

METHOD FOR GEOLOCATING A FLEET OF COMMUNICATING OBJECTS
WITHOUT GPS-TYPE SYSTEM

The invention relates to a method for geolocating a fleet of
5 communicating objects without using a GPS-type system ('Global
Positioning System'). The invention finds a particularly
advantageous application in locating men and equipments in a
limited, but possibly mobile area. For example, the invention
can be used by the members of a task force for locating not
10 only themselves but also relative to each other.

It is known that a geolocation can be carried out through a
communication between a client device (the object to be
located) and a centralized server (the system geolocating the
15 object such as a geostationary satellite). The GPS system
works in this manner.

However, in the context of locating men and equipments in a
mobile limited area, while data exchanges with the outside are
20 forbidden, a system including a centralized server does not
meet the constraints of the previously-mentioned problem.

Furthermore, centralizing the location system involves
transmitting a signal according to a star-shaped structure
25 (transmission of a signal between each object to be located
and the location server). Such a transmission structure
requires to solve problems related to the existence of
obstacles that may hinder or prevent the signal transmission
between an object to be located and the server.

30

In addition, the data transmission in a star-shaped structure
requires the presence of the server for relaying data between
the objects to be located, when each of them requires to know
the relative position of their counterparts in the limited

area. The location system based on a GPS-type exchange between the client and the server does not meet this need when the context prohibits any exchange with a point outside the limited area containing all the objects to be located.

5

Traditional GPS-type location systems for example imperfectly allow the location of two points having the same latitude and longitude but having different altitudes, making it difficult to locate two objects having the same coordinates, for example
10 on different floors of a building.

The invention aims to effectively solve the drawbacks of existing geolocation systems by proposing a decentralized method for locating objects without data exchange with a point
15 outside the area containing the objects to be located and regardless of the spatial organization of the fleet of points (bi- or three-dimensional).

More specifically, the invention relates to a method for
20 locating a fleet of communicating objects, characterized by comprising the following steps of:

- i - defining an absolute reference in which the coordinates of the positions of communicating objects will be defined,
- ii - defining at least three positions by their coordinates in
25 the absolute reference system,
- iii - associating the above-defined positions with three communicating objects, so-called reference objects,
- iv - detecting, through at least one of the reference objects, the other two reference objects,
- 30 v - measuring, through at least one of the reference objects, the distance of at least one of the reference objects from the two other reference objects,
- vi - measuring the distance of at least two reference objects from a fourth communicating object, the geometric locus of the

distant points of a reference object from the object to be located being called orbit of the reference object concerned, and

- vii - locating, through at least one communicating object, the fourth communicating object from at least two previously-established orbits and at least one distance among the distances between the three reference objects.

According to one embodiment, when implementing the method for locating the fourth object, only the positions of the reference objects used to locate said object are to be defined, the positions of said reference objects may remain unknown before and/or after the location of the communicating object to be located.

15

According to one embodiment, at least one communicating object among the three reference objects, so-called locating object, locates the fourth communicating object.

According to one embodiment, the locating object receives, from the other two reference geolocating objects, the distances between the object to be located and each of these two reference geolocating objects.

According to one embodiment, the location is obtained by calculating the intersection of at least two orbits where the object to be located can be placed from the point of view of two of the three reference objects.

According to one embodiment, in the case of a fleet of objects in a plane, an intersection of the orbits of two of the three reference objects comprises two points, the selection of the point corresponding to the position of the object to be located being the point from said two points whose distance

from the third reference object is closest to the value of a radius of the orbit of said third object.

According to one embodiment, in the case of a fleet of objects
5 having different altitudes, a geometric locus where the object
to be located can be placed from the point of view of two of
the three reference objects is a sphere, an intersection of
said two spheres is a nappe, the selection of a point in said
10 nappe corresponding to the position of the object to be
located being the point among those of the nappe whose
distance from the third reference object is closest to the
value of a radius of the orbit of said third reference object.

According to one embodiment, the at least two of the three
15 calculated orbits are measured with a relative uncertainty,
the method comprises the step of constrained minimization of
the difference between the distances of the points in an
intersection of at least two orbits from the third reference
object and the value of the distance of said points from the
20 third reference object.

