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A SYSTEM AND METHOD FOR DETERMINING POSITION BASED ON REFLECTED SIGNALS

Field of the Invention

The present invention relates to a system and method for determining position of a system based on reflected signals.

Background of the Invention

Positioning is a common requirement for many applications such as robot control, fire fighting, and entertainment. Many conventional methods for determining the position of an object are based on external reference points such as those described in US patent numbers 6,707,424 and 6,646,596.

The reference points may be active, such as a transmitter or receiver, or passive such as a reflector. The position of the device may be calculated by measuring the distance, delay and/or direction from the reference point to the device. Whilst these methods for determining the position of a device may perform well, the requirement of pre-setting the reference points is not generally convenient and may even be impossible in some situations.

Many conventional methods use a transmitter/receiver device in conjunction with at least one active/reflective device situated at a pre-determined position as a point of reference. Frequently, a system is provided which is capable of monitoring its own position relative to the active/reflective device, and this system is attached to the object. The best known of such systems is the GPS system, using satellites.

US patent numbers 5977958 and 6054950 describe methods for measuring time-of-arrival with ultrashort RF pulses (UWB) transmitted from a transmitter to an array of receivers. Despite the differences in technical details, both patents require devices at pre-known positions. US patent number 5977958

uses four receivers for its 2D scenario and US patent number 6054950 needs at least four receivers or beacons for 3D applications (these receivers or beacons are here termed "explicit references"). There are other similar technologies which are based on angles of arrival of received signals instead of their times of arrival. In such technologies, multiple references are needed. Again, the problem with this type of system is the requirement for references at pre-known positions, which increases the number of devices needed and introduces difficulty in setting up the systems in certain situations or surroundings. Furthermore, such systems require direct line of sight (LOS) between the transmitter and receivers, and the performance decreases sharply in the areas where LOS is not available.

Self-positioning methods employed in robotics often use a ring of ultrasonic transducers or laser range finders to obtain a measurement of the respective distance from an object to a surrounding environment in each of a number of directions. A sonar/laser range image may be formed from the distances between the detector and nearby objects. This image may be compared to a known floor plan or trained database in order to find the location of the robot. However, the known floor plan information and trained database may not be available in some environments.

Another US patent number 6112095 proposes a method of location determination in which a transmitter transmits a radio signal and a receiver device uses an array of antennas to receive the signal both directly and along paths which include reflections (multipath signals). Different locations of the transmitter cause the set of reflected paths to differ, so the received signals constitute a signature of the position. The determination of the location of the transmitter is based on a set of pre-calibrated signal covariance matrices corresponding to possible transmitter locations. However, the uniqueness of the signature is, in principle, not guaranteed and sometimes leads to large errors when the multipath features of one location are similar to those of other

locations. Furthermore, the teaching in this citation is intended for outdoor application, and a base-station is required for its implementation.

A type of self-positioning device for vehicle use is described in US patent number 6,671,622. Another form of positioning system is able to determine its location without the need of external references, by using a north finder, an inertial measuring system, a velocimeter and an odometer. Such systems are very convenient, but the calculated position may not be sufficiently accurate.

In view of the foregoing problems with conventional methods and devices, a need exists for an easily applied self-positioning method which does not require the pre-setting of external reference points.

Summary of the Invention

In general terms, the present invention proposes a method and system for determining the position of a device by transmitting/receiving reflection signals to/from surrounding objects, and calculating the distances to the objects and the directions of reflections so as to determine the position of the device itself.

An advantage of a preferred embodiment is that there is no need to pre-set external references to obtain the position of the device and the method and system is thereby reference-free and self-positioning. Also, there is no need for training the system to enable its operation nor to include a database or floor plan in the system.

The signal used for the distance and direction estimations in a preferred embodiment may be, for example, narrow-band radio frequency (RF), ultra-wide band (UWB), ultrasound or infrared signals.

A further advantage of one or more embodiments of the invention is that the position information may be calculated in real-time.

According to a first aspect of the present invention there is provided a system comprising:

a transmitter for transmitting signals in a number of directions within a range of directions; wherein the transmitter comprises a first rotatable antenna;

a receiver for receiving echoes of the signals from any direction in the range; wherein the receiver comprises a second rotatable antenna, the first antenna being mechanically couplable to the second antenna; and

a processor for processing the received echoes to derive echo data signals indicative of the distance of the system to one or more reflective surfaces and the direction of the one or more reflective surfaces relative to the system; wherein the processor is arranged to determine the position of the system relative to a starting position from the derived echo data signals indicative of the distance of the system to one or more of the one or more reflective surfaces and the direction of the one or more of the one or more reflective surfaces relative to the system.

In a preferred embodiment, the first and/or second antennae comprise one or more mechanically rotatable antennae each having an associated beam pattern gain associated with a beam pattern, the system further comprising one or more electrically rotatable antennae, wherein the one or more electrically rotatable antennae are arranged to be rotatable by varying the gain of the beam pattern(s) of the one or more mechanically rotatable antennae.

