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(71) Applicant (for all designated States except US): **AUTOLIV DEVELOPMENT AB** [SE/SE]; **WALLENTINSVÄGEN 22, 44783 VÄRGÅRDA** (SE).

(72) Inventors; and

(71) Applicants (for US only): **ERIKSSON, Olof** [SE/SE]; Vältstigen 13, 12534 Älvsjö (SE). **ADERUM, Tobias** [SE/SE]; Slotsskogsgatan 75, 41470 Göteborg (SE). **CHAFIK, Driouichi** [SE/SE]; Stralsundvägen 70, 22470 Lund (SE). **ZHU, Meifang** [CN/SE]; Stralsundvägen 70, 22470 Lund (SE).

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(54) Title: ENHANCED OBJECT POSITION DETECTION

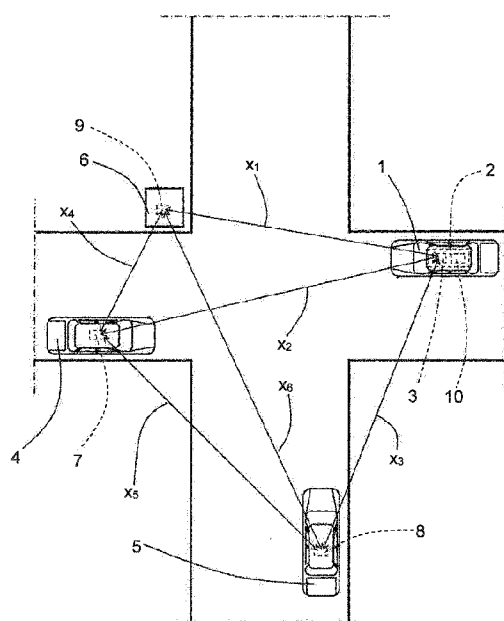


FIG. 1

(57) Abstract: The present disclosure relates to a position estimation unit (2) comprising a first transceiver device (3) and a processing unit (10) that is arranged to repeatedly: - calculate time-of-flight (TOF) for radio signals (x₁, x₂, x₃, x₄, x₅, x₆) sent pair-wise between two transceivers among the first transceiver device (3) and at least two other transceiver devices (7, 8, 9); - calculate possible positions for the transceiver devices (3, 7, 8, 9), which results in possible positions for each transceiver device (3, 7, 8, 9); and - perform Multidimensional scaling (MDS) calculation in order to obtain relative positions of the transceiver devices (3, 7, 8, 9) in a present coordinate system; After two initial MDS calculations, between every two consecutive MDS calculations, the processing unit (10) is arranged to repeatedly: - perform a procrustian procedure comprising translation, scaling and rotation of present coordinate system such that a corrected present coordinate system is acquired. The procrustian procedure is arranged to determine the corrected present coordinate system such that a smallest change for the relative positions of the transceiver devices (3, 7, 8, 9) between said consecutive MDS calculations is obtained.

TITLE

Enhanced object position detection

DESCRIPTION OF THE DISCLOSURE

- 5 The present disclosure relates to a position estimation unit comprising a first transceiver device, arranged for sending and receiving radio signals, and a processing unit.

Today, there are many vehicle environment detection systems,
10 such as for example camera systems, Doppler radar systems and LIDAR systems, that can be mounted on a vehicle in order to detect objects in order to implement functions such as speed control and collision prevention, as well as other such as auto alignment, online bumper fascia calibration, ego motion
15 estimation and scene understanding.

It is, however, desired to obtain a high degree of accuracy regarding an ego vehicle's position relative other vehicles and objects for certain application such as collision prediction
20 algorithms like Intersection Movement Assist (IMA), Left Turn Assist (LTA), Forward Collision Warning (FCW) or Lane Change Warning (LCW). Inaccuracies can lead to both false-positives and false-negatives. GPS (Global position system) and GNSS (Global Navigation Satellite Systems) are not providing sufficient
25 degree of accuracy, especially in urban conditions.

