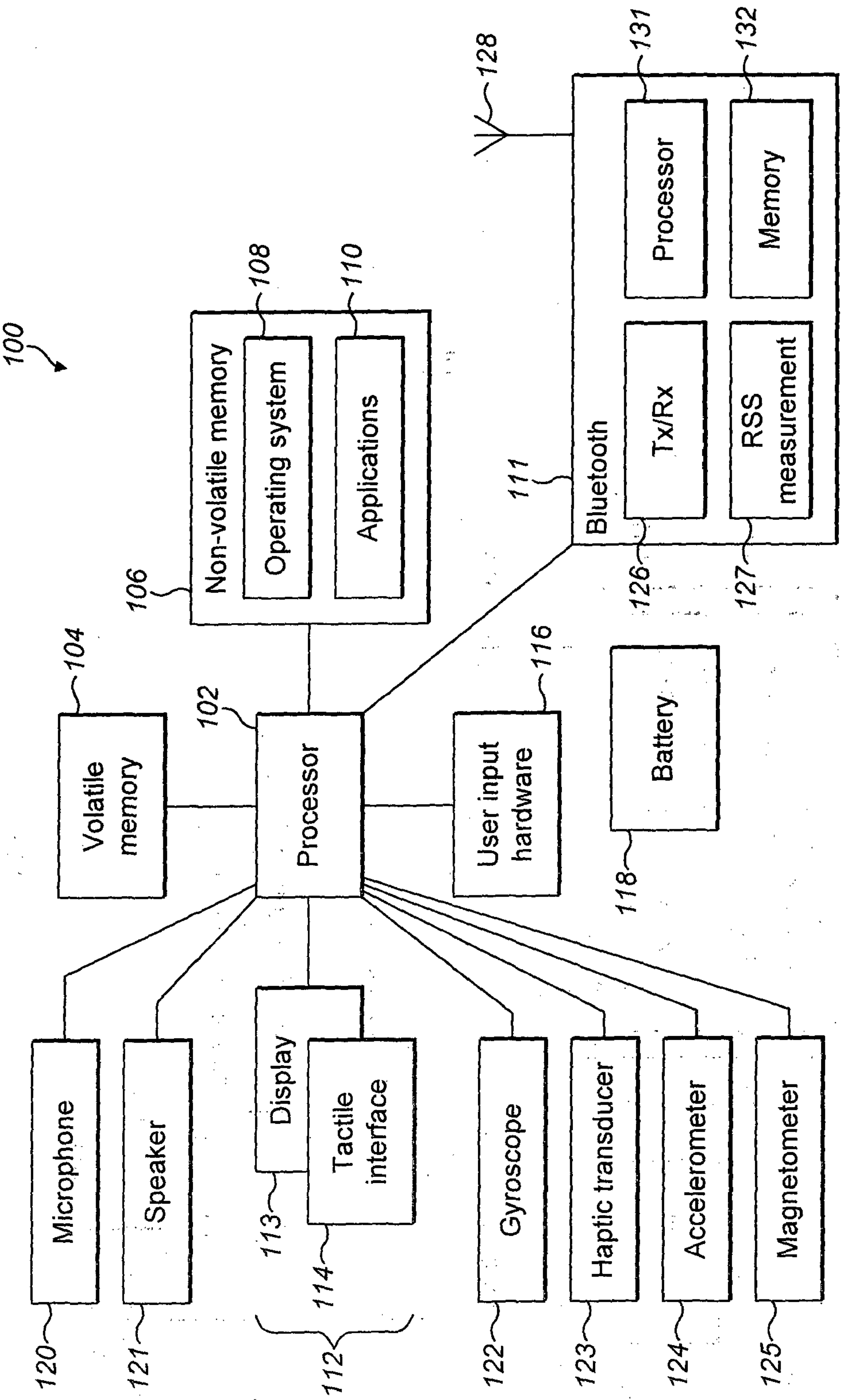
100
Microphone
Speaker
Display
Tactile interface
Gyroscope
Haptic transducer
Accelerometer
Magnetometer
Volatile memory
Processor
User input hardware
Battery
Non-volatile memory
Operating system
Applications
Bluetooth
Tx/Rx
RSS measurement
Processor
Memory
102
104
106
108
110
111
112
113
114
116
118
120
121
122
123
124
125
126
127
128
131
132