According to a second aspect of the present invention there is provided a method for determining the position of a system comprising

transmitting signals in a number of directions within a range of directions using a transmitter comprising a first rotatable antenna;

receiving using a receiver echoes of the signals from any direction in the range; wherein the receiver comprises a second rotatable antenna, the first antenna being mechanically couplable to the second antenna; and

processing the received echoes to derive echo data signals indicative of the distance of the system to one or more reflective surfaces and the direction of the one or more reflective surfaces relative to the system; wherein the step of processing comprises determining the position of the system relative to a starting position from the derived echo data signals indicative of the distance of the system to one or more of the one or more reflective surfaces and the direction of the one or more of the one or more reflective surfaces relative to the system.

In a preferred embodiment, the receiving step comprises receiving signals using one or more mechanically rotatable antennae each having an associated beam pattern gain associated with a beam pattern, the receiving step further comprising receiving signals using one or more electrically rotatable antennae by varying the gain of the beam pattern(s) of the one or more mechanically rotatable antennae.

In a further preferred embodiment, the transmitting step comprises transmitting signals from one or more mechanically rotatable antennae each having an associated beam pattern gain associated with a beam pattern, the transmitting step further comprising transmitting signals using one or more electrically rotatable antennae by varying the gain of the beam pattern(s) of the one or more mechanically rotatable antennae.

Brief Description of the Drawings

Preferred features of the invention will now be described, for the sake of illustration only, with reference to the following Figures in which:

Figure 1a is a schematic diagram showing a directional antenna and its sectors of rotation according to an embodiment of the invention;

Figure 1b is a graph of the variation of amplitude and direction of the received reflection from a farthest object in a system including the directional antenna of Figure 1a;

Figures 2a to 2h show a series of graphs of amplitude against time at various stages of processing of a received signal from system including the directional antenna of Figure 1a;

Figure 3 is a graph showing a Gaussian function of amplitude against direction obtained using a non-linear least-square fitting process and corresponding to a series of samples of processed received signals obtained from a system including the directional antenna of Figure 1a;

Figure 4 is a block schematic diagram of a positioning device according to an embodiment of the invention;

Figure 5 is a plan view of a working area showing a positioning device according to an embodiment of the invention at its origin and at a new position;

Figure 6 is an enlarged plan view of a part of Figure 5 showing the positioning device according to an embodiment of the invention at its origin and at a new position;

Figure 7 is an enlarged plan view of a part of Figure 5 showing the positioning device according to an embodiment of the invention at its origin and at a new position and showing construction lines for calculating the new position from the origin;

Figure 8 is a schematic view of the system of Figure 7 illustrating the effects of distance and direction errors; and

Figure 9 is a plan view of an irregular positioning area for use with an embodiment of the present invention.

Detailed Description of Preferred Embodiments

The method for determining a position of an object such as a robot according to a preferred embodiment of the invention will be described in connection with Figures 1a to 9 and comprises two basic steps. The first step is a distance measurement and direction determination step and is illustrated with reference to Figures 1a to 3. The second step is a position determination step and is illustrated with reference to Figures 5 to 9. A positioning system for determining the position of an object according to a preferred embodiment of the invention is illustrated in Figure 4.

Figure 1a shows a positioning system according to a preferred embodiment which comprises a transmitter (not shown) coupled to a first rotating antenna 2 which is able to rotate a full 360 degrees in a substantially horizontal plane. The transmitter transmits bursts of signals, for example, ultrawide band (UWB) pulses, which are reflected back to a second rotating antenna 3. The second rotating antenna 3 is mechanically coupled to the first rotating antenna 2 and the output of the second rotating antenna 3 is electrically coupled to a receiver (not shown). The circle of rotation of the antennae 2, 3 may be considered to be divided into M sectors. In Figure 1a, a farthest object 5 is located in sector m.

Figure 1b shows the amplitude of the signal reflected back from the farthest object 5 which is in sector m and received at the receiver.

In use, the antennae 2, 3 rotate through 360 degrees and in so doing take M samples. Each sample consists of firing a pulse and processing the reflected

signals. Thus there are M sampling angles θ_1 to θ_M . Thus, at sampling angle θ_m , the directional antennae will cover the range covered by sector m . After each pulse is transmitted, the waveform corresponding to the received signal is recorded for an interval sufficient to recover the main reflection from the farthest object in the working area.

In the directional antenna system shown in Figure 1a, the received signal from a transmitted pulse may be, for example, as shown in Figure 2a and, for each sample, the envelope of the received waveform is detected, as shown in Figure 2b.

The average value of the waveform in each sector is calculated, as shown in Figure 2c. The average value of the waveform in sector m is ζ_m . A threshold value, " ν " (where $0 < \nu$) is then set, as shown in Figure 2c.