It is previously known to use periodic broadcasts to perform inter-vehicle range estimation, where a propagation delay of a wireless signal from a transmitter to a receiver is used for
30 estimating a distance. Round-trip-time (RTT) is used for estimating such a distance more accurately by sending a wireless signal between three or more vehicles or objects, one at a time. This is described in the paper "Inter-vehicle range estimation

from periodic broadcasts" by Urs Niesen, Venkatesan N. Ekambaram, Jubin Jose, and Xinzhou Wu.

In order to establish initial positions from the measured ranges,
5 MDS (Multidimensional scaling) is used, for example as described in the paper "Joint relative position and velocity estimation for an anchorless network of mobile nodes" by Raj Thilak Rajan, Geert Leus, and Alle-Jan van der Veen.

10 However, using RTT for estimating relative positions results in a multitude of solutions, since there are more unknowns than the number of equations.

It is therefore desired to obtain more reliable and unambiguous
15 methods and devices for obtaining relative distances between objects by means of RTT measurements.

This is achieved by means of a position estimation unit comprising a first transceiver device, arranged for sending and
20 receiving radio signals, and a processing unit. The processing unit is arranged to repeatedly:

Calculate time-of-flight (TOF) for radio signals sent pair-wise between two transceivers among the first transceiver device and at least two other transceiver devices.

25 calculate possible positions for the transceiver devices, which results in a plurality of possible positions for each transceiver device.

Perform Multidimensional scaling (MDS) calculation in order to obtain relative positions of the transceiver devices in a present
30 coordinate system.

After two initial MDS calculations, between every two consecutive MDS calculations, the processing unit (10) is arranged to repeatedly perform a procrusting procedure comprising translation, scaling and rotation of present

coordinate system such that a corrected present coordinate system is acquired. The procrusting procedure is arranged to determine the corrected present coordinate system such that a smallest change for the relative positions of the transceiver devices between said consecutive MDS calculations is obtained.

This is also achieved by means of a position estimation method comprising repeatedly:

Calculating time-of-flight (TOF) for radio signals sent pairwise between two transceivers among a first transceiver device and at least two other transceiver devices.

Calculating possible positions for the transceiver devices, which results in a plurality of possible positions for each transceiver device.

Performing Multidimensional scaling (MDS) calculation for obtaining relative positions of the transceiver devices in a present coordinate system.

After two initial MDS calculations, between every two consecutive MDS calculations, the method comprises performing a procrusting procedure comprising translation, scaling and rotation of present coordinate system such that a corrected present coordinate system is acquired. The procrusting procedure is used for determining the corrected present coordinate system such that a smallest change for the relative positions of the transceiver devices between said consecutive MDS calculations is obtained.

According to some aspects, for each pair of transceivers, the processing unit is arranged to calculate time-of-flight either as the time from that a radio signal travels from a transmitting transceiver to a receiving transceiver, or as the time from that a radio signal travels from a transmitting transceiver to a receiving transceiver and back to the transmitting transceiver,

at least one time, such that round-trip time (RTT) is acquired for each pair of transceivers.

According to some aspects, the processing unit is arranged to
5 calculate time-of-flight either with knowledge of a delay time between each re-transmission, or by repeated transmissions with time stamps at the different transceivers.

Other examples are disclosed in the dependent claims.

10

A number of advantages are obtained by means of the present disclosure. Mainly, relative positions for objects are obtained with high accuracy and in a more reliable and unambiguous manner than presented by prior art.

15

BRIEF DESCRIPTION OF THE DRAWINGS

The present disclosure will now be described more in detail with reference to the appended drawings, where:

20 Figure 1 shows a schematic top view of a vehicle with a position estimation unit in a traffic situation; and

Figure 2 shows a flowchart for a method according to the present disclosure.

