

METHOD AND SYSTEM FOR COLLABORATIVE GEOLOCALIZATION

The invention relates to a method and a system for collaborative management within a collaborative radiocommunication system comprising several nodes.

5 It applies, for example, in respect of geolocalization or geo-tracking by telemetry (better known by the term ranging), either by beacons (known as "Anchor Based Localization" or ABL), or in a collaborative manner on neighbours, geolocalization on friendly signals, thus forming part of the techniques known as "Anchor Free Localization" or AFM.

10 The technical problem of the invention relates to geolocalization in a heterogeneous network comprising several mobile nodes, in which the nodes or pins have different mobilities and are liable to change state dynamically, for example to switch from a mobile state to a static state. The nodes or pins are, for example, pedestrians, vehicles, boats, drones or
15 aeroplanes. The change of state may result from decisions unrelated to navigation. It may also be decided to improve or maintain the geolocalization capability, for example faced with a loss of geolocalization signal of GPS (Global Position System) or GNSS (Global Navigation System Satellite) type.

Various geolocalization solutions are offered in the techniques of
20 the prior art of collaborative navigation. For example, techniques exist for ranging-based geolocalization by considering imprecise anchor positions, by assigning predefined covariances to the fixed anchors and by applying a tracking filter to each pin, the filter being chosen as a function of the type of mobility of the pins.

25 The methods and the systems described in the applicant's two patent applications FR1601190 and FR1601189 perform geolocalization by ranging by considering imprecise anchor positions.

The solutions known from the prior art taking three-dimensional navigation into account consist in defining a state in the three dimensions,
30 thereby giving three state variables to zero order, six variables to order one and nine variables to order two.

Very few solutions take into account the heterogeneity of the types of mobility, and still less the dynamic change of types of mobility. Although certain solutions potentially make it possible to distinguish (fixed) beacons and mobile nodes by assigning predefined covariances to the fixed anchors, they are sub-optimal in the event of a change of mobility of a node. Indeed, they rely on the static allocation of a model which takes no account of a possible change of type of mobility (fixed or mobile) and the tracking filter becomes inappropriate after a change of type of mobility. Moreover, the solutions which take 3D navigation into account assume 3D observability, this being only rarely the case when most of the nodes are globally in the same plane, particularly if some of the nodes are on the ground.

The object of the present patent application is to offer a system and a method which are capable of geolocating various pins or nodes in a network, whatever the type of mobility of these nodes, while allowing changes of type of mobility at any instant. In particular, this may entail mobility on the ground or aerial (aircraft) mobility. Thus, the idea implemented by the invention will consist notably in using adapted tracking filters and in taking into account various models of evolution, change whereof is controlled by the nodes themselves. The invention also relates to heterogeneous collaborative networks consisting mainly of nodes moving on the ground but also comprising one or more low-altitude aircraft. Because these networks generally are very nearly unobservable in 3D when they rely mainly on telemetry in particular in the event of degradation of the GPS service, the idea consists in firstly solving the 2D geolocalization (the latter generally being very observable) by neglecting the altitude of the various aircraft and then, subsequently, in estimating their altitudes on the basis of the 2D geolocalizations.

The invention relates to a method making it possible to geolocate one or more nodes in a communication network, said nodes communicating with one another by appropriate radio means, characterized in that it comprises at least the following steps:

- Upon a change of type of mobility for a first node, said node as well as the other nodes of the network which receive the information item regarding a change of type of mobility of said first node choose an appropriate tracking filter to follow the tracking of said node by geolocalization,
- In case of loss of the geolocalization signal, three nodes of the network are elected and their state of mobility is switched to a state of quasi-static mobility, said three nodes being used as anchors to geolocate the other nodes.

For the aircraft nodes, the method implements a step of geolocalization in three dimensions comprising a first step of geolocalization by trilateration making it possible to determine a ground trace of the aircraft in two dimensions and a second step of estimating the altitude of the aircraft.

According to a variant embodiment, the change of type of mobility, fixed, static, change of navigation route of a node is detected automatically by a node.

According to another variant, the change of type of mobility, fixed, static, change of navigation route of a node is controlled by an order external to the network.

The method uses, for example, the following tracking filters:

- for a fixed Anchor, a two-dimensional, 2D, fixed position Kalman model,
- for a mobile Pedestrian, a two-dimensional, 2D, NCP (Near Constant Position) Kalman model,
- for a Drone, a three-dimensional, 3D, NCV (Near Constant Velocity) Kalman model.

