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(54) Device and method for control of a weapon system.

(57) Control device (2) suitable for application with a weapon system (3), e.g. a gun (14b), for generating control signals, e.g. aiming signals SP_R for the gun, using target trajectory data P_d obtained with a sensor (1), e.g. a pulse radar apparatus (5). Additionally, the control device (2) additionally generates quality-factor representing signals, e.g. indicating a misdistance between a present predicted hitting point (TP) of a gun-fired projectile with the target and a present target position. For this purpose, the control device (2) stores during a certain time span in a memory 15 signals, such as hitting points TP and time of flight TTP, on the basis of which the aiming signals SP_R are generated.

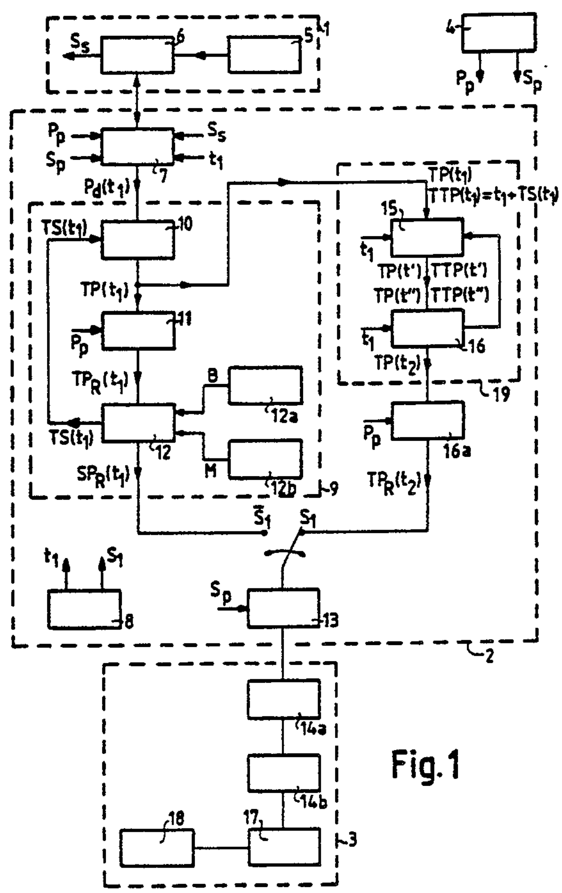

Fig.1

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The invention relates to a control device suitable for application with a weapon system, for generating control signals with which at least one object can be manoeuvred towards a second object and where, for the purpose of generating the control signals, the control device is provided with target data obtained with a first sensor indicating the present position of the second object.

The invention also relates to a method, suitable for application in a weapon system, for generating control signals with which at least one object can be manoeuvred towards a second object and where control signals are generated on the basis of target data obtained with a first sensor, indicating the present position of the second object.

An example of an embodiment of such a weapon control system is known from patent specification GB-A 2.140.538. In this specification the weapon system, in this case a gun, is controlled by the control device, in this case a weapon control computer, which for that purpose is provided with target data from a radar tracking device suitable for tracking a moving target.

The control device computes an optimal gun aiming point for the gun to achieve that the first object, in this case a missile, fired by the gun is directed towards the vicinity of the moving target representing the second object.

To determine the availability of the weapon system against certain targets and the operation of the entire chain in the weapon control system as part of a test procedure or exercise it is necessary to be able to assess the system's operation under operational conditions. In the case of the above-mentioned embodiment, a measure for the operational quality of the system may be the hitting probability with respect to the projectile hitting the target. Actually, under operational conditions the hitting probability is not only determined by the operation of a target tracking sensor, the control device and the weapon system, but also by the target. The effectiveness of the control device is strongly determined by the quality of target measurements by the target tracking sensor and by the behaviour of the target. An unexpected change in the target trajectory after a non- or partly correctable projectile has been fired by the weapon system may result in the projectile missing the target. This will occur especially in case of projectile times of flight which are long when compared to the intervals between the unexpected target manoeuvres.

A well-known test procedure to specify the hitting probability of a weapon control system is to fire projectiles at a towed target. Although in this procedure all factors determining the hitting probability are included in the assessment, the procedure remains limited to a non-realistic target and target trajectory. Another disadvantage of this test procedure is that real ammunition is used, leading to high costs.

Another well-known test procedure for a weapon system provided with a gun, in which no firing takes place, is to aim the gun, which is provided with well-known video registration equipment including a barrel camera, at a hitting point of projectile with target calculated by the control device, while a zero projectile time of flight is assumed. A disadvantage of this test procedure is that it does not include the influence of unexpected target manoeuvres occurring during the projectile time of flight.

The present invention has for its object to provide a device and method for control, suitable for application with a weapon system, for generating control signals such as described in the opening paragraph, offering a possibility for a test procedure under operational conditions against realistic targets, while the above-mentioned objections are obviated.

