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(54) Title: A RELATIVE POSITIONING METHOD

(57) Abstract: The invention relates to a method comprising receiving distances between a first and a second devices from the second device, wherein the distances are based on strength of wireless signals sent by the first device at two points, measuring a heading angle and a moving distance of the first device between the locations at two points, receiving a heading angle and a moving distance between the locations of the second device at two time points, calculating angles between the devices at two points by the first device on the basis of measured and received data, and determining the coordinates of the devices at two points. The invention further relates technical equipment implementing the method.
A RELATIVE POSITIONING METHOD

Background

Position based services are becoming more and more popular in our daily life and position based service applications are widely used in today’s portable electronic devices, e.g. in mobile phones and other smart devices.

Existing localization services of portable electronic devices are mostly based on an absolute position method. Absolute position methods need a GPS system which is of high power consumption. However, portable electronic devices have limited power capacity, which limited power capacity may restrict the use of the GPS system, especially in circumstances with limited charging capacity of portable electronic devices.

Summary

Now there has been invented an improved method and technical equipment implementing the method. Various aspects of the invention include a method, an apparatus and a computer readable medium comprising a computer program stored therein, which are characterized by what is stated in the independent claims. Various embodiments of the invention are disclosed in the dependent claims.

According to a first aspect, there is provided a method comprising: receiving distances between a first and a second device from the second device, wherein the distances are based on strength of wireless signals sent by the first device at a first time point and a second time point, wherein the locations of the first and second device are different at the first time point and at the second time point, measuring a moving distance of the first device between the location at the first time point and the location at the second time point, receiving a heading angle of the first device at the first time point and at the second time point, receiving a moving distance between the location of the second device at the first time point and the location at the second time point, receiving a heading
angle of the second device at the first time point and at the second time point, calculating angles between the first device and the second device at the first time point and at the second time point by the first device on the basis of measured and received data and determining the coordinates of the first device and the second device at the first time point and at the second time point.

According to an embodiment, the method further comprises displaying relative position of the first device and the second device on the basis of determined coordinates. According to an embodiment, measuring the moving distance of the first device between the location at the first time point and the location at the second time point of the first device is done by an accelerometer. According to an embodiment, measuring of the heading angle of the first device at the first time point and at the second time point is done by the accelerometer and a magnetometer. According to an embodiment, the strength of the wireless signal sent by the first device is measured by a wireless chip of the second device. According to an embodiment, the wireless signal is Wi-Fi, Bluetooth, or ZigBee signal.

According to a second aspect, there is provided an apparatus comprising means for transmitting wireless signal, means for measuring a moving distance between two time points, means for measuring heading angle, means for receiving data from a second device and at least one processor, memory including computer program code, the memory and the computer program code configured to, with the at least one processor, cause the apparatus to perform at least the following: receive distances between the apparatus and the second device from the second device, wherein the distances are based on strength of wireless signals sent by the apparatus at a first time point and a second time point, wherein the locations of the apparatus and the second device are different at the first time point and at the second time point, measure a distance of the apparatus between the location at the first time point and the location at the second time point, measure a heading angle of the apparatus at the first time point and at the second time point, receive a distance between the location of the second device at the first time point and at the second time point;
receive a heading angle of the second device at the first time point and at the second time point, calculate angles between the apparatus and the second device at the first time point and at the second time point by the apparatus on the basis of measured and received data, and determine the coordinates of the apparatus and the second device at the first time point and at the second time point.

According to an embodiment, the at least one processor is arranged to cause the apparatus to perform displaying relative position of the first device and the second device on the basis of determined coordinates. According to an embodiment, measurement of the moving distance of the first device between the location at the first time point and the location at the second time point of the first device is done by an accelerometer. According to an embodiment, measurement of the heading angle of the first device at the first time point and at the second time point is done by the accelerometer and a magnetometer. According to an embodiment, the strength of the wireless signal sent by the first device is measured by a wireless chip of the second device. According to an embodiment, the wireless signal is Wi-Fi, Bluetooth, or ZigBee signal.

