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(54) **STEP FILTER FOR ESTIMATING DISTANCE IN A TIME-OF-FLIGHT RANGING SYSTEM**

(75) Inventors: **Hasib Hassan**, Belleville, MI (US); **Dale R. Benton**, Davison, MI (US); **John Lu**, Grand Blanc, MI (US); **Brian A. Gorman**, Burton, MI (US)

(73) Assignee: **MAGNA ELECTRONICS INC.**, Holland, MI (US)

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G01S 11/06	(2006.01)
G01S 11/08	(2006.01)

(52) **U.S. Cl.**

CPC ***G01S 11/02*** (2013.01); ***G01S 11/06*** (2013.01); ***G01S 11/08*** (2013.01)

(58) **Field of Classification Search**

CPC G01S 11/02; G01S 11/06; G01S 11/08
USPC 340/539.1, 992; 342/458
See application file for complete search history.

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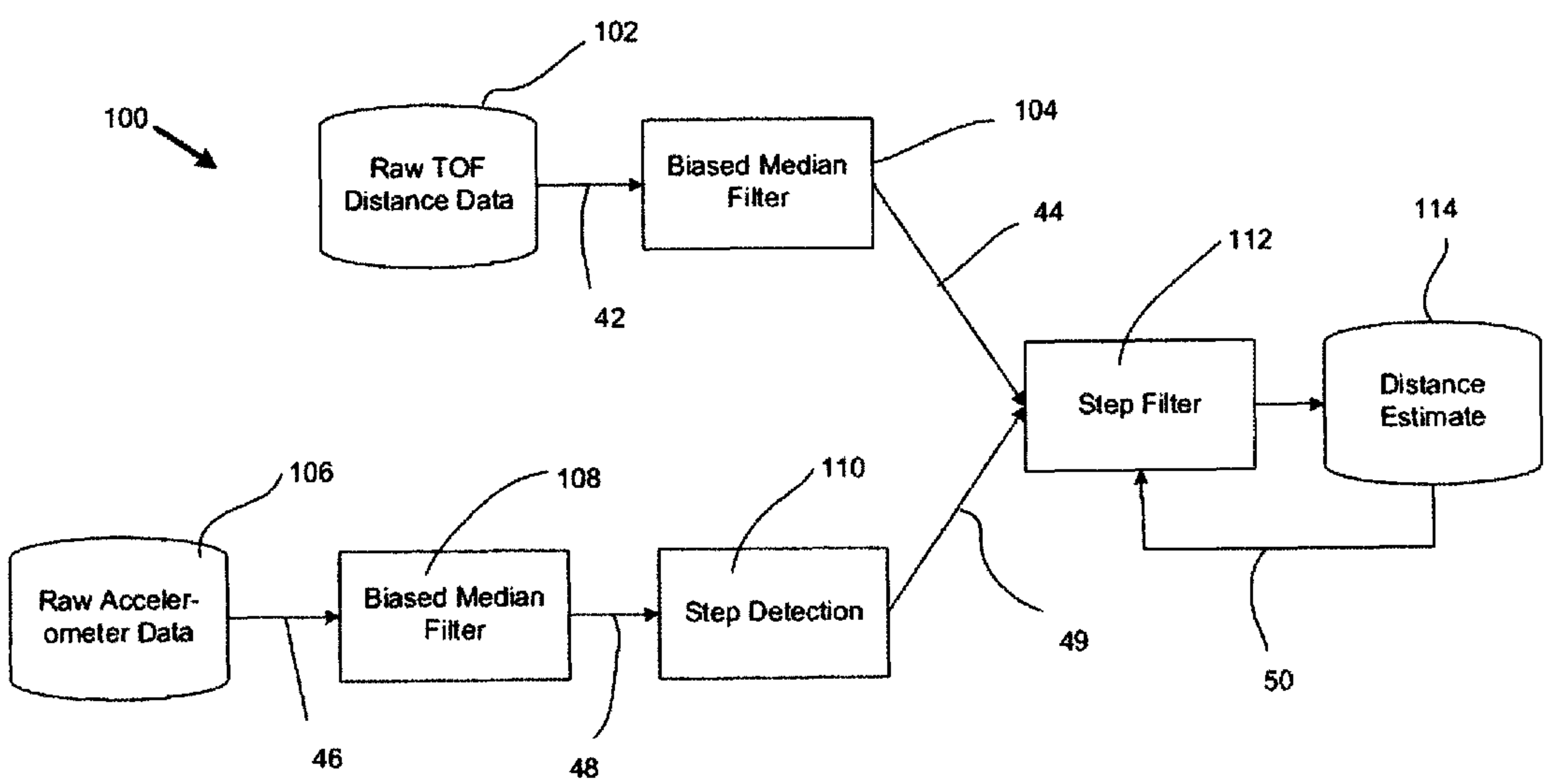
Primary Examiner — Cassie Galt
(74) *Attorney, Agent, or Firm* — Gardner, Linn, Burkhart & Flory, LLP

(57) **ABSTRACT**

A ranging system includes a time of flight subsystem including circuitry incorporated in a mobile node and a base station for generating a TOF signal between the mobile node and the base station, measuring the time taken for transmission of the TOF signal, and generating a TOF distance signal based on the measured time. An accelerometer, mounted in the mobile node, generates an accelerometer signal. A distance filter generates the distance estimate. The filter is configured to (i) initialize the value of a distance estimate signal based on the TOF distance signal, (ii) detect a human step based on variances in the accelerometer signal, and (iii) change the value of the distance estimate signal by a predetermined quantum only upon detection of the human step, the change being positive or negative depending on a direction of the TOF distance signal relative to the distance estimate signal.

