



159159



G00002

Method and system for detecting the position of an object such as a hand-held data input device

Field of the invention

5 The present invention is directed to a method and system for detecting the position of an object. The object may be a data input device manipulated by a user, so detecting the position of the object permits data to be entered into a computer system.

Background of Invention

10 Detecting the positions of objects by measuring the time of flight of radio waves between the objects and detector apparatus is a well-established technique, used for example in radar systems, and by global positioning satellites (GPS). These systems are for detecting the positions of objects such as vehicles, and achieve only a low spatial resolution, of the order of several
15 metres. Additionally, such systems either require high power and a directional antenna (in the case of radar), or else require multiple transmitters (in the case of GPS).

By contrast, when it is required to detect automatically the position of objects
20 moving on a distance scale of millimetres or centimetres, completely different detection techniques are conventionally used. There are various reasons why such detection is performed. Foremost among these is data input, when the object is to be moved manually by a user, e.g. recognition of handwriting by detecting the movement of a pen; or interactive media arts; even inputting
25 data to a touch sensitive screen may be treated as detection of the position of a manually operated object, where the object in question is a user's finger tip. Another reason for such detection could be in robotics.

In these systems there is a continual need for improved position detection with a spatial resolution accuracy of less than 1mm. Such systems operate in a working area which is at most a few metres wide, and often only a few tens of centimetres wide.

5

Many such systems have been proposed in the past. Some of these, such as the references [1] to [4] are based on measuring the time of flight of radio waves. In all these systems, the object which moves needs to carry either a radio transmitter or transceiver, and the systems further require active
10 detection equipment (that is, detection equipment including active receivers and/or transceivers). Moreover, the relative positions of these detectors must be known a priori. The transmitters, transceivers and receivers require multiple power supplies, and these power supplies have to be set up in each location where the system is to be used, which means the systems are hard
15 to deploy.

Alternatively, reference [5] proposed a positioning system based on ultrasonic waves. However, the spatial resolution of such a system is not high enough for handwriting input. Other systems, based on optical techniques, have been
20 proposed in references [6] to [8]. However, these systems require line-of-sight operation, or the use of external detection devices. Optical systems, though, are expensive to implement.

Summary of the Invention

25 The present invention aims to provide a new and useful system for detecting the position of an object.

In general terms the present invention proposes that the object includes a transceiver which emits electromagnetic pulses. The pulses are reflected from two reflectors of different types, so that the pulses, when received by the

transceiver, can be distinguished. The echo delay times of the two echoes are determined, and are measures of the distances of the object to the two reflectors. Thus, the position of the object relative to the reflectors is found.

Thus, in contrast to the known positioning systems, only a single transceiver
5 is required. There is no need for any other active elements, or for mutual collaboration among them.

The different reflection characteristics of the reflectors may be due to different radar cross sections (RCS), so that the echoes can be distinguished based on their amplitude differences. Alternatively, the reflectors may have different
10 polarization or frequency response characteristics.

The reflectors have flat reflection surfaces, which are preferably arranged orthogonal to each other.

The transceiver preferably obtains a measure of the echo delay of the pulse by determining the intersection of the echo signal with more than one level,
15 including one or more non-zero levels (preferably two), and estimating the echo delay from these multiple intersection times.

The transceiver is also arranged to transmit out of itself the determined distances between the object and the reflectors, thereby transmitting the position of the object relative to the reflectors. Conveniently, this transmission
20 can be done by modulating the pulses which the transceiver is in any case arranged to generate.

The object may be a data input device, which is connected to a computer system arranged to receive the object position measurements, whereby a user manipulating the object can input data to the computer, for example for
25 controlling a software application running on the computer. Conveniently, the data input device may be elongate (i.e. pen-like), and the transceiver includes a antenna provided near one of its tips.

Specifically, a first expression of the invention is a position detection system including:

an object including a transceiver for emitting electromagnetic pulses
5 and receiving a reflected echo signal,

at least two reflectors having respective reflection surfaces, for reflecting the pulses with different characteristics,

the transceiver being arranged to analyse the echo signal to distinguish the echoes from the reflectors, and to determine the respective echo delays as
10 measures of the distances of the object from the reflection surfaces.