25

DETAILED DESCRIPTION

With reference to Figure 1, showing a first example, an ego vehicle 1 comprises a position estimation unit 2 that in turn comprises a first transceiver device 3 arranged for sending and
30 receiving radio signals, according to some aspects it is a short-range transceiver device such as a Wi-Fi (Wireless Fidelity) transceiver device arranged for DSRC (dedicated short-range communication). Such communications can for example be V2V (vehicle to vehicle) and V2X (vehicle to infrastructure)

communication. There is a first target vehicle 4, a second target vehicle 5 and a fixed object 6 which also comprise a corresponding second transceiver device 7, third transceiver device 8 and fourth transceiver device 9.

5

The position estimation unit 2 further comprises a processing unit 10 that is arranged to calculate round-trip time (RTT) for radio signals x_1 , x_2 , x_3 sent between the first transceiver device 3 and the other transceiver devices 7, 8, 9, radio signals x_2 , x_4 , x_5 sent between the second transceiver device 7 and the other transceiver devices 3, 8, 9, radio signals x_3 , x_5 , x_6 sent between the third transceiver device 8 and the other transceiver devices 3, 7, 9 as well as radio signals x_1 , x_4 , x_6 sent between the fourth transceiver device 9 and the other transceiver devices 3, 7, 8. Starting from these RTT:s, The processing unit 10 is arranged to calculate possible positions for the transceiver devices 3, 7, 8, 9, which results in a plurality of possible positions for each transceiver device 3, 7, 8, 9 since there are more unknowns than the number of equations.

20

Calculating RTT is only one example, the processing unit 10 is generally arranged to calculate time-of-flight (TOF) pair-wise between two transceivers among three or more transceivers, for each pair of transceivers either as:

- 25 1) the time from that a radio signal x_1 , x_2 , x_3 , x_4 , x_5 , x_6 travels from a transmitting transceiver 3 to a receiving transceiver 7, or as
- 2) the time from that a radio signal x_1 , x_2 , x_3 , x_4 , x_5 , x_6 travels from a transmitting transceiver 3 to a receiving transceiver 7 and back to the transmitting transceiver 3,
- 30 possibly including a delay time, one or more times.

In the first case, it is necessary that the transceivers in question have accurately synchronized clocks, and in the second

case, which is what is referred to as RTT in this context, it is not necessary that the transceivers in question have synchronized clocks, but that the delay time is known. If the delay time is not known, repeated transmissions are needed, with
5 time stamps at the different transceivers.

Having calculated the possible positions for the transceiver devices 3, 7, 8, 9, the processing unit 10 is arranged to perform a first MDS (Multidimensional scaling) in order to obtain first
10 relative positions of the first transceiver device 3, the second transceiver device 7, the third transceiver device 8 and the fourth transceiver device 9 in a first coordinate system.

The processing unit 10 is then arranged to perform a second MDS,
15 at a later time, in order to obtain second relative positions of first transceiver device 3, the second transceiver device 7, the third transceiver device 8 and the fourth transceiver device 9 in a second coordinate system. The second MDS results in other relative positions of the transceiver devices 3, 7, 8, 9 since
20 another coordinate system has been used.

According to the present disclosure, the processing unit 10 is then arranged to perform a procrusting procedure comprising translation, scaling and rotation of the second coordinate
25 system such that a corrected coordinate system is acquired, where the procrusting procedure is arranged to determine the corrected coordinate system such that a smallest change for the relative positions of the transceiver devices 3, 7, 8, 9 from the first MDS to the second MDS is achieved.

30 For each following MDS, a procrusting procedure comprising translation, scaling and rotation of the present coordinate system is performed such that a corrected present coordinate system is obtained.

This means that the processing unit 10 is arranged to repeatedly:

- 5 - Calculate TOF, possibly as RTT, for radio signals at least sent between the first transceiver device 3 and the other transceiver devices 7, 8, 9.
- Calculate possible positions for the transceiver devices 3, 7, 8, 9, which results in a plurality of possible positions for each transceiver device 3, 7, 8, 9.
- 10 - Perform MDS calculations in order to obtain relative positions of the transceiver devices 3, 7, 8, 9 in a present coordinate system.