According to the invention, the control device is characterised in that it generates quality-factor representing signals resulting from a continuous comparison of first signals, comprising information on the basis of which a certain time span ago control signals were generated, and second signals comprising information on the present position of the second object.

The method according to the invention is characterised in that quality-factor representing signals are generated resulting from a continuous comparison of first signals, comprising information on the basis of which a certain time span ago control signals were generated, and second signals comprising information on the present position of the second object.

The advantage of the present invention is that the influence of target manoeuvres occurring during the said time span on the control device is taken into account in the test procedure.

It should be noted that patent specification WO-A 81/00149 describes a device where calculated aiming values are stored in a memory during a projectile flight time or part thereof, and are compared with target position measurements. However, this patent specification concerns a correction device with a completely different objective, viz. the automatic correction of calculated aiming values for guns. The correction device therefore does not calculate quality-factor representing signals. Storage and comparison in the correction device leads to active intervention in the calculation of the aiming values by means of feed-back, while in the device according to the invention, storage and comparison of the first signals do not affect the aiming values but only serve to obtain quality-factor representing signals as an assessment of the operation of the control device.

A special embodiment is obtained when the second signals are obtained by means of an electro-optic sensor which is aimed by means of the first signals. Besides enabling assessment of the operation of the first sensor, this method also makes it possible to obtain a visual impression of the operation of the weapon control chain.

In an embodiment in which the first signals represent, among other things, a predicted hitting point of the first and second objects, a difference in predicted hitting point and present position of the second object can thus be shown.

In an embodiment where the control device is suitable for mounting on a moving platform and where the control device is provided with platform signals containing information on the orientation, velocity and position of the platform with respect to a reference coordinate system, a further advantage is obtained because the control device by means of the platform signals continuously calculates the displacement of the platform and stores these displacement values during at least a certain time span in a memory. Thus a parallax occurring as a result of displacement of the platform may be corrected. Moreover, a way is provided to assess whether the platform signals are processed correctly and in the proper manner.

The device and method for control according to the invention may be applied in various weapon systems.

In an application where the first object is a projectile fired by a gun at a moving target representing the second object, where the gun is aimed with control signals from the control device, for the purpose of generating the control signals, the control device continuously calculates, by means of a prediction of a projectile trajeotory and a target trajectory, future hitting points and corresponding times of impact of target and projectile, an embodiment of the invention is characterised in that the first signals relate to present hitting points and times of impact calculated a certain time span ago and relating to the present.

In an application where the first object is a projectile correctable by the control device, an embodiment is obtained by the control device calculating a future maximum interception area of the projectile with the second object and the first signals concern the present interception area calculated a certain time span ago and relating to the present.

The system and method according to the invention will now be described with reference to the accompanying figures of which:

Fig. 1 is a first embodiment of a control device according to the invention applied in a weapon control system provided with a gun, a target tracking sensor and an electro-optic sensor using the same aiming means as the gun;

Fig. 2 is a second embodiment of a control device in a similar weapon control system in an application where the electro-optic sensor is provided with its own aiming means;

Fig. 3 is a third embodiment of a control device in a similar weapon control system suitable for mounting on a moving platform.

Fig. 1 represents a first embodiment of a control device according to the invention applied in a weapon control system which is provided with a target sensor 1, the control device 2 and a weapon system 3. This figure shows a platform sensor unit 4 which is provided with suitable sensors for measuring the orientation S_p and position P_p of the platform on which the weapon control system is fitted.

Target sensor 1 is fitted with a pulse radar apparatus 5 supplying bearing and range information of a target with respect to a line of sight of an antenna of the pulse radar apparatus. Target sensor 1 can also be an electro-optic sensor such as an IR or a TV camera, possibly provided with a laser range finder. The antenna is provided with aiming means 6, placing the antenna in the desired orientation by means of orientation readers recording the orientation S_s of the antenna with respect to the platform. For this purpose, aiming means 6 are provided with servos and so-called synchros. The bearing and range information of the target, the information relating to the orientation S_s of the antenna, the information with respect to the orientation S_p of the platform and the data relating to the position P_p of the platform are supplied to control device 2. The measured target data are, by means of data relating to the orientation S_s of the antenna, the orientation S_p and position P_p of the platform, preferably converted (block 7) to a first reference coordinate system, which is preferably earth-orientated. Moreover, the measured target data are filtered ("target track filtering", block 7) for the purpose of control signals for aiming means 6. The converted target data $P_d(t_1)$, indicated at regular intervals at a first point in time with t_1 (block 8), are used to calculate a gun aiming point $SP_R(t_1)$ for weapon system 3 (block 9). For this purpose, by means of a target trajectory model and an initial estimation of a time of flight $TS(t_1)$ of a projectile to be fired from weapon system 3, a future target position after this time of flight is calculated (block 10). This future hitting point $TP(t_1)$ calculated at a first point in time t_1 is converted by means of data concerning the position P_p of the platform to a relative future hitting point $TP_R(t_1)$ with respect for the platform (block 11). Subsequently, a model of the projectile trajectory is used to make a new calculation (block 12) of the projectile time of flight $TS(t_1)$, which calculation is used as an improved estimation of the projectile time of flight in the new calculation of the future hitting point $TP(t_1)$. If, after this reiteration, the relative future hitting point $TP_R(t_1)$ is calculated sufficiently accurately, a relative gun aiming point $SP_R(t_1)$ for weapon system 3 is calculated (block 12) by means of the projectile trajectory model. The projectile trajectory model uses stored ballistic and meteorological data B and M (blocks 12a and 12b).