The signal is then passed to a slicing stage where it is sliced at a level $\nu + \zeta_m$. Where the signal is below this slicing level, the output of the stage is zero. Where the input signal exceeds the slicing level, the output of the stage is equal to the input signal level. The output of the stage is shown in Figure 2d for sector m .

The output of the slicing stage is then passed to a pulse width filtering stage in which the sliced signal is pulse width filtered, that is, a time threshold T is set, as shown in Figure 2e. If the non-zero signal in the sliced waveform is less than T in width, the output of this stage is zero. However, if the width of the pulse is greater than T , the output of this stage will be equal to the input signal of this stage, as shown in Figure 2f for sector m . The resulting waveforms are stored.

After the antennae have completed a full revolution, there will be M sample waveforms stored, as shown in Figure 2g which illustrates the amplitudes of

the stored waveforms over time, the time axis in Figure 2g corresponding to the time after each pulse is transmitted, rather than real time. The stored waveforms are then filtered in the space domain in a space domain filtering stage. A space domain threshold " s ", where $0 < s$, is set for the stored waveforms. If at any time point along the time axis, the signal amplitudes in K neighbouring sectors (which are continual locations along the space axis) are larger than zero, and $K > s$, the output of the space filtering stage at this point in the K sectors will be equal to their input values. Otherwise, their output is set to zero. Figures 2g and 2h illustrate this for a case where s is equal to 3.

The next stage is to determine the distance and direction of each major reflection. As the distances from major objects to the antennae 2, 3 will vary from one to another, there is one maximum signal in each sector. The point τ along the time axis at which the maximum signal occurs is the time taken from transmission of the pulse until the signal is received back at the receiver, taking the instant of transmission as zero. The distance d from the object to the positioning device is given by $d = c\tau/2$, where c is the speed of light.

Figure 3 shows a graph of a Gaussian function of amplitude against direction obtained using a non-linear least-square fitting process and corresponding to a series of samples of processed received signals obtained from a system including the directional antenna of Figure 1a. To determine the direction of the object from which the transmitted signal is being reflected, the reflected signal corresponding to a group of signals in the space-time domain, the sector containing the maximum signal is selected together with its neighbouring sectors which contain a corresponding signal. P neighbouring sectors are taken which occur before the maximum and P sectors are taken which occur after the maximum, where P should be as large as possible, but $2P+1 \leq K$.

The central angle of the sector which contains the maximum is denoted as θ_m , as shown in Figure 1, and the central angles of the samples being considered are denoted by θ_{m-p} to θ_{m+p} .

The direction of the object may be determined by determining the Gaussian function which best fits the distribution of the amplitudes of the reflections from the object. The Gaussian function may be determined using a non-linear least square fitting technique. The nonlinear least-square fitting is a well-known technique, which can be checked on the website, for example, <http://mathworld.wolfram.com/NonlinearLeastSquaresFitting.html>. Figure 3 shows an example of fitting the Gaussian function to the amplitudes. In a further preferred embodiment, to reduce the fitting complexity, a conventional polynomial fitting technique may be used instead of a non-linear least-square fitting technique.

The estimated angular direction of the object with respect to the origin of the sectors corresponds to the peak of the Gaussian function and is denoted by the angle θ_k (where k means the k th reflection), as shown in Figure 3.

Other methods are also possible for determining the direction.

Figure 4 is a block schematic diagram of a positioning device according to a preferred embodiment of the invention. The device comprises a transmitter 20 which generates pulses which are passed to a directional transmitting antenna 22. The pulses transmitted from the antenna 22 strike an object 24 and are reflected back to a directional receiving antenna 26. The signals from the directional receiving antenna 26 are passed to a receiver 28 where they are recovered in a signal reform stage 30. The output of the signal reform stage 30 is passed to an envelope detection stage 32. The output of the envelope detection stage 32 is connected to the input of an amplitude threshold stage 34. In the amplitude threshold stage 34, the average level of

the signal in a particular sector is determined and is added to a predetermined threshold level. The combined level is then compared with the incoming signal from the envelope detection stage 32. The signals exceeding the combined threshold are then passed to a pulse width filtering stage 36. In the pulse width filtering stage 36, the pulses from the amplitude threshold stage 34 are compared with a predetermined pulse width T and pulses narrower than T are rejected.

The output of the pulse width filtering stage 36 is passed to a space domain filtering stage 38 where the pulses in a given sector are compared with pulses in neighbouring sectors. The output of the space domain filtering stage 38 depending on whether or not the system is in a first state or a second state, passes to a direction and delay estimation stage 40 if in state 1 or to a delay estimation and direction decision stage 42 if in state 2. States 1 and 2 are explained in more detail below.