After two initial MDS calculations, between every two consecutive MDS calculations, the processing unit (10) is
15 arranged to repeatedly perform a procrusting procedure comprising translation, scaling and rotation of present coordinate system such that a corrected present coordinate system is acquired. The procrusting procedure is arranged to determine the corrected present coordinate system such that a
20 smallest change for the relative positions of the transceiver devices 3, 7, 8, 9 between said consecutive MDS calculations is obtained.

According to some aspects, the procrusting procedure is
25 performed by means of an MLE (Maximum Likelihood Estimation) algorithm or an LSE (Least Squares Estimation).

According to some aspects, in order to enhance the accuracy, vehicle dynamics comprising gyro data, acceleration data and
30 velocity data are used by the processing unit 10.

With reference to Figure 2, the present disclosure also relates to a position estimation method comprising repeatedly:

11: Calculating time-of-flight (TOF) for radio signals x_1 , x_2 , x_3 , x_4 , x_5 , x_6 sent pair-wise between two transceivers among a first transceiver device 3 and at least two other transceiver devices 7, 8, 9.

5 12: Calculating possible positions for the transceiver devices 3, 7, 8, 9, which results in a plurality of possible positions for each transceiver device 3, 7, 8, 9.

13: Performing Multidimensional scaling, (MDS) calculation for obtaining relative positions of the transceiver devices 3, 7, 8,
10 9 in a present coordinate system.

After two initial MDS calculations, between every two consecutive MDS calculations, the method comprises:

14: Performing a procrusting procedure comprising translation, scaling and rotation of present coordinate system such that a
15 corrected present coordinate system is acquired, where the procrusting procedure is used for determining the corrected present coordinate system such that a smallest change for the relative positions of the transceiver devices 3, 7, 8, 9 between said consecutive MDS calculations is obtained.

20

The present disclosure is not limited to the examples above, but may vary freely within the scope of the appended claims. For example, the transceiver devices 3, 7, 8, 9 are assumed to be of a previously known design. The processing unit 10 is for example
25 connected to a warning and/or information device comprised in the vehicle 1 in a previously known manner.

The calculations and determining procedures are performed by the processing unit 10, where the processing unit 10 should be
30 regarded as a processing unit arrangement that is in the form of one unit or several units that either co-operate or handle different tasks more or less independently. In the case of several units, these may be placed adjacent to each other, or in a distributed manner.

According to some aspects, the transceiver device 3 in the ego vehicle does not exclude other vehicle environment detection devices such as radar devices, camera devices, LIDAR devices and
5 other similar arrangements.

According to some aspects, the transceiver devices 7, 8 in the other vehicles 4, 5 are also comprised in corresponding position estimation units in these vehicles 4, 5.

10

The fixed object 6 can be any type of infrastructure object such as for example a traffic sign, traffic light or part of a building.

15 The transceiver devices 3, 7, 8, 9 can be fixed and/or mobile in any suitable combination. Each TOF calculation is performed pair-wise for the transceiver devices 3, 7, 8, 9, and at least three transceiver devices 3, 7, 8, 9 are required for the calculations described.

20

According to some aspects, in order to acquire a suitable estimate of the relative positions of the transceiver devices 3, 7, 8, 9, the processing unit 10 is arranged to repeatedly perform at least five procrusting procedures with intermediate
25 MDS calculations.

In this context, the term repeatedly generally means that a procedure or calculation is repeated a plurality of times, without specifying how many times.

30

All details given in the examples are of course only given as an illustration of the present disclosure, and should not be regarded as limiting in any way.

Generally, the present disclosure relates to a position estimation unit 2 comprising a first transceiver device 3, arranged for sending and receiving radio signals, and a processing unit 10, where the processing unit 10 is arranged to

5 repeatedly:

- calculate time-of-flight (TOF) for radio signals $x_1, x_2, x_3, x_4, x_5, x_6$ sent pair-wise between two transceivers among the first transceiver device 3 and at least two other transceiver devices 7, 8, 9;
- 10 - calculate possible positions for the transceiver devices 3, 7, 8, 9, which results in a plurality of possible positions for each transceiver device 3, 7, 8, 9; and
- perform Multidimensional scaling (MDS) calculation in order to obtain relative positions of the transceiver devices 3, 7, 8, 9 in a present coordinate system.