When using the control device in a normal weapon control mode, indicated by control signal $\overline{S}_1$, the calculated relative gun aiming point $SP_R(t_1)$ is converted to platform coordinates by means of data concerning the orientation S_p of the platform (block 13). On the basis of the converted gun aiming point, control signals are generated (block 13) for aiming means 14a which aim a launching system 14b.

Use of the control device in a mode suitable for assessment of the aiming of the weapon system at the target according to the invention is indicated with control signal S_1. In this mode, at time t_1, weapon system 3 is not controlled on the basis of gun aiming point $SP_R(t_1)$, but on the basis of a previously calculated and stored (block 19) hitting point $TP_R(t_2)$, which is valid at the present time t_1. Time t_2 relates to the point in time at which this hitting point was calculated.

For this purpose, at certain intervals, the calculated future hitting points $TP(t_1)$, a time validity $TTP(t_1)$ corresponding with this hitting point and the point in time t_1 at which these data were calculated, are stored in a memory (block 15) during a certain period of time. The time validity $TTP(t_1)$ is obtained by adding to t_1 the corresponding projectile time of flight $TS(t_1)$. This memory consists of a cyclic buffer whose cycle time is longer than the longest expected projectile time of flight. In order to find the present hitting point $TP(t_2)$ valid at time t_1, two hitting points $TP(t')$ and $TP(t'')$ are taken from the memory in which the future hitting points are stored, together with the corresponding time validity $TTP(t')$ and $TTP(t'')$ for which $t' < t_1 \leq t''$ (blocks 15 and 16). The present hitting point $TP(t_2)$, together with the time validity of t_1, is calculated by means of a linear interpolation between hitting points $TP(t')$ and $TP(t'')$ (block 16).

The above-described method of interpolation is simple and hence requires less computing time than extensive methods of interpolation. If a higher accuracy is required, it is also possible to use non-linear interpolation between more than two hitting points.

Instead of storing the calculated hitting points $TP(t_1)$, an embodiment may also store, during a particular time, the target trajectory data $P_d(t_1)$ or data derived thereof. The present hitting point calculation will then have to be carried out at a time t_1, on the basis of the stored target trajectory data which were valid at an earlier time t_2.

The present hitting points $TP(t_2)$ are converted by means of data P_{pi} relating to the position of the platform (block 16a), to present hitting points $TF_R(t_2)$ relative to the position of the platform. These relative present hitting points $TP_R(t_2)$ are subsequently converted (block 13) by means of data S_p, relating to the orientation of the platform, to a coordinate system connected to the platform for the purpose of generating control signals for continuous aiming of weapon system 3 at these present hitting points.

A launching system 14b in the form of a gun has, for the purpose of the use of the control device in mode S_1, been provided with a well-known barrel camera 17 for aligning the gun. Equipment 18, processing the barrel camera video to check the alignment with a target sensor in the form of radar apparatus, is used in mode S_1 to assess the aiming of the gun.

A difference between the present hitting point and the present target position as visible on video 18 from barrel camera 17 may subsequently be further processed in various ways. In the embodiment described, the video information is continuously supplied to a user for assessment, which user is able to obtain an impression of the operation of the weapon control system.

Another embodiment is obtained when assessment is automated by the calculation of quality values, such as hitting probability, by means of data concerning dispersion relating to the trajectory, effectiveness of the projectile and target dimensions. An embodiment including a barrel camera 17 is, strictly speaking, not required if the orientation of the gun has been calculated accurately enough. This orientation can be measured by the said readers, such as synchros, and compared by the control device with the stale hitting points.

Fig. 2 shows an embodiment of a control device in an application in a similar weapon control system which, for the purpose of aiming at the present hitting points, has been fitted with a second target sensor 22 provided with its own aiming means 20. The control device 2 is executed in such a way that, besides conversion of gun aiming points (block 13), simultaneous conversion of present hitting points is executed (block 21). In this embodiment, the second target sensor is coupled in mode S_1 to the control device and continuously aimed at the present hitting points. In mode $\overline{S}_1$, the second target sensor is available for another weapon control channel 23.