According to one embodiment, in the case of a fleet of objects
in a plane, one of the methods of constrained minimization
consists in calculating an intersection of median circles for
25 each ring forming the potential positions of the object to be
located, the radius of the middle circle being defined as a
historical average of measured radiuses, exceptional values
being dismissed.

30 According to one embodiment, exceptional values are dismissed
by using the following iterative methodology consisting in:
- calculating an absolute average radius from the measurements
for estimating the distance from the object to be located,

- dismissing the measures, whose standard deviations are greater than a threshold, by taking into account a weight assigned to each measure according to a signal quality allowing the associated measure, and
- 5 - recalculating a relative mean radius on the basis of the remaining values.

According to one embodiment, the method comprises an iterative process for eliminating reference objects used to start a
10 process of dynamic localization of the fleet.

According to one embodiment, the location of a fifth communicating object is performed by the fourth located object and two of the reference objects.

15

In one embodiment, the location of a sixth communicating object is performed from only one reference object and the fourth and fifth communicating objects whose location is known.

20

According to one embodiment, the location of the subsequent communication objects is performed by all or some objects whose coordinates are known, and which preferentially belongs to the newly localized objects, different from the reference
25 objects initially used to start the method.

According to one embodiment, the fourth communicating object is located from the measure made by only two reference communicating objects when a potential position of the fourth
30 communicating object is outside a detection zone defined by a maximum detection range for the communicating objects of the fleet.

According to one embodiment, a length of the fleet is greater than the detection range of the communicating objects, a given communicating object exchanges identity data and location data with communicating objects in its immediate environment, the objects in the immediate environment of the given object then relaying said data to all the communicating objects in their immediate environment, and so on until each communicating object of the fleet has knowledge of all the communicating objects of the fleet.

10

According to one embodiment, the method comprises the step of determining a trajectory of a communicating object of the fleet, from a sampling interval, defined as the time interval between an initial instant and a final instant, during which time is sampled into M instants when the location of the communicating object, whose trajectory is sought, will be calculated.

15

According to one embodiment, the locating object receives, from objects in its detection zone defined by a maximum detection range, the knowledge of other objects of the fleet and their position, determines among them the objects capable of measuring their distance from the object whose trajectory is to be determined at the sampling instant concerned, and selects at least two reference objects among said objects in order to locate the object to be located at said sampling instant.

20

25

According to one embodiment, the choice of at least two reference objects from said objects in order to locate the object to be located at said sampling instant is made under the constraint of a list of objects whose locations are known by the locating object at the sampling instant concerned.

30

According to one embodiment, a time distribution of the sampling instants is linear in the interval and controls the determination of all the instants.

- 5 According to one embodiment, a distribution of the sampling instants is non-linear in all or part of the sampling interval.

According to one embodiment, the non-linear distribution is
10 defined by a predefined rule such as a statistical law.

According to one embodiment, the non-linear distribution is dynamically determined by external conditions such as motion data provided by an accelerometer of the communicating object
15 or a request for establishing a more precise trajectory a sampling sub-interval.

According to one embodiment, the trajectory of the communicating object is obtained according to a method or
20 interpolating positions between the positions determined at each sampling instant.

According to one embodiment, the choice of the interpolation method is established from a calibration method consisting in
25 causing the communicating object to follow a predefined trajectory, then calculating interpolated trajectories by using different interpolation methods, such as linear, polynomial, logarithmic and sine interpolation methods and a combination thereof, and calculating areas delimited by two
30 trajectory curves, namely a predefined trajectory, so-called standard trajectory, and one of the interpolated trajectories, and selecting the interpolation method corresponding to the interpolated trajectory that provides the smallest surface area in the previous calculation.

According to one embodiment, the communicating objects may equally initiate at least detection requests and distance measurement requests and directly transmit this detection and distance information.

According to one embodiment, the communicating objects may be requested, by any communicating object of the fleet, to directly transmit a detection data or a distance measure data.

The invention will be better understood from the following description and the accompanying figures. These figures are given as an illustration but not a limitation of the invention.