According to a third aspect, there is provided an apparatus comprising: means for receiving distances between the first device and the second device from the second device, wherein the distances are based on strength of wireless signals sent by the first device at a first time point and a second time point, wherein the locations of the first device and the second device are different at the first time point and at the second time point, means for measuring a distance of the first device between the location at the first time point and the location at the second time point, means for measuring a heading angle of the first device at the first time point and at the second time point, means for receiving a distance between the location of the second device at the first time point and at the second time point, means for receiving a heading angle of the second device at the first time point and at the second time point, means for calculating angles between the first device and the second device at the first time point and at the second time point by the apparatus on the basis of measured and received data, and means for determining the
coordinates of the first device and the second device at the first time point and at the second time point.

According to a fourth aspect, there is provided a computer program product embodied on a non-transitory computer readable medium, comprising computer program code configured to, when executed on at least one processor, cause an apparatus to: receive distances between the first device and the second device from the second device, wherein the distances are based on strength of wireless signals sent by the first device at a first time point and a second time point, wherein the locations of the first device and the second device are different at the first time point and at the second time point, measure a distance of the first device between the location at the first time point and the location at the second time point, measure a heading angle of the first device at the first time point and at the second time point, receive a distance between the location of the second device at the first time point and at the second time point, receive a heading angle of the second device at the first time point and at the second time point, calculate angles between the first device and the second device at the first time point and at the second time point by the apparatus on the basis of measured and received data, and determine the coordinates of the first device and the second device at the first time point and at the second time point.

According to an embodiment, the at least one processor is arranged to cause the apparatus to perform displaying relative position of the first device and the second device on the basis of determined coordinates. According to an embodiment, measurement of the moving distance of the first device between the location at the first time point and the location at the second time point of the first device is done by an accelerometer. According to an embodiment, measurement of the heading angle of the first device at the first time point and at the second time point is done by the accelerometer and a magnetometer. According to an embodiment, the strength of the wireless signal sent by the first device is measured by a wireless chip of the second device. According to an embodiment, the wireless signal is Wi-Fi, Bluetooth, or ZigBee signal.
Description of the Drawings

In the following, various embodiments of the invention will be described in more detail with reference to the appended drawings, in which

Fig. 1 shows a flow chart of a relative positioning method according to an example embodiment;

Fig. 2 shows a measurement situation of the distance between a terminal device A and a terminal device B at time T1 according to an example embodiment;

Fig. 3 shows a measurement situation of distances and heading angles during moving process of the terminal device A 21 in period T1-T2 according to an example embodiment;

Fig. 4 shows a view of magnetic field vector decomposition according to an example embodiment;

Fig. 5 shows a roll angle and a pitch angle of terminal devices A and B according to an example embodiment;

Fig. 6 shows statistical result of acceleration in a period T1-T2 according to an embodiment of the invention;

Fig. 7 shows relative position between terminal devices A and B at time T1 and T2 according to an embodiment of the invention;

Fig. 8 shows a measurement situation of the angles between a terminal device A and a terminal device B at time points T1 and T2 according to an example embodiment; and

Fig. 9 shows relative position between device A and device B at time T2 according to an example embodiment.

Description of Example Embodiments
Usually prior art localization services, especially real-time localization services, of portable electronic devices are based on an absolute position method with a GPS system. However, there exist other localization services for portable electronic devices without the GPS system. One existing localization service comprises a method of displaying relative position of other portable electronic devices. In this method, wireless signals are received directly from the second device. Distances between the first and second devices are measured based on strength of the received wireless signals when the first device is at three or more different locations. Distances between the three or more different locations of the first device are measured. Direction and distance between the first and second devices are measured based on the measured distances between the first and second devices and the measured distances between the three or more different locations of the first device. A position of the second device relative to the first wireless communication device is displayed on the first device based on the determined direction and distance between the first and second devices. In this method, the second device has to be motionless, which is contrary to the mobile features of portable electronic device characteristics. In addition, in this method angles and distances have to be measured at three or more positions, which will extend the positioning time and may therefore prevent meeting of real-time requirements.