In case of complete GNSS service denial, the method comprises a step of electing at least three nodes of the network which are positioned in a state of quasi-static mobility and the use of said three nodes as anchors to geolocate the other nodes by telemetry measurements.

The invention also relates to a system for geolocating one or more nodes in a communication network, said nodes communicating with one another by appropriate radio means, the nodes comprising:

- a knowledge device for ascertaining the position of a node,
- 5 • a control module adapted to detect a change in the type of mobility of the node,
- a communication module configured to transmit at least information regarding position, state of mobility for a node,
- 10 • a processor configured to execute the steps of the method according to the invention so as to choose a set of CMM tracking filters adapted to the various types of mobility of the nodes so as to geolocate said node and to geolocate the nodes of the network that have exchanged information with said node.

The type of mobility of the nodes in the system may be very heterogeneous, for example, a network of terrestrial vehicles which is
15 supplemented with one or more aircraft and/or with fixed beacons.

A node can comprise a GNSS device.

Other characteristics and advantages of the present invention will be better apparent on reading the description of exemplary embodiments
20 given by way of wholly nonlimiting illustration, together with the appended figures which represent:

- Figure 1, an exemplary network comprising three nodes able to change state,
- Figure 2, the network in an initial instant with four pedestrians and a
25 drone,
- Figure 3, a representation of the system after loss of GPS link,
- Figure 4, a flowchart describing the steps implemented by the invention.

The description which follows is given by way of illustration in the
30 case of a collaborative radiolocation network comprising several pedestrians communicating with one another by virtue of appropriate radiocommunication

means and a drone that can be piloted by a pedestrian. In the example given, a change of type of mobility can notably be decided so as to improve or maintain the geolocalization capability, for example faced with a loss of geolocalization signal of GPS or GNSS type. In this example, certain nodes
 5 may become immobilized and become fixed beacons alleviating the loss of GNSS coverage and making it possible to ensure continuity of geolocalization of the nodes of the network. The choice of the nodes to be immobilized may be decided by an operational decision centre or according to a predefined operative mode, for example according to a system of
 10 priorities associated with the nodes of the network.

The collaborative radiolocation system 1 comprises several nodes M_i such as is illustrated in Figure 1 with three nodes. Each node M_i (M_1 , M_2 , M_3) comprises, for example, a communication module 10 adapted to transmit to the other nodes of the network information relating to its state of mobility
 15 and to its position, a control module 15 for controlling the state of the node, adapted to detect a change in the type of mobility of the node, a processor 12 configured to choose the CMM tracking filters (multi modal control) adapted for the various types of mobility of the nodes so as to geolocate said node and also to geolocate the other nodes of the network and a battery 13 or
 20 power supply device. Each node can have a GNSS sensor. A node comprises a memory or database 14 which will contain the CMM tracking filters to be used as a function of the present state of mobility of a node, at a given instant or over a given time period. The memory can also integrate a parameter relating to the priority level of a node in a given state of mobility.
 25 This information regarding type of mobility and optionally regarding priority level will be transmitted to a control module 15, the state of mobility of a node, can be controlled by an operator. A node can also comprise a device 16, such as an inertial platform making it possible to determine the state of the node at a given instant, for example, the node is mobile or the node has
 30 come to a stop. This motion detection device is linked to the tracking filter control module which, on receiving the node state information, will select the

model or tracking filter to be used to perform the measurements of distance $d_{i,j}$ between nodes M_i, M_j . The nodes M_i communicate between one another information regarding position, state of mobility, priority level, and regarding optional measurements, such as telemetry measurements on the other nodes, etc., for example, by radio means, a radiofrequency link, wirelessly or
 5 by other means known to the person skilled in the art.

The system also comprises a device for determining the absolute position of all or some of the nodes. Thus, all or some of the nodes may for example be equipped with a receiver 11 which, coupled with a satellite
 10 device 20, allows the node equipped with the receiver 11 to geolocate itself. The receiver 11 is also adapted to detect a loss of the satellite signal, an item of information that it will transmit to the processor 12 so that the latter chooses a type of mobility so as to make it possible to continue the geolocalization process. This satellite device 20 can be a GPS (Global
 15 Positioning System) geolocalization system, a GNSS system (Global Navigation Satellite System), a topography means, etc. In Figure 2, the node M_2 is equipped with a receiver, whilst the node M_3 is not.