Figure 1 is a representation of the fixed positions where the reference communicating objects are located;

Figure 2 shows the probabilities of presence of the communicating object to be located when implementing the method according to the present invention;

Figure 3 shows the trilateration leading to the location of the object to be located;

Figure 4 shows as a diagram the steps of the iterative elimination method for the reference objects used to initiate the dynamic geolocation;

Figure 5 illustrates the selection method for the reference objects used to iteratively locate an object in a cloud of objects whose size is greater than the maximum detection range for an object;

Figures 6a and 6b show two different distribution methods for sampling instants;

Figure 7 illustrates the iterative method for determining the trajectories of each object to be located a mobile limited area.

Identical, similar or analogous elements have the same references throughout the figures.

10

It is described below, with reference to Figures 1 to 3, the steps of an initialization phase for the locating method for a communicating object O_4 in a fleet F of communicating objects O_1 - O_N , three communicating objects O_1 - O_3 of which are located at known positions when starting the method.

15

The communicating objects O_1 - O_N have a maximum detection range P as well as a maximum measurable distance D_{max} from another object (see Figure 5). The expression 'maximum detection range' means the greatest distance between two objects able to detect each other. The expression 'maximum measurable distance D_{max} between two objects' means the greatest distance between two objects able to measure this distance. These two characteristics (maximum detection range P and maximum measurable distance D_{max} from another object) may be the same or different for the same object O_i . These characteristics may also vary from one object of the fleet F to another.

20

25

Specifically, as shown in Figure 1, an absolute reference system $Rep(O, X, Y)$ is chosen at first in which all the positions of the objects to be located will be calculated. The coordinate system associated with this reference system is a Cartesian one in our example. Alternatively, this coordinate system may be cylindrical, elliptical, or of any other nature.

30

The method is based on the initial knowledge either of the map location of three communicating objects, so-called reference objects O1, O2, O3, when calculating the geolocation of the communicating object O4, or the data of coordinates O1, O2, O3 in the selected reference system. For example, the following two processes are eligible initialization process: as part of a first process, it is indicated to the objects O1, O2, O3 the instant when they are correctly positioned on a map at an easily recognizable point such as a gateway, or a monument (the coordinates of the objects O1, O2, O3 are not explicitly known in this case). In the context of a second process, the coordinates in the chosen reference system of the objects O1, O2, O3 are directly placed therein.

15

Thus, as shown in Figure 1, three positions P1, P2, P3 are defined by their coordinates (XP1, YP1; XP2, YP2; XP3, YP3) in the absolute coordinate system Rep(O, X, Y.). The table in Figure 1 thus shows the coordinates of the three reference objects O1-O3. The object O1 is positioned at position P1, the object O2 at position P2, the object O3 at position P3. However, this step is unnecessary if the initialization process is the first process above.

25 The reference objects O1, O2 and O3 detect each other, i.e. the object O1 detects the objects O2 and O3, the object O2 detects the object O1 and O3; the object O3 detects the objects O1 and O2. Alternatively, it is also possible that only one or two of the objects O1-O3 detect two or only one of the other communicating objects. At least one of the communicating objects, so-called locating object Oloc to which the other objects transmit measured values, comprises the devices necessary for the distance calculation and measurement

30

function in order to locate another object individually. The locating object Oloc could be for example the object O1.

5 The objects O1, O2 and O3 measure the distance between them and each other communicating object, i.e. the object O1 estimates the distance between O1 and O2 and between O1 and O3, the object O2 estimates the distance between O2 and O1 and between O2 and O3, and the object O3 estimates the distance between O3 and O1 and between O3 and O2. These distances are
10 transmitted to the locating object Oloc=O1. Alternatively, it is also possible that only one or two of the objects O1-O3 evaluates the distance from two or only one of the other communication objects.

15 The objects O1, O2 and O3 measure the distance between them and a fourth communicating object O4 to be located (distance O4-O2, distance O4-O1 and distance O4-O3). Figure 2 thus illustrates the three orbits Orb1, Orb2, Orb3 of the possible positions of the communicating object O4. Each orbit ORB1, Orb2, Orb3 corresponds to all the equidistant geometrical
20 positions of the object O4 to be located relative to the reference object O1, O2 or O3 considered.

These orbits Orb1, Orb2, Orb3 of the three reference objects
25 O1-O3 have a circular shape if the fleet F of the communicating objects O1-O3 have a flat configuration, i.e. the communicating objects of the fleet F are located at the same altitude, or on a sphere if the fleet F has a non-flat configuration, i.e. the communicating objects of the fleet F
30 are located at different altitudes.