Today a mobile user expects immediate access to the positioning information and further he expects that information is real-time information. In addition, the mobile user expects, when needed, to receive relative positioning information instead of power consuming absolute information. A situation when relative position information is needed may be any situation where user wants to determine the position of one device, for example, own device, with the position of the other device/other devices; for example, a tour guide may need position information of all the visitors in order to ensure they are not left behind, a teacher may want to track pupils' movements, parents may want to track children's position or nursing staff may want to watch elderly people in the area of a nursing institution etc. On the bases of the relative position, the mobile user can track, follow and/or find users of other devices. The portable electronic device user may also expect to receive positioning information from moving devices while he is moving.
Instead of prior art localization services, the embodiments of the present invention use a relative positioning method based on devices equipped with inertial sensors and wireless chips without a need of any externally deployed infrastructures. Embodiments of the present invention need measurements of the angle and moving distance of a device and distance between devices only at two different locations for determining relative position of the devices relative to each other. Small number of measurements produces a small quantity of data to be calculated when compared to quantity of data measured at three or more different locations. In addition, devices to be positioned by a method of present invention can all move during the positioning process without any limitations.

A device with a relative positioning system of the present invention comprises means for measuring a relative position of the device and a second device relative to each other. The measuring means comprises inertial sensors for measuring distance and heading angle (direction) of the device while moving and a wireless chip for receiving wireless signal, for example, e.g., Wi-Fi, Bluetooth or ZigBee signal, so that the wireless signal strength can be measured for determining the distance between the device and the second device. In addition, the device comprises means for sending wireless signal. The wireless chip may send and receive wireless signals, it may also measure the strength of received signal, and send the measurement data to the upper layer in the communication procedure i.e. a system interface. Means for sending wireless signal may be, for example, a Bluetooth transmitter or a WLAN transmitter. The device may be a mobile device, a terminal device, a portable device or any other device suitable for measuring relative position by using inertial sensors and wireless signal strength measurement. The device may be any device, for example, a mobile phone, a mobile computer, a mobile collaboration device, a mobile internet device, a smart phone, a tablet computer, a tablet personal computer (PC), a personal digital assistant, a portable media player, a digital still camera (DSC), a digital video camera (DVC or digital camcorder), a pager, or a personal navigation device (PND).
A relative positioning system and a method of measuring relative position of at least two devices relative to each other are based on measuring the distances between the devices twice i.e. at two time points at two different locations i.e. the devices have moved between those two time points. In more detail, in the method, at time points T1 and T2, a device A sends wireless signal to a device B by means of sending wireless signal. Device B receives the signal and measures the distance between A and B with the signal strength on the basis of wireless signal measurement means. In period T1-T2 i.e. between time points T1 and T2, inertial sensors of the devices A and B measure distances and heading angles of the moving device A and device B; a magnetometer measures the heading angle and an accelerometer measures the tilt angle information to make tilt compensation in order to get more precise heading angle. In addition to those measurements, the accelerometer is further used to measure the moving distance of the devices A and B with a gait detection and a step length detection method. Next, equations may be established with the data that have been measured on the basis of the position relations and then the angle of device A, B at time T1 and T2 may be calculated. After calculation, the coordinates of device A with the coordinates of device B at time T1 and T2 may be presented on the display. The length of the time period T1-T2 may be predetermined for the devices i.e. the user of the device A starts this method at the time point T1 and after a certain predetermined time the second time point T2 appears or the user of a device may determine time points T1 and T2 for the device A.

In other words, when the method is considered in terms of the device A, the device A sends wireless signal to the device B at time point T1, which sends the distance between the devices to the device A after calculation. Then, the device A moves and measures the moving distance and angle while moving to time point T2. The device A sends wireless signal to the device B at time point T2, which sends the distance between the devices to the device A after calculation. The device A may further receive the moving distance and angle of the device B during time period T1-T2 at this time point or before the distance measurement at the time point T2. It is also possible, that the device B transmits all measured data together to the device A after the second distance has been measured i.e. after the time point T2. On the bases of received
data, the device A may calculate and display coordinates of positions of devices A and B.

An example embodiment of the present invention and its potential advantages are understood by referring to figures 1 through 8 of the drawings.