21 Claims, 7 Drawing Sheets



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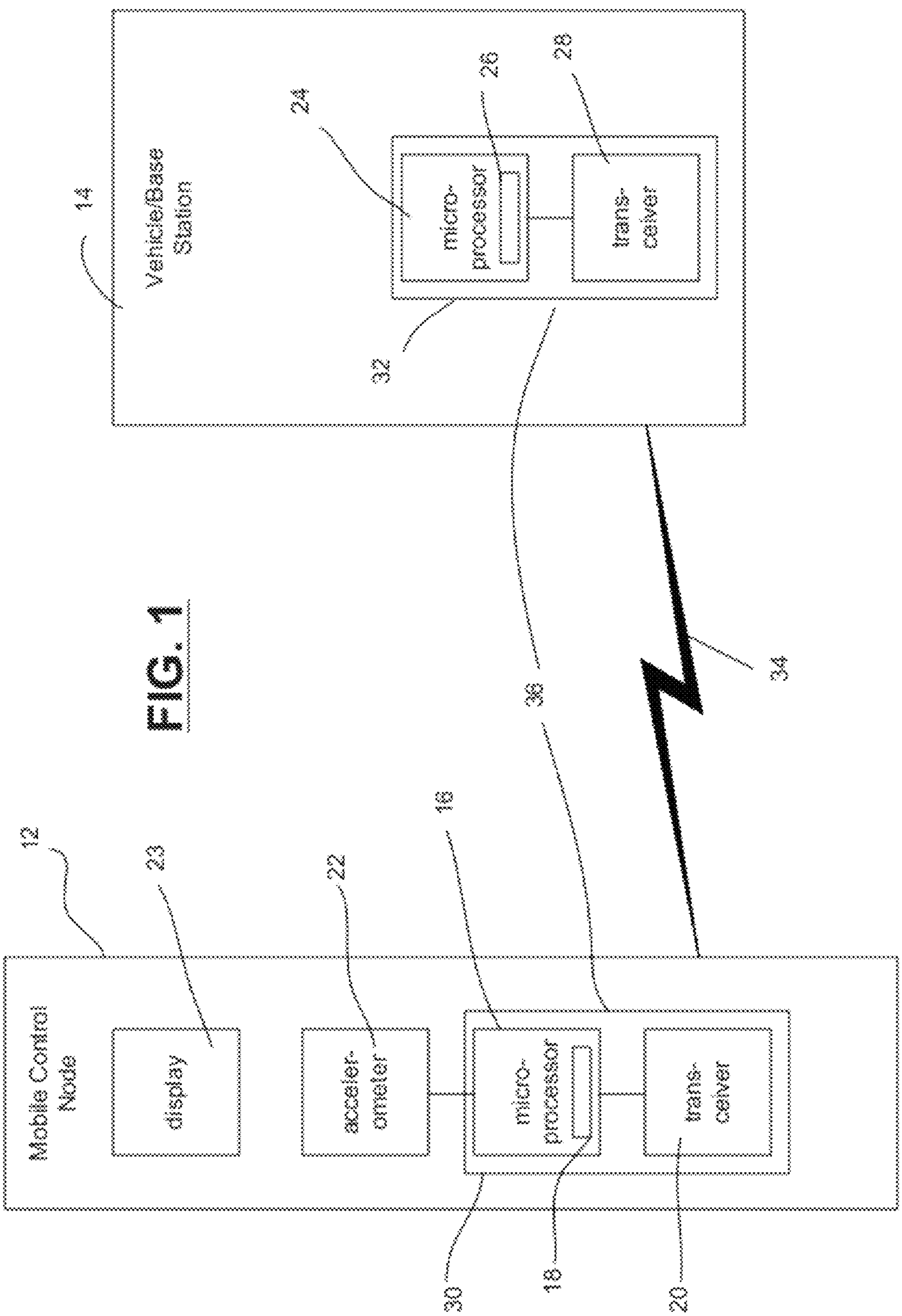
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24
26
28
micro-processor
trans-ceiver
32
36
34
Mobile Control Node
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display
acceler-ometer
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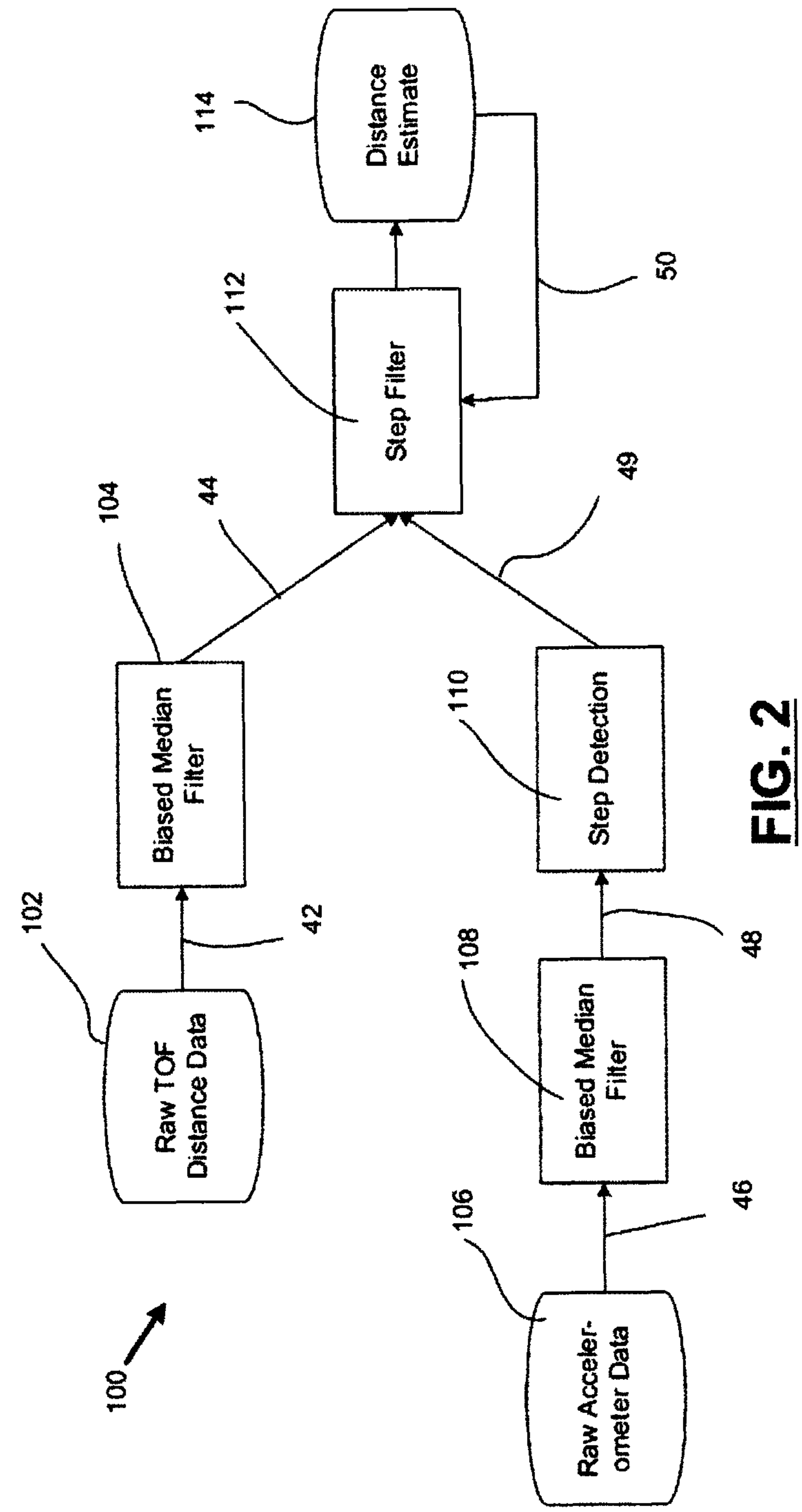
trans-ceiver
30
18
20

FIG. 1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102
42
Biased Median Filter
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44
Raw Acceleration-ometer Data
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48
Step Detection
110
49
Step Filter
112
Distance Estimate
114
50