15 After two initial MDS calculations, between every two consecutive MDS calculations, the processing unit 10 is arranged to repeatedly:

- perform a procrusting procedure comprising translation, 20 scaling and rotation of present coordinate system such that a corrected present coordinate system is acquired, where the procrusting procedure is arranged to determine the corrected present coordinate system such that a smallest change for the relative positions of the transceiver devices 3, 7, 8, 9 between said consecutive MDS calculations 25 is obtained.

According to some aspects, for each pair of transceivers, the processing unit 10 is arranged to calculate time-of-flight 30 either as the time from that a radio signal $x_1, x_2, x_3, x_4, x_5, x_6$ travels from a transmitting transceiver to a receiving transceiver, or as the time from that a radio signal $x_1, x_2, x_3, x_4, x_5, x_6$ travels from a transmitting transceiver to a receiving transceiver and back to the transmitting transceiver, at least

one time, such that round-trip time (RTT) is acquired for each pair of transceivers.

5 According to some aspects, the processing unit 10 is arranged to calculate time-of-flight either with knowledge of a delay time between each re-transmission, or by repeated transmissions with time stamps at the different transceivers.

10 According to some aspects, the processing unit 10 is arranged to perform the procrusting procedure by means of an MLE (Maximum Likelihood Estimation) algorithm.

15 According to some aspects, the position estimation unit 2 is positioned in an ego vehicle 1, where the processing unit 10 is arranged acquire vehicle dynamics for the ego vehicle 1, at least comprising one of gyro data, acceleration data and velocity data, and to apply these data in the calculation of relative positions of the transceiver devices 3, 7, 8, 9.

20 Generally, the present disclosure also relates to a position estimation method comprising repeatedly:

- 25 - calculating time-of-flight (TOF) for radio signals x_1 , x_2 , x_3 , x_4 , x_5 , x_6 sent pair-wise between two transceivers among a first transceiver device 3 and at least two other transceiver devices 7, 8, 9;
- calculating possible positions for the transceiver devices 3, 7, 8, 9, which results in a plurality of possible positions for each transceiver device 3, 7, 8, 9; and
- 30 - performing Multidimensional scaling (MDS) calculation for obtaining relative positions of the transceiver devices 3, 7, 8, 9 in a present coordinate system.

After two initial MDS calculations, between every two consecutive MDS calculations, the method comprises:

- performing a procrusting procedure comprising translation, scaling and rotation of present coordinate system such that a corrected present coordinate system is acquired, where the procrusting procedure is used for determining the corrected present coordinate system such that a smallest change for the relative positions of the transceiver devices 3, 7, 8, 9 between said consecutive MDS calculations is obtained.
- 10 According to some aspects, for each pair of transceivers, the method comprises calculating time-of-flight either as the time from that a radio signal $x_1, x_2, x_3, x_4, x_5, x_6$ travels from a transmitting transceiver to a receiving transceiver, or as the time from that a radio signal $x_1, x_2, x_3, x_4, x_5, x_6$ travels from
- 15 a transmitting transceiver to a receiving transceiver and back to the transmitting transceiver, at least one time, such that round-trip time (RTT) is acquired for each pair of transceivers.
- According to some aspects, the method comprises calculating
- 20 time-of-flight either with knowledge of a delay time between each re-transmission, or by repeated transmissions with time stamps at the different transceivers.
- According to some aspects, the method comprises performing the
- 25 procrusting procedure by means of an MLE (Maximum Likelihood Estimation) algorithm.
- According to some aspects, the method comprises acquiring vehicle dynamics for an ego vehicle 1, the vehicle dynamics at
- 30 least comprising one of gyro data, acceleration data and velocity data, and applying these data in the calculation of relative positions of the transceiver devices 3, 7, 8, 9.