Figure 1 shows a flow chart of a relative positioning method 100 according to an example embodiment. In step 110, at time T1, a terminal device A sends i.e. transmits wireless signal, for example, a radio energy signal, to a terminal B, the terminal device B measures the distance D1 between terminal devices A and B, and the measuring is based on signal strength of the received signal. In step 120, in period T1-T2, inertial sensors of terminal devices A and B measure the distance and angle of the moving terminal device A and the moving terminal device B. In step 130, at time T2, the terminal device A sends wireless signal to the terminal device B, and the terminal device B again measures the distance D2 between the terminal device A and the terminal device B. In step 140, the angle of terminal devices A and B at time T1 and T2 is calculated according to the measured data by the terminal devices A and B. In step 150, the coordinates of the terminal device A with the coordinates of terminal B at time T2 are shown on the display of the terminal device A and/or the terminal device B. It is also possible that the terminal device A or the terminal device B device transmits the measured data for calculation to some other device or the coordinates to some other device to be shown on the display of that some other device.

Figure 2 shows a measurement situation of the distance between a terminal device A 21 and a terminal device B 22 at time T1 according to an example embodiment. Step 110 of figure 1 is an example of this kind of measurement situation. In figure 2, a1 represents the angle between radial B1A1 and positive direction of the X-axis. D1 is the distance between terminal devices A 21 and B 22 at time T1, wherein at time point T1 the terminal device A is marked by A 1 and the terminal device B is marked by B 1. The position of the terminal device B 22 at time T1 is the origin of coordinates.
The terminal device A 2 1 sends wireless signals periodically. The terminal B 2 2 receives the signal and calculates the distance between the two terminals with the signal strength according to RSSI ranging principle. Gradient model is commonly used in wireless signal transmission:

\[ [P(d)]_{Bm} = [P(d_0)]_{dBm} - 10 \log_{10} \left( \frac{d}{d_0} \right) + X_{dBm} \]  

(1)

In formula 1, \( P(d) \) represents the power of the signal the receiver receives when the distance away from the sender is \( d \), namely RSSI. \( P(d_0) \) represents the power of the signal the receiver receives when the distance away from the sender is \( d_0 \). \( d_0 \) is reference distance and \( n \) is a Pass Loss Index.

Simplified gradient model is as below:

\[ [P(d)]_{dBm} = [P(d_0)]_{dBm} - 10 \log_{10} \left( \frac{d}{d_0} \right) \]  

(2)

The value of \( d_0 \) is 1 meter, so the formula can be converted to the form as below:

\[ R_{RSSI} = A - 10 \log(d) \]  

(3)

wherein \( d_1 \):

\[ d_1 = 10^{\frac{A-ESSI}{10n}} \]  

(4)

In formula 3, \( A \) is the value of RSSI when the distance between the sender (the device A 2 1) and the receiver (the device B 2 2) is 1 meter. Formula 3 is the classic model for RSSI ranging which describes the relationship between RSSI and distance. The value of \( A \) and \( n \) can be obtained in a specific environment i.e. they depend on the measuring environment. When the terminal device B 2 2 has measured the value of RSSI, the distance \( d_1 \) between the two terminals 2 1, 2 2 can be calculated with formula 4. The distance of two terminal devices 2 1, 2 2
will also be measured similarly at time point T2 (step 130 of figure 1 is an example of this kind of measurement situation).

Figure 3 shows a measurement situation of moving distances and heading angles during moving process of the terminal device A 21 in period T1-T2 according to an example embodiment. Moving distances in period T1-T2 are distances between locations of devices at the first time point T1 and the second point T2 and heading angles are directions at time points T1 and T2. Moving distances and heading angles during moving process (T1-T2) of the terminal device B 22 in period T1-T2 may be measured similarly. Step 120 of figure 1 is an example of this kind of measurement situation. In figure 3, A1 represents location of terminal A 21 at time point T1 and A2 represents location of terminal A 21 at time point J2. In period T1-T2 the user of the terminal device A has taken a step with the terminal device A 21. Terminal device A 21 uses inertial sensors to measure the distances, namely L_A (L_B for the terminal device B 22) and heading angles, namely m_A, (m_B for the terminal device B 22) during time points T1 and J2. The method of measuring terminal distances and heading angles may be based on pedestrian dead reckoning (PDR). The PDR method makes use of pedestrian stepping exercise physiology characteristics to detect the gait and length of the steps. Its realization is as follows. Firstly, the heading angle is measured with an accelerometer and a magnetometer and then the length of the step is determined with relevant model. The implementation process may be as follows:

a) Measure the heading angle M_A and M_B with an accelerometer and a magnetometer.