FIG. 2

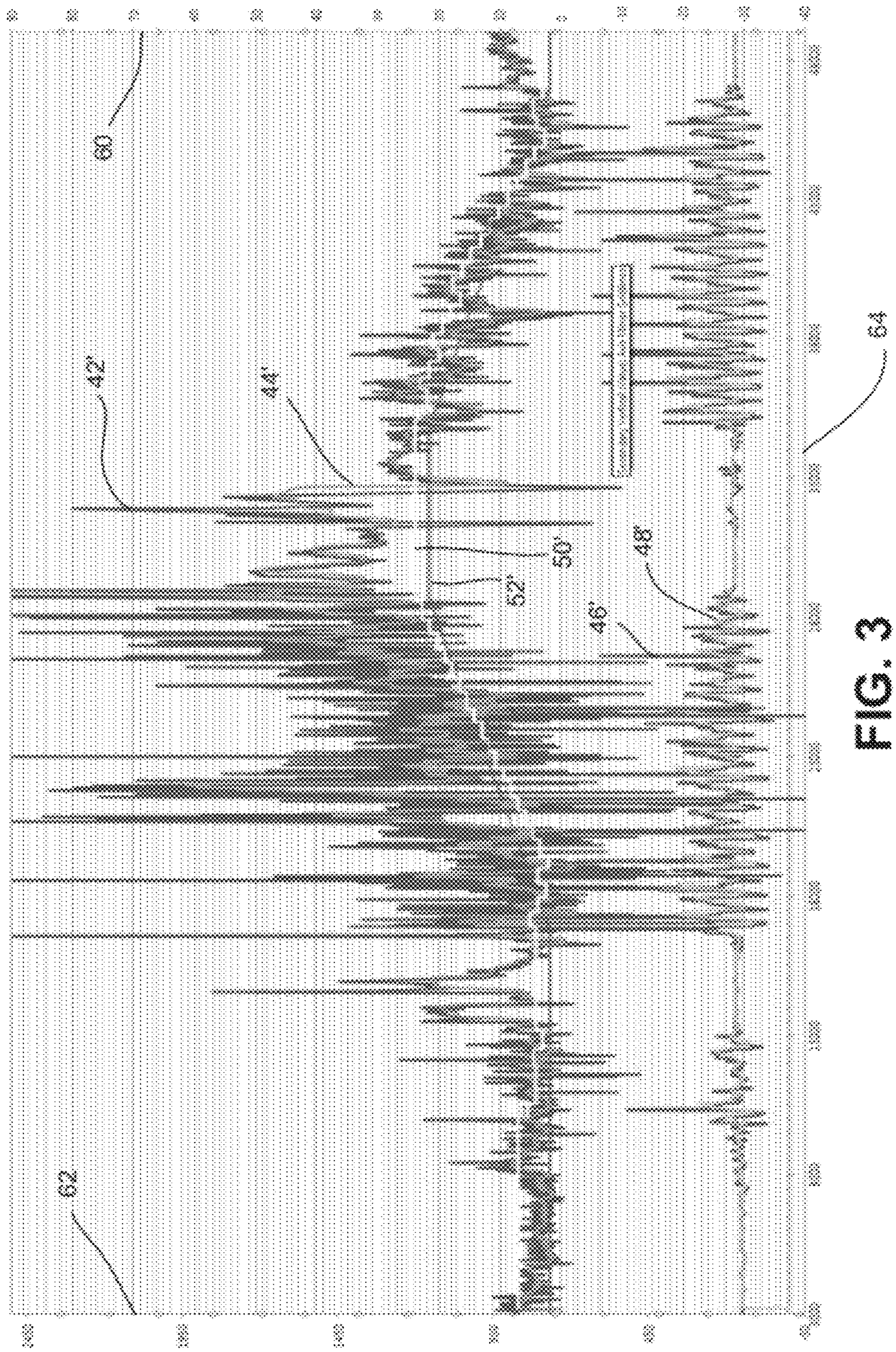

FIG. 3

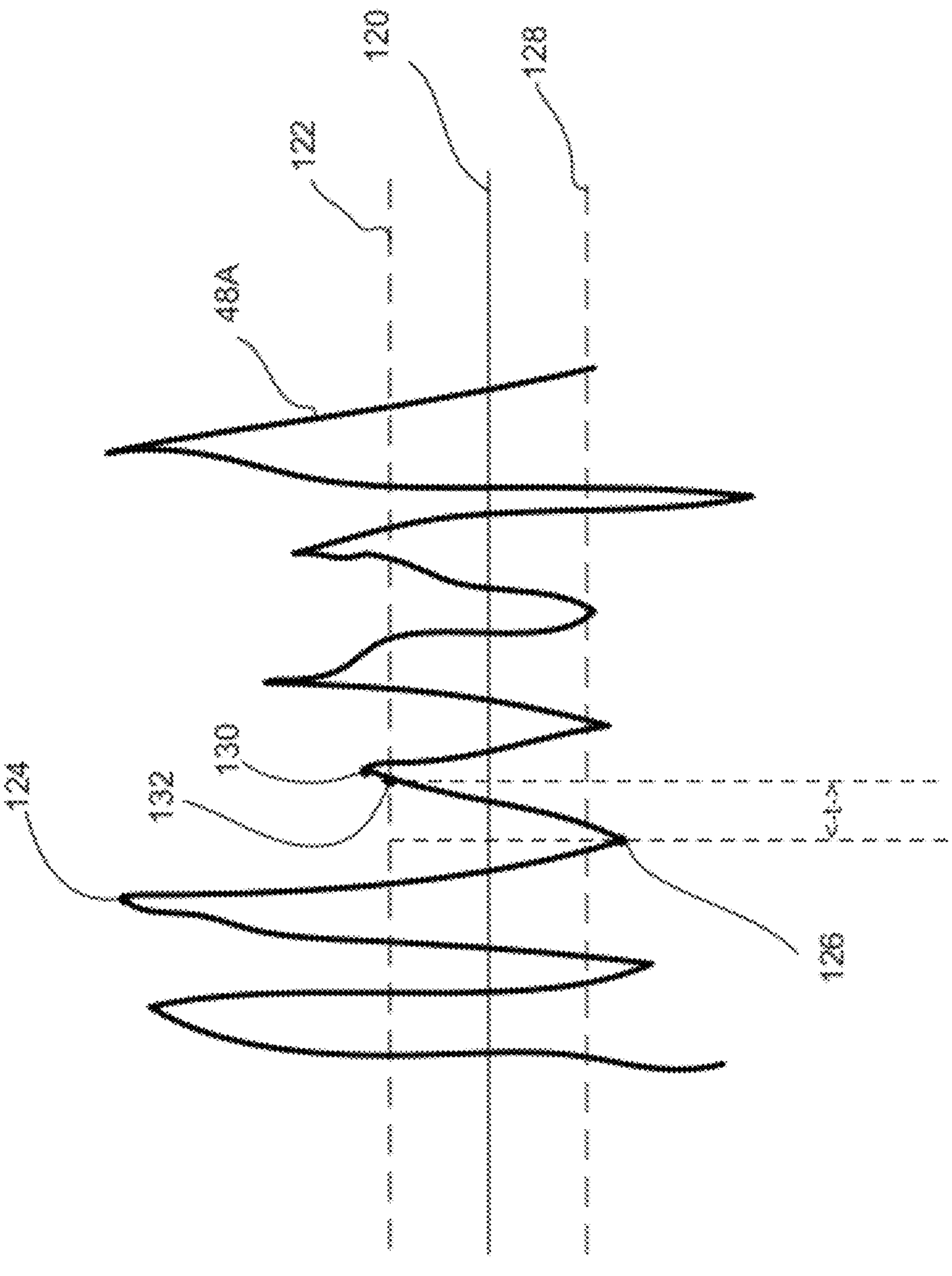

FIG. 4

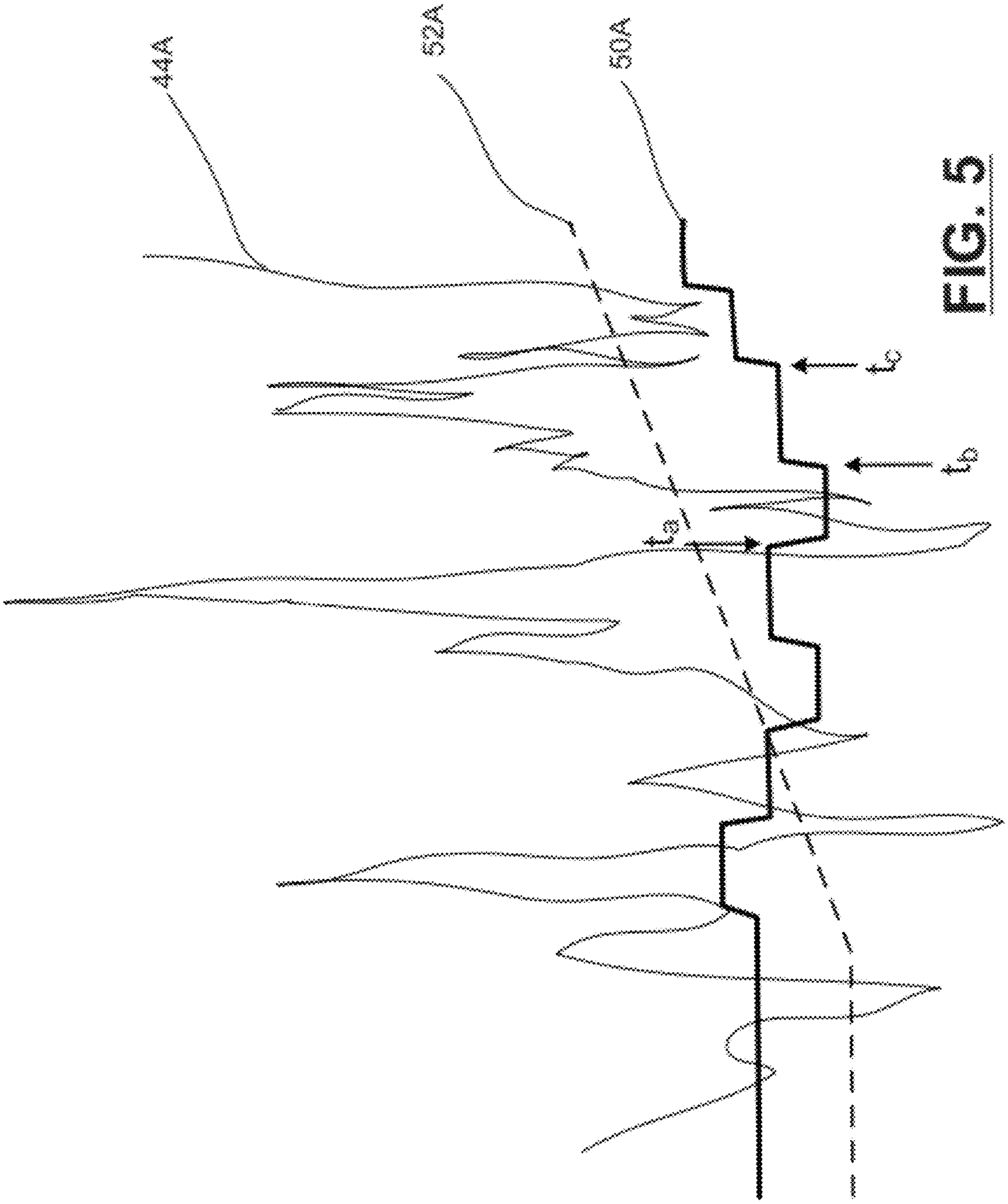

FIG. 5

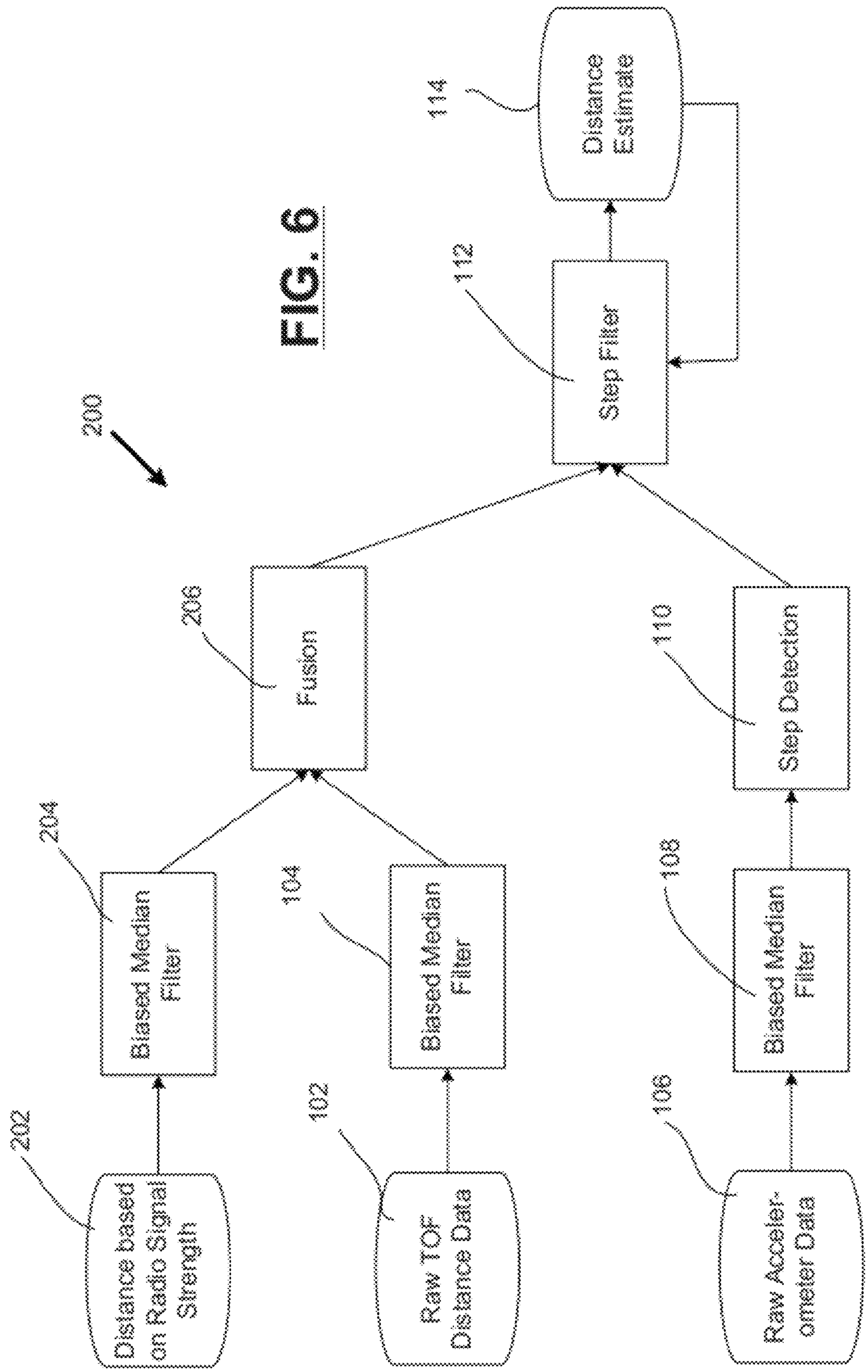
200
Distance based on Radio Signal Strength
202
Biased Median Filter
204
Raw TOF Distance Data
102
Biased Median Filter
104
Fusion
206
Raw Accelerometer Data
106
Biased Median Filter
108
Step Detection
110
Step Filter
112
Distance Estimate
114

FIG. 6

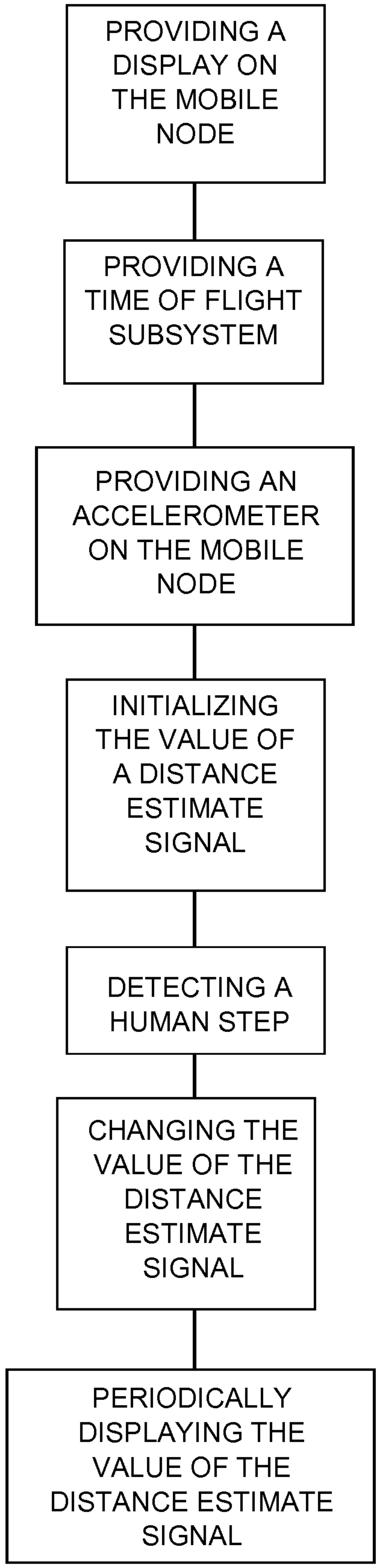
PROVIDING A DISPLAY ON THE MOBILE NODE
PROVIDING A TIME OF FLIGHT SUBSYSTEM
PROVIDING AN ACCELEROMETER ON THE MOBILE NODE
INITIALIZING THE VALUE OF A DISTANCE ESTIMATE SIGNAL
DETECTING A HUMAN STEP
CHANGING THE VALUE OF THE DISTANCE ESTIMATE SIGNAL
PERIODICALLY DISPLAYING THE VALUE OF THE DISTANCE ESTIMATE SIGNAL

FIG. 7

STEP FILTER FOR ESTIMATING DISTANCE IN A TIME-OF-FLIGHT RANGING SYSTEM

CROSS REFERENCE TO RELATED APPLICATION

The present application claims the filing benefit of U.S. provisional application Ser. No. 61/474,471, filed Apr. 12, 2011, which is hereby incorporated herein by reference in its entirety.

FIELD OF THE INVENTION

The invention relates to the field of filters, and more particularly to a step filter for estimating a range or distance between two components that utilize a time-of-flight (TOF) ranging system.

BACKGROUND OF THE INVENTION

U.S. Publication No. 2010/0171642, owned by the assignee of the present application, proposes a remote vehicle control system for a vehicle. The system includes a mobile control node, such as a key fob having some display capability, that interacts via a bi-directional radio link with a base unit in the vehicle. The base unit is connected to the vehicle control system and allows the mobile control node to function as an input and output node on a vehicle control network, allowing remote control of the vehicle and providing functions such as remote or passive keyless entry. The remote control system also provides a vehicle location function wherein the range or distance and the bearing between the mobile control node and the vehicle can be determined and displayed on the mobile control node. The distance estimate and bearing are calculated by determining the range between the mobile control node and vehicle using a time of flight (TOF) methodology (in which distance is estimated by measuring the time taken for a signal to circumnavigate two components), and by processing the travel distance of the mobile control node and compass data in order to triangulate the position of the vehicle relative to the mobile control node.

One of the technical issues that arises in the aforementioned remote vehicle control system is the accuracy of the distance estimate in noisy environments where there are many reflection sources in the region between the vehicle and the mobile control node. In such an environment the TOF signal may follow multiple paths resulting in potentially inaccurate distance estimations from the TOF subsystem, with consequences to the performance of the remote vehicle system. It is desired to improve the accuracy of the distance estimation.