Brief Description of The Figures

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

15 Fig. 1 is a schematic overview of an embodiment of the invention;

Fig. 2 illustrates the principle of position detection employed by the embodiment;

Fig. 3, which is composed of Figs. 3(a) and 3(b), shows echo signals received by a transceiver of the embodiment when an object is in two different
20 respective positions;

Fig. 4 is a block diagram of the transceiver of the embodiment; and

Fig. 5 illustrates a centre detection algorithm employed by the embodiment.

25 Detailed Description of the embodiments

Referring to Fig. 1, an embodiment of the invention is shown having two main components. The first of these is an object 1, e.g. an elongate object, such as a pen. The second is a reference structure 3, which is static. The embodiment is for measuring the position of the moving object 1 relative to the reference structure 3, as the object 1 moves in a volume 5 referred to as the working area. The embodiment is for detecting the position of the object within this volume as a position in the two-dimensional x-y plane shown in Fig. 1, and neglecting the position of the object 1 in the third dimension (i.e. the direction extending into the page).

10

The moving object 1 includes a radio transceiver 2 which transmits and receives electromagnetic waves, specifically radio waves, through an antenna located near a tip of the object 1. The transceiver 2 transmits and receives a radio waveform which is a very short pulse, e.g. about 100ps, for example in the range 50ps to 200ps. The pulse is broadcast at regular intervals, e.g. with an interval or period in the range of 10ns to 1 μ s. The pulse repeat frequency (PRF) may alternatively be in the range from several hundreds of kilohertz to several tens of megahertz. The maximum allowable PRF is decided by the required maximum size of the working volume. Provided this condition is met, a higher PRF is preferred to increase the measurement accuracy. However, a higher PRF will cause the far range echoes of a given pulse (i.e. the echoes 19 described below with reference to Fig. 3) to enter the next period, and also increase the power consumption. Therefore, the PRF should be selected as a trade-off of the above factors. For example, to achieve a measurement range which is as wide as 50cm, the PRF should be no more than 20MHz.

25

The very short pulse emitted by the transceiver 2 is an ultra-wideband (UWB) signal. Its pulse power is spread over a very wide frequency range, so that its power spectrum density is very low. The spectrum density can be designed in such a way that it complies with the FCC (Federal Communications

30

Commission) regulations on UWB systems. Therefore, the transceiver 2 does not interfere with the operation of any other wireless systems near the embodiment. Indeed, the transceiver of the present invention may optionally be arranged with the functionality of existing UWB devices, such as
5 communication with other UWB devices, e.g. to transmit measured position detection data to other UWB devices, or to receive information from them.

The reference structure 3 includes two reflectors 7, 9, which are placed at right angles, extending along respective sides of the working area 5. The
10 reflectors 7, 9 are shown in Fig. 1 as panels. They are viewed in Fig. 1 from a direction which lies in the plane of both of the reflectors 7, 9 so that both panel are seen side-on with respective flat reflection surfaces facing the working area 5. The reflectors 7, 9 may be joined, but alternatively may not be. In the case that they are joined, they may be permanently fixed in the orthogonal
15 configuration, or, more preferably, are foldable, so that they can be folded together for greater portability while not in use. The lengths of these two reflector panels (in the plane shown in Fig. 1) are slightly larger than the respective dimensions of the working area 5. The height of the reflector panels 7, 9 (i.e. in the direction which is into the page in Fig. 1) has an
20 influence on the extension of the working area 5 in this direction, but may be much less than the extension of the working area in this direction. For example, we have found that even if the reflector panels have a height in the direction which is into the page in Fig. 1 of as little as 3cm, this provides a working area which extends to a height of about 50cm in both the x and y
25 directions.

A first reflector panel 7 is composed of material having large radar cross section (RCS), such as aluminium. The other reflector panel 9 is composed of a material having a low RCS, such as wood, or metal painted with radar

absorbing material. Each of the reflector panels 7, 9 should have a flat face, so that incident radio waves are reflected sufficiently well.