A node M_i also comprises a distance measuring device or ranging device or a telemetry sensor 21 colocated for example on a node M_i or on
 20 each of the nodes M_i of the system. For example, the ranging device can take the form of an electronic card carried by the node. According to another variant embodiment, this could be a functionality of the communication system at the level of a node measuring the time taken by the radio wave to travel between the nodes.

25 The nodes belonging to the communication network can exhibit very heterogeneous types of mobility. It is thus possible to envisage a network of terrestrial vehicles which is supplemented with one or more aircraft and/or with fixed beacons.

The drone 22 is considered to be a node of the network.

30 Tracking filters are known to the person skilled in the art and will not be detailed in the present description. Tracking filters can correspond to

the following models: fixed position, quasi-fixed position, 2D or 3D mobility with uniform rectilinear type of motion, 2D or 3D mobility with gyration, road type mobility, etc.

Figure 2 illustrates at a given moment a collaborative radiolocation network comprising four mobile pedestrians and a drone. The pedestrians M_1 , M_2 , M_3 and M_4 and the drone 22 are geolocated by GPS and by ranging measurements according to a technique known to the person skilled in the art.

Figure 3 illustrates an exemplary evolution of the initial situation of Figure 1 subsequent to the loss of GPS coverage. In a state of mobility, the pedestrians can no longer self-locate or be located. The method will use various CMM tracking filters, a filter being adapted to the type of mobility of each node.

In this example, subsequent to GPS signal loss, three pedestrians M_1 , M_2 , M_3 become immobilized and become fixed anchors and the pedestrian M_4 remains mobile. The drone 22 continues to move around. Owing to the presence of the three fixed pedestrians (who having switched to a fixed anchor model, continue to broadcast their absolute position to their neighbours despite the loss of GPS), the mobile pedestrian M_4 will be able to continue to self-geolocate using these three static pedestrians that it considers to be beacons. The drone 22 self-locates firstly in two dimensions with the beacons (fixed pedestrians) and the mobile pedestrian, and then estimates its altitude as will be explained hereinafter.

Throughout the loss of the GPS link or when a node records a power decrease of the signal, the receiver 11 of a node signals to the control module 15 of the tracking filter to be used that the GPS link is no longer available or insufficient to geolocate itself. This information regarding loss of useful signal for geolocalization can also be transmitted manually by an operator by means, for example, of a trigger button 30 fitted to the pedestrian's device. On receipt of this signal loss information, a node will decide to switch to a static state so as to serve as fixed anchor to allow the

geolocalization process to continue. The processor 12 of the node M_i will identify the IMM(mobility) tracking filter stored in its database which corresponds to its new state of mobility at an instant t . From this instant onwards, the pedestrian M_1 will communicate this new state to the other nodes, fixed pedestrians and mobile pedestrian, and to the drone, by radio means for example.

At least three nodes will switch to a fixed position so as to allow geolocalization of the set of nodes of the system. As long as there are not three nodes or pedestrians in a quasi-static position, the method cannot continue the geolocalization.

The change of mobility may result from a decision unrelated to geolocalization, the node M_i decides, for example, to change type of mobility, 401a, 402. This may be initiated, for example, by the operator or else on automatic detection. A change of type of mobility of a node may also result from a decision to maintain a geolocalization after detecting loss of GPS coverage 401b, thus leading to the choice of three nodes, 403. Hence, upon a change of type of mobility, the node concerned as well as the nodes which have received the information regarding a change of type of mobility will modify their tracking filter.

The pedestrians M_1 , M_2 , M_3 have exchanged the information relating to their state, mobile or static. Each pedestrian chooses a type of mobility 402. Each pedestrian in a static state chooses 404 an IMM(static) tracking filter adapted to this static state to continue to estimate their position (on the basis of the telemetry measurements on their static pedestrian neighbours), respectively P_1 , P_2 , P_3 , transmit this mobility and position information to the mobile pedestrian M_4 . The mobile pedestrian M_4 and the drone 22 will use, 407 the position information transmitted by at least three pedestrians in a static state and the telemetry measurements on these three pedestrians so as to be able to geolocate itself by trilateration techniques known to the person skilled in the art. In the case of the drone, this step corresponds to a geolocalization in two dimensions which will be

supplemented as described hereinafter to geolocate same in three dimensions, with a first step of geolocalization by trilateration making it possible to determine a ground trace of the aircraft in two dimensions and to determine a ground trace of the aircraft in two dimensions and a second step
 5 of estimating the altitude. In the absence of at least three static nodes, geolocalization is not possible 406.