SUMMARY OF THE INVENTION

According to an aspect of the invention a system and related method are provided for estimating a distance between a mobile node and a base station. The system includes a time of flight subsystem including circuitry incorporated in the mobile node and the base station. The TOF subsystem generates a TOF distance signal by periodically transmitting a TOF signal between the mobile node and the base station and measuring the time taken for transmission of the TOF signal therebetween, which leads to a distance reading. The mobile node includes an accelerometer for generating an accelerometer signal. The system includes a filter which: initializes the value of a distance estimate signal based on the TOF distance signal; detects a human step based on

variances in the accelerometer signal; and changes the value of the distance estimate signal by a predetermined quantum only upon detection of a human step, the distance estimate signal being increased or decreased depending on a direction of the TOF distance signal relative to the distance estimate signal.

Optionally, a raw TOF distance signal generated by the time of flight subsystem may be passed through a smoothing filter such as a digital biased median filter to thereby generate a smoothed TOF distance signal utilized in changing the value of the distance estimate. Likewise, a raw accelerometer signal generated by the accelerometer is preferably passed through a smoothing filter such as a digital median filter to thereby generate a smoothed accelerometer signal utilized in detecting a human step.

The direction of the smoothed TOF distance signal may be determined based on the value of smoothed TOF distance signal at the substantially the same instant in time when a human step is detected. Alternatively, the direction of the smoothed TOF distance signal may be determined based on an average of the smoothed TOF distance signal for a period of time before a human step is detected.

Optionally, the quantum for increasing the value of the distance estimate may be lower than the quantum for decreasing the value of the distance estimate signal. These quantums are generally approximately the expected maximum stride length.

The process of detecting a human step preferably includes examining the smoothed accelerometer signal for the occurrence of two serial local peaks, each of which exceeds a predetermined amplitude, within a predetermined range of time periods indicative of human gait. In addition, the process of detecting a human step preferably further includes examining the smoothed accelerometer signal for a slope within a predetermined range of slopes indicative of human gait.