FIG. 2

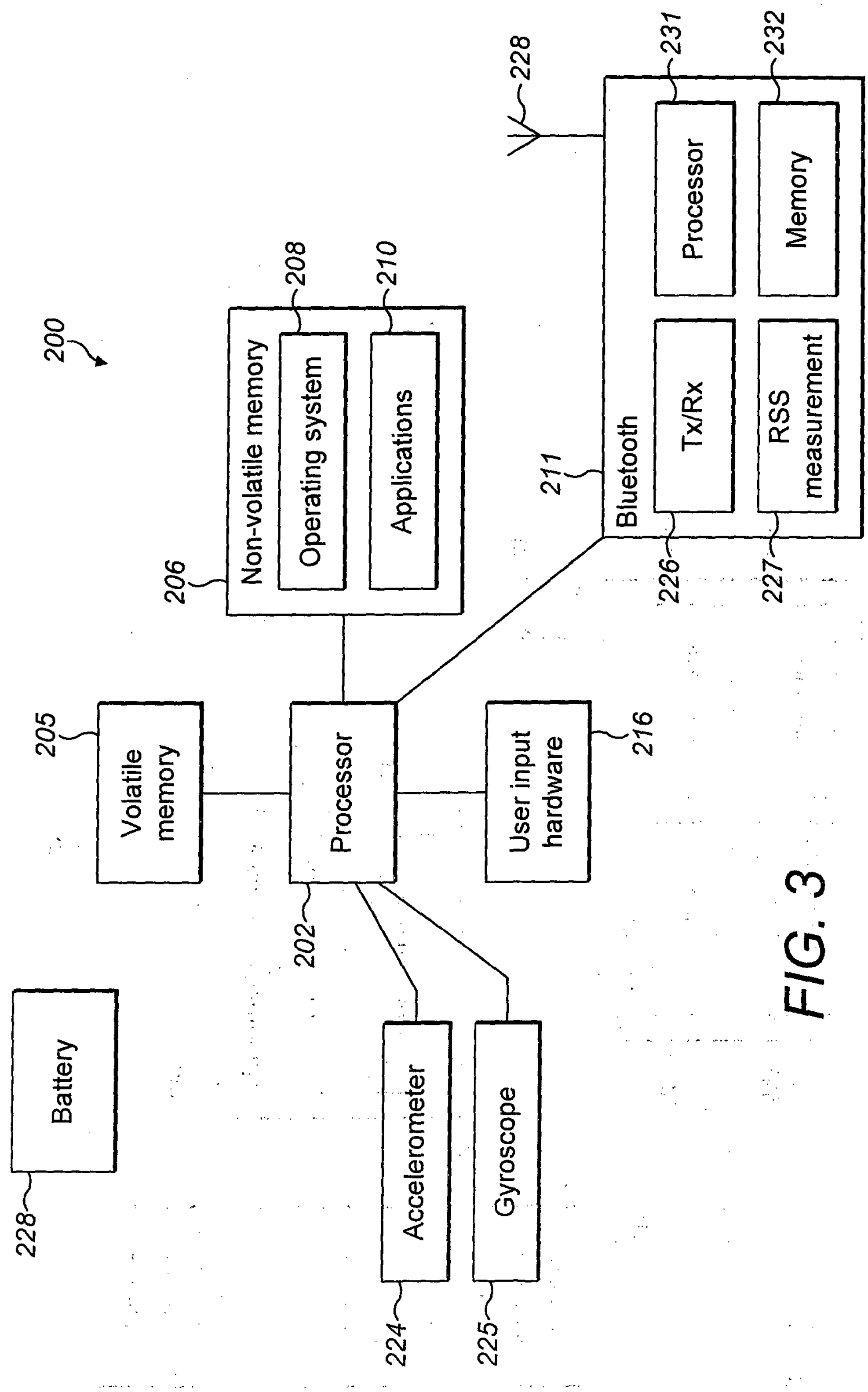
200
Non-volatile memory
Operating system
Applications
206
208
210
Volatile memory
205
Processor
202
User input hardware
216
Bluetooth
211
Tx/Rx
RSS measurement
Processor
Memory
226
227
231
232
228
Battery
228
Accelerometer
224
Gyroscope
225

