(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
30 April 2009 (30.04.2009)

PCT

(10) International Publication Number
WO 2009/054010 A1

(51) International Patent Classification:
G01S 3/786 (2006.01) *G01C 3/08* (2006.01) *G01S 5/16* (2006.01) *G01C 21/20* (2006.01) *G01S 11/12* (2006.01)

(21) International Application Number: PCT/IT2007/000740

(22) International Filing Date: 23 October 2007 (23.10.2007)

(25) Filing Language: Italian

(26) Publication Language: English

(71) Applicant (*for all designated States except US*): GALILEO AVIONICA S.p.A. [IT/IT]; Via Albert Einstein, 35, I-50013 Campi Bisenzio (IT).

(72) Inventor; and
(75) Inventor/Applicant (*for US only*): MANETTI, Valerio [IT/IT]; Via Cordaioli, 45, I-34170 GORIZIA (IT).

(74) Agents: JORIO, Paolo et al.; c/o Studio Torta S.r.l., Via Viotti, 9, I-10121 Torino (IT).

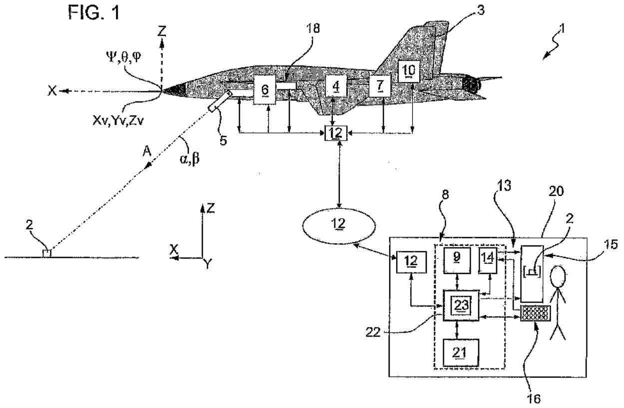
(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

(54) **Title:** SYSTEM FOR THE PRECISION LOCALIZATION OF A TARGET ON THE GROUND BY A FLYING PLATFORM AND ASSOCIATED METHOD OF OPERATION

FIG. 1



(57) **Abstract:** An operating method of a system for the precision localization of a target (2) present on the ground without the aid of a laser range-finder device is described. The method comprises the phases of : calculating, in two successive moments in time (tl,t2) during the flight of an aircraft (3) along a rectilinear flight segment, two points of intersection (Pl (i),P2 (i)) between a tracking axis (A) of a camera (5) mounted on the aircraft (3) and a theoretical plane (PTi) associated with the ground and having.a preset initial altitude (QTi), repeatedly varying the altitude (QTi) of the theoretical plane (PTi) by a preset value (ΔQTi) and calculating the position of the two points of intersection (Pl (i),P2 (i)) on the same theoretical plane (PTi) at each variation in altitude (ΔQTi) of the theoretical plane (PTi), until a condition of precision localization is achieved, which is satisfied when the distance (Dx) between the two points of intersection (Pl (i), P2 (i)) has a minimum value less than a preset threshold (SX).

WO 2009/054010 A1

SYSTEM FOR THE PRECISION LOCALIZATION OF A TARGET ON THE GROUND BY A FLYING PLATFORM AND ASSOCIATED METHOD OF OPERATION

TECHNICAL FIELD

The present invention concerns a system for the precision localization of a target on the ground by a flying platform and the associated method of operation.

In particular, the present invention concerns a system that is able to localize a target by means of a flying platform corresponding to an aircraft flown by a pilot or, in alternative, a so-called UAV (Unmanned Aerial Vehicle), the position of which is controlled from a remote control station and to which the treatment herein makes explicit reference, but without any loss in generality.

BACKGROUND ART

As is known, the systems currently used for so-called RISTA missions (Reconnaissance, Intelligence, Surveillance & Target Acquisition), for the localization of a target in an area monitored by a flying platform, typically include: a flying platform composed of an aircraft, a camera mounted on the aircraft with adjustable training to take images of the ground below and a camera movement device, which is able to adjust the tracking angles moment by moment, within the camera's tracking axis space.

The above-mentioned localization systems also comprise a device able to detect the position of the aircraft moment by moment, typically consisting of a GPS (Global Position System) receiver, and a measurement device corresponding to a laser range-finder device, which is able to measure the distance between the aircraft and the target framed by the camera.

The system also comprises a central processing unit that includes storage means containing a digital cartographic map representing the ground to monitor in an X,Y,Z Cartesian reference system, and a computing unit that is able to calculate the position of the target on the ground in function of a series of parameters, such as: the instantaneous position of the aircraft, the angles that identify the attitude of the aircraft with respect to a local vertical and the direction of the prow of the aircraft with respect to the geographical north, the tracking angles of the camera and, lastly, the measurement of the distance between the aircraft and the target framed by the camera.

In the above-described systems, the use of the laser range-finder is found to be quite disadvantageous, as besides heavily affecting the overall cost of making the localization system, it is particularly heavy and complex to control, therefore causing an increase in the structural and manufacturing complexity of the electronic system dedicated to controlling the flying platform when it is in flight.

To this end, target localization systems have been made that work without the aid of a laser range-finder device, in which the position of the target is determined on the basis of the altitude of the ground indicated on the cartographic map instead of the distance between the aircraft and the target to be detected. However, although these target localization systems are cheaper, on the whole, than systems that use a laser range-finder device, they have the significant drawback of not being very precise, as they are implicitly affected by an error, which is directly correlated to the discretization error introduced by the ground altitude data contained in the digital cartographic map.

In the case in point, experimental tests have demonstrated that the altitude error results in a localization error in the target's position of approximately 25-50 m in the more favourable cases, and up to 200-400 m in cases of insufficient discretization of the altitude data contained in the digital cartographic map.

DISCLOSURE OF INVENTION

The object of the present invention is therefore that of embodying a system for the precision localization of a target by means of a flying platform that, on the one hand, is devoid of the laser range-finder device and therefore economic to manufacture and, on the other, guarantees a precision in the target's position having an order of precision substantially the same as that which can be achieved with systems using a laser range-finder device.

According to the present invention, a system for the precision localization of a target is embodied as propounded in claim 1 and preferably, but not necessarily, in any of the claims directly or indirectly dependent on claim 1.

According to the present invention, a method for the precision localization of a target is also provided, as propounded in claim 8 and preferably, but not necessarily, in any of the claims directly or indirectly dependent on claim 8.

According to the present invention, a computer is also embodied, as propounded in claim 14.

Lastly, according to the present invention, a software product is embodied, as propounded in claim 15.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention shall now be described with reference to the enclosed drawings, which illustrate a non-limitative example of embodiment, where:

- Figure 1 schematically shows a system for localizing a target on the ground, embodied according to the principles of the present invention,
- Figure 2 is the first part of a flowchart of the operations implemented by the system shown in Figure 1 during its operation,
- Figure 3 is the second part of the flowchart shown in Figure 2,
- Figure 4 shows a schematic side view of the system in two different operational moments,
- Figure 5 shows a schematic aerial view of the system shown in Figure 4 during the calculation of the first distance,
- Figure 6 shows a perspective view of the system shown in Figure 4 during the calculation of the second distance, and
- Figure 7 shows an aerial view of the system shown in Figure 4 during the calculation of the second distance.

BEST MODE FOR CARRYING OUT THE INVENTION

With reference to Figure 1, reference numeral 1 indicates, in its entirety, a system using a flying platform to monitor an area in order to identify and localize a target 2 present inside the monitored area with high precision.