The outputs of whichever of the direction and delay estimation stage 40 or the delay estimation and direction decision stage 42 is active is passed to a curve fitting stage 44. The output of the curve fitting stage 44 is passed to a direction estimation stage 46. In addition, the output of the direction and delay estimation stage 40 or the delay estimation and direction decision stage 42, is passed to a distance calculation stage 48. The estimated direction data and the calculated distance data are passed to an arranging stage 50 where the distance and direction data for each object are grouped in sequence. This data is then passed to a positioning algorithm stage 52 in which the position of the device is calculated.

When the system is operating in state 1, for example, when the antenna system is at the origin, the directions and delays of all major reflections detected in one rotation of the antenna system, are estimated and recorded.

The estimated direction will be taken from the output of the space domain filtering stage 38, that is, from reflections currently obtained.

If, however, the system is operating in "state 2", that is, the delay is estimated and recorded but the direction is only estimated, the positioning algorithm stage 52 will select a direction from several known directions as the determined direction. These known directions are directions which have already been estimated at the origin. The decision criterion is preferably denotable by, but is not limited to, the expression:

$$direction = \underset{k}{arc\min} |\hat{\vartheta} - \vartheta_k|$$

where $\hat{\vartheta}$ is the direction estimation result at the current location, and ϑ_k with various values of k denotes the directions which have already been estimated at origin.

When the system is operating in state 2, the major reflections are estimated but only reflections whose direction has not changed from the previous position are used to calculate the new position. If there are no reflections whose state has not changed, then the system operates in state 1.

Occasionally, there are several maximum values in one non-zero range of the space-time domain, which means that there are several objects in different directions around the device having almost the same distance to the device. In this case, there may be several maximum values found. The corresponding direction of each reflection found is estimated using a non-linear least square fitting technique with the same Gaussian function described above.

Using the above procedure, the major reflections around the positioning device may be determined, and the distances and directions of the reflecting

object from the positioning device may also be determined. From these, the position of the positioning device may be determined.

In a preferred embodiment of the system of Figure 4, one or more of the envelope detection stage 32, the amplitude threshold stage 34, the pulse width filtering stage 36, the space domain filtering stage 38, the direction and delay estimation stage 40, the delay estimation and direction decision stage 42, the curve fitting stage 44, the direction estimation stage 46, distance calculation stage 48, the arranging stage 50 and the positioning algorithm stage 52 may be implemented by hardware and/or software in a processor.

Two methods of determining the position of the positioning device are proposed, according to preferred embodiments of the invention. A first preferred method may be used where the layout of the positioning area is unknown but it is known to be a convex polygon totally enclosing the positioning area, such as a triangle, a rectangle, or a pentagon, for example. A second preferred method may be used where the layout of the positioning area is unknown and it is not a convex polygon.

With regard to the first method, initially the positioning device is located in the centre of the positioning area, which may be regarded as the origin, so that each side of the polygon will cause a reflection to the device.

The positioning device may be oriented with a compass. Using the procedures outlined above, distance and/or direction estimation values of the reflections may be obtained from all sides of the polygon. These values are stored then in the device.

Figure 5 shows a pentagonal positioning area 60 and a positioning device 62 located therein currently situated in a position defined as the origin 64. The various distances of the positioning device 62 from the sides of the positioning area 60 are denoted by l_1 , l_2 , l_3 , l_4 and l_5 . An X-Y system of co-ordinates may

be defined with its origin [0,0] at a current location and direction, that is the centre of the positioning area, as shown in Figure 5.

When the positioning device moves to a new location 66 in the positioning area 60, as shown in Figure 5, the directions of the sides of the positioning area from which the reflections are sent and return and the distances l_1, l_2, l_3, l_4 and l_5 from the sides of the polygonal positioning area to the positioning device are recalculated. The results are then examined to determine which of the reflections from the sides of the polygon have the same directions as found at the origin. The distance and direction information of two of the reflections may be used to calculate the X and Y values of the new location (X' and Y').

Figure 6 shows the origin 64 and the new position 66 of the positioning device 62 together with two sides 68, 70 of the positioning area 60, the reflections from which are used to calculate the new position 66 of the positioning device.

In Figure 6, ϑ_1 is the angle between a line passing through the origin and normal to side 68, and the x-axis; ϑ_2 is angle between line passing through the origin and normal to the side 70 and the x-axis; l'_1 is the distance from side 68 to the new position 66, and l'_2 is the distance from side 70 to the new position 66. As the distances and directions for the two reflections from the sides 68 and 70 are known, $\vartheta_1, \vartheta_2, l_1, l'_1, l_2, l'_2$ are known. Hence, the change in l_1 may be denoted as $\Delta l_1 = l'_1 - l_1$. Similarly, the change in l_2 may be denoted as $\Delta l_2 = l'_2 - l_2$.