Another method for estimating a distance between a mobile node and a base station is disclosed. This method includes providing or provisioning a time of flight subsystem including circuitry incorporated in the mobile node and the base station and generating a TOF distance signal by periodically transmitting a TOF signal between the mobile control node and the base station and measuring the time taken for transmission of the TOF signal therebetween; providing or provisioning a radio signal strength subsystem including circuitry incorporated in the mobile node and the base station and generating an SSI distance signal based on a strength of a radio signal received by one of the mobile node and the base station; provisioning an accelerometer on the mobile node and generating an accelerometer signal therewith; fusing the SSI distance signal and the TOF distance signal to generate a fused distance signal; initializing the value of a distance estimate signal based on the fused distance signal; detecting a human step based on variances in the accelerometer signal; and changing the value of the distance estimate signal by a predetermined quantum only upon detection of a human step, the change being an increase or decrease depending on a direction of the fused distance signal relative to the distance estimate signal.

These and other objects, advantages, purposes and features of the present invention will become apparent upon review of the following specification in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic hardware block diagram of a system for estimating the range or distance between two components capable of communicating wirelessly with one another;

FIG. **2** is a software-oriented system block diagram of a filter according to one embodiment of the invention utilized by the distance estimating system of FIG. **1**;

FIG. **3** is a graph exemplifying various input, intermediate and output signals processed by the distance filter shown in FIG. **2**;

FIG. **4** is detailed view of an accelerometer signal shown in FIG. **3**, highlighting certain characteristics of the signal which are utilized by the filter to detect the occurrence of a human step;

FIG. **5** is detailed view of various signals shown in FIG. **3**, highlighting certain relationships between the signals which are utilized by the filter to detect the direction of motion;

FIG. **6** is a software-oriented system block diagram of a filter according to another embodiment of the invention; and

FIG. **7** is a flow chart showing a method in accordance with the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

This application incorporates by reference in its entirety U.S. Publication No. 2010/0171642, published Jul. 8, 2010, and entitled "Mobile Control Node System and Method for Vehicles".

As is generally discussed in the above noted publication, and referring additionally to FIG. **1** herein, it is desired to estimate the distance between a mobile control node **12** and a base station **14**, which may be installed in a vehicle. The mobile control node **12** includes a microprocessor **16** including program store and data memory **18**. A transceiver **20** is connected to the microprocessor. An accelerometer **22** is also connected to the microprocessor. A display **23** is provided for user interface purposes.

The base station **14** is likewise configured to include a microprocessor **24** with program store and data memory **26**. A transceiver **28** is connected to microprocessor **24**.

The microprocessor and transceiver combination may be provided as a single integrated circuit **30** in mobile control node **12** and single integrated circuit **32** in base station **14**. The circuits **30**, **32** are configured to communicate with one another over a wireless link **34** as discussed in U.S. Publication No. 2010/0171642 and together provide a time-of-flight (TOF) ranging subsystem **36** that generates a reading of the range or distance between the mobile control node **12** and base station **14**.

The mobile control node **12** includes a distance filter **100**, as may be provided by suitable programming of microprocessor **16**, which strives to generate stable and accurate estimates of the range or distance between the mobile control node **12** and base station **14** for view on display **23**.

FIG. **2** shows a system block diagram for a preferred distance filter **100**. In a first functional block **102** the raw distance data from the TOF subsystem **36** is received and output as a digital signal **42**. An example of the raw TOF distance signal is shown as signal **42'** in FIG. **3**.

The raw TOF distance signal **42** is passed through a smoothing filter such as a biased median filter **104**, as discussed in greater detail below, which provides a smoothed TOF distance signal **44**. An example of the smoothed TOF distance signal is shown as signal **44'** in FIG. **3**.

In parallel, the distance filter **100** receives raw accelerometer data at functional block **106** which outputs a digital signal **46**. An example of the raw accelerometer signal is shown as signal **46'** in FIG. **3**.

The raw accelerometer signal **46** is passed through a smoothing filter such as a biased median filter **108**, as discussed in greater detail below, which provides a smoothed accelerometer signal **48**. An example of the smoothed accelerometer signal is shown as signal **48'** in FIG. **3**.

The smoothed accelerometer signal **48** is fed into a step detection block **110** that detects if and when a human step has occurred, as discussed in greater detail below. Bock **110** generates a signal **49** that is acted on by functional block **112**.

Functional block **112** is a step filter which couples or applies the output of the step detection block **110** to the smoothed TOF distance signal **44** provided by block **104** in order to constrain the distance estimated by filter **100**. Generally speaking, the step filter block **112** utilizes the detection of a person's step as a quantum to limit the increase or decrease in the distance estimate and utilizes the smoothed TOF signal **44** to determine the direction of the distance estimate, or in other words, to determine whether or not to increase or decrease the estimated distance.

Each of the functional blocks will now be discussed in greater detail.

The smoothing filters of functional blocks **104** and **108** are preferably digital biased median filters. A median filter selects a median value in a set of n input values. The set selection window can be a serial window (e.g., selecting input values 1 . . . n, n+1 . . . 2n, 2n+1 . . . 3n, etc.,) or a sliding window (e.g., selecting input values 1 . . . n, 2 . . . n+1, 3 . . . n+2, etc.), preferably a sliding window. A biased median filter will, after ordering the values in the set, discard a predetermined number of higher or lower placed values to thus bias the filter to either high or low values. In the preferred embodiment, the biased median filter is characterized by three variables or parameters; Sample Size, Number of High Values to Discard, and Number of Low Values to Discard. The output of the biased median filter is the median of the remaining values in the set, or alternatively the arithmetic average of the remaining values in the set.

In the biased median filter **104**, the data being smoothed is the raw TOF distance signal **42**. This data tends to error on the high side due to the existence of reflections and multipath propagation of the TOF signal. Accordingly, the biased median filter **104** is preferably biased to the low side. For example, to generate the smoothed TOF distance signal **44** shown in FIG. **3**, the Sample Size for filter **104** was set to ten (in circumstances where the input raw TOF signal **42** is collected at forty samples per second), the Number of High Values to Discard was set to four, and the Number of Low Values to Discard was set to two. The remaining four values in the set were averaged to generate the output of the filter **104**.

In the biased median filter **108**, the data being smoothed is the raw accelerometer signal **46**. The noise in this data tends to be random and thus not biased towards high or low values. However, it is important that the sample size is selected to be smaller than the number of samples that may be obtained during a single step. Thus, for example, to generate the smoothed accelerometer signal **48** shown in FIG. **3**, the Sample Size for filter **108** was set to ten in circumstances where the input raw accelerometer signal **46** is collected at forty samples per second, the Number of High Values to Discard was set to zero, and the Number of Low Values to Discard was set to zero.

The step detection block **110** examines the smoothed accelerometer signal **48** to determine if two local peaks occur in the signal within a certain period of time, thus signifying the occurrence of a human step. For example, referring to FIG. **4**, the step detection block **110** signals the occurrence of a human step when two local peaks **124**, **130** occur in a period of time T, where $t1<T<t2$. This block is characterized by three

variables or configurable parameters: Minimum Step Amplitude, Minimum Step Period (t1), and Maximum Step Period (t2).

The Minimum Step Amplitude is device dependent. For example, the accelerometer that was used to generate the data illustrated in FIG. 3 had a steady state value ranging between about zero and fifty due to system noise. The peak values that were experienced when a step was taken by a wide variety of people ranged between about one hundred to about three hundred. Hence, a value between fifty and one hundred, e.g., eighty, can be selected for the Minimum Step Amplitude.

The Minimum Step Period and Maximum Step Period are selected to encompass the maximum and minimum anticipated pace of human steps, respectively. To generate the data in FIG. 3, the Minimum Step Period was set to 0.3 m and the Maximum Step Period was set to 1.2 m.

In practice, the step detection block **110** references a base level **120** (such as zero) in the smoothed accelerometer signal **48**, which is exemplified in FIG. 4 by signal portion **48**A. When the level of the smoothed accelerometer signal **48**A exceeds the base level by the Minimum Step Amplitude as represented by stippled line **122**, the block **110** notes a maximum local level, e.g. at point **124**. Then, a local minimum level is identified at point **126**. In order to qualify as a human step, the local minimum level must also be below a threshold value represented by stippled line **128**. In addition, the time stamp or occurrence of the local minimum level **126** is compared against the time stamp or occurrence of the local maximum level **124** to ensure that the time difference falls within a predetermined range that represents a permissible acceleration slope, otherwise no step is determined. The permissible range of acceleration slopes identifies an important behavior of pedal locomotion or human gait, being a relatively rapid deceleration profile within expected limits. Then, the functional block **110** looks for the next local maximum level, e.g. at point **130**. If, commencing from local minimum level **126**, the level of the smoothed accelerometer signal **48**A exceeds the Minimum Step Amplitude during a period of time t between one half the Minimum Step Period and one half the Maximum Step Period, the block **110** determines that a single human step has been taken. Thus for example, the block **110** concludes that a human step has occurred at point **132** in FIG. **4**. The process repeats continuously.