The system 1 is preferably, but not necessarily, employed for carrying out so-called RISTA missions (Reconnaissance, Intelligence, Surveillance & Target Acquisition) and basically comprises a flying platform consisting of an aircraft 3 that, in the example shown, corresponds to a UAV (unmanned aircraft), which can be controlled from a control station 20 situated in a remote location with respect to the area to monitor. Nevertheless, it is opportune to specify that the aircraft 3 could be an aircraft with a pilot, or rather an aircraft directly controlled by an pilot onboard the aircraft itself, in which localization takes place on the aircraft 3 and the various components of the system 1, described in detail in the following, are integrated within the aircraft 3 itself.

With reference to Figure 1, the aircraft 3 comprises a measurement device 4 able to determine the attitude of the aircraft 3, moment by moment. In particular, the measurement device 4 comprises a series of electronic sensors (not shown) that, moment by moment, measure the Heading ψ, Pitch θ and Roll φ angles of the aircraft 3, and a processing unit (not shown) that, based on the measured angles, determines the attitude of the craft 3 with respect to a vertical reference axis (not shown) and the direction of the prow of the aircraft with respect to the geographical north. It is opportune to specify that the Heading ψ, Pitch θ and Roll φ angles are a representation of the Euler angles corresponding to the possible rotations of the aircraft 3 in space around the respective X, Y or Z-axes of a Cartesian reference system. The determination of the attitude of an aircraft 3 in space based on the Heading ψ, Pitch θ and Roll φ angles is known and therefore shall not be described any further.

In particular, the Heading ψ angle corresponds to the angle between a vertical plane on which the aircraft 3 lies and a vertical plane passing through the longitudinal axis of the aircraft 3 when positioned with its prow in the direction of a certain reference point, corresponding to the geographical north.

The aircraft 3 also comprises a camera 5, working in the visible and/or infrared band, which is mounted on the aircraft 3 with its own tracking axis A, freely adjustable in space, to allow the acquisition of images of the ground below.

The aircraft 3 also comprises a mechanical positioner member 6, which is able to control the movement of the camera 5 with respect to the aircraft 3 to change the Pan α and Tilt β tracking angles, and a device 7, such as a GPS (Global Position System) receiver for example, which has the function of detecting, moment by moment, the position XV,YV,ZV of the aircraft 3 in space with respect to a spatial reference system, preferably of the X,Y,Z Cartesian type.

The system 1 also comprises a remote-control system 8 capable of allowing an operator at the remote station 20 to control the route of the aircraft 3 according to a certain flight segment. The remote-control system 8 comprises a remote-control device 9 installed in the control station 20 to generate the commands regarding a flight route established by the operator, a remote-control unit 10 installed onboard the aircraft 3 to pilot the aircraft 3 according to the flight route generated by the remote-control device 9, and a data transmission and reception system 12 able to provide two-way data communications between the aircraft 3 and the remote control station 20 so as to allow the exchange of data between the various devices present at the control station 20 and the equipment mounted onboard the aircraft 3.

The system 1 also comprises a video-tracking system 13, which has the task of controlling the mechanical positioner member 6 in order to keep the camera 5 with its own tracking axis A trained on a target 2 selected by the operator during the flight of the aircraft 3.

In this case, the video-tracking system 13 comprises a first processing module 14 that is installed at the control station 20 to receive the images captured by the camera 5 from the transmission and reception system 12 and is able to display them to the operator via a video display unit 15, and a control device 16, such as a keyboard for example, to allow the operator to control the processing module 14 to select or mark the target that must be localized on the image of the ground shown by the video display unit 15.

The video-tracking system 13 also comprises a first control unit 18 mounted onboard the aircraft 3 that receives a series of information from the processing module 14, via the data transmission and reception system 12, regarding the target marked or selected by the operator and, on the basis of this information, controls the mechanical positioner member 6 so that the camera 5 remains constantly trained on the target 2 selected by the operator.

The remote-control 8 and video-tracking 13 systems are known and therefore shall not be described any further, except for specifying that the remote-control module 9 and the first processing module 14 can be integrated in a single processing unit, for example, a Personal Computer located at the remote control station.

The system 1 also comprises a memory device 21 preferably, but not necessarily, installed at the remote control station 20 and preferably, but not necessarily, containing at least one digital cartographic map associated with the area to be monitored, and a processing device 22 that is preferably, but not necessarily, installed at the remote control station 20 for localizing the position of the target 2 on the ground.

In particular, the processing device 22 comprises a computation module 23 that implements an algorithm, described in detail further on, able to localize the position of the target 2 on the ground with precision.

With reference to Figures 2-6, the precision localization algorithm implemented by the computation module 23 is essentially based on the concept of:

- temporarily piloting the aircraft 3 along a rectilinear flight segment TR above the ground on which the target 2 is present,
- calculating, at two successive moments in time during the flight of the aircraft 3 along the rectilinear flight segment TR, at least two points of intersection between the tracking axis A of the camera 5 and a theoretical plane associated with the ground and having a preset initial altitude,
- repeatedly varying the altitude of the theoretical plane by a preset value and calculating the reciprocal position of the two points of intersection at each variation in altitude until a first condition of precision localization is reached, in which the distance between the two points of intersection has a minimum value lower than a first preset threshold, and
- assigning the altitude value associated with a condition of precision localization, which is found to be satisfied when the calculated distance has a minimum value below the preset threshold, to the position of the target 2.

In other words, the precision localization algorithm is essentially based on the principle of:

a) establishing a theoretical plane PTi associated with the area to monitor and having an initial theoretical altitude QTi, which indicates the height of the theoretical plane PTi with respect to a preset reference plane PTO, positioned at zero altitude for example,

b) localizing a target 2 on the ground via the camera 5 mounted onboard the aircraft 3 and keeping the tracking axis A of the camera 5 trained on the target 2 via the video-tracking system 13,

c) during localization, keeping the flight of the aircraft 3 substantially rectilinear, at a given height with respect to the reference plane PTO and substantially parallel to the theoretical plane PTi,

d) at a first time t1, determining a first point P1(i) of intersection between the tracking axis A of the camera 5 trained on the target 2 and the theoretical plane PTi set at theoretical altitude QTi,

e) at a second time t2, after the first time t1, determining a second point P2(i) of intersection between the tracking axis A of the camera 5 trained on the target 2 and the theoretical plane PTi set at theoretical altitude QTi,

f) calculating a first distance Dx between the points P1(i) and P2(i) of intersection calculated at times t1 and t2 respectively, and

g) in the case in which the first calculated distance Dx is less than or equal to a first preset error threshold SX, detecting a first condition of precision localization and assigning the theoretical altitude QTi associated with the theoretical plane PTi to the position of the target PZo, or

h) instead, if the first calculated distance Dx exceeds a preset error threshold SX, changing the theoretical altitude QTi assigned to the theoretical plane PTi by a preset value ΔQTi according to the relation QTi+1=QTi+ΔQTi and reiterating phases c), d), e), f), g) and h) again, until the first condition of precision localization indicated in point g) is satisfied.

With reference to Figures 2 and 3, the method of operation of the system 1 for the precision localization of the target 2 shall now be described in detail.

In the initial phase, the remote-control system 8 takes care of piloting the aircraft 3 above the area to be monitored at a certain height with respect to the reference plane PTO, maintaining a substantially horizontal and rectilinear flight path (Figures 4, 5 and 6) (block 100).

In this phase, the mechanical positioner member 6 actuates the movements of the camera 5 until a condition of localization of the target 2 occurs, i.e. it is framed by the camera 5, this last condition being satisfied when the target 2 is displayed by the video display unit 15.