FIG. 3

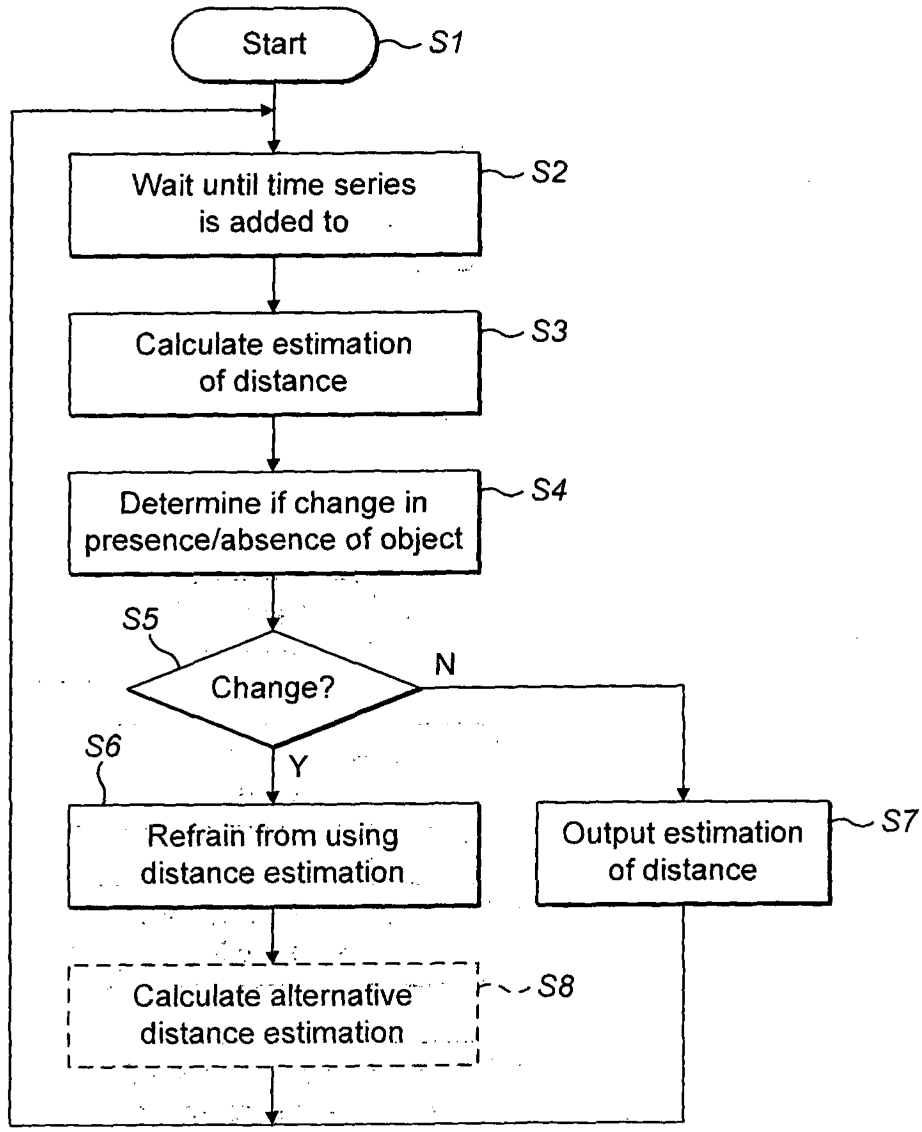
Start
S1
Wait until time series is added to
S2
Calculate estimation of distance
S3
Determine if change in presence/absence of object
S4
S5
Change?
N
Y
S6
Refrain from using distance estimation
Output estimation of distance
S7
Calculate alternative distance estimation
S8