As previously mentioned, the step filter block **112** utilizes the output of the step detection block **110** in order to constrain the smoothed TOF distance data **44** in order to arrive at a distance estimate. FIG. **3** shows the distance estimate **50'** generated by the step filter block **112** in comparison to an actual measured distance **52'** and in relation to the smoothed raw TOF distance data **44'** and the raw TOF distance data **42'**. These distance data are graphed in relation to the right vertical axis **60**, which represents a distance in meters between the mobile control node and the base transceiver. FIG. **3** also plots the raw accelerometer data **46'** and smoothed accelerometer data **48'** in relation to the left vertical axis **62**, which represents the output of the accelerometer. The horizontal axis **64** represents the sample number that is common to both TOF and accelerometer data.

As can be seen in FIG. **3**, whenever the step detection block **110** signals the occurrence of a step, the step filter block **112** will vary the distance estimate **50'** by a predestined quantum of either a Maximum Positive Distance Change per Step, applicable when distance between the base transceiver and the mobile control node increases, or a Maximum Negative Distance Change Per Step, applicable when distance between the base transceiver and the mobile control node decreases. Since reflections and multipath propagation will likely cause a positive error in the TOF distance data, it is beneficial to limit the Maximum Positive Distance Change Per Step more than the Maximum Negative Distance Change Per Step. Both quantities should be close to the maximum expected stride length expected, for example 1.2 m and 1.5 m, respectively.

In order to determine the direction, i.e., whether to increase or decrease the value of distance estimate signal **50**, the step filter block **112** of the preferred embodiment compares the current distance estimate against the smoothed TOF distance signal **44**. If, at the instance a step is detected, the smoothed TOF distance signal **44** is greater than the current distance estimate signal **50** then its current value is incremented by the Maximum Positive Distance Change Per Step, otherwise the current value of the distance estimate signal **50** is decremented by the Maximum Negative Distance Change Per Step. This can be seen best in FIG. **5**, which shows a portion **44**A of the smoothed TOF distance signal **44'**, a portion **50**A of the distance estimate signal **50'**, and a portion **52**A of the measured distance signal **52'**. As seen in FIG. **5**, a human step is detected at time instants t_a, t_b, and t_c. At t_a, the smoothed TOF measured distance signal **52'** is less than the distance estimate signal **50'**, so the distance estimate signal **50'** is reduced at that time. At each of times t_b and t_c, the smoothed TOF measured distance signal **52'** is greater than the distance estimate signal **50'**, so the distance estimate signal **50'** is increased at those instances.

It will be appreciated that in the event noise is not random, the performance of the preferred embodiment could suffer due to the fact that the direction of the distance estimate is determined substantially at the instance each human step is detected by block **110**. In order to counteract such phenomenon, the smoothed TOF distance data samples may be averaged for a discrete time period in order to use this quantity as the comparison, with the distance estimate being incremented in the event the average is greater than the distance estimate or decremented in the event the average is less than the distance estimate.

The initial value of the distance estimate signal **50** may be based on an initial value of the raw TOF distance data, as shown in FIG. **3**. In the alternative, some conditions may be placed prior to registering the initial value, such as requiring no substantive changes to the accelerometer data and TOF data for a certain period of time in order to obtain an estimate under relatively steady state conditions.

FIG. **6** shows another embodiment of a distance filter **200**. In this embodiment, the distance filter also utilizes radio signal strength as measured by the base station as another indicator in estimating the distance between the mobile control node and the base station. The raw radio signal strength is provided to functional block **202** which computes a raw SSI distance signal based on the strength of the battery in the mobile control node and the radio signal strength received at the base station, which are correlated to distance. Alternatively, the raw SSI distance signal can be based on the radio signal strength received at the mobile control node, it being presumed that the battery level of the base station, which may the relatively large 12V accessory battery of the vehicle, remains constant. This raw distance signal is fed to another biased median filter **204** similar to those described above to generate a smoothed SSI distance signal, based on signal strength. Functional block **206** fuses the smoothed SSI distance signal and the smoothed TOF distance signal derived from the TOF subsystem. The fusion block **206** may be as simple as a weighted average of the two signals, or a more sophisticated algorithm, such as a Kalman filter or the like. In either event, a smoother distance estimate is expected in comparison to the TOF data taken in isolation. The output of the fusion block **206** is fed to the step filter **112** along with the output of the step detection block **110**.

The circuitry for the distance filter **100** or **200**, which can be provided by a suitably programmed microprocessor or digital signal processor (DSP), may be incorporated in the base station or the mobile control node, or may be implemented by circuitry located on both components. The specific physical location is not important since the base station and the mobile control node are able to communicate with one another and pass appropriate messages therebetween.

The display and/or the system of the present invention may be associated with a camera or imaging sensor of the vehicle that is operable to capture images, such as video images of a scene occurring within the camera's field of view. The camera or sensor may comprise any suitable camera or sensor. Optionally, the camera may comprise a "smart camera" that includes the imaging sensor array and associated circuitry and image processing circuitry and electrical connectors and the like as part of a camera module, such as by utilizing aspects of the vision systems described in U.S. provisional application Ser. No. 61/565,713, filed Dec. 1, 2011; and/or Ser. No. 61/563,965, filed Nov. 28, 2011, which are hereby incorporated herein by reference in their entireties.

The vehicle may include any type of sensor or sensors, such as imaging sensors or radar sensors or lidar sensors or ultrasonic sensors or the like. The imaging sensor or camera may capture image data for image processing and may comprise any suitable camera or sensing device, such as, for example, an array of a plurality of photosensor elements arranged in 640 columns and 480 rows (a 640×480 imaging array), with a respective lens focusing images onto respective portions of the array. The photosensor array may comprise a plurality of photosensor elements arranged in a photosensor array having rows and columns. The logic and control circuit of the imaging sensor may function in any known manner, such as in the manner described in U.S. Pat. Nos. 5,550,677; 5,877,897; 6,498,620; 5,670,935; 5,796,094; and/or 6,396,397, and/or U.S. provisional applications, Ser. No. 61/614,880, filed Mar. 23, 2012; Ser. No. 61/615,410, filed Mar. 26, 2012; Ser. No. 61/613,651, filed 2012; Ser. No. 61/607,229, filed Mar. 6, 2012; Ser. No. 61/605,409, filed Mar. 1, 2012; Ser. No. 61/602,878, filed Feb. 24, 2012; Ser. No. 61/602,876, filed Feb. 24, 2012; Ser. No. 61/600,205, filed Feb. 17, 2012; Ser. No. 61/588,833, filed Jan. 20, 2012; Ser. No. 61/583,381, filed Jan. 5, 2012; Ser. No. 61/579,682, filed Dec. 23, 2011; Ser. No. 61/570,017, filed Dec. 13, 2011; Ser. No. 61/568,791, filed Dec. 9, 2011; Ser. No. 61/567,446, filed Dec. 6, 2011; Ser. No. 61/559,970, filed Nov. 15, 2011; Ser. No. 61/552,167, filed Oct. 27, 2011; Ser. No. 61/540,256, filed Sep. 28, 2011; Ser. No. 61/513,745, filed Aug. 1, 2011; Ser. No. 61/511,738, filed Jul. 26, 2011; and/or Ser. No. 61/503,098, filed Jun. 30, 2011, which are all hereby incorporated herein by reference in their entireties. The system may communicate with other communication systems via any suitable means, such as by utilizing aspects of the systems described in PCT Application No. PCT/US10/038477, filed Jun. 14, 2010, and/or U.S. patent application Ser. No. 13/202,005, filed Aug. 17, 2011 and published Mar. 15, 2012 as U.S. Publication No. US 2012-0062743, and/or U.S. provisional applications, Ser. No. 61/567,150, filed Dec. 6, 2011; Ser. No. 61/565,713, filed Dec. 1, 2011; and/or Ser. No. 61/537,279, filed Sep. 21, 2011, which are hereby incorporated herein by reference in their entireties.