The position of the object 1 within the working area 5 is determined as shown in Fig. 2, as a point in the x-y plane shown in Fig. 1.

In a radar system, the coordinates of an object are determined by measuring simultaneously its range and direction from a detector device. The former is determined by measuring the time of flight of a signal to the object, and the latter is determined by using a scanning motor to scan an antenna producing a highly directional beam of radio waves across a range of angles until a strong reflection is found. Such a system is not employed in the present embodiment, and would be inappropriate since both the scanning motor and the narrow beam antenna are bulky, and would be difficult to provide within a the hand-held object 1. Also, large power would be required to drive the scanning motor.

By contrast, the embodiment the object 1 may employ a transducer 2 which is substantially omni-directional. The omni-directional antenna is cylindrical, and placed in close proximity to a tip of the object 1 (e.g. in the case that the object 1 is a pen, near the writing tip), so that the tip traces almost the same path as the antenna. The pen's coordinates can be determined by distances to the two reflectors 7, 9. Assuming that the measured echo delay to the reflector 7 is τ_1 , then the distance d_1 from the reflector 7 to the pen tip is given simply by

$$d_1 = \frac{c\tau_1}{2} \quad (1)$$

where c is the speed of light. d_2 can be measured in a similar way using the echo time τ_2 to the reflector 9. Therefore, the co-ordinates (x, y) of the tip of the pen can be easily and unambiguously determined as (d_1, d_2) .

In practice, the transceiver 2 will receive many echoes after transmitting a pulse from an omni-directional antenna. To determine the co-ordinates correctly, the transceiver 2 must identify whether a given echo comes from one of the reflectors 7, 9, and if so which one, or if it is an undesired echo from another nearby object.

The two desired echoes can be identified in two steps, as shown in Fig. 3., which illustrates the amplitude of the signal ("echo signal") detected by the antenna over a period of time t . Fig. 3(a) is the echo signal amplitude in the case that the transceiver 2 is closer to the reflector 7 than to the reflector 9, and Fig. 3(b) is the echo signal amplitude in the case that the transceiver 2 is closer to the reflector 9 than to the reflector 7.

The echo signals shown in Figs. 3(a) and Fig. 3(b) each include 5 portions. A first portion 11 is the leakage of the transmitting pulse to the receiver. Portion 13 is the echo from near-range objects (such as the user's hand, in the case that the pen is hand-held). Portion 15 is the echo from the reflector 7, so it is earlier in the case of Fig. 3(a) than in the case of Fig. 3(b). Portion 17 is the reflection from the reflector 9, and accordingly is weaker than the echo 15. It is earlier in the case of Fig. 3(b) than in the case of Fig. 3(a). Portion 19 is echoes received from "far-range objects", i.e. objects a longer distance away, such as walls of the room in which the system is used.

Of course, in practice there may be more than one near-range object, and hence more than one echo such as portion 13. Similarly, there may be more than one far-range object, and hence more than one echo such as portion 19. However, it can be assumed that there will only be two main echoes 15, 17 from the reflectors 7, 9. This is not only because the two reflectors 7, 9 are near to the pen, but also because their surfaces directed towards the working

area 5 are flat, so they will reflect the incident wave back into the direction from which it came like a mirror, thus producing relatively strong echoes received by the transceiver. By contrast, the echoes 13, 19 will tend to be weaker, since the corresponding near-range and far-range objects will reflect
 5 a smaller proportion of the energy they receive back towards the transceiver. On the other hand, the echoes 13 will tend to have larger amplitude because the near-range objects are closer to the transceiver.

In a first step of the method, the embodiment applies a time-gate 21 to the
 10 measured signal, i.e. removes parts of the echo signal which are outside a period of time 21 having a defined starting time and finishing time. In this way, the echo portions 11, 13, 19 are removed.