Once the target 2 has been framed, tracking of the target 2 is activated via the video-tracking system 13 (block 110), which after the operator has selected the target 2 takes care of moving the mechanical positioner member 6 in a manner such that the tracking axis A of the camera 5 remains constantly trained on the target 2 during the flight of the aircraft 3. In this phase of tracking the target 2 with the video-tracking system 13, the image of the target 2 preferably, but not necessarily, remains in a viewable point of the video display unit 15, for example, located in the central part of the same video display unit 15.

During the flight of the aircraft 3 along the rectilinear segment TR and after training the target 2, at a time t1, the computation module 23 determines the position in space of the tracking axis A of the camera 5 on the basis of the absolute position of the aircraft XV,YV,ZV, the Heading ψ, Pitch θ and Roll φ angles of the aircraft 3, and the Pan α and Tilt β tracking angles (block 130). In this phase, the computation module 23 calculates a first point P1(i) of intersection between the tracking axis A of the camera 5 and a theoretical plane PTi set at an initial theoretical altitude QTi (in which i is a numeric value indicating the calculation cycle implemented by the computation module 23).

It is opportune to specify that the initial theoretical plane PTi can preferably, but not necessarily, correspond to the surface plane of the cartographic map, while the theoretical altitude QTi can preferably, but not necessarily, correspond to the altitude assigned to the cartographic map itself.

At a time $t2=t1+\Delta t$, following time t1, the computation module 23 determines the position in space of the tracking axis A of the camera 5 on the basis of the absolute position of the aircraft XV,YV,ZV, the Heading ψ, Pitch θ and Roll φ angles of the aircraft 3, and the Pan α and Tilt β tracking angles. In this phase, the computation module 23 calculates a second point P2(i) of intersection between the tracking axis A of the camera 5 and the theoretical plane PTi set at the initial theoretical altitude QTi (block 140).

Following the determination of the two points of intersection P1(i) and P2(i), the computation module 23 calculates a first distance Dx of the distance vector D between the first P1(i) and the second point P2(i) (block 150). It is opportune to specify that the first distance Dx corresponds to the value of the component of the distance vector D on a vertical plane PT' orthogonal to the reference plane PTO passing through a line coincident with the rectilinear path TR flown by the aircraft 3 (Figures 5 and 6). In particular, the first distance Dx is preferably, but not necessarily, determined by calculating the distance between the points P1'(i) and P2'(i) obtained from the orthogonal projection of the first and second points of intersection P1(i) and P2(i) on the plane PT' (Figures 5 and 6).

Furthermore, it is opportune to specify that the first distance Dx is directly correlated to the localization error as, in error-free conditions of detecting the position of the target 2, the first P1(i) and the second P2(i) points of intersection are substantially coincident and consequently the first distance Dx is found to be null.

Following the calculation of the first distance Dx, the computation module 23 compares the first distance Dx with a first distance threshold SX and checks, on the basis of this comparison, whether or not a first condition of precision localization is satisfied (block 160). In particular, the first condition of precision localization is satisfied when the first distance Dx is less than or equal to the first distance threshold SX. In this case, the computation module 23 detects if the first condition of precision localization is satisfied via the following relation:

$Dx <= SX$

If the first distance Dx is greater than the first threshold SX (NO exit from block 160), the computation module 23 implements a series of operation to minimize the first distance Dx.

In particular, the convergence of the first distance Dx to a minimum value contemplates changing the altitude QTi of the theoretical plane PTi of the cartographic map by a preset increment or decrement of preset value ΔQT, according to the relation

$QTi+1=QTi+/-\Delta QT$ (block 180).

Following the assignment of the new altitude QTi+1 to the theoretical plane PTi of the cartographic map, the computation module 23 reiterates the operations implemented in block 130 so as to determine the first point P1(i+1) of intersection associated with time t1 and, successively, the operations implemented in block 140 so as to determine the second point P2(i+1) of intersection associated with time t2.

At this point, the computation module 23 implements the following operations: recalculate the first distance Dx between points P1(i+1) and P2(i+1) in the manner described in block 150, compare the first distance Dx with the first threshold SX (block 160) and, in the case where the first distance Dx is less than or equal to the first distance threshold SX, assign the last calculated altitude QTi+2=QTi+1+ΔQT to the target position, or, failing this, change last value of the altitude QTi again, assigning the preset value ΔQT, for example with ΔQT equal to around 10 metres, according to the relation QTi+2=QTi+1+/-ΔQT, and implementing the calculation and comparison operations described in blocks 130-160.

Instead, when the first distance Dx is less than or equal to the first distance threshold SX (YES exit from block 160), the computation module 23 assigns the theoretical altitude of the ground QTi+n, assigned in the course of the last calculation cycle (cycle n) according to the relation QTR=QTi+n, to a target altitude parameter QTR, indicating the real altitude of the target on the ground (block 170).

In this phase, the computation module 23 determines the component PZo of the position of the target with respect to the Z-axis, assigning it the target altitude QTR via the relation PZo=QTR and, at the same time, determines the component PXo of the position of the target with respect to the X-axis, assigning it the position of one of the two points of intersection, for example point P1(i+n), calculated in the last cycle via the relation PXo=P1X(i+n) (block 190).

At this point, in order to determine with precision the third component PYo of the position of the target with respect to the Y-axis as well, the computation module 23 implements the following operations. In particular, at a time t1', the computation module 23 measures the Heading angle ψ1 of the aircraft 3 and, from a position Pv1, calculates a first point C1(i) of intersection between the tracking axis A of the camera 5 and a theoretical plane PTi set preferably, but not necessarily, at the target altitude QTR (block 200).

At time $t2'=t1'+\Delta t$, following time t1', the computation module 23 measures the Heading angle $\psi 2$ and, from a point Pv2, calculates a second point C2(i) of intersection between the tracking axis A of the camera 5 and the theoretical plane PTi (block 210).

Following the two measurements of the Heading angles $\psi 1$ and $\psi 2$ and the determination of the two points of intersection C1(i) and C2(i), the computation module 23 calculates a second distance Dy of the distance vector D' between the first C1(i) and the second C2(i) points (block 220).

It is opportune to specify that the second distance Dy corresponds to the value of the component of the distance vector D between the first C1(i) and the second C2(i) points projected on a vertical plane PV arranged orthogonally to the rectilinear path TR flown by the aircraft 3 (Figure 6).

In particular, the second distance Dy is preferably, but not necessarily, determined by calculating the distance between the points C1'(i) and C2(i)' obtained from the orthogonal projection of the first and second points of intersection C1(i) and C2(i) on the vertical plane PV (Figure 6).

Following the calculation of the second distance Dy, the computation module 23 compares the second distance Dy with a second distance threshold SY and, on the basis of this comparison, checks whether or not a second condition of precision localization is satisfied (block 230).

In particular, the second condition of precision localization is satisfied when the second distance Dy is less than or equal to the second distance threshold SY:

Dy <= SY

In detail, if the second distance Dy is greater than the second threshold SY (NO exit from block 230), the computation module 23 implements a series of operations to minimize the second distance Dy between the two points C1(i)' and C2(i)' of the target 2 calculated in the two successive times t1' and t2'.

In particular, the minimization of the second distance Dy contemplates changing the Heading angles $\psi1i+1=\psi1i+/-\Delta\psi$ and $\psi2i+1=\psi2i+/-\Delta\psi$ by an equal amount, with a preset increment $+\Delta\psi$ or decrement $-\Delta\psi$, (block 250).

Following the assignment of the new value to the Heading angles $\psi1i+1$ and $\psi2i+1$, the computation module 23 reiterates the calculation operation for the first point C1(i+1) of intersection associated with time t1' and the Heading angle $\psi1i+1$ implemented in block 200, and the calculation operation for the second point C2(i+1) of intersection associated with time t2' and the Heading angle $\psi2i+1$ implemented in block 210.