The imaging device and control and image processor and any associated illumination source, if applicable, may comprise any suitable components, and may utilize aspects of the cameras and vision systems described in U.S. Pat. Nos. 5,550,677; 5,877,897; 6,498,620; 5,670,935; 5,796,094; 6,396,397; 6,806,452; 6,690,268; 7,005,974; 7,937,667; 7,123,168; 7,004,606; 6,946,978; 7,038,577; 6,353,392; 6,320,176; 6,313,454; and 6,824,281, and/or International Publication No. WO 2010/099416, published Sep. 2, 2010, and/or PCT Application No. PCT/US10/47256, filed Aug. 31, 2010, and/or U.S. patent application Ser. No. 12/508,840, filed Jul. 24, 2009, and published Jan. 28, 2010 as U.S. Pat. Publication No. US 2010-0020170; and/or U.S. provisional applications, Ser. No. 61/511,738, filed Jul. 26, 2011; and/or Ser. No. 61/503,098, filed Jun. 30, 2011, which are all hereby incorporated herein by reference in their entireties. The camera or cameras may comprise any suitable cameras or imaging sensors or camera modules, and may utilize aspects of the cameras or sensors described in U.S. patent application Ser. No. 12/091,359, filed Apr. 24, 2008 and published Oct. 1, 2009 as U.S. Publication No. US 2009-0244361; and/or Ser. No. 13/260,400, filed Sep. 26, 2011, now U.S. Pat. No. 8,542,451, and/or U.S. Pat. Nos. 7,965,336 and/or 7,480,149, which are hereby incorporated herein by reference in their entireties. The imaging array sensor may comprise any suitable sensor, and may utilize various imaging sensors or imaging array sensors or cameras or the like, such as a CMOS imaging array sensor, a CCD sensor or other sensors or the like, such as the types described in U.S. Pat. Nos. 5,550,677; 5,670,935; 5,760,962; 5,715,093; 5,877,897; 6,922,292; 6,757,109; 6,717,610; 6,590,719; 6,201,642; 6,498,620; 5,796,094; 6,097,023; 6,320,176; 6,559,435; 6,831,261; 6,806,452; 6,396,397; 6,822,563; 6,946,978; 7,339,149; 7,038,577; 7,004,606; 7,720,580; 7,965,336; and/or 8,070,332, and/or PCT Application No. PCT/US2008/076022, filed Sep. 11, 2008 and published Mar. 19, 2009 as International Publication No. WO/2009/036176, and/or PCT Application No. PCT/US2008/078700, filed Oct. 3, 2008 and published Apr. 9, 2009 as International Publication No. WO/2009/046268, which are all hereby incorporated herein by reference in their entireties.

The camera module and circuit chip or board and imaging sensor may be implemented and operated in connection with various vehicular vision-based systems, and/or may be operable utilizing the principles of such other vehicular systems, such as a vehicle headlamp control system, such as the type disclosed in U.S. Pat. Nos. 5,796,094; 6,097,023; 6,320,176; 6,559,435; 6,831,261; 7,004,606; 7,339,149; and/or 7,526,103, which are all hereby incorporated herein by reference in their entireties, a rain sensor, such as the types disclosed in commonly assigned U.S. Pat. Nos. 6,353,392; 6,313,454; 6,320,176; and/or 7,480,149, which are hereby incorporated herein by reference in their entireties, a vehicle vision system, such as a forwardly, sidewardly or rearwardly directed vehicle vision system utilizing principles disclosed in U.S. Pat. Nos. 5,550,677; 5,670,935; 5,760,962; 5,877,897; 5,949,331; 6,222,447; 6,302,545; 6,396,397; 6,498,620; 6,523,964; 6,611,202; 6,201,642; 6,690,268; 6,717,610; 6,757,109; 6,802,617; 6,806,452; 6,822,563; 6,891,563; 6,946,978; 7,720,580; 7,859,565; and/or 8,070,332, which are all hereby incorporated herein by reference in their entireties, a trailer hitching aid or tow check system, such as the type disclosed in U.S. Pat. No. 7,005,974, which is hereby incorporated herein by reference in its entirety, a reverse or sideward imaging system, such as for a lane change assistance system or lane departure warning system or for a blind spot or object detection system, such as imaging or detection systems of the types disclosed in U.S. Pat. Nos. 7,881,496; 7,720,580; 7,038,577; 5,929,786 and/or 5,786,772, which are hereby incorporated herein by reference in their entireties, a video device for internal cabin surveillance and/or video telephone function, such as disclosed in U.S. Pat. Nos. 5,760,962; 5,877,897; 6,690,268; and/or 7,370,983, and/or U.S. patent application Ser. No. 10/538,724, filed Jun. 13, 2005 and published Mar. 9, 2006 as U.S. Publication No. US-2006-0050018-A1, which are hereby incorporated herein by reference in their entireties, a traffic sign recognition system, a system for determining a distance to a leading or trailing vehicle or object, such as a system utilizing the principles disclosed in U.S. Pat. Nos. 6,396,397 and/or 7,123,168, which are hereby incorporated herein by reference in their entireties, and/or the like.

Optionally, the circuit board or chip may include circuitry for the imaging array sensor and or other electronic accessories or features, such as by utilizing compass-on-a-chip or EC driver-on-a-chip technology and aspects such as described in U.S. Pat. No. 7,255,451 and/or U.S. Pat. No. 7,480,149; and/or U.S. patent application Ser. No. 11/226,628, filed Sep. 14, 2005 and published Mar. 23, 2006 as U.S. Publication No. US-2006-0061008, and/or Ser. No. 12/578,732, filed Oct. 14, 2009 and published Apr. 22, 2010 as U.S. Publication No. US 2010-0097469, which are hereby incorporated herein by reference in their entireties.

Optionally, the display of the system may be operable to display images captured by one or more of the imaging sensors for viewing by the driver of the vehicle while the driver is normally operating the vehicle. Optionally, for example, the vision system may include a video display device disposed at or in the interior rearview mirror assembly of the vehicle, such as by utilizing aspects of the video mirror display systems described in U.S. Pat. No. 6,690,268 and/or U.S. patent application Ser. No. 13/333,337, filed Dec. 21, 2011 and published Jun. 28, 2012 as U.S. Publication No. US 2012-0162427, which are hereby incorporated herein by reference in their entireties. The video mirror display may comprise any suitable devices and systems and optionally may utilize aspects of the compass display systems described in U.S. Pat. Nos. 7,370,983; 7,329,013; 7,308,341; 7,289,037; 7,249,860; 7,004,593; 4,546,551; 5,699,044; 4,953,305; 5,576,687; 5,632,092; 5,677,851; 5,708,410; 5,737,226; 5,802,727; 5,878,370; 6,087,953; 6,173,508; 6,222,460; 6,513,252; and/or 6,642,851, and/or European patent application, published Oct. 11, 2000 under Publication No. EP 0 1043566, and/or U.S. patent application Ser. No. 11/226,628, filed Sep. 14, 2005 and published Mar. 23, 2006 as U.S. Publication No. US-2006-0061008, which are all hereby incorporated herein by reference in their entireties. Optionally, the video mirror display screen or device may be operable to display images captured by a rearward viewing camera of the vehicle during a reversing maneuver of the vehicle (such as responsive to the vehicle gear actuator being placed in a reverse gear position or the like) to assist the driver in backing up the vehicle, and optionally may be operable to display the compass heading or directional heading character or icon when the vehicle is not undertaking a reversing maneuver, such as when the vehicle is being driven in a forward direction along a road (such as by utilizing aspects of the display system described in PCT Application No. PCT/US2011/056295, filed Oct. 14, 2011 and published Sep. 30, 2010 as International Publication No. WO 2010/111465, which is hereby incorporated herein by reference in its entirety). Optionally, the system (utilizing a forward and/or rearward facing camera and other cameras disposed at the vehicle with exterior fields of view) and/or the camera or cameras as part of a vehicle vision system (such as utilizing a rearward facing camera and sidewardly facing cameras and a forwardly facing camera disposed at the vehicle) may provide a display of a top-down view or birds-eye view of the vehicle or a surround view at the vehicle, such as by utilizing aspects of the vision systems described in PCT Application No. PCT/US10/25545, filed Feb. 26, 2010 and published on Sep. 2, 2010 as International Publication No. WO 2010/099416, and/or PCT Application No. PCT/US10/47256, filed Aug. 31, 2010 and published Mar. 10, 2011 as International Publication No. WO 2011/028686, and/or PCT Application No. PCT/US11/62755, filed Dec. 1, 2011 and published Jun. 7, 2012 as International Publication No. WO 2012/075250, and/or U.S. patent application Ser. No. 13/333,337, filed Dec. 21, 2011 and published Jun. 28, 2012 as U.S. Publication No. US 2012-0162427, and/or U.S. provisional applications, Ser. No. 61/615,410, filed Mar. 26, 2012; Ser. No. 61/588,833, filed Jan. 20, 2012; Ser. No. 61/570,017, filed Dec. 13, 2011; Ser. No. 61/568,791, filed Dec. 9, 2011; Ser. No. 61/559,970, filed Nov. 15, 2011; Ser. No. 61/540,256, filed Sep. 28, 2011, which are hereby incorporated herein by reference in their entireties.