Two lines *line1* and *line2* may be defined as follows where *line1* is substantially parallel to side 70 and *line2* is substantially parallel to side 68:

$$\text{line1: } Y = \tan(\vartheta_1 - \pi/2)X - \Delta l_1 / \sin(\vartheta_1 - \pi/2) \quad (1)$$

$$\text{line2: } Y = \tan(\vartheta_2 + \pi/2)X + \Delta l_2 / \sin(\vartheta_2 + \pi/2) \quad (2)$$

These two lines intersect at the new location 66 of the positioning device 62. The position of the new location 66 is the point of intersection of *line1* and *line2*. Thus, X' and Y' are solutions to the above two linear equations.

Figure 7 again shows a section of the positioning area 60 including the origin 64, the new position 66 and the two sides 68, 70 of the positioning area which are being used to determine the position of the positioning device 62.

In Figure 7, the angle α is the angle made by *line1* through the new position 66 to the x axis. The angle β is the angle between a line 72 parallel to side 68 passing through the origin 64. The angle γ is the angle between the line 72 parallel to side 68 passing through the origin 64 and a line 74 joining the origin 64 to the new position 66. The angle ψ is the angle between *line1* and line 72. The distance between a line normal to line 68 passing through the new position 62 and the intersection of *line1* and line 72 is denoted as the distance a ; distance b is the distance from the origin 64 to the intersection 76 of *line1* and line 72; distance c is the distance between the origin 64 and a line normal to side 68 passing through the new position 66; and distance d is the distance between the origin 64 and the new position 62.

The angles and distances may be calculated as follows

$$\beta = \vartheta_1 - \pi/2, \quad (3)$$

$$\alpha = \pi/2 - \vartheta_2, \quad (4)$$

$$\psi = \pi - \beta - \alpha = \pi - (\vartheta_2 - \vartheta_1). \quad (5)$$

$$a = \Delta l_1 / \tan \psi, \quad (6)$$

$$b = \Delta l_2 / \cos \psi, \quad (7)$$

$$c = b - a = \Delta l_2 / \cos \psi - \Delta l_1 / \tan \psi, \quad (8)$$

$$\gamma = \arctan \frac{\Delta l_1}{c}, \quad (9)$$

$$d = \sqrt{c^2 + \Delta l_1^2}. \quad (10)$$

and the co-ordinates of the new position 66 may be calculated as follows:

$$X' = d \sin(\beta - \gamma) \text{ and } Y' = d \cos(\beta - \gamma) \quad (11)$$

The effects of errors in distance and direction on the accuracy of the positioning of the positioning device, are illustrated in Figure 8. In Figure 8, four positions 78, 80, 82 and 84 show the extreme positions (maximum and minimum) corresponding to the maximum errors in distance and direction.

The maximum error for distance measurement is denoted by ε_1 and the maximum error for direction estimation is ε_2 . The real angle between the two reflecting sides 68, 70 is given by $\pi - (\vartheta_1 - \vartheta_2)$. The distance from the maximum error location to the real location may be given by:

$$d_e = \left[\left(\varepsilon_1 + \sqrt{X'^2 + Y'^2} \tan \varepsilon_2 \right) \cos \varepsilon_2 \right] / \sin(\pi - (\vartheta_1 - \vartheta_2) - 2\varepsilon_2) \quad (12)$$

d_e is associated with the distance from the new position to the origin.

If it is assumed that the angle between the two reflecting sides 68, 70 is $\geq \pi/4$, it may be possible to detect a number of reflections at one location, and a couple of reflections which satisfy the requirements may be found easily. Numerically, in a preferred embodiment, the radius of the positioning area may be around 3m, the maximum error for distance measurement may be around 0.1m, and the direction error may be around $\pi/180$. The maximum error should be smaller than

$$d_e = \left[\left(0.1 + 3 \cdot \tan\left(\frac{\pi}{180}\right) \right) \cos\left(\frac{\pi}{180}\right) \right] / \sin\left[\left(\frac{\pi}{4} - 2\varepsilon_2\right) / 2\right] = 0.279 \text{ m}$$

Preferably, the X and Y errors, that is the distances from the true new position 66 to the extreme error positions, 78, 80, 82 and 84 are smaller than d_e .

Other reflections, which satisfy the angle requirement, that is, where the angle between the two reflecting sides 68 and 70 is $\geq \pi/4$, may be processed in a similar manner to calculate X' and Y' which are the co-ordinates of the new position 66. The corresponding values of X' and Y' may be averaged for all pairs of these reflections.

Note that the direction estimation is only performed at the origin ("state 1" in Figure 4). When the positioning device moves to a new position, it is only necessary to determine which side the reflection is from ("state 2" in Fig.4) as this may assist in avoiding accumulated errors.

When the positioning device moves from the origin to a new position, the reflections from some sides may disappear and this may be due either to the beam being blocked or the angle being such that the reflected beam is not returned to the device. However, other reflections received will guarantee the positioning output. Therefore, the system is capable of overcoming the blocking effect in some situations.