In a second step of the method, the embodiment determines which of the two
 15 echoes in the time gate 21 is the echo 15 and which is the echo 17 (i.e. whether the echo signal is as shown in Fig. 3(a) or as shown in 3(b)). The embodiment does this easily, by comparing the amplitudes of the first and second echoes in the time gate 21. In this way, it can always be determined that the larger echo corresponds to d_1 , while the small echo corresponds to
 20 d_2 . The materials for the reflectors 7, 9 should be selected in such a way that even when d_1 and d_2 are at their maximum and minimum ranges within the working area 5, the echo from reflector 7 is always larger than the echo from reflector 9.

25 Note that in other possible embodiments of the invention the echoes from the two reflectors 7, 9 can be distinguished in other ways than as described above. For example, the two reflectors 7, 9 may be arranged to polarize the radio signal in different ways, e.g. one producing a right-rotation circular polarized backscattered wave, and the other one producing a left-rotation
 30 circular polarized backscattered wave. In this case, the antenna may include

two separated circular polarized channels, for identifying the echoes at the transceiver.

In another example, if the two reflectors 7, 9 have different frequency
5 responses to the UWB pulse, the reflected echoes will have greatly different waveforms. Therefore, a waveform recognition technique can be employed at the transceiver to identify the echoes.

Fig. 4 shows the structure of the UWB transceiver 2 used in the invention. The
10 transceiver has two operation modes: a first operation mode ("positioning mode") in which the device determines the values (d_1, d_2) . The second operation mode ("communication mode") is a UWB communication mode, in which the transceiver 2 exchanges information with one or more other UWB devices using the UWB pulses. For example, the measured position (d_1, d_2)
15 of the object 1 may be transmitted to other devices in real time. Alternatively, the measured position (d_1, d_2) may be temporarily recorded in a data RAM storage area of the object 1, for future transmission with other measured positions in a batch mode.

20 The transceiver comprises an antenna 31. The antenna 31 is in communication with a transceiver switch 41 which allows echo signals received by the antenna 31 to be processed by the circuitry of the transceiver, and further sends pulse signals generated within the transceiver to the antenna 31 for broadcast. These pulse are broadcast at the moments when
25 the transceiver 2 transmits a pulse which is later received as an echo, and also at moments at which the transceiver 2 is transmitting pulses in the second mode of operation.

The transceiver 2 generates the pulses using a timing unit 43 which generates
30 a periodic timing signal. The timing signal is transmitted to a first terminal 47

of a second switch 49, and also to a modulation unit 51, which transmits its output to a second terminal 45 of the second switch 49. The modulation unit 51 modulates the timing signal according to any data it receives from a coding unit 55.

5

In the case that the transceiver is in its the first operating mode, the pulses are used only for detection of the object's position and do not carry any information, and in this case the second switch 49 is in a first position at which it connects the first terminal 47 to a pulse generator unit 53 (as shown in Fig. 4). However, in the case that the transceiver is in its second operating mode, the second switch 49 is in a second position in which it connects the second terminal 51 to the pulse generator unit 53, so that the pulse generator unit 53 receives the timing signal modulated by any data from the coding unit 55.

10 In any case, the pulse generator unit 53 uses the signal it receives from the second switch 49 to produce a UWB pulse (which in the case that it receives the signal from the modulation unit 51 encodes the data modulated onto the waveform and/or timing of the pulse signal), and sends this pulse to an amplifier 57, which passes it to the transceiver switch 41 for transmission to the antenna 31.

Signals received by the antenna 31 are transmitted to an amplifier 33. The amplifier 33 is controlled by an automatic gain control (AGC) unit 35 including an average over a long time. Due to the long time, the AGC unit 35 adjusts the gain based on the value of an average of the echo signal over the time gate 21. The time gate 21 is pre-determined and is generated by timing unit 43. It is used to control the charging time of the AGC circuit. Therefore, the average is only carried out within the time gate. The reason for incorporating the AGC unit 35 is that the amplitudes of the echo portions 15, 17 vary considerably according to the position of the object 1 within the working area

25
30

5, and the AGC unit 35 is able to partly normalise the signal to compensate for this.