At this point, the computation module 23 implements the following operations: recalculate the second distance Dy between the points C1'(i+1) and C2'(i+1) in the manner described in block 220 and compare the second distance Dy with the second maximum threshold SY (block 230); in the case where the second distance Dy is greater than the second maximum distance threshold SY (NO exit from block 230), the computation module 23 changes the Heading angles $\psi1i+1$ and $\psi2i+1$ again by the value $\Delta\psi$, equal for example to around two milliradians, and implements the calculation and comparison operations described in blocks 200-250.

If instead there is a convergence of the second distance Dy towards a value lower or equal to the second maximum distance threshold SY (YES exit from block 230), the computation module 23 determines the target position PYo with respect to the Y-axis, i.e. it assigns the component C1Y(i) of the point C1(i) along the Y-axis calculated during the last calculation cycle, or rather the i'th cycle, to the component of the target position PYo along the same Y-axis.

Regarding that described above, it is opportune to specify that the times t1' and t2' can correspond to the times t1 and t2, such that the determination of the points C1(i) and C2(i) of intersection takes place at the same times of calculation of the intersection points P1(i) and P2(i), or be different from them.

The advantages of the above-described system and associated method of operation are evident: the system is able to localize the position of the target with precision without the aid of a laser range-finder device, thereby reducing its manufacturing costs.

In particular, the sequential variation in the altitude of the aircraft 3 effected through the operations implemented in the above-described blocks 130-190 allows error cancellation in the calculation of both the ground altitude, thus permitting the exact position of the target along the Z-axis to be calculated, and the correct position of the target along an axis parallel to the direction of flight of the aircraft, or rather the second component of the target position.

In fact, the system is able to localize a target with a precision in the order of 10 m without resorting to a laser range-finder device and/or a precision inertial platform.

In addition, the method conveniently allows the position of the target to be determined with precision along the Y-axis, thus cancelling the incidence on this measurement of possible errors present in the measurement and determination of the Heading angle. It is evident however that in the case in which the error present in the Heading angle is not very significant, it is possible to determine the position PYo of the target along the Y-axis by assigning it the component along the same Y-axis of one of the points of intersection P1(i) or P2(i) that satisfy the first condition indicated in block 160.

Lastly, it is clear that modifications and variants can be made to the system and method described and shown herein without however leaving the scope of the present invention, as defined according to the enclosed claims.

CLAIMS

1. System (1) for the precision localization of a target (2) present on the ground by means of an aircraft (3) without the aid of a laser range-finder device, said system (1) comprising an aircraft (3), at least one camera (5) mounted on said aircraft (3) and trained according to its own tracking axis (A), means of movement (6,13) able to adjust the position of said camera (5) with respect to said aircraft (3) such that said tracking axis (A) remains trained on the target (2) during the flight of the aircraft (3), control means (8) for temporarily piloting the aircraft (3) along a substantially rectilinear flight segment above the area to monitor, and processing means (22) able to localize a target present on the ground and framed by said camera (5), said system (1) being characterized in that said processing means (22) comprise:
- calculation means (23) able to calculate during the flight of the aircraft (3) along said substantially rectilinear flight segment (TR), in at least two successive moments in time (t1,t2), at least two points of intersection (P1(i),P2(i)) between said tracking axis (A) and a theoretical plane (PTi) associated with the ground and having a preset initial altitude (QTi), said calculation means 23) being able to repeatedly vary the altitude (QTi) of said theoretical plane (PTi) by a preset value (ΔQT) and calculate, at each said altitude variation (ΔQT) of said theoretical plane (PTi), the position of said at least two points of intersection (P1(i))(P2(i)) in the theoretical plane (PTi) itself, until a first condition of precision localization is achieved, in which a first distance (Dx) between the two points of intersection (P1(i),P2(i)) has a minimum value less than a first preset threshold (SX), said calculation means (23) assign the altitude (QTi) of the theoretical plane (PTi) that satisfies said first condition of precision localization, in which said first distance (Dx) between the two points of

intersection (P1(i),P2(i)) is less than said first preset threshold (SX), to the position of the localized target.

2. System according to claim 1, in which said calculation means (23) determine the first distance (Dx), calculating the distance (Dx) between two points (P1'(i),P2'(i)) that are obtained from the projection of said first (P1(i)) and respectively second point of intersection (P2(i)) on a plane (PT') substantially orthogonal to said theoretical plane (PTi) and passing through a line coincident with the rectilinear flight segment (TR) flown by the aircraft (3).

3. System according to claim 1 or 2, comprising first sensor means measuring the Heading (ψ), Pitch (θ) and Roll (φ) angles of the aircraft (3) to determine the attitude of the aircraft (3) itself, second sensor means to detect the Pan (α) and Tilt (β) tracking angles of said camera (5) and means of detection (4) of the position of said aircraft (3), said calculation means (23) determine the spatial position of said tracking axis (A) at said first (t1) and second times (t2) based on the Heading (ψ), Pitch (θ) and Roll (φ) angles of the aircraft (3), the Pan (α) and Tilt (β) angles of said camera (5) and the positions of the aircraft (3) at the same two times (t1,t2).

4. System according to any of claims 1 to 3, comprising a video-tracking system (13) controlling said means of movement (6) to move said camera (5) in space to keep its tracking axis (A) trained on said target (2).

5. System according to any of the previous claims, comprising memory means (21) containing at least one digital cartographic map in which each point of the territory represented by the cartographic map is associated with a ground altitude, said theoretical plane (PTi) corresponding to the plane of said

digital cartographic map, and said initial theoretical altitude (QTi) corresponding to said altitude associated with said digital cartographic map.

6. System according to any of the previous claims in which said calculation means (23) measure the Heading angle (ψi) of said aircraft (3) in at least two successive moments in time (t1′,t2′) during the flight of the aircraft (3) along said substantially rectilinear flight segment (TR), and calculate in said two successive moments in time (t1′,t2′) at least two points of intersection (C1(i),C2(i)) between said tracking axis (A) and a theoretical plane (PTi) associated with the ground and having a preset altitude (QTR), said calculation means (23) being able to repeatedly vary the Heading angles (ψi) measured at said two successive moments in time (t1′,t2′) by the same preset value ($\Delta\psi$), and calculate the position of said two points of intersection (C1(i),C2(i)) on said preset theoretical plane (PTi) at each said variation ($\Delta\psi$), until a second condition of precision localization is achieved, in which a second distance (Dy) between said two points of intersection (C1(i), C2(i)) has a value less than a second preset threshold (SY), said means of calculation (23) being able to assign a component of one of the points of intersection (C1(i),C2(i)) that satisfy said second condition of precision localization to the position of the localized target.

7. System according to claim 6, in which said calculation means (23) determine said second distance (Dy) by calculating the distance (Dy) between two points (C1′(i),C2′(i)), which are obtained from the projection of said first point of intersection (C1(i)) and respectively second point of intersection (C2(i)) on a plane (PV) substantially orthogonal to said rectilinear path (TR) flown by said aircraft (3).

8. Method for the precision localization of a target (2) present on the ground without the aid of a laser range-finder device by means of a system (1) comprising an aircraft (3), at least one camera (5) mounted on said aircraft (3) and trained along its own tracking axis (A), means of movement (6,13) able to adjust the position of said camera (5) in space with respect to said aircraft (3) such that said tracking axis (A) remains trained on the target (2) during the flight of the aircraft (3), control means (8) for temporarily piloting the flight of the aircraft (3) along a rectilinear flight segment (TR), and processing means (22) able to localize the position of said target (2), said method being characterized in that it comprises the phases of:

a) calculating (130, 140), in at least two successive moments in time (t1, t2) during the movement of the aircraft (3) along said rectilinear flight segment (TR), at least two respective points of intersection (P1(i),P2(i)) between said tracking axis (A) and a theoretical plane (PTi) associated with the ground and having a preset initial altitude (QTi),

b) repeatedly varying said altitude (QTi) of said theoretical plane by a preset value (ΔQT),

c) calculating, at each said variation (ΔQT) in altitude of the theoretical plane (PTi), the position of said at least two points of intersection (P1(i), P2(i)) in the same theoretical plane (PTi), until a first condition of precision localization is reached, which is satisfied when a first distance (Dx) between the two points of intersection (P1(i), P2(i)) has a value lower than a first preset threshold (SX), and

d) assigning the altitude (QTi) of the theoretical plane (PTi) that satisfies said first condition of precision localization to the position of the localized target (2).