Figure 9 illustrates the alternative method of operating the system in which there is no defined polygon around the positioning area to provide regular reflections. In Figure 9, the positioning area 86 is shown together with a series of locations 1 to 7 as the positioning device progresses around the area. Location 1 is the origin 64.

In this situation, it is possible that none of the reflections received at some of the locations will have the same direction as one of reflections at the origin 64.

The position must therefore be determined step-by-step, that is, the current position is determined by the position of the last location and the direction and distance differences between this locations and the current location (for example, location 1 and location 7 in Figure 9).

For example, if the device 62 moves from location 1 to location 2 to location 3 to location 4...to location 7 in sequence as shown, the first position (location 1) will be fixed as the origin. Distance and direction estimations from all surrounding objects will be determined (state 1) and the values recorded. The x and y axes are defined at this point. Based on the location of the start point, it is possible to build a 2D-axis (X-Y) system.

As the device moves, distance and direction estimations are made periodically. Note that the state in Figure 4 is always "state 1". It may be assumed that the sampling locations are sufficiently close together so that most of the reflection parameters (directions and distances) do not change suddenly (mutation) as compared with the last result, that is to say there is no mutation.

When the device is moved to a new sampling location, it first scans around to obtain information on all the reflections it receives. From this information, it calculates the increases ΔX and ΔY between the new and last location using the reflections which have the same direction as that in last sampling location.

For example, if the co-ordinates of the last position are denoted by $[X, Y]$, then the co-ordinates of the new position are $[X', Y'] = [X + \Delta X, Y + \Delta Y]$. The remaining reflections, which have different directions from those detected at the last sampling location, are considered as mutations and are not used at this location. The mutations may be caused by irregular objects or blocking by human beings. Information on all reflections received is recorded for

possible use at the next location. The above procedure is performed at each location as the device continues to move.

One or more embodiments of the invention may be utilized in personal devices for real time positioning. As one or more embodiments of the invention do not require preset references or training processes, they are more convenient and flexible than conventional devices requiring preset references or training processes.

Various modifications to the embodiments of the present invention described above may be made. For example, other components and method steps may be added or substituted for those described above. Thus, although the invention has been described above using particular embodiments, many variations are possible within the scope of the claims, as will be clear to the skilled reader, without departing from the spirit and scope of the invention.

Claims:

1. A system comprising:

a transmitter for transmitting signals in a number of directions within a range of directions; wherein the transmitter comprises a first rotatable antenna;

a receiver for receiving echoes of the signals from any direction in the range; wherein the receiver comprises a second rotatable antenna, the first antenna being mechanically couplable to the second antenna; and

a processor for processing the received echoes to derive echo data signals indicative of the distance of the system to one or more reflective surfaces and the direction of the one or more reflective surfaces relative to the system; wherein the processor is arranged to determine the position of the system relative to a starting position from the derived echo data signals indicative of the distance of the system to one or more of the one or more reflective surfaces and the direction of the one or more of the one or more reflective surfaces relative to the system.

2. A system according to claim 1, wherein the processor further comprises a store for storing data indicative of the distances and directions of the system relative to one or more of the one or more reflective surfaces.

3. A system according to claim 1, wherein the first and second antennae are rotatable in a rotating path, the rotating path being divided into a number of sectors, the processor being arranged to process the received echoes in each sector sequentially.

4. A system according to claim 1, wherein the receiver comprises an envelope detection stage for detecting an envelope of waveforms corresponding to each of the received echo signals.

5. A system according to claim 4, wherein the receiver further comprises an amplitude threshold stage couplable to the envelope receiving stage and arranged to slice the envelope of each waveform corresponding to each of the received echo signals at a reference level relative to an average level of the received echo signals in selected a sector of rotation of the first and second antennae.
6. A system according to claim 5, wherein the receiver further comprises a first filter couplable to the amplitude threshold stage for filtering in the time domain each sliced waveform.
7. A system according to claim 6, wherein the receiver further comprises a second filter couplable to the first filter to filter in the space domain each sliced waveform filtered in the time domain and to group in the space domain the reflected signals according to the reflective surface from which each signal was reflected, the second filter having an output.
8. A system according to claim 7, wherein the receiver further comprises a Gaussian fitting stage for determining a Gaussian function fitting the space domain filtered output from the second filter.
9. A system according to claim 8, wherein the Gaussian fitting stage determines a Gaussian function fitting the space domain filtered output from the second filter using a least squares method.
10. A system according to any one of claims 8 or 9, the receiver further comprising a peak determination stage couplable to the Gaussian fitting stage to determine a peak of the Gaussian function corresponding to the direction of the one or more of the one or more reflective surfaces relative to the system.
11. A system according to claim 10, the receiver further comprising a time measuring stage for measuring time taken from transmission of a signal by the transmitter to reception of an echo signal received by the receiver

corresponding to the transmitted signal to determine a distance indicative of the distance of the system to a reflective surface from which the received echo signal is reflected.