CLAIMS

1. A position estimation unit (2) comprising a first transceiver device (3), arranged for sending and receiving radio signals, and a processing unit (10), where the processing unit (10) is arranged to repeatedly:

- calculate time-of-flight, TOF, for radio signals (x_1 , x_2 , x_3 , x_4 , x_5 , x_6) sent pair-wise between two transceivers among the first transceiver device (3) and at least two other transceiver devices (7, 8, 9);
- calculate possible positions for the transceiver devices (3, 7, 8, 9), which results in a plurality of possible positions for each transceiver device (3, 7, 8, 9); and
- perform Multidimensional scaling, MDS, calculation in order to obtain relative positions of the transceiver devices (3, 7, 8, 9) in a present coordinate system;

characterized in that, after two initial MDS calculations, between every two consecutive MDS calculations, the processing unit (10) is arranged to repeatedly:

- perform a procrusting procedure comprising translation, scaling and rotation of present coordinate system such that a corrected present coordinate system is acquired, where the procrusting procedure is arranged to determine the corrected present coordinate system such that a smallest change for the relative positions of the transceiver devices (3, 7, 8, 9) between said consecutive MDS calculations is obtained.

2. A position estimation unit (2) according to claim 1, **characterized in** that for each pair of transceivers, the processing unit (10) is arranged to calculate time-of-flight either as the time from that a radio signal (x_1 , x_2 , x_3 , x_4 , x_5 , x_6) travels from a transmitting transceiver to a receiving transceiver, or as the time from that a radio signal (x_1 , x_2 , x_3 ,

x_4, x_5, x_6) travels from a transmitting transceiver to a receiving transceiver and back to the transmitting transceiver, at least one time, such that round-trip time, RTT, is acquired for each pair of transceivers.

5

3. A position estimation unit (2) according to claim 2, **characterized in** that the processing unit (10) is arranged to calculate time-of-flight either with knowledge of a delay time between each re-transmission, or by repeated transmissions with
10 time stamps at the different transceivers.

4. A position estimation unit (2) according to any one of the previous claims, **characterized in** that the processing unit (10) is arranged to perform the procrusting procedure by means
15 of an MLE, Maximum Likelihood Estimation, algorithm.

5. A position estimation unit (2) according to any one of the previous claims, **characterized in** that the position estimation unit (2) is positioned in an ego vehicle (1), where
20 the processing unit (10) is arranged acquire vehicle dynamics for the ego vehicle (1), at least comprising one of gyro data, acceleration data and velocity data, and to apply these data in the calculation of relative positions of the transceiver devices (3, 7, 8, 9).

25

6. A position estimation method comprising repeatedly:
- calculating time-of-flight, TOF, for radio signals ($x_1, x_2, x_3, x_4, x_5, x_6$) sent pair-wise between two transceivers among a first transceiver device (3) and at least two other
30 transceiver devices (7, 8, 9);
- calculating possible positions for the transceiver devices (3, 7, 8, 9), which results in a plurality of possible positions for each transceiver device (3, 7, 8, 9); and

- performing Multidimensional scaling, MDS, calculation for obtaining relative positions of the transceiver devices (3, 7, 8, 9) in a present coordinate system;

characterized in that, after two initial MDS calculations,
5 between every two consecutive MDS calculations, the method comprises:

- performing a procrusting procedure comprising translation, scaling and rotation of present coordinate system such that a corrected present coordinate system is acquired, where
10 the procrusting procedure is used for determining the corrected present coordinate system such that a smallest change for the relative positions of the transceiver devices (3, 7, 8, 9) between said consecutive MDS calculations is obtained.

15

7. The position estimation method according to claim 6,
characterized in that for each pair of transceivers, the method comprises calculating time-of-flight either as the time from that a radio signal ($x_1, x_2, x_3, x_4, x_5, x_6$) travels from a
20 transmitting transceiver to a receiving transceiver, or as the time from that a radio signal ($x_1, x_2, x_3, x_4, x_5, x_6$) travels from a transmitting transceiver to a receiving transceiver and back to the transmitting transceiver, at least one time, such that round-trip time, RTT, is acquired for each pair of
25 transceivers.