Optionally, the video mirror display may be disposed rearward of and behind the reflective element assembly and may comprise a display such as the types disclosed in U.S. Pat. Nos. 5,530,240; 6,329,925; 7,855,755; 7,626,749; 7,581,859; 7,446,650; 7,370,983; 7,338,177; 7,274,501; 7,255,451; 7,195,381; 7,184,190; 5,668,663; 5,724,187 and/or 6,690,268, and/or in U.S. patent application Ser. No. 12/091,525, filed Apr. 25, 2008, now U.S. Pat. No. 7,855,755; Ser. No. 11/226,628, filed Sep. 14, 2005 and published Mar. 23, 2006 as U.S. Publication No. US-2006-0061008; and/or Ser. No. 10/538,724, filed Jun. 13, 2005 and published Mar. 9, 2006 as U.S. Publication No. US-2006-0050018, which are all hereby incorporated herein by reference in their entireties. The display is viewable through the reflective element when the display is activated to display information. The display element may be any type of display element, such as a vacuum fluorescent (VF) display element, a light emitting diode (LED) display element, such as an organic light emitting diode (OLED) or an inorganic light emitting diode, an electroluminescent (EL) display element, a liquid crystal display (LCD) element, a video screen display element or backlit thin film transistor (TFT) display element or the like, and may be operable to display various information (as discrete characters, icons or the like, or in a multi-pixel manner) to the driver of the vehicle, such as passenger side inflatable restraint (PSIR) information, tire pressure status, and/or the like. The mirror assembly and/or display may utilize aspects described in U.S. Pat. Nos. 7,184,190; 7,255,451; 7,446,924 and/or 7,338,177, which are all hereby incorporated herein by reference in their entireties. The thicknesses and materials of the coatings on the substrates of the reflective element may be selected to provide a desired color or tint to the mirror reflective element, such as a blue colored reflector, such as is known in the art and such as described in U.S. Pat. Nos. 5,910,854; 6,420,036; and/or 7,274,501, which are hereby incorporated herein by reference in their entireties.

Optionally, the display or displays and any associated user inputs may be associated with various accessories or systems, such as, for example, a tire pressure monitoring system or a passenger air bag status or a garage door opening system or a telematics system or any other accessory or system of the mirror assembly or of the vehicle or of an accessory module or console of the vehicle, such as an accessory module or console of the types described in U.S. Pat. Nos. 7,289,037; 6,877,888; 6,824,281; 6,690,268; 6,672,744; 6,386,742; and 6,124,886, and/or U.S. patent application Ser. No. 10/538,724, filed Jun. 13, 2005 and published Mar. 9, 2006 as U.S. Publication No. US-2006-0050018, which are hereby incorporated herein by reference in their entireties.

While the above describes a particular embodiment(s) of the invention, it will be appreciated that modifications and variations may be made to the detailed embodiment(s) described herein without departing from the spirit of the invention.

The invention claimed is:

1. A method of estimating a distance between a mobile node and a base station, said method comprising:

providing a display on the mobile node;

providing a time of flight subsystem including circuitry incorporated in the mobile node and the base station and generating a time of flight distance signal by periodically transmitting a time of flight signal between the mobile node and the base station and measuring the time taken for transmission of the time of flight signal therebetween;

providing an accelerometer on the mobile node and generating an accelerometer signal therewith;

initializing the value of a distance estimate signal based on the time of flight distance signal;

detecting a human step based on variances in the accelerometer signal;

changing the value of the distance estimate signal by a predetermined quantum only upon detection of a human step, wherein the value of the distance estimate signal is increased by the predetermined quantum responsive to the time of flight distance signal being greater than the distance estimate signal and wherein the value is decreased by the predetermined quantum responsive to the time of flight distance signal being less than the distance estimate signal; and

periodically displaying the value of the distance estimate signal on the display.

2. A method according to claim **1**, including passing a raw time of flight distance signal generated by the time of flight subsystem through a smoothing filter to thereby generate a smoothed time of flight distance signal utilized by said changing step.

3. A method according to claim **2**, wherein the smoothing filter is a digital biased median filter that is biased low.

4. A method according to claim **2**, including passing a raw accelerometer signal generated by the accelerometer through a smoothing filter to thereby generate a smoothed accelerometer signal utilized by said detecting step.

5. A method according to claim **4**, wherein the smoothing filter comprises a digital median filter.

6. A method according to claim **4**, wherein whether the smoothed time of flight distance signal is greater than or less than the distance estimate signal is determined based on the value of smoothed time of flight distance signal at the substantially the same instant in time when a human step is detected.

7. A method according to claim **4**, wherein whether the smoothed time of flight distance signal is greater than or less than the distance estimate signal is determined based on an average of the smoothed time of flight distance signal as generated over a predetermined period of time before the detection of the human step.

8. A method according to claim **4**, wherein detecting a human step includes examining the smoothed accelerometer signal for the occurrence of two serial local peaks, each of which exceeds a predetermined amplitude, within a predetermined range of time periods indicative of human gait.

9. A method according to claim **8**, wherein detecting a human step further includes examining the smoothed accelerometer signal for a slope within a predetermined range of slopes indicative of human gait.

10. A method according to claim **1**, wherein the value of the distance estimate signal is changed by a different predetermined quantum depending on whether the distance estimate signal is being increased or decreased, and wherein the predetermined quantum by which the distance estimate signal is increased is lower than the predetermined quantum by which the distance estimate signal is decreased.

11. A system that provides an estimate of the distance between a mobile node and a base station, said system comprising:

a display disposed on the mobile node;

a time of flight subsystem including circuitry incorporated in the mobile node and the base station for generating a time of flight signal between the mobile node and the base station, measuring the time taken for transmission of the time of flight signal, and generating a time of flight distance signal based on the measured time;

an accelerometer, mounted in the mobile node, for generating an accelerometer signal;

a distance filter for generating the distance estimate, the distance filter configured to (i) initialize the value of a distance estimate signal based on the time of flight distance signal, (ii) detect a human step based on variances in the accelerometer signal, and (iii) change the value of the distance estimate signal by a predetermined quantum only upon detection of said human step, wherein the value of the distance estimate signal is increased by the predetermined quantum responsive to the time of flight distance signal being greater than the distance estimate signal and wherein the value is decreased by the predetermined quantum responsive to the time of flight distance signal being less than the distance estimate signal; and

wherein said system is operable to periodically display the value of the distance estimate signal on the display.

12. A system according to claim **11**, including a smoothing filter, wherein the smoothing filter receives a raw time of flight distance signal generated by the time of flight subsystem, and generates a smoothed time of flight distance signal that is utilized in determining the change in the distance estimate signal.

13. A system according to claim **12**, wherein the smoothing filter comprises a digital biased median filter that is biased low.

14. A system according to claim **12**, including a smoothing filter, wherein the smoothing filter receives a raw accelerometer signal generated by the accelerometer and generates a smoothed accelerometer signal utilized in the detection of the human step.

15. A system according to claim **14**, wherein the smoothing filter comprises a digital median filter.

16. A system according to claim **14**, wherein whether the smoothed time of flight distance signal is greater than or less than the distance estimate signal is determined based on the value of smoothed time of flight distance signal at the substantially the same instant in time when a human step is detected.

17. A system according to claim **14**, wherein whether the smoothed time of flight distance signal is greater than or less than the distance estimate signal is determined based on an average of the smoothed time of flight distance signal as generated over a predetermined period of time before the detection of the human step.

18. A system according to claim **14**, wherein the distance filter detects a human step by examining the smoothed accelerometer signal for the occurrence of two serial local peaks, each of which exceeds a predetermined amplitude, within a predetermined range of time periods indicative of human gait.

19. A system according to claim **18**, wherein the distance filter detects a human step by examining the smoothed accelerometer signal for a slope within a predetermined range of slopes indicative of human gait.

20. A system according to claim **11**, wherein the value of the distance estimate signal is changed by a different predetermined quantum depending on whether the distance estimate signal is being increased or decreased, and wherein the predetermined quantum by which the distance estimate signal is increased is lower than the predetermined quantum by which the distance estimate signal is decreased.

21. A method of estimating a distance between a mobile node and a base station, said method comprising:

providing a display on the mobile node;

providing a time of flight subsystem including circuitry incorporated in the mobile node and the base station and generating a time of flight distance signal by periodically transmitting a time of flight signal between the mobile control node and the base station and measuring the time taken for transmission of the time of flight signal therebetween;

providing a radio signal strength subsystem including circuitry incorporated in the mobile node and the base station and generating an SSI distance signal based on a strength of a radio signal received by one of the mobile node and the base station;

providing an accelerometer on the mobile node and generating an accelerometer signal therewith;

fusing the SSI distance signal and the time of flight distance signal to generate a fused distance signal;

initializing the value of a distance estimate signal based on the fused distance signal;

detecting a human step based on variances in the accelerometer signal;

changing the value of the distance estimate signal by a predetermined quantum only upon detection of a human step, wherein the value of the distance estimate signal is increased by the predetermined quantum responsive to the fused distance signal being greater than the distance estimate signal and wherein the value is decreased by the predetermined quantum responsive to the fused distance signal being less than the distance estimate signal; and

periodically displaying the value of the distance estimate signal on the display.

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