The choice of the nodes to be immobilized can be decided by an operational decision centre (not represented for the sake of simplification of figure) or according to a predefined operative mode, for example according to
 10 a system of priorities associated with the nodes of the network. A pedestrian can then decide to switch from a mobile state to a static or fixed state while taking account of the levels of priorities $N_p(M_i)$ defined in advance in the system for the various nodes. The nodes exchange this information about their priority level according to techniques known to the person skilled in the
 15 art. For example, certain pedestrians may not stop since their action has priority with respect to the others. An example is the case of a brigade of firemen attending to a blaze. In this case, the processor 12 of the device fitted to a pedestrian will look at, in the information transmitted by the other pedestrians and the drone, the priority levels and the pedestrians whose
 20 priority level is the lowest will stop so as to become fixed anchors. The latter will then select the 'fixed anchor' type of mobility, the effect of which will be to communicate the change of type of mobility to the other nodes of the network and, initially, to broadcast the current position on the basis of the last estimated position. In the case of loss of GPS signal by the fire brigade, the
 25 mobile nodes will be able to continue to geolocate themselves by using the pedestrians who have switched to a static state. Subsequently, the fixed nodes will be able to refine and update their position estimation by utilizing the telemetry measurements on the neighbouring fixed nodes.

The drone can use at least three pedestrians in a static state to
 30 estimate its ground trace, positioning in a two-dimensional plane. This ground trace $T(\text{drone})$ can be estimated by trilateration on the basis of the telemetry

measurements on the nodes which have a geolocalization (and in particular the three fixed pedestrians) by neglecting the altitude. This approximation is acceptable when the altitude is small compared with the lengthwise extension of the network and the distances between the drone and the geolocated nodes, which is the underlying assumption. On the basis of this ground trace, charting of its x , y position, and of the measurements of distance between the geolocated nodes (and in particular the static pedestrians) and the drone, the drone will be capable of estimating its z -wise altitude and therefore its position P_d in three dimensions. In the case where the drone is equipped with an altimeter or with an equivalent device, it will be possible to utilize the altitude information and to estimate the 3D position directly.

At each change of CMM tracking filter (static, fixed, change of mobility, ...), the state vector of the filter can be reinitialized if the state variables change. Within the mobile node framework, and according to the sensors available, this reinitialization may rely on a "path initialization", well known to those in the art, for example determination of several successive positions so as to estimate a velocity vector upon a change of type of mobility from "fixed anchor" to "uniform rectilinear motion".

Without departing from the scope of the invention, the system could be centralized, a node of the network then centralizing all the inter-node distance measurements and retransmitting the results of its geolocalization calculations for the nodes of the network to each of the nodes.

The method applies in the case of heterogeneous nodes that are able to change kinematics in a dynamic manner, for example in the following manner:

- Switch to fixed station (stop, set down) or restart,
- Change of behaviour: route following, change of direction, etc.

The nodes concerned are for example pedestrians, terrestrial vehicles, ships, drones, etc.

The detailed example, with numbers, which follows is given by way of illustration in conjunction with Figure 4 showing the main steps of the method.

A collaborative network is considered, consisting of five nodes
 5 deployed over a square zone 1 km by 1 km. Four pedestrians are moving around on the ground and a mini drone 22 is remotely operated by one of the pedestrians, flying at an altitude of a few tens of metres. Each node has a GPS and a telemetry measurement about the neighbours (on the MANET waveform or with the aid of specific equipment). In the "normal" situation, all
 10 the nodes geolocate themselves and navigation is possible on all the nodes simply with a tracking filter of NCP Kalman type, the abbreviation standing for Nearly Constant Position, Kalman filter of order 0 with noise in the position. Faced with a risk of loss of the GPS (jamming for example), 401, the three pedestrian nodes that are not remotely operating the drone decide to become
 15 fixed anchors, 402, 403. The pedestrian who is piloting the drone may also decide to toggle the drone to a tracking model of NCV type, the abbreviation standing for Nearly Constant Velocity, which is more precise for the tracking of uniform rectilinear motion segment navigation sequences.

In the presence of a complete GPS service denial, the three fixed
 20 anchor nodes continue to deliver a position. The navigation algorithm (present on each of the nodes) dependent on the type of mobility then uses the tracking filters adapted to the various types of mobility, for example, 404:

- For a fixed anchor, a 2D Fixed Position Kalman model,
- For a pedestrian, a 2D NCP Kalman model,
- 25 - For a Drone, a 3D NCV Kalman model.