8. The position estimation method according to claim 7,
characterized in that the method comprises calculating time-of-flight either with knowledge of a delay time between each re-
30 transmission, or by repeated transmissions with time stamps at the different transceivers.

9. The position estimation method according to any one of the claims 6-8, **characterized in** that the method comprises

performing the procrusting procedure by means of an MLE, Maximum Likelihood Estimation, algorithm.

10. The position estimation method according to any one of
5 the claims 6-9, **characterized in** that the method comprises acquiring vehicle dynamics for an ego vehicle (1), the vehicle dynamics at least comprising one of gyro data, acceleration data and velocity data, and applying these data in the calculation of relative positions of the transceiver devices (3, 7, 8, 9).

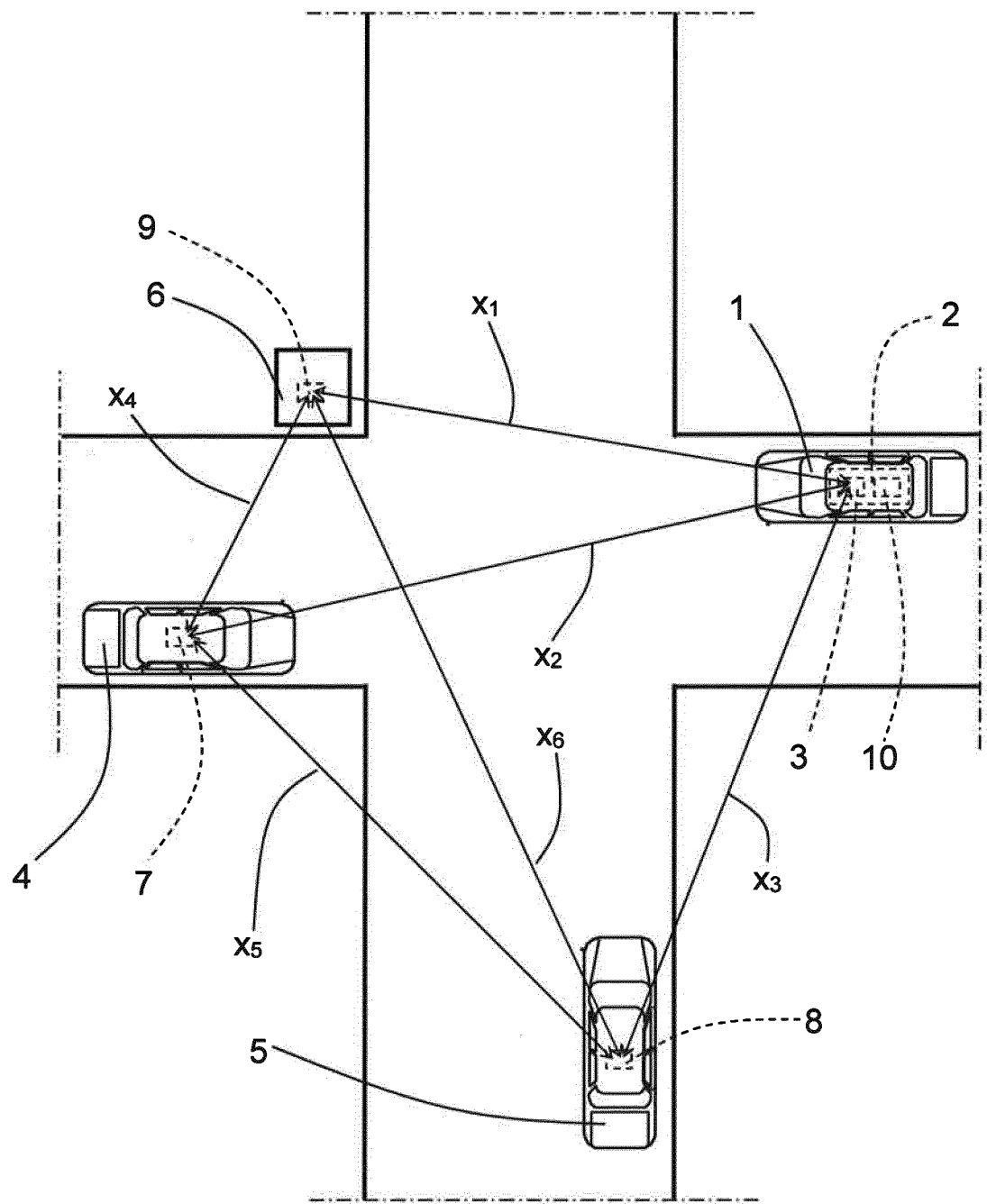
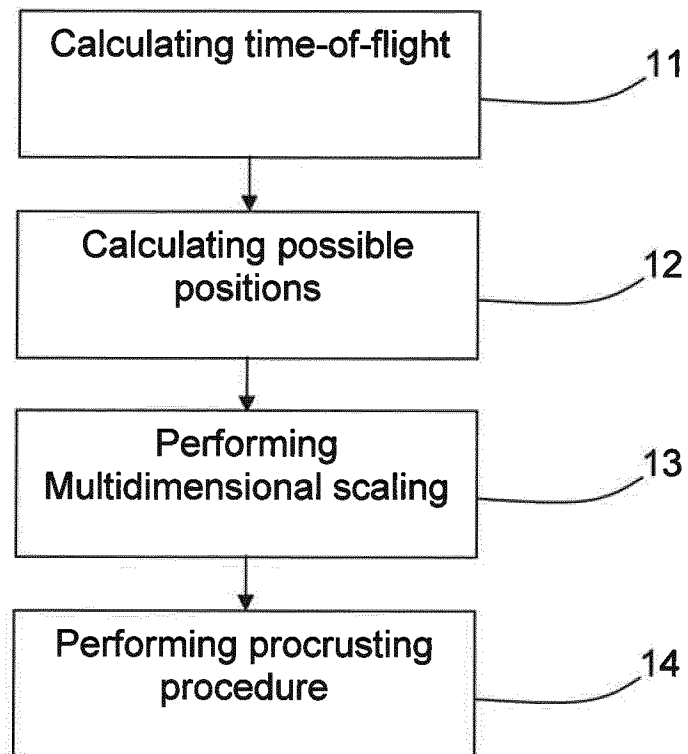