Figure 4 shows a view of magnetic field vector decomposition according to an example embodiment. Magnetometer may measure magnetic field data of the X, Y, Z axis of the terminal devices A 21 and B 22. Magnetic field points to magnetic north pole from magnetic south pole. It is a vector. As can be seen in figure 4, for a specific location on earth, the magnetic field can be decomposed into one vertical component and two horizontal components. The vector sum of the two horizontal components always points to the magnetic north. So, when the terminal
remains horizontal, the heading angle can be calculated with the magnetic field data of X, Y axis with following formula:

\[ \alpha = 3T \text{tcsn}(M_y/M_x) \]  \hspace{1cm} (5)

However, the terminal devices A21 and B22 may not always remain horizontal which would bring roll angle and pitch angle. The angles will affect the accuracy of the heading angle. Thus, a tilt compensation may be done by an accelerometer.

Figure 5 shows a roll angle and a pitch angle of terminal devices A and B according to an example embodiment. As can be seen in figure 5, the solid line represents the coordinates when the terminal is horizontal and the dotted line represents the coordinates when the terminal is bias. \( \gamma \) is the roll angle which represents the angle between X-axis and the horizontal plane. \( \Theta \) is the pitch angle which represents the angle between Y-axis and the horizontal plane.

Firstly, the acceleration on X, Y, Z axis, namely \( A_x, A_y, A_z \) are measured. Then \( \gamma \) and \( \Theta \) may be calculated by the formulas 6 and 7:

\[ \theta = \text{-arctan}(A_y/A_z) \] \hspace{1cm} (6)

\[ \gamma = \text{arctan}^\Lambda (A_y/A_z) \] \hspace{1cm} (7)

Then, with the magnetic field data of the three axes, namely \( M_x, M_y, M_z \), the magnetic field data of X, Y axis which have been converted to horizontal plane, namely \( M'_x, M'_y \), can be calculated with the following formulas 8 and 9:

\[ M'_x = M_x \cos \gamma + M_z \sin \gamma \] \hspace{1cm} (8)
\[ M'_{Y} = M_{Y} \cos \theta + M_{X} \sin \theta \sin \gamma - M_{Z} \cos \sin \theta \]  

(9)

Then the heading angle can be calculated by the formula 10:

\[ \alpha' = \arctan \left( \frac{M'_{Y}}{M'_{X}} \right) \]  

(10)

Then \( a_{A} \) and \( \alpha_{B} \) can be calculated as follows with formulas 11 and 12:

\[ a_{A} = \arctan \left( \frac{M'_{Y}}{M'_{X}} \right) \]  

(11)

\[ a_{B} = \arctan \left( \frac{M'_{B}}{M'_{X}} \right) \]  

(12)

\( M'_{X}, M'_{Y}, M'_{Z}, M'_{X} \) respectively represent the magnetic field data on X, Y axis of terminal devices A 21 and B 22.

In order to simplify the calculation, \( a_{A} \) and \( \alpha_{B} \) are converted to the angles between the ray BA and east direction, namely \( m_{A} \) and \( m_{B} \).

If \( \alpha_{A} \leq 0 \), \( m_{A} = - \alpha_{A} + \frac{\pi}{2} \).

If \( 0 < \alpha_{A} \leq \frac{\pi}{2} \), \( m_{A} = \frac{\pi}{2} - \alpha_{A} \).

If \( \frac{\pi}{2} < \alpha_{A} \leq \pi \), \( m_{A} = \frac{5\pi}{2} - \alpha_{A} \).

Transformation rule of \( m_{B} \) is the same as \( m_{A} \).

b) Measure the moving distance of terminal devices A 21 and B 22. This process may include two steps. Firstly, user’s walking gait is detected by acceleration signal. Next, the step length is estimated with relevant models.
Walking gait detecting process may be implemented as follows: The accelerometer inside a terminal device may measure three dimensional accelerations during walking process of a user of the terminal device. During walking, acceleration values in three directions change periodically. It is based on the principle that when the user takes steps, the two legs will take periodically alternating movements. One single step includes two-step stages. The first stage starts from the time the foot leaves the ground ends at the time the foot lifts to the highest point. The second stage starts from the moment when the foot is at the highest point ends at the moment the foot reaches to the ground. In the first stage, vertical acceleration increases as the body of the user shifts. While the body reaches the highest point, the vertical acceleration reaches the maximum. In the second phase, vertical acceleration begins to decrease. The value of the vertical acceleration reaches the minimum when the foot reaches the ground. As long as the data of the vertical acceleration of one cycle can be measured, pedestrian gait can be determined.