12. A system according to any one of the preceding claims, wherein the one or more reflective surfaces are located within a positioning area.
13. A system according to claim 12, wherein the positioning area has a fixed peripheral shape in a first plane, the first and second antennae being rotatable in the first plane.
14. A system according to claim 13 wherein the positioning area has a polygonal peripheral shape in the first plane.
15. A system according to claim 14, wherein the processor further comprises an origin determining stage for determining an origin position for the system.
16. A system according to claim 15, wherein the processor is further arranged to determine if two or more reflected echo signals have maintained their directions relative to the system.
17. A system according to claim 16, wherein the processor is further arranged to select a pair of the two or more reflected echo signals determined to have maintained their directions relative to the system as determined at the origin position.
18. A system according to claim 17, wherein the selected pair of the two or more reflected echo signals differ in their directions by at least $\pi/4$.
19. A system according to any one of claims 17 or 18, wherein the processor is further arranged to determine a change in distance of the system

from the reflective surfaces causing the reflected echo signals of the selected pair.

20. A system according to claim 19, wherein the processor is further arranged to determine the position of the system relative to the origin based on the determined change in distance of the system from the reflective surfaces.

21. A system according to claim 16, wherein the processor is further arranged to select any two or more pairs of the two or more reflected echo signals which have been determined to have maintained their directions relative to the system, and determining the position of the system relative to the origin based on an average of the position determined from each pair.

22. A system according to claim 15, wherein the processor is further arranged to determine if any of the one or more reflective surfaces have not changed their direction relative to the system from the direction measured at the origin position, and if it is determined that none of the one or more reflective surfaces has not changed its direction the processor is arranged to determine the position of the system based on the change in the distance(s) of the one or more reflective surfaces from a previously measured position.

23. A system according to claim 22, wherein the processor is further arranged to select a pair of reflected echo signals determined not to have changed their directions relative to the system as determined at the previously measured position.

24. A system according to claim 23, wherein the selected pair of the two or more reflected echo signals differ in their directions by at least $\geq \pi / 4$.

25. A system according to claim 22, wherein the processor is further arranged to determine a change in distance of the system from the reflective surfaces causing the reflected echo signals of the selected pair.

26. A system according to claim 25, wherein the processor is further arranged to determine the position of the system relative to the previously measured position based on the determined change in distance of the system from the reflective surfaces.
27. A system according to claim 22, wherein the processor is further arranged to select any two or more pairs of the two or more reflected echo signals which have been determined to have maintained their directions relative to the system at the previously measured position, and determining the position of the system relative to the origin based on an average of the position determined from each pair.
28. A system according to claim 22, wherein the processor is further arranged to determine the position of the system relative to the origin by adding the changes in position determined from a previously measured position to the position determined previously.
29. A system according to any one of the preceding claims, wherein the transmitted signals comprise any one or more of ultrawide band signals, radio frequency signals, ultrasound, or infrared.
30. A system according to any one of the preceding claims, wherein the first and/or the second antenna comprises a directional antenna.
31. A system according to claim 30, wherein the first and/or second antennae comprise one or more mechanically rotatable antennae each having an associated beam pattern gain associated with a beam pattern, the system further comprising one or more electrically rotatable antennae, wherein the one or more electrically rotatable antennae are arranged to be rotatable by varying the gain of the beam pattern(s) of the one or more mechanically rotatable antennae.

32. A method for determining the position of a system comprising transmitting signals in a number of directions within a range of directions using a transmitter comprising a first rotatable antenna;

receiving using a receiver echoes of the signals from any direction in the range; wherein the receiver comprises a second rotatable antenna, the first antenna being mechanically couplable to the second antenna; and

processing the received echoes to derive echo data signals indicative of the distance of the system to one or more reflective surfaces and the direction of the one or more reflective surfaces relative to the system; wherein the step of processing comprises determining the position of the system relative to a starting position from the derived echo data signals indicative of the distance of the system to one or more of the one or more reflective surfaces and the direction of the one or more of the one or more reflective surfaces relative to the system.

33. A method according to claim 32, wherein the processing step further comprises storing data indicative of the distances and directions of the system relative to one or more of the one or more reflective surfaces.

34. A method according to any one of claims 32 or 33, wherein the first and second antennae are rotatable in a rotating path, the processing step further comprising dividing the rotating path into a number of sectors and processing the received echoes in each sector sequentially.

35. A method according to any one of claims 32 to 34, wherein the processing step further comprises detecting in the receiver an envelope of waveforms corresponding to each of the received echo signals.

36. A method according to claim 35, wherein the processing step further comprises slicing in an amplitude threshold stage in the receiver the envelope

of each waveform corresponding to each of the received echo signals at a reference level relative to an average level of the received echo signals in a selected sector of rotation of the first and second antennae.