It is also possible that only one or two objects estimate the distance from both or only one of the other communication objects. For example, in the context of the geolocation of an

object at the periphery of a fleet F of communicating objects O1-ON, the use of the distance from the third reference object O3 may not be necessary particularly in case one of the potential positions of the object O4 to be located would
 5 locate the object to be located at a distance greater than the detection range P as explained in more details below.

Then, the fourth communicating object O4 is located, i.e. its coordinates are provided, in the absolute coordinate from all
 10 or part of the predetermined orbits Orb1, Orb2, Orb3.

Figure 3 shows the relative reference system Rep' and shows the two possible positions of O4: O4' and O4''. They correspond to the intersection of Orb1 and Orb2 which are the
 15 geometric locus of potential positions of O4 relative to O1 and O2.

The coordinates of O4' and O4'' are expressed in a relative reference system Rep' comprising (O1, V1, V2), wherein V1 is
 20 the unit vector along the straight line O1O2 and V2 is the unit vector normal to V1. These coordinates $(X_{O4'}^{Rep'}, Y_{O4'}^{Rep'})$ and $(X_{O4''}^{Rep'}, Y_{O4''}^{Rep'})$ are determined from the following relationships:

$$X_{O4'}^{Rep'} = \frac{O_1 O_2^2 - (O_2 O_4'^2 - O_1 O_4'^2)}{2 O_1 O_2^2}$$

$$Y_{O4'}^{Rep'} = + \sqrt{O_1 O_2^2 - X_{O4'}^{Rep'^2}}$$

$$Y_{O4''}^{Rep'} = - \sqrt{O_1 O_2^2 - X_{O4''}^{Rep'^2}}$$

25 These formulas eliminate among all the possible positions represented by the orbits Orb1 and Orb2 except two:

$$P_4' = (X_{O4'}^{Rep'}, Y_{O4'}^{Rep'})$$

and

$$P_4'' = (X_{O4''}^{Rep'}, Y_{O4''}^{Rep'})$$

The method then consists in eliminating one of the positions $P4'$ or $P4''$ by removing one of the two the distance of which from $O3$ is the furthest value from the radius of the orbit $Orb3$.

5

The coordinates of $O4$ in the absolute reference system Rep are derived from its coordinates in the reference system Rep' by a traditional formula of change of reference.

10 The result is associated with a measurement uncertainty which is mainly due to the measurement accuracy of the distances O_1O_2 , O_1O_4 , O_2O_4 . According to the desired accuracy of the geolocation of the object $O4$, the aforementioned location method can be improved as follows.

15

The uncertainty of the measurement of the distance O_1O_2 , O_1O_4 , O_2O_4 results in a geometric locus of the potential positions of $O4$ which has the shape of a ring and not of a circle, in a flat configuration, or the shape of a spherical cap and not of
20 a sphere, in the case of the configuration of a fleet F composed of points at different altitudes.

Consequently, the intersection of geometric loci of the potential positions of the object $O4$ to be located has the
25 shape of a flat surface instead of two points, in a flat configuration, or the shape of a spherical cap instead of a nappe in a non-flat configuration.

In order to identify the actual position of the object $O4$ to
30 be located, from all the possible positions, i.e. the positions at the predetermined distance O_4O_2 , O_4O_1 relative to said two objects $O1$, $O2$ among the three predetermined reference objects $O1$, $O2$, $O3$, are dismissed those the distance of which from the object $O4$ presents, relative to the distance

of the object 04 from said third reference object 03, a difference greater than a predetermined threshold.

One of the methods of constrained minimization thus consists
5 in calculating the intersection of the median circles of each ring forming the potential positions of the object 04, the radius of the middle circle being defined as the historical average of the measured radii, after dismissing exceptional values.

10

The exceptional values are dismissed according to the following iterative methodology. An absolute average radius is calculated from the measurements for estimating the distance from the object 04. By taking into account the weight assigned
15 to each measure according to the signal quality allowing the measure associated, the measures whose standard deviations are greater than a threshold, are dismissed and a relative average radius is recalculated from the remaining values. This threshold is an empirical value adjusted according to the
20 historical performances of the method and the external conditions of use of the device, and the expected accuracy. For example, a threshold of 30% is selected.