Figure 6 shows statistical result of acceleration in a period T1-T2 according to an embodiment of the invention. In figure 6, there is a peak value of acceleration during a walking cycle.

Step length estimation process may be implemented as follows: Pedestrian's step length is determined by a number of factors, such as the pedestrian's height, weight, stride frequency and road conditions, etc., with strong randomness. A non-linear model may be used as the calculation model; however, there may exist other calculation models such as a constant model, linear model, and artificial intelligence model etc. The non-linear model may be calculated by formula 13:

\[ L = K \times \sqrt[4]{A_{\text{max}} - A_{\text{min}}} \]  \hspace{1cm} (13)

\(A_{\text{max}}\) represents the maximum acceleration, and \(A_{\text{min}}\) the minimum acceleration. K is coefficient. Once the K value is determined, the value of L can be calculated.
Next, the distance between terminal device A 2 1 and terminal device B 2 2 may be measured at time T 2 (step 1 3 0 of figure 1). The method of measuring the distance of terminal devices A and B at time point T 2 is the same as the method of measuring of terminal devices A and B at time point T 1, which measuring method is disclosed in context with figure 2.

Figure 7 shows relative position between terminal devices A 2 1 and B 2 2 at time T 1 and T 2 according to embodiment of the invention. D 1 is the distance between terminal devices A 2 1 and B 2 2 at time T 1, wherein at time point T 1 the terminal device A is marked by A 1 and the terminal device B is marked by B 1, and D 2 is the distance between terminal devices A 2 1 and B 2 2 at time T 2, wherein at time point T 2 the terminal device A is marked by A 2 and the terminal device B is marked by B 2. In figure 7, \( a_2 \) represents the angle between radial B2A2 and positive direction of the X-axis.

Figure 8 shows a measurement situation of the angles between a terminal device A 2 1 and a terminal device B 2 2 at time points T 1 and T 2 according to an example embodiment. Step 1 4 0 of figure 1 is an example of this kind of measurement situation. As can be seen in figure 8, A 1 and B 1 again respectively represent the positions of the terminal devices A and B at time T 1 and A 2 and B 2 respectively represent the positions of the terminal devices A and B at time T 2.

The equations according to the position relationships shown in figure 8 may be calculated as follows:

\[
\begin{align*}
X_{a_i} &= D_1 \times \cos \alpha_1 \\
Y_{a1} &= D_1 \times \sin \alpha_1 \\
X_{b2} &= L_b \times \cos(m_b) \\
Y_{b2} &= L_b \times \sin(m_b) \\
X_{b2} - X_{a1} &= L_A \times \cos(m_A) - D \times \cos \alpha_2 \\
Y_{b2} - Y_{a1} &= L_A \times \sin(m_A) - D \times \sin \alpha_2
\end{align*}
\]

The natural text continues with the mathematical expressions and further details on the method of measuring distances and angles between terminal devices using radial and positive directions.
, wherein

\[
\alpha_2 = \arcsin \left( \frac{D1^2 - (L_B \cos(mg) - L_A \cos(m_A))^2 - (L_B \sin(mg) - L_A \sin(m_A))^2 - D2^2}{2D2 \sqrt{(L_B \cos(mg) - L_A \cos(m_A))^2 + (L_B \sin(mg) - L_A \sin(m_A))^2}} \right)
\]

\[
-\arctan \left( \frac{L_B \sin(mg) - L_A \sin(m_A)}{L_B \cos(mg) - L_A \cos(m_A)} \right)
\]

After calculation of distances and angles between the terminal devices A 21 and B 22, the relative position between the terminal devices A 21 and B 22 may be shown, for example, for a user of the terminal devices A and/or B at time point T2 that is the current time i.e. as real-time presentation. Thus, the relative position of the terminal devices A 21 and B 22 as real-time presentation may be shown in a display of the terminal devices A 21 and/or B 22, for example, as in figure 9 showing the relative position according to an example embodiment.