The output of the amplifier 33 is transmitted also to an analogue/digital (A/D) converter 37 which converts the echo signal into a digital signal. Since the movement of the pen is very slow compared to the PRF, tens of thousands of echoes can be received while the object 1 is in a single position, to within the resolution the embodiment aims to achieve. Therefore, a sampling gate 39 may be provided, controlling the times at which the A/D converter 37 is on such that the A/D converter 37 samples just one point per pulse repetition period. This greatly reduces the rate of the computation the A/D converter 37 is required to perform in each pulse repetition period, and therefore the required working speed of the A/D converter 37.

The timing at which the sampling gate 39 takes the sample depends on a signal from the timing unit 43, as delayed by a delay unit 57 which imposes a variable delay on the timing signal. In successive pulse repetition periods this delay is different, so that, the point during the period at which the sampling gate 39 controls the A/D converter 37 to be turned on is varied, typically by increments of 1ps, sweeping across the time gate 21. This means that an equivalent high sampling rate can be achieved. The output of the A/D converter 37 is sent to a digital signal processor 39 for further processing to estimate the positions of the echoes 15, 17 within the time gate, and thereby derives the values (d_1, d_2) .

When the digital signal processor 39 has derived these values it sends them to the coding unit 55 which is arranged periodically to set the second switch 47 to the second position and transmit the data (d_1, d_2) to the modulation unit 51, for transmission as modulation to one of the pulses. Since the data rate of UWB communication is very high, and the rate at which data values

(d_1, d_2) have to be obtained is relatively very low, only a very short communication duration is needed in the communication mode.

We now turn to the operation performed by the digital signal processor 39. In principle, the digital signal processor 39 could be implemented easily by attempting to determine the position of the object 1 based on a detection of the position of the pulse. This would give an accuracy which is about the width of the UWB pulse. However, the present inventors have found that even with a short UWB pulse (such as a 100ps pulse width), the spatial resolution would still only be 15mm. To obtain higher accuracy, such as a determination of the position of the object 1 to within a millimetre, the embodiment employs a more subtle time-of-arrival estimation method to estimate the centre of the pulse. This is more accurate than determining the position of the edge of the pulse, since the single edge (rising or falling) detection is sensitive to the amplitude of the echo, and the amplitudes of the two echoes 15, 17 vary a great deal when as the position of the object 1 varies.

The centre detection method is depicted in Fig. 5, which shows a portion of the echo signal, at a larger scale than as shown in Figs. 3(a) and (b). The signal includes a noise. The centre detection method is similar to a technique known in radar systems, called constant false alarm rate (CFAR) detection. In a first step, the variance σ of the noise is estimated. In a second step, this value σ is then used to set two levels: a positive level I_1 which for example may be 5σ , and a negative level I_2 which may be -5σ . The times at which the echo signal crosses these two levels are then determined. The centre point of the echo is the middle of these two crossing points. The times 61, 63 can be obtained by interpolation of the sampled data if needed.

The final positioning accuracy is dependent on several factors. The first factor is the stability of the timing provided by the timing unit 43. The local oscillator

of the timing unit 43 , the delay unit 57 and the sampling gate 39 itself must have high short-term stability. Their long-term stability is not important, however, since the embodiment is only required to measure the relative change of position of the object 1 to be useful for data entry purposes. The
 5 embodiment does not have to measure the absolute position of the object 1 in most applications. Another factor influencing the positioning accuracy is noise within the circuit, and small echoes surrounding the desired echo. They will affect the two CFAR levels and therefore the estimation of the centre of the echo. The digital signal processor 39 can reduce this noise by averaging
 10 multiple cycles of the received data. It has been found that by carefully designing the circuit and using proper signal processing techniques, sub-millimetre resolution is achievable.

Another problem which needs to be addressed is that when the values d_1 and
 15 d_2 are almost equal, the long tail of the large echo 15 from the reflector 7 will be mixed with the small echo 17 from the reflector 9, so that the small echo 17 is masked. However, since the reference reflector 7 is quite flat, its reflecting echo 15 will always be substantially the same. Therefore, by recording the large echo 15 and subtracting it from the echo signal, the small echo 17 can
 20 be revealed, so that the determination of the position of the centre of the small echo 17 is carried out.