37. A method according to claim 36, wherein the processing step further comprises filtering in the time domain each sliced waveform.

38. A method according to claim 37, wherein the processing step further comprises filtering using a filter in the space domain each sliced waveform filtered in the time domain and grouping in the space domain the reflected signals according to the reflective surface from which each signal was reflected, the filter having an output.

39. A method according to claim 38, wherein the processing step further comprises determining a Gaussian function fitting the space domain filtered output from the filter.

40. A method according to claim 39, wherein the Gaussian function determination step comprises determining a Gaussian function fitting the space domain filtered output from the filter using a least squares method.

41. A method according to any one of claims 39 or 40, wherein the processing step further comprises determining a peak of the Gaussian function corresponding to the direction of one or more of the one or more reflective surfaces relative to the system whose position is being determined.

42. A method according to claim 41, wherein the processing step further comprises measuring time taken from transmission of a signal by the transmitter to reception of an echo signal received by the receiver corresponding to the transmitted signal to determine a distance indicative of the distance of the system to a reflective surface from which the received echo signal is reflected.

43. A method according to any one of claims 32 to 42, wherein the one or more reflective surfaces are located within a positioning area having a peripheral shape in a first plane, the first and second antennae being rotatable in the first plane, the processing step further comprising determining an origin position for the system whose position is to be determined.
44. A method according to claim 43, wherein the positioning area has a polygonal peripheral shape in the first plane, and wherein the processing step further comprises determining if two or more reflected echo signals have maintained their directions relative to the system whose position is to be measured.
45. A method according to claim 44, wherein the processing step further comprises selecting a pair of the two or more reflected echo signals determined to have maintained their directions relative to the system as determined at the origin position.
46. A method according to claim 45, wherein selecting step comprises selecting a pair of the two or more reflected echo signals which differ in their directions by at least $\pi/4$.
47. A method according to any one of claims 45 or 46, wherein the processing step further comprises determining a change in distance of the system from the reflective surfaces causing the reflected echo signals of the selected pair.
48. A method according to claim 47, wherein the processing step further comprises to determining the position of the system relative to the origin based on the determined change in distance of the system from the reflective surfaces.
49. A method according to claim 44, wherein the processing step further comprises selecting any two or more pairs of the two or more reflected echo

signals which have been determined to have maintained their directions relative to the system, and determining the position of the system relative to the origin based on an average of the position determined from each pair.

50. A method according to claim 43, wherein the processing step further comprises determining if any of the one or more reflective surfaces have not changed their direction relative to the system from the direction measured at the origin position, and if it is determined that none of the one or more reflective surfaces has not changed its direction, determining the position of the system based on the change in the distance(s) of the one or more reflective surfaces from a previously measured position.

51. A method according to claim 50, wherein the processing step further comprises selecting a pair of reflected echo signals determined not to have changed their directions relative to the system as determined at the previously measured position.

52. A method according to claim 51, wherein the step of selecting comprises selecting a pair of the two or more reflected echo signals which differ in their directions by at least $\pi/4$.

53. A method according to claim 50, wherein the processing step is further arranged to determine a change in distance of the system from the reflective surfaces causing the reflected echo signals of the selected pair.

54. A method according to claim 53, wherein the processing step further comprises determining the position of the system relative to the previously measured position based on the determined change in distance of the system from the reflective surfaces.

55. A method according to claim 50, wherein the processing step further comprises selecting any two or more pairs of the two or more reflected echo signals which have been determined to have maintained their directions

relative to the system at the previously measured position, and determining the position of the system relative to the origin based on an average of the position determined from each pair.

56. A method according to claim 55, wherein the processing step further comprises determining the position of the system relative to the origin by adding the changes in position determined from a previously measured position to the position determined previously.

57. A method according to any one of claims 32 to 56, wherein the transmitting step comprises transmitting signals comprised of any one or more of ultrawide band signals, radio frequency signals, ultrasound, or infrared.

58. A method according to any one of claims 32 to 57, wherein the transmitting step comprises transmitting signals from a directional antenna.

59. A method according to any one of claims 32 to 58, wherein the receiving step comprises receiving signals using a directional antenna.

60. A method according to claim 58, wherein the transmitting step comprises transmitting signals from one or more mechanically rotatable antennae each having an associated beam pattern gain associated with a beam pattern, the transmitting step further comprising transmitting signals from one or more electrically rotatable antennae by varying the gain of the beam pattern(s) of the one or more mechanically rotatable antennae.

61. A method according to any one of claims 58 to 60, wherein the receiving step comprises receiving signals using one or more mechanically rotatable antennae each having an associated beam pattern gain associated with a beam pattern, the receiving step further comprising receiving signals using one or more electrically rotatable antennae by varying the gain of the beam pattern(s) of the one or more mechanically rotatable antennae.