It should be noted, that means for showing the relative position of the terminal devices A and B is not restricted. The relative position may be shown on any display by any means i.e. it is not necessary to show pictures of mobile phones as representing the terminal devices A and B as in many shown embodiments. In addition to the relative position, it is possible to show the distance, for example, as meters on the display. In addition, the terminal device may determine relative position of other terminal devices than the terminal device B simultaneously and show them on the display simultaneously.

The various embodiments may provide advantages such as the positioning process requiring only simple mobile devices i.e. terminal devices with standard wireless chips and inertial sensors, which enhance the applicability of the invention. In addition, the relative positioning can be used indoors and outdoors. Further, the method and system according to this invention allow the two devices to move without limitation in positioning process thus greatly improving the flexibility of the relative positioning. By the positioning method of the present invention it is possible to show relative positioning of two or more devices; for example, user of the device A may want to determine relative positions of two, three, four or ten devices and show their relative position on the display of the device A.
The various embodiments of the invention can be implemented with the help of computer program code that resides in a memory and causes the relevant apparatuses to carry out the invention. For example, a device may comprise circuitry and electronics for handling, receiving and transmitting data, computer program code in a memory, and a processor that, when running the computer program code, causes the device to carry out the features of an embodiment. Yet further, a network device like a server may comprise circuitry and electronics for handling, receiving and transmitting data, computer program code in a memory, and a processor that, when running the computer program code, causes the network device to carry out the features of an embodiment.

It is obvious that the present invention is not limited solely to the above-presented embodiments, but it can be modified within the scope of the appended claims.
WHAT IS CLAIMED IS:

1. A method, comprising:

   receiving distances between a first and a second device from the second device, wherein the distances are based on strength of wireless signals sent by the first device at a first time point and a second time point, wherein the locations of the first and second device are different at the first time point and at the second time point;

   measuring a moving distance of the first device between the location at the first time point and the location at the second time point;

   measuring a heading angle of the first device at the first time point and at the second time point;

   receiving a moving distance between the location of the second device at the first time point and the location at the second time point;

   receiving a heading angle of the second device at the first time point and at the second time point;

   calculating angles between the first device and the second device at the first time point and at the second time point by the first device on the basis of measured and received data; and

   determining the coordinates of the first device and the second device at the first time point and at the second time point.

2. The method according to claim 1, wherein the method further comprises displaying relative position of the first device and the second device on the basis of determined coordinates.

3. The method according to claim 1 or 2, wherein measuring the moving distance of the first device between the location at the first time point and the location at the second time point of the first device is done by an accelerometer.
4. The method according to claim 1, 2 or 3, wherein measuring of the heading angle of the first device at the first time point and at the second time point is done by the accelerometer and a magnetometer.

5. The method according to any of the claims 1 to 4, wherein the strength of the wireless signal sent by the first device is measured by a wireless chip of the second device.

6. The method according to any of the claims 1 to 5, wherein the wireless signal is Wi-Fi, Bluetooth, or ZigBee signal.

7. An apparatus comprising means for transmitting wireless signal, means for measuring a moving distance between two time points, means for measuring heading angle, means for receiving data from a second device and at least one processor, memory including computer program code, the memory and the computer program code configured to, with the at least one processor, cause the apparatus to perform at least the following:

receive distances between the apparatus and the second device from the second device, wherein the distances are based on strength of wireless signals sent by the apparatus at a first time point and a second time point, wherein the locations of the apparatus and the second device are different at the first time point and at the second time point;

measure a distance of the apparatus between the location at the first time point and the location at the second time point;

measure a heading angle of the apparatus at the first time point and at the second time point;

receive a distance between the location of the second device at the first time point and at the second time point;

receive a heading angle of the second device at the first time point and at the second time point;
calculate angles between the apparatus and the second device at the first time point and at the second time point by the apparatus on the basis of measured and received data; and

determine the coordinates of the apparatus and the second device at the first time point and at the second time point.

8. The apparatus according to claim 7, wherein the at least one processor is arranged to cause the apparatus to perform displaying relative position of the first device and the second device on the basis of determined coordinates.

9. The apparatus according to claim 7 or 8, wherein measurement of the moving distance of the first device between the location at the first time point and the location at the second time point of the first device is done by an accelerometer.