Figure 4 illustrates the implementation of the method for
25 doing without the three reference objects 01-03 and ensuring the iterative location of all the devices in the fleet F from other reference objects the definition of which will vary over time.

30 More specifically, in a first step E1, a fourth object 04 is located from three communicating objects 01-03 whose location is known at the time of using the method.

In a second step E2, a fifth object 05 is located from two reference objects 02 and 03 and the fourth object 04 whose locations are known at the time of implementation of the process. A first initial reference object is thus eliminated,
 5 for example object 01.

In a third step E3, a sixth object 06 is located from only one reference object 03 and fourth 04 and fifth 5 communicating objects whose locations are known at the time of
 10 implementation of the method. Two initial reference objects, such as objects 01 and 02, are thus eliminated.

In a fourth step E4, a seventh communicating object 07 is located from the fourth 04, fifth 05 and sixth 06
 15 communicating objects whose locations are known at the time of implementation of the method. The three initial reference objects 01-03 of the method are thus eliminated.

It should be noted that the location of each object O_i is
 20 performed from three reference communicating objects (which may be the initial reference objects at the beginning of the method or other objects after their elimination) whose position needs to be known only at the time of the location of the object O_i . It is thus induced that only the positions at
 25 the time of using the location method for the object O_i , objects used to locate the object O_i , must then be defined in the method. In particular, the positions of the objects, used for locating the object O_i before and/or after the time of locating the communicating object O_i , may be unknown, for
 30 example because of a mobility of the objects. This will not disturb the implementation of the method.

Furthermore, as illustrated in Figure 5, the length L of the fleet F , defined by the distance between the two communicating

objects O_1 - O_N , which are the farthest objects of the fleet F from one another, can be much greater than the detection range of the communicating objects. The method allows all the objects to know the existence, the position, and if necessary
 5 the direction of all the other communicating objects of the fleet F , even those distant by a distance greater than the maximum detection range of the communicating objects O_1 - O_N through the following iterative communication method.

- 10 An object O_i exchanges identity data and location data with communicating objects in its immediate environment. The immediate environment is defined by the communicating objects distant from the object O_i by a distance inferior to the maximum detection range P and/or a distance inferior to the
 15 measurable maximum distance D_{max} and/or the communicating objects in direct line with O_i , i.e. the communicating objects that are not separated from the object O_i by an obstacle that may interfere with the communication between two communicating objects. The objects in the immediate environment of the
 20 object O_i then relay these data to all communicating objects in their immediate environment and so on until each communicating object O_1 - O_N of the fleet F has knowledge of all the communicating objects of the fleet F , including those which do not fall within its detection perimeter defined by
 25 the range P .

Furthermore, as the ability to measure the distance between two communicating objects is limited by technical means (maximum detection range P), there are configurations of
 30 fleets F in which one of the two potential positions O_4' and O_4'' , defined as the two intersections of Orb_1 and Orb_2 , is located outside of the detection area ZD defined by the maximum detection range P of the communicating objects of the entire fleet. In this case, O_4 can be located from the

distance measurement, relative to O_4 , of two communicating objects having only known positions. This is due to the adhesion phenomenon of one of the objects relative to the fleet F of objects.

5

Moreover, in order to locate a fleet F composed of N communicating objects, for a fleet F whose length L is greater than the maximum detection distance $D_{\max}$ (Figure 5), the choice of the locating object O_{loc} as well as the object or
 10 objects whose coordinates are already known and used to locate a fourth object in the fleet F , is made by a successive iteration in the fleet F . This iteration is controlled by the measurable maximum distance $D_{\max}$ of an object of the fleet F from another object of the fleet F .

15

More specifically, the choice of the fourth object to be located by the first three objects (the three reference objects) is made exclusively from points distant at the most by the measurable maximum distance $D_{\max}$ from the first three
 20 objects. In this way, in case a fleet has a length L greater than the measurable maximum distance $D_{\max}$, all the points outside the detection zone ZD are excluded. The choice of the fourth object O_4 is also made with the constraint of propagating the location information towards the most distant
 25 points of the fleet F .

Preferably, the communicating objects O_1 - O_N can may equally initiate at least detection requests and distance measurement requests and directly transmit this detection and distance
 30 information. In particular, they can transit this information without using any means of communication, such as servers, proxies or satellites or other platform whose principal or secondary purpose is to federate or relay this detection and distance information.