9. Method according to claim 8, in which said phase of determining said first distance (Dx) comprises the phase of calculating a first distance (Dx) between two points

(P1'(i),(P2'(i)) obtained from the projection of said first (P1(i)) and respectively second point of intersection (P2(i)) on a plane (PT') substantially orthogonal to a reference plane (PTO) and passing through a line coincident with the rectilinear flight segment (TR) flown by the aircraft (3).

10. Method according to claim 9, comprising the phases of:
- measuring the Heading (ψ), Pitch (θ) and Roll (φ) angles of the aircraft (3) to determine the attitude of the aircraft (3),
- detecting the Pan (α) and Tilt (β) tracking angles of said camera (5) and the position of said aircraft (3),
- said phase c) comprising the phase of determining the spatial position of said tracking axis (A) in said first (t1) and second (t2) times based on the Heading (ψ), Pitch (θ) and Roll (φ) angles of said aircraft (2), the Pan (α) and Tilt (β) angles of said camera (5) and the spatial position assumed by the aircraft (3) at the same two times (t1,t2).

11. Method according to claim 9 or 10, in which said system (1) comprises memory means (21) containing a digital cartographic map having a preset altitude, said phase a) comprising the phase of assigning the plane of said digital cartographic map to the theoretical plane (PTi), and assigning the ground altitude represented in said digital cartographic map to said initial theoretical altitude (QTi).

12. Method according to any of claims 8 to 11, comprising the phases of:
- measuring in at least two successive moments in time (t1',t2') during the flight of the aircraft (3) along said flight segment (TR), the Heading angle (ψi1,ψi2) of said aircraft (3),
- calculating during said successive moments in time (t1',t2'), at least two points of intersection (C1(i),C2(i))

between said tracking axis (A) and a theoretical plane (PTi) associated with the ground and having a preset altitude (QTR),
- repeatedly varying the measured Heading angles (ψi1,ψi2) by a preset value ($\Delta\psi$),
- calculating the position of said two points of intersection (C1(i), C2(i)) on said preset theoretical plane (PTi) at each said variation ($\Delta\psi$), until a second condition of precision localization is achieved, in which a second distance (Dy) between said two points of intersection (C1(i),C2(i)) has a minimum value lower than a second preset threshold (SY), and
- assigning a component of one of the points of intersection (C1(i),C2(i)) that satisfies said second condition of precision localization to the position of the localized target.

13. Method according to claim 12, comprising the phase of determining said second distance (Dy), calculating the distance (Dy) between two points (C1'(i), C2'(i)), which are obtained from the projection of said first (C1(i)) and respectively second point of intersection (C2(i)) on a plane (PV) substantially orthogonal to said rectilinear path (TR) flown by said aircraft (3).

14. Computer characterized in that it implements a method as indicated in any of claims 8 to 13.

15. Software product that can be loaded into the memory of the processing means and is designed to implement, when executed, the method according to any of claims 8 to 13.

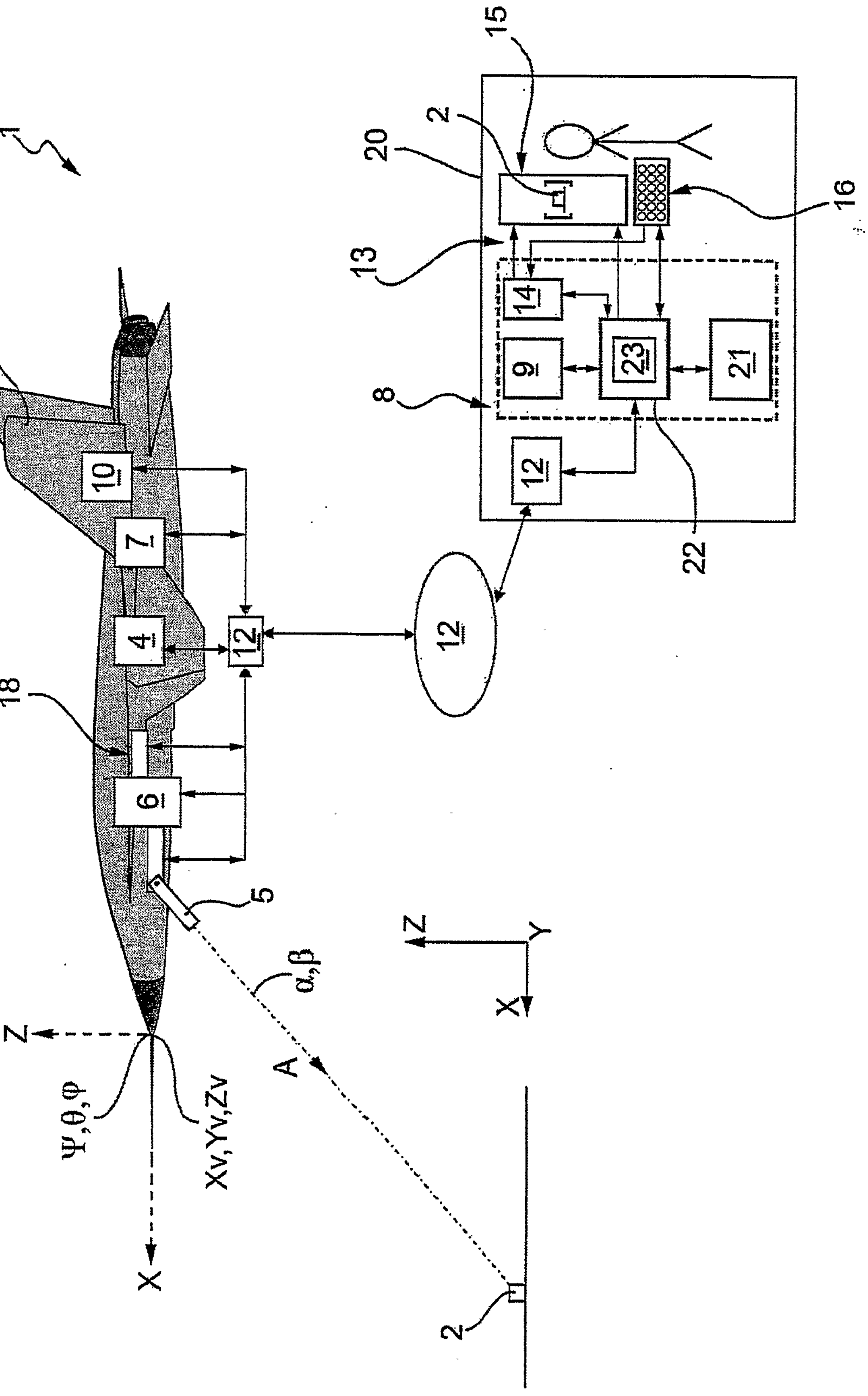

1
3
18
4
7
10
12
6
5
A
α,β
Z
X
Ψ,θ,φ
Xv,Yv,Zv
2
Z
Y
X
12
8
13
20
2
15
16
14
9
23
21
12
22