FIG. 1

2/2

FIG. 2

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2018/056449

A. CLASSIFICATION OF SUBJECT MATTER

INV. G01S5/02 G01S5/00
ADD.

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)

G01S

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)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	HAMED BASTANI ET AL: "Precise realtime localization by RF transceiver ToF measurements", ADVANCED ROBOTICS, 2009. ICAR 2009. INTERNATIONAL CONFERENCE ON, IEEE, PISCATAWAY, NJ, USA, 22 June 2009 (2009-06-22), pages 1-6, XP031497273, ISBN: 978-1-4244-4855-5 p. 1-3 ----- -/--	1-4,6-9



Further documents are listed in the continuation of Box C.



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9 May 2018

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Name and mailing address of the ISA/

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NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

González Moreno, J

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2018/056449

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	BECK BRIAN ET AL: "Anchor free node tracking using ranges, odometry, and multidimensional scaling", 2014 IEEE INTERNATIONAL CONFERENCE ON ACOUSTICS, SPEECH AND SIGNAL PROCESSING (ICASSP), IEEE, 4 May 2014 (2014-05-04), pages 2209-2213, XP032616656, DOI: 10.1109/ICASSP.2014.6853991 p. 2209-2211 -----	1,3-6, 8-10
A	D. L. THEOBALD ET AL: "Empirical Bayes hierarchical models for regularizing maximum likelihood estimation in the matrix Gaussian Procrustes problem", PROCEEDINGS NATIONAL ACADEMY OF SCIENCES PNAS, vol. 103, no. 49, 5 December 2006 (2006-12-05), pages 18521-18527, XP055411937, US ISSN: 0027-8424, DOI: 10.1073/pnas.0508445103 the whole document -----	4,9