The communicating objects O_1 - O_N may be equally requested by any object O_1 - O_N of the fleet F for directly transmitting a given detection or distance measurement data. In particular,
5 the objects have the same status in the settlement agreement, i.e. they can be either a server or a client regardless of the type of information relayed and especially those of detection and distance.

10 Thereafter, it is described, with reference to Figures 6 and 7, the method of determining a trajectory of a communicating object O_1 - O_N of the fleet F .

To this end, a sampling interval V_e is defined as the time
15 interval between an initial instant I_0 and a final instant I_F , during which time is sampled into a set of m instants I_i when the location of the communicating object, whose trajectory is sought, will be calculated.

20 The distribution of instants I_i may be linear within V_e as shown in Figure 6a, in this case there is a fixed sampling period T_e controlling the determination of the instants I_i .

However, the distribution of instants I_i may be non-linear and
25 is either defined according to a preset rule such as a Gaussian-type statistical distribution law, or dynamically determined by an external request such as the interpretation of movement data provided by an accelerometer, requiring a concentration of instants I_i in a sub-interval V_e' included in
30 the interval V_e as shown in Figure 6b. For example, for a trajectory TO_i of an object O_i , the detection of a sudden change in direction generates a request for location information in the sub-interval V_e' .

The locating object O_{loc} receives from objects in the detection area the knowledge of the other objects of the fleet F and the position of those already located at this instant of the iteration. The locating object O_{loc} determines among these
 5 objects those which are capable of measuring their distance from the object O_i whose trajectory is to be determined at the sampling instant concerned. The locating object O_{loc} chooses at least two reference objects from these objects to locate the object to be located O_i , at this sampling instant, under
 10 the constrain of the list of objects whose locations are known by the locating object O_{loc} at the sampling instant concerned.

Figure 7 illustrates the interpolation of the positions between the positions determined by the previous location for
 15 an object O_p at three successive instants I_p , I_{p+1} and I_{p+2} . The positions of the object O_p are determined by using the three reference objects O_n , O_{n+1} , O_{n+2} which do not necessarily correspond to the initial reference objects O_1 - O_3 . For a better understanding, the three objects shown in the
 20 figures are identical at the three instants I_p , I_{p+1} , I_{p+2} . However, in practice, the three reference objects used for locating the object O_p at the successive instants I_p , I_{p+1} , I_{p+2} may be different from one instant to the next.

25 At instant I_p , the reference objects $O_n(I_p)$, $O_{n+1}(I_p)$, $O_{n+2}(I_p)$ locate the object $O_p(I_p)$.

At instant I_{p+1} , the reference objects $O_n(I_{p+1})$, $O_{n+1}(I_{p+1})$, $O_{n+2}(I_{p+1})$ locate the object $O_p(I_{p+1})$.

30

An object of the fleet F , which can be one of the reference objects O_n , O_{n+1} , O_{n+2} , or the object to be located itself or another object of the fleet F , calculates, in the simplest case, the single right line segment passing through the two

points $Op(Ip)$, $Op(Ip+1)$ or, in the more elaborate case, the polynomial of degree M passing through $Op(Ip)$ and $Op(Ip+1)$ and meeting constraints of continuity and possibly derivabilities, imposed by $Op(Ip)$ and $Op(Ip+2)$. In the latter case, the
 5 interpolation of the segments $[Op(Ip), Op(Ip+1)]$ is carried out a posteriori after the locations of the positions of Op at each of the m instants Ip .

At the instant $Ip+2$, the reference objects $On(Ip+2)$,
 10 $On+1(Ip+2)$, $On+2(Ip+2)$ locate the object $Op(Ip+2)$. A similar interpolation to the one described above is carried out between the points $Op(Ip+1)$ and $Op(Ip+2)$ or the interpolation of the trajectory is carried out a posteriori on the three points $Op(Ip)$, $Op(Ip+1)$ and $Op(Ip+2)$ in order to determine the
 15 interpolated trajectory of the object Op .