FIG. 1

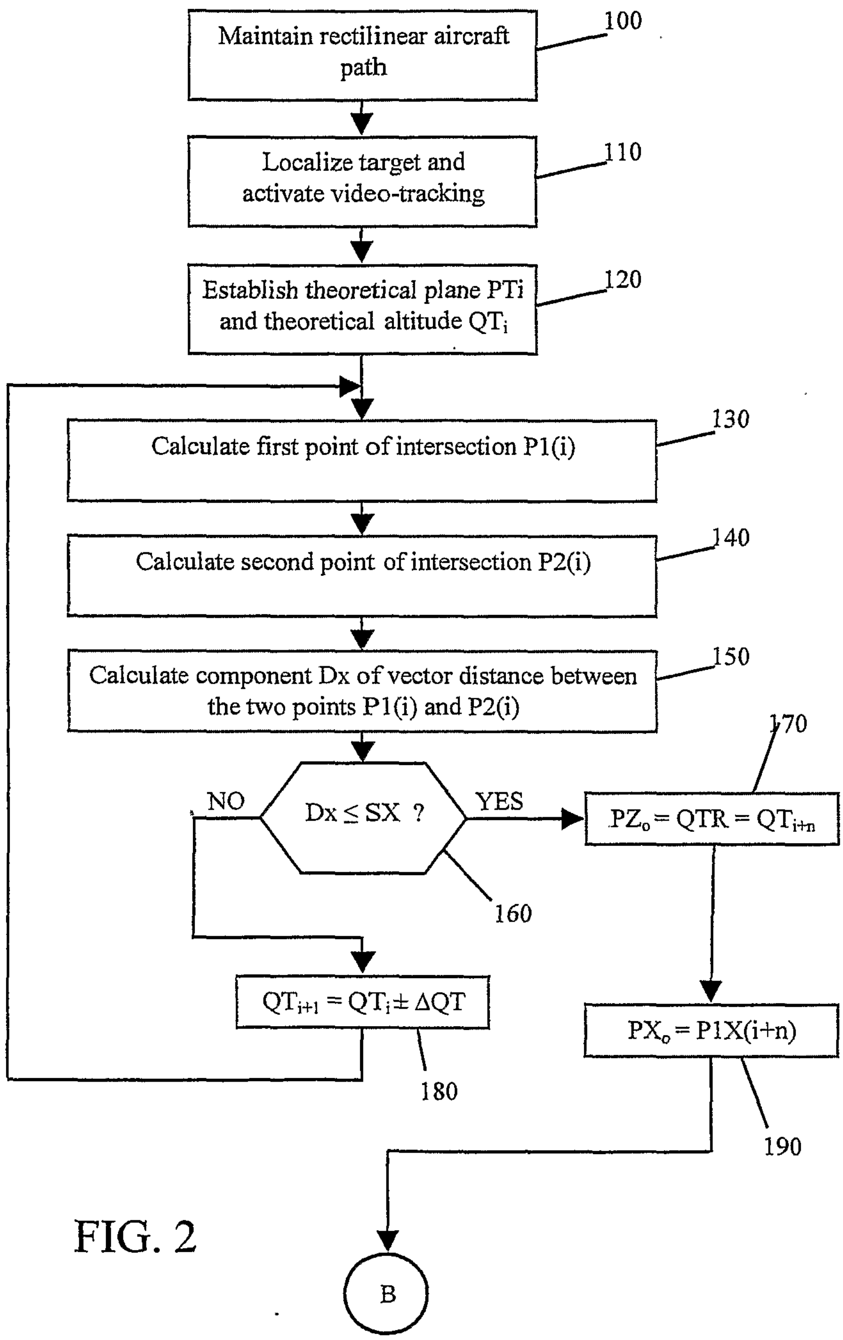

Maintain rectilinear aircraft path
100
Localize target and activate video-tracking
110
Establish theoretical plane PTi and theoretical altitude QT$_i$
120
Calculate first point of intersection P1(i)
130
Calculate second point of intersection P2(i)
140
Calculate component Dx of vector distance between the two points P1(i) and P2(i)
150
Dx ≤ SX ?
NO
YES
160
$PZ_o = QTR = QT_{i+n}$
170
$QT_{i+1} = QT_i \pm \Delta QT$
180
$PX_o = P1X(i+n)$
190
B

FIG. 2

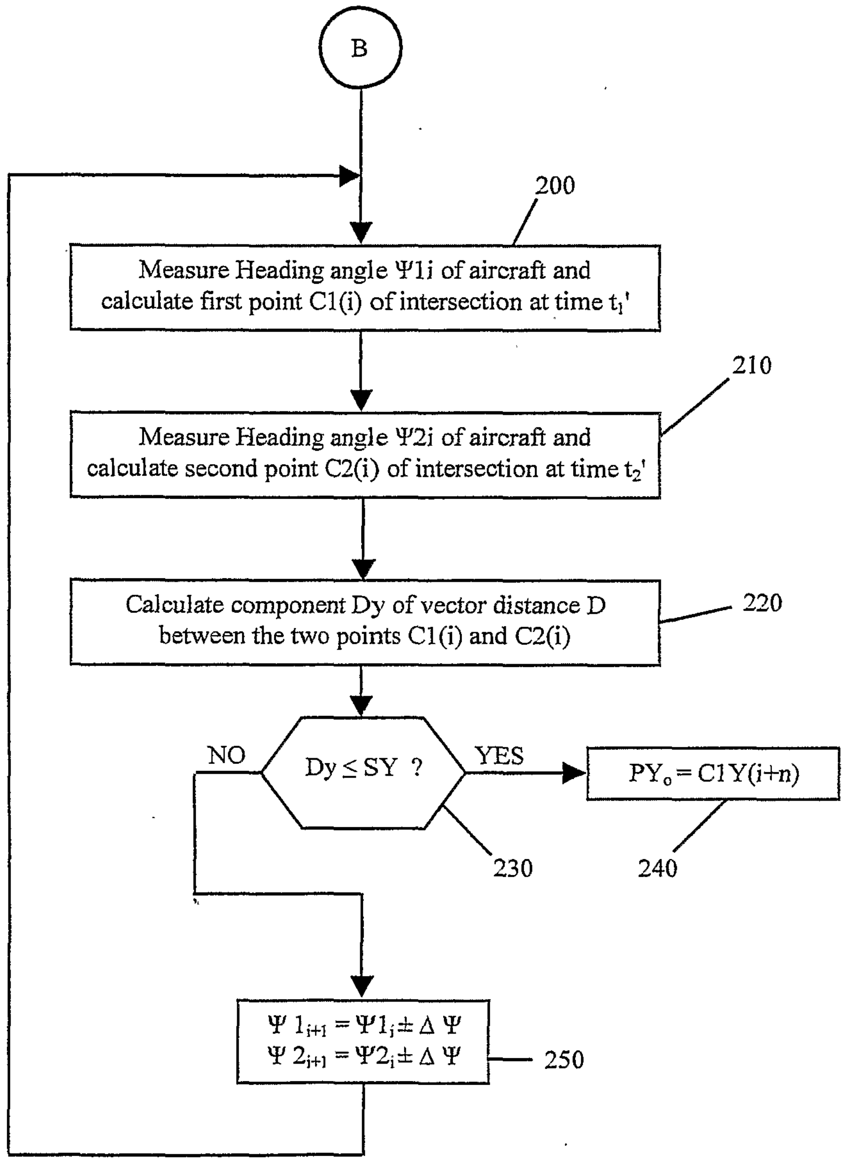

B
200
Measure Heading angle Ψ1i of aircraft and calculate first point C1(i) of intersection at time t1'
210
Measure Heading angle Ψ2i of aircraft and calculate second point C2(i) of intersection at time t2'
Calculate component Dy of vector distance D between the two points C1(i) and C2(i)
220
NO
Dy ≤ SY ?
YES
PYo = C1Y(i+n)
230
240
Ψ 1i+1 = Ψ1i ± Δ Ψ
Ψ 2i+1 = Ψ2i ± Δ Ψ
250