On the basis of these nodes, the current node and at least three neighbouring nodes are geolocated, 405. Next the method will geolocate at least in two dimensions, the other nodes of the network and the ground trace of the drone 22.

30 In case of complete GNSS service denial, the method is capable of choosing at least three of the network's nodes 404, 405 which are made to

switch to a state of quasi-static mobility. These three nodes are used as anchors to geolocate the other nodes by telemetry measurements.

With a conventional navigation solution, after some time (variable depending on whether the nodes do or do not have inertial navigation sensors), none of the pins would be able to self-locate owing to the loss of the GPS.

With the innovative solution, the five pins always succeed in geolocating themselves and in determining a navigation solution:

- The three nodes that have become fixed anchors do not drift over time (as in the previous case) and deliver good positioning precision, which not only does not deteriorate, but improves progressively owing to the telemetry measurements carried out between the three nodes and to the selection of the "fixed node" navigation model,
 - The other two mobile pins (remote-operator pedestrian and drone) do not have any trouble sustaining their navigation solution since they continue to geolocate themselves without any difficulties in 2D by virtue of the three previous nodes. For the drone, despite the fact that the altitude is neglected, its position in terms of latitude and longitude is given approximately by the 2D estimated position since the lengthening of the 3D ranging measurements, which is due to the altitude of the drone and to the altitude difference with the pedestrians on the ground, is small compared with the lengthwise extensions on the ground,
 - The altitude of the drone can thereafter be estimated by utilizing the 2D position estimation and the ranging measurements on the other nodes.
- In the case where the network does not comprise sufficient nodes, then it is impossible to geolocate the nodes, 406.

The method according to the invention makes it possible in particular to take into account the heterogeneity of the types of mobility of nodes in a communication network as well as the dynamic change of type of mobility on one or more nodes. The invention offers service continuity by taking account of the evolution of the state of the nodes.

CLAIMS

- 1 – Method making it possible to geolocate one or more nodes in a communication network, said nodes communicating with one another by appropriate radio means, comprising at least the following steps:
Upon a change of type of mobility for a first node, said node as well as the other nodes of the network which receive the information item regarding a change of type of mobility of said first node choose an appropriate tracking filter to follow the tracking of said node by geolocalization (402, 403),
In case of loss of the geolocalization signal, three nodes (404, 405) of the network are elected and their state of mobility is switched to a state of quasi-static mobility, said three nodes being used as anchors to geolocate the other nodes.
- 2 – Method according to Claim 1, characterized in that it comprises for aircraft nodes a step of geolocalization in three dimensions comprising a first step of geolocalization by trilateration so as to determine a ground trace of the aircraft in two dimensions and a second step of estimating the altitude of the aircraft.
- 3 – Method according to one of Claims 1 or 2, characterized in that the change of type of mobility, fixed, static, change of navigation route of a node is detected automatically by a node.
- 4 – Method according to one of Claims 1 or 2, characterized in that the change of type of mobility, fixed, static, change of navigation route of a node is controlled by an order external to the network.
- 5 – Method according to one of Claims 1 to 4, characterized in that according to the type of mobility of a node, an adapted filter is used:
- For a fixed Anchor, a 2D "Fixed Position" Kalman model,

- For a mobile Pedestrian a 2D NCP Kalman model,
- For a Drone, a 3D NCV Kalman model.

5 6 – Method according to one of the preceding claims, characterized in that in the event of complete GNSS service denial, it comprises a step of electing at least three nodes (404, 405) of the network which are positioned in a state of quasi-static mobility and the use of said three nodes as anchors to geolocate the other nodes by telemetry measurements.

10 7 – System for geolocating one or more nodes in a communication network, said nodes communicating with one another by appropriate radio means, in which the nodes comprise:

- a knowledge device for ascertaining the position of a node,
- a control module (15) adapted to detect a change in the type of mobility of the node,
- a communication module adapted to transmit at least information regarding position, state of mobility for a node,
- a processor (12) configured to execute the steps of the method according to the invention so as to choose a set of CMM tracking filters adapted to the various types of mobility of the nodes so as to geolocate said node and to geolocate the nodes of the network that have exchanged information with said node.

25 8 – System according to Claim 7, characterized in that it comprises nodes of very heterogeneous type of mobility such as a network of terrestrial vehicles which is supplemented with one or more aircraft (22) and/or with fixed beacons.

30 9 – System according to one of Claims 7 or 8, characterized in that a node comprises a GNSS device.