The choice of the interpolation method will be made particularly on the basis of a calibration method of this trajectory determination method. This calibration method
 20 consists in optimizing the choice of the interpolation method according to the following method. At first, the communicating object is caused to follow a predefined trajectory. Then interpolated trajectories are calculated by different interpolation methods including a linear, polynomial,
 25 logarithmic, sine interpolation method and a combination thereof. The areas defined by the two curves, namely the predefined trajectory, so-called standard trajectory, and one of the interpolated trajectories. The optimization consists in selecting the interpolation method corresponding to the
 30 interpolated trajectory that provides the smallest surface area in the previous calculation.

Of course, the above description has been given as an example only and does not limit the scope of the invention the limits

of which are not exceeded when replacing the details of execution by any other equivalents.

CLAIMS

1. Method of locating communicating objects (O1-ON) forming a fleet, characterized by comprising the following steps of:
 - 5 i - defining an absolute reference (Rep) in which the coordinates of the positions of communicating objects (O1-ON) will be defined,
 - ii - defining at least three positions (P1-P3) by their coordinates in the absolute reference system (Rep),
 - 10 iii - associating the above-defined positions (P1-P3) with three communicating objects (O1-O3), so-called reference objects,
 - iv - detecting, through at least one of the reference objects (O1-O3), the other two reference objects,
 - 15 v - measuring, through at least one of the reference objects (O1-O3), the distance of at least one of the reference objects (O1-O3) from the two other reference objects,
 - vi - measuring the distance of at least two reference objects (O1-O3) from a fourth communicating object (O4), the geometric
 - 20 locus of the distant points of a reference object from the object to be located (O4) being called orbit of the reference object considered (Orb1-Orb3), and
 - vii - locating, through at least one communicating object (O1-O3), the fourth communicating object (O4) from at least two
 - 25 previously-established orbits (Orb1-Orb3) and at least one distance among the distances between the three reference objects,
- a length (L) of the fleet (F) is greater than the detection range (P) of the communicating objects (O1-ON), a
- 30 given communicating object (O) exchanges identity data and location data with communicating objects in its immediate environment, the objects in the immediate environment of the given object (Oi) then relaying said data to all the communicating objects in their immediate environment, and so

on until each communicating object of the fleet has knowledge of all the communicating objects (O1-ON) of the fleet (F).

2. Method according to claim 1, characterized in that, when
5 implementing the method for locating the fourth object (O4), only the positions of the reference objects used to locate said object (O4) are to be defined, wherein the positions of said reference objects (O1-O3) may remain unknown before and/or after the location of the communicating object to be
10 located (O4).

3. Method according to claim 1 or 2, characterized in that at least one communicating object among the three reference objects, so-called locating object (Oloc), locates the fourth
15 communicating object (O4).

4. Method according to claim 3, characterized in that the locating object (Oloc) receives, from the other two reference geolocating objects, the distances between the object to be
20 located (O4) and each of these two reference geolocating objects.

5. Method according to any one of claims 1 to 4, characterized in that the location is obtained by calculating
25 the intersection of at least two orbits where the object to be located (O4) can be placed from the point of view of two of the three reference objects (O1-O3).

6. Method according to claim 5, characterized in that, in
30 the case of a fleet (F) of objects in a plane, an intersection of the orbits of two objects (O1, O2) of the three reference objects (O1-O3) comprises two points (O4', O4''), the selection of the point corresponding to the position of the object to be located (O4) being the point from said two points

(O4', O4'') whose distance from the third reference object (O3) is closest to the value of a radius of the orbit (Orb3) of said third object (O3).

5 7. Method according to claim 5, characterized in that, in the case of a fleet (F) of objects having different altitudes, a geometric locus where the object to be located (O4) can be placed from the point of view of two objects (O1, O2) of the three reference objects (O1-O3) is a sphere, an intersection
10 of said two spheres is a nappe, the selection of a point in said nappe corresponding to the position of the object to be located (O4) being the point among those of the nappe whose distance from the third reference object (O3) is closest to the value of a radius of the orbit (Orb3) of said third
15 reference object (O3).

8. Method according to any one of claims 5 to 7, characterized in that the at least two of the three calculated orbits (Orb1-Orb3) are measured with a relative uncertainty,
20 the method comprises the step of constrained minimization of the difference between the distances of the points in an intersection of at least two orbits (Orb1, Orb2) from the third reference object (O3) and the value of the distance of said points from the third reference object (O3).