10. The apparatus according to claim 7, 8 or 9, wherein measurement of the heading angle of the first device at the first time point and at the second time point is done by the accelerometer and a magnetometer.

11. The apparatus according to any of the claims 7 to 10, wherein the strength of the wireless signal sent by the first device is measured by a wireless chip of the second device.

12. The apparatus according to any of the claims 7 to 11, wherein the wireless signal is Wi-Fi, Bluetooth or ZigBee signal.

13. An apparatus comprising:

means for receiving distances between the first device and the second device from the second device, wherein the distances are based on strength of wireless signals sent by the first device at a first time point and a second time point, wherein the locations of the first device and the second device are different at the first time point and at the second time point;
means for measuring a distance of the first device between the location at the first time point and the location at the second time point;

means for measuring a heading angle of the first device at the first time point and at the second time point;

means for receiving a distance between the location of the second device at the first time point and at the second time point;

means for receiving a heading angle of the second device at the first time point and at the second time point;

means for calculating angles between the first device and the second device at the first time point and at the second time point by the apparatus on the basis of measured and received data; and

means for determining the coordinates of the first device and the second device at the first time point and at the second time point.

14. A computer program product embodied on a non-transitory computer readable medium, comprising computer program code configured to, when executed on at least one processor, cause an apparatus to:

receive distances between the first device and the second device from the second device, wherein the distances are based on strength of wireless signals sent by the first device at a first time point and a second time point, wherein the locations of the first device and the second device are different at the first time point and at the second time point;

measure a distance of the first device between the location at the first time point and the location at the second time point;

measure a heading angle of the first device at the first time point and at the second time point;

receive a distance between the location of the second device at the first time point and at the second time point;
receive a heading angle of the second device at the first time point and at the second time point;

calculate angles between the first device and the second device at the first time point and at the second time point by the apparatus on the basis of measured and received data; and

determine the coordinates of the first device and the second device at the first time point and at the second time point.

15. The computer program product according to claim 14, wherein the at least one processor is arranged to cause the apparatus to perform displaying relative position of the first device and the second device on the basis of determined coordinates.

16. The computer program product according to claim 14 or 15, wherein measuring the moving distance of the first device between the location at the first time point and the location at the second time point of the first device is done by an accelerometer.

17. The computer program product according to claim 14, 15 or 16, wherein measurement of the heading angle of the first device at the first time point and at the second time point is done by the accelerometer and a magnetometer.

18. The computer program product according to any of the claims 14 to 17, wherein the strength of the wireless signal sent by the first device is measured by a wireless chip of the second device.

19. The computer program product according to any of the claims 14 to 18, wherein the wireless signal is Wi-Fi, Bluetooth, or ZigBee signal.
Start

At time T1, terminal A sends wireless signal to terminal B, terminal B measures the distance D1 between A and B based on signal strength.

In period T1-T2, measure the distance and angle during the moving process of terminal A and terminal B.

At time T2, terminal A sends wireless signal to terminal B, terminal B measures the distance D2 between terminal A and terminal B based on signal strength.

Calculate the angle of terminal A, B at time T1 and T2.

Present the coordinates of terminal A with the coordinates of terminal B at time T1 and T2.

End

Fig. 1
Fig. 5
INTERNATIONAL SEARCH REPORT

PCT/CN2013/085400

A. CLASSIFICATION OF SUBJECT MATTER

H04W 64/00(2009.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04W; G01S; G01C

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

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

CNABS, CNXTX, CNKI, VEN, USTXT, EPTXT, WOTXT: relative, positioning, locating, moving, shifting, movement, distance, range, displacement, direction, bearing, heading, orientation, adjacent, neighbor, neighbour, contiguous, near, vicinal, close, two, first, second, pair, couple, mobile, cellular, portable, phone, pda, accelerometer, gyro, magnet, RSSI, intensity, intensity, strength

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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* Special categories of cited documents:
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  "E" - earlier application or patent but published on or after the international filing date
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Date of the actual completion of the international search 18 June 2014

Date of mailing of the international search report 08 July 2014

Name and mailing address of the ISA/

STATE INTELLECTUAL PROPERTY OFFICE OF THE P.R.CHINA/(ISA/CN)
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YU,Xin

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## INTERNATIONAL SEARCH REPORT

Information on patent family members

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