FIG. 4

FIG. 5

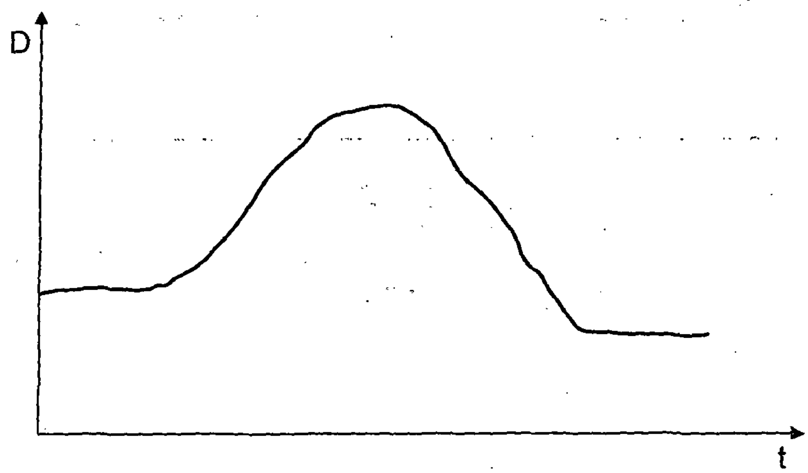

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI2013/050784

A. CLASSIFICATION OF SUBJECT MATTER

See extra sheet

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: G01S, G08C, H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

FI, SE, NO, DK

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI, INSPEC, XP3GPP, XPAIP, XPESP, XPESP2, XPETSI, XPI3E, XPIEE, XPTK

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	Zhou Y. et al. 'RSS-based node localization in the existence of moving obstructions', Proceedings of 2012 IEEE Vehicular Technology Conference, Quebec City, Canada, 3 – 6 Sep. 2012, pp.1 – 5, doi:10.1109/VTCFall.2012.6398970 abstract; sections I, III, IV; figures 1, 2	1 – 3, 8 – 16, 21 – 30, 35 – 43, 48 – 53
X	US 2011069627 A1 (SRIDHARA V. [US] et al.) 24 March 2011 (24.03.2011) paragraphs [0001] – [0006], [0015], [0026] – [0041]; figures 3, 7	1, 14, 27, 28, 41
A	US 2010134276 A1 (ZARUBA G. V. [US] et al.) 03 June 2010 (03.06.2010) abstract; paragraphs [0009], [0031] – [0038]; claim 3; figures 1 – 3	1 – 53

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
08 April 2014 (08.04.2014)	10 April 2014 (10.04.2014)

Name and mailing address of the ISA/FI	Authorized officer
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/FI2013/050784

Patent document cited in search report	Publication date	Patent family members(s)	Publication date
US 2011069627 A1	24/03/2011	TW 201118405 A	01/06/2011
		WO 2010107821 A1	23/09/2010
US 2010134276 A1	03/06/2010	EP 1660176 A2	31/05/2006
		EP 1665110 A2	07/06/2006
		US 2005182447 A1	18/08/2005
		US 7010347 B2	07/03/2006
		US 2005043895 A1	24/02/2005
		US 7065400 B2	20/06/2006
		US 2007168127 A1	19/07/2007
		US 7592909 B2	22/09/2009
		US 2007179390 A1	02/08/2007
		US 7653436 B2	26/01/2010
		US 8179253 B2	15/05/2012
		US 2006235480 A1	19/10/2006
		US 2007191901 A1	16/08/2007
		WO 2005018570 A2	03/03/2005
		WO 2005020025 A2	03/03/2005

CLASSIFICATION OF SUBJECT MATTER

Int.Cl.
G01S 11/06 (2006.01)
H04B 17/00 (2006.01)
G01S 1/68 (2006.01)
G08C 17/02 (2006.01)