25

9. Method according to claim 8, characterized in that, in the case of a fleet (F) of objects in a plane, one of the methods of constrained minimization consists in calculating an intersection of median circles for each ring forming the
30 potential positions of the object to be located (O4), the radius of the middle circle being defined as a historical average of measured radiuses, exceptional values being dismissed.

10. Method according claim 9, characterized in that exceptional values are dismissed by using the following iterative methodology consisting in:

- calculating an absolute average radius from the measurements for estimating the distance from the object to be located (O4),
- dismissing the measures, whose standard deviations are greater than a threshold, by taking into account a weight assigned to each measure according to a signal quality allowing the associated measure, and
- recalculating a relative mean radius on the basis of the remaining values.

11. Method according to any one of claims 1 to 10, characterized in that it comprises an iterative process for eliminating reference objects (O1-O3) used to start a process of dynamic localization of the fleet (F).

12. Method according to claim 11, characterized in that the location of a fifth communicating object (O5) is performed by the fourth located object (O4) and two of the reference objects (O1-O3).

13. Method of claim 12, characterized in that the location of a sixth communicating object (O6) is performed from only one reference object (O3) and the fourth (O4) and fifth (O5) communicating objects whose location is known.

14. Method according to claim 13, characterized in that the location of the subsequent communication objects is performed by all or some objects whose coordinates are known, and which preferentially belongs to the newly localized objects, different from the reference objects (O1-O3) initially used to start the method.

15. Method according to any one of claims 1 to 14, characterized in that the fourth communicating object (O4) is located from the measure made by only two reference communicating objects (O1-O3) when a potential position of the fourth communicating object (O4' and O4'') is outside a detection zone (ZD) defined by a maximum detection range for the communicating objects of the fleet.

16. Method according to any of the preceding claims, characterized in that it comprises the step of determining a trajectory of a communicating object (Op) of the fleet, from a sampling interval (Ve), defined as the time interval between an initial instant (IO) and a final instant (IF), during which time is sampled into M instants (Ii) when the location of the communicating object (Op), whose trajectory is sought, will be calculated.

17. Method according to claims 3 and 16 characterized in that the locating object (Oloc) receiving, from objects in its detection zone defined by a maximum detection range (P), the knowledge of other objects of the fleet and their position, determines among them the objects capable of measuring their distance from the object whose trajectory is to be determined at the sampling instant concerned, and selects at least two reference objects among said objects in order to locate the object to be located at said sampling instant (Ii).

18. Method according to claim 17, characterized in that the choice of at least two reference objects from said objects in order to locate the object to be located, at said sampling instant (Ii), is made under the constraint of a list of objects whose locations are known by the locating object (Oloc) at the sampling instant concerned.

19. Method according to claim 16, characterized in that a time distribution of the sampling instants (I_i) is linear in the interval (V_e) and controls the determination of all the instants (I_i).

20. Method according to claim 16, characterized in that a distribution of the sampling instants (I_i) is non-linear in all or part of the sampling interval (V_e).

21. Method according to claim 20, characterized in that the non-linear distribution is defined according to a predefined rule such as a statistical law.

22. Method according to claim 20 or 21, characterized in that the non-linear distribution is dynamically determined by external conditions such as motion data provided by an accelerometer of the communicating object or a request for establishing a more precise trajectory a sampling sub-interval (V_e').

23. Method according to claim 16, characterized in that the trajectory of the communicating object is obtained according to a method or interpolating positions between the positions determined at each sampling instant (I_i).

24. Method according to claim 23, characterized in that the choice of the interpolation method is established from a calibration method consisting in causing the communicating object to follow a predefined trajectory, then calculating interpolated trajectories by using different interpolation methods, such as linear, polynomial, logarithmic and sine interpolation methods and a combination thereof, and calculating areas delimited by two trajectory curves, namely a

predefined trajectory, so-called standard trajectory, and one of the interpolated trajectories, and selecting the interpolation method corresponding to the interpolated trajectory that provides the smallest surface area in the previous calculation.

25. Method according to any one of the preceding claims, characterized in that the communicating objects (O1-ON) may equally initiate at least detection requests and distance measurement requests and directly transmit this detection and distance information.

26. Method according to any one of the preceding claims, characterized in that the communicating objects (O1-ON) may be requested, by any communicating object of the fleet (F), to directly transmit a detection data or a distance measure data.