Although only a single embodiment of the invention has been shown, many variations are possible within the scope of the invention, as will be clear to a
 25 skilled reader. For example, it would be possible to include a third reflector having a reflection surface orthogonal to the first two and having yet different reflection characteristics so that the position of the object could be found in three-dimensions.

References

The disclosure of the following citations is incorporated by reference in their
 5 entirety:

- [1] US patent 5,977,958, "Method and system for digitising handwriting", Ehud Baron, Victor Korsensky and Omry Genossar.
- [2] US patent 5,510,800, "Time-of-flight radio location system", Thomas E.
 10 McEwan.
- [3] US patent 5,589,838, "Short Range Radio Locator System", Thomas E. McEwan.
- [4] US patent no. 6,002,708, "Spread Spectrum Localizer", Robert A. Fleming and Cherie E. Kushner.
- 15 [5] US patent no. 4,506,354, "Ultrasonic position detecting system", Per K. Hensen.
- [6] US patent no. 5,227,622, "Wireless input system for computer using pen position detection", Tore Suzuki.
- [7] US patent no. 6,330,057, "Optical translation measurement", Gilad
 20 Lederer, Ppher Kinrot and Uri Kinrot.
- [8] PCT patent application, WO 99/60647, "Device and method for recording hand-written information", Fahraeus Christer.

Claims

1. A position detection system including:

an object including a transceiver for emitting electromagnetic pulses and receiving a reflected echo signal,
- 5 at least two reflectors having respective reflection surfaces, for reflecting the pulses with different characteristics,

the transceiver being arranged to analyse the echo signal to distinguish the echoes from the reflectors, and to determine the respective echo delays as measures of the distances of the object from the reflection surfaces.
- 10 2. A system according to claim 1 in which the pulse is less than 500ps, preferably less than 200 ps.
3. A system according to claim 1 or claim 2 in which the pulse is a UWB pulse.
4. A system according to claim 1, claim 2 or claim 3 in which the two

15 reflectors have different radar cross sections.
5. A system according to any preceding claim in which the two reflectors have different polarization effects on the pulses.
6. A system according to any preceding claim in which the two reflectors have different frequency-dependent effects on the pulses.
- 20 7. A system according to any preceding claim in which the object is an elongate object having a tip, the transceiver having an antenna located proximate the tip.
8. A system according to any preceding claim in which the reflectors are arranged with the reflection surfaces mutually orthogonal.

9. A system according to any preceding claim in which the reflectors are connected with an adjustable angle between the reflection surfaces.

10. A system according to any preceding claim in which the transceiver is arranged to neglect portions of the echo signal which have an echo delay less than a first value.

11. A system according to any preceding claim in which the transceiver is arranged to neglect portions of the echo signal which have an echo delay more than a second value.

12. A system according to any preceding claim in which the transceiver is arranged to determine the times of the respective intersections of the echo signal with at least two threshold levels, and to determine the centre portion using the intersection times.

13. A system according to claim 12 in which transceiver is arranged to vary the values of the threshold levels are adjusted based on a measurement of the echo signal.

14. A system according to any preceding claim in which the receiver has means to modulate the pulses based on the respective determined echo delays, thereby transmitting an encoded representation of the position of the object.

15. A system according to any preceding claim in which the transceiver includes a converter for converting the received echo to a digital signal, and a digital signal processor for processing the digital signal.

16. A system according to claim 15 in which the transceiver includes:
an antenna;

a sampling gate between the antenna and the digital signal processor, the sampling gate selecting a sample of the echo signal and transmitting it to the digital signal processor, and

5 a delay unit controlling the sampling gate to varying the sample of the echo signal.

17. A method of detecting the position of an object, the method including:

emitting electromagnetic pulses from the object and receiving echoes of the pulses reflected to the object,

10 reflecting the pulses using at least two reflectors having respective reflection surfaces with different characteristics,

distinguishing the echoes from the reflectors and determining the respective echo delays.