FIG. 3

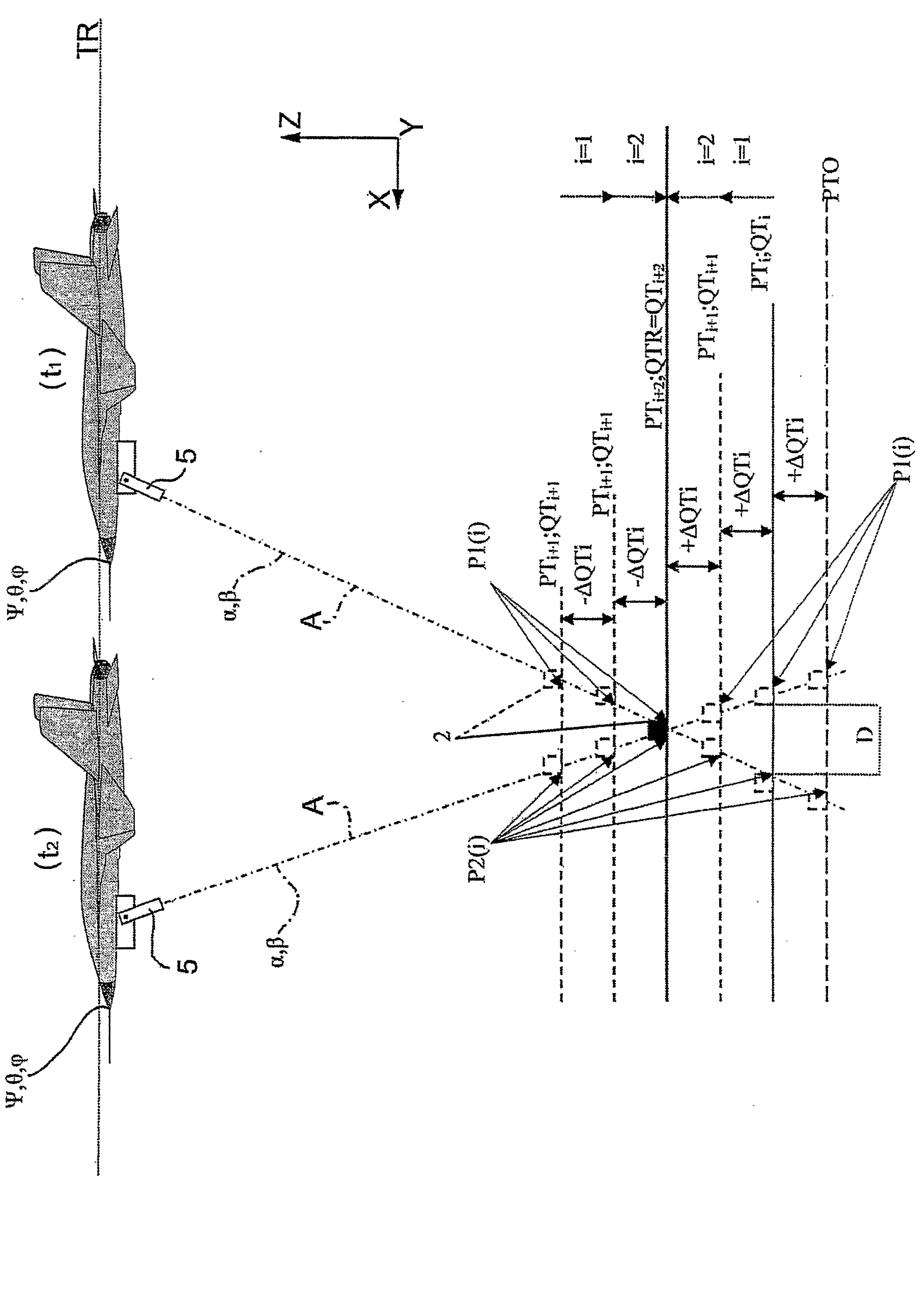

TR
Z
Y
X
(t1)
(t2)
5
5
Ψ,θ,φ
Ψ,θ,φ
α,β
α,β
A
A
2
P1(i)
P1(i)
P2(i)
D
PTO
i=1
i=2
i=2
i=1
-ΔQTi
-ΔQTi
+ΔQTi
+ΔQTi
+ΔQTi

FIG. 4

FIG. 5

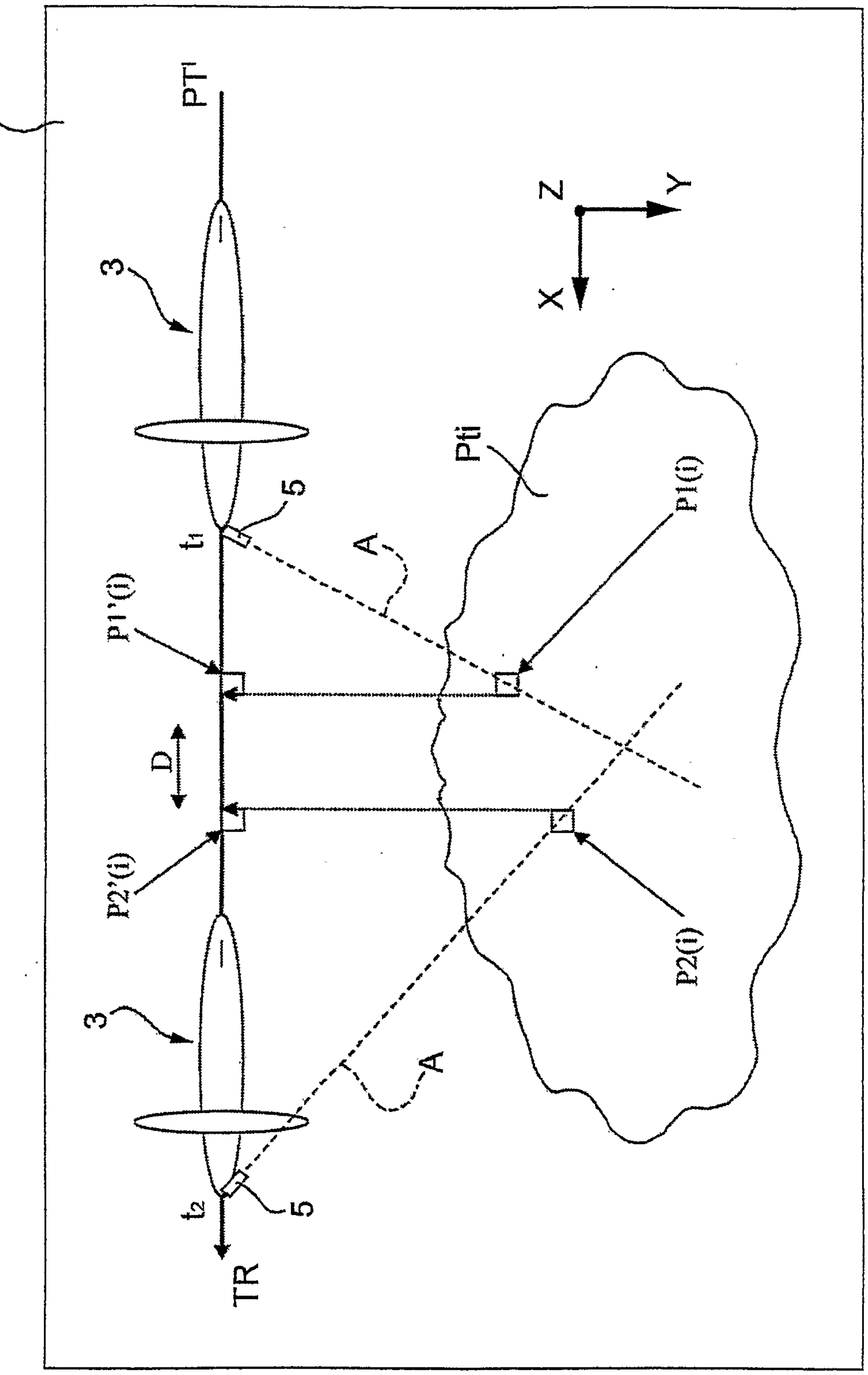


FIG. 6

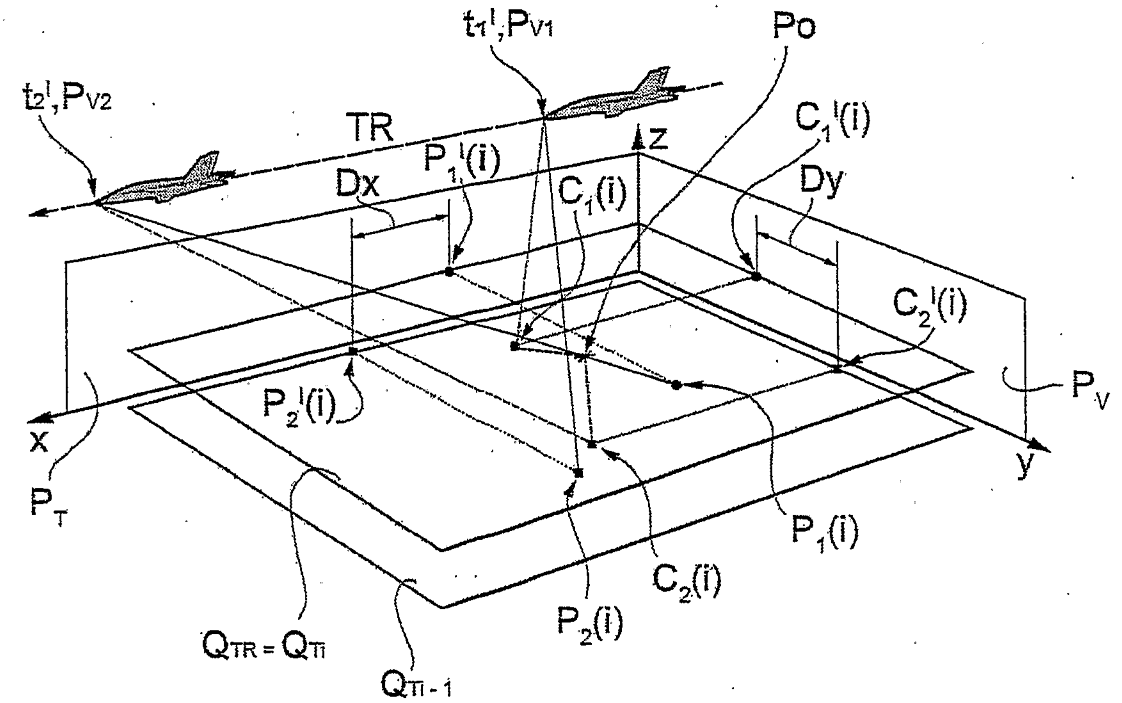
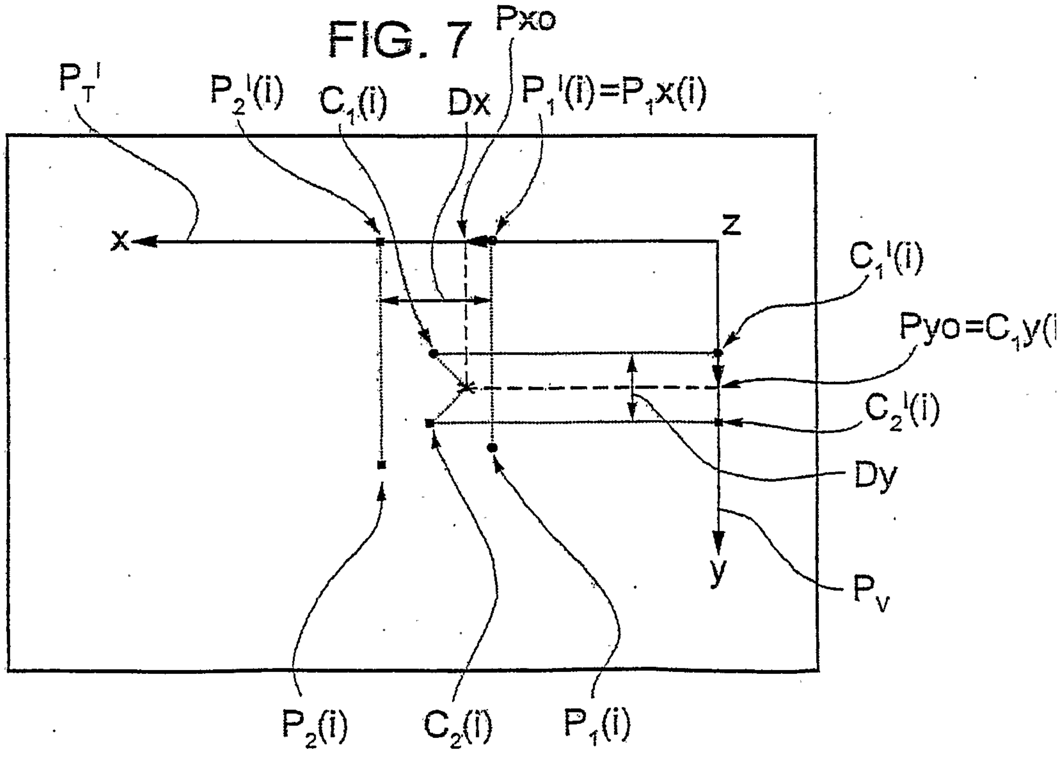

t2I,PV2
t1I,PV1
Po
TR
z
C1I(i)
Dx
P1I(i)
C1(i)
Dy
C2I(i)
PV
x
P2I(i)
y
PT
P1(i)
C2(i)
P2(i)
QTR = QTi
QTi-1

FIG. 7


Pxo
PTI
P2I(i)
C1(i)
Dx
P1I(i)=P1x(i)
x
z
C1I(i)
Pyo=C1y(i
C2I(i)
Dy
y
PV
P2(i)
C2(i)
P1(i)

INTERNATIONAL SEARCH REPORT

International application No
PCT/IT2007/000740

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01S3/786 G01S5/16 G01S11/12 G01C3/08 G01C21/20

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 G01C

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

Electronic data base consulted during the international search (name of data base and, where practical, 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.
A	EP 1 801 610 A (ROHDE & SCHWARZ [DE]) 27 June 2007 (2007-06-27) paragraph [0008] - paragraph [0010]; figures 1,2	1-15
A	DE 37 35 062 A1 (SCHWEGLER H FLORIAN DR [DE]) 27 April 1989 (1989-04-27) column 2, line 58 - column 4, line 12; figure 1	1-15
A	EP 1 783 455 A (RAFAEL ARMAMENT DEV AUTHORITY [IL]) 9 May 2007 (2007-05-09) abstract paragraph [0045] - paragraph [0050]	1-15

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 April 2008	13/05/2008

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Dollinger, Franz

3

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IT2007/000740

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
EP 1801610	A	27-06-2007	DE 102005061596 A1	28-06-2007
DE 3735062	A1	27-04-1989	NONE	
EP 1783455	A	09-05-2007	NONE	