The weapon control systems according to Figs. 1 and 2 are intended for mounting on a fixed platform. In the most simple embodiment, platform sensors 4 consist of means for once-only determination of the platform data relating to orientation S_p and position P_p. In a simpler embodiment, a distinction between earth-oriented coordinates and coordinates determined by the platform is not required. Conversion from and to relative coordinates is therefore no longer necessary.

Fig. 3 shows an embodiment of a control device applied in a weapon control system suitable for mounting on a moving platform. Platform sensors 4 continuously supply data relating to orientation S_p, data relating to position P_p, but also data relating to the own velocity V_p of the platform. The platform sensors 4 may consist of well-known gyro's, acceleration and velocity meters. The control device 2, by means of data relating to position P_p and velocity V_p of the platform, calculates the displacement of the platform at certain intervals at points in time indicated with t_1 (block 24). Position $P_p(t_1)$ at this time, velocity $V_p(t_1)$ at this time and the time t_1 are stored in a memory (block 25) during a certain period of time. This memory is executed as cyclic memory of which the cycle time exceeds the maximum expected projectile time of flight. Subsequently, the present hitting point $TP(t_2)$ (block 19) corresponding with a time t_1 is corrected (block 16a) for own displacement $\Delta P_p(t_2)$ of the platform from time t_2 till time t_1. To determine this own displacement, two stored platform positions $P_p(t')$ and $P_p(t'')$ are retrieved from memory 25, with $t' < t_2 < t''$ (block 26). Subsequently, the platform displacement $\Delta P_p(t_2)$ as from time t_2 is found by linear interpolation between these platform positions (block 26).

It should finally be stated that this description does not include the processing times required for data processing and measurement in order to avoid unnecessarily complicating the description.

Claims

1. Control device suitable for application with a weapon system, for generating control signals with which at least one object can be manoeuvred towards a second object and where, for the purpose of generating the control signals, the control device is provided with target data obtained with a first sensor indicating the present position of the second object, characterised in that the control device generates quality-factor representing signals resulting from a continuous comparison of first signals, comprising information on the basis of which a certain time span ago control signals were generated and second signals comprising information on the present position of the second object.

2. Control device as claimed in claim 1, characterised in that the second signals are obtained by means of the first sensor.

3. Control device as claimed in claim 1, characterised in that the second signals are obtained by means of an electro-optic sensor which is aimed by means of the first signals.

4. Control device as claimed in one of the above claims, characterised in that the control device is provided with a memory for storing at least during the said time span information on the basis of which control signals are obtained for the purpose of generating the first signals.

5. Control device as claimed in one of the above claims, characterised in that the certain time span at least equals the time required by the first object for covering a trajectory from a starting position of the first object up to a position in the vicinity of the second object.

6. Control device as claimed in one of the claims 1-4, characterised in that the certain time span equals the time required for covering a part of a trajectory from a starting position of the first object up to a position in the vicinity of the second object.

7. Control device as claimed in one of the above claims, where the control device is suitable for mounting on a moving platform and where the control device is provided with platform signals containing information on the orientation, velocity and position of the platform with respect to a reference coordinate system, characterised in that the control device by means of the platform signals continuously calculates the displacement of the platform and stores these displacement values during at least a certain time span in a memory.

8. Control device as claimed in claim 7, characterised in that the control device continuously corrects the first signals for the present orientation and the displacement of the platform during the certain time span with respect to the reference coordinate system.

9. Control device as claimed in one of the above claims, where the first object is executed as a projectile suitable for being fired by a gun at the second, moving object, where the gun is aimed by the control signals from the control device and the control device, for the purpose of generating the control signals, continuously calculates future hitting points and accompanying times of impact of the second object and the projectile on the basis of a prediction of a projectile trajectory and a trajectory of the second object, characterised in that the

first signals concern the present hitting points and times of impact calculated the certain time span ago and relating to the present.

10. Control device as claimed in one of the claims 1-8, where the first object is executed as a projectile correctable by the control device, characterised in that the control unit calculates a future maximum interception area of the projectile with the second object and the first signals concern the present interception area calculated a certain time span ago and relating to the present.

11. Control device as claimed in claims 3 and 9, characterised in that the electro-optic sensor is fitted on the gun.

12. Method suitable for application in a weapon system for generating control signals with which at least one object can be manoeuvered towards a second object and where control signals are generated on the basis of target data obtained with a first sensor indicating the present position of the second object, characterised in that quality-factor representing signals are generated resulting from a continuous comparison of first signals, comprising information on the basis of which a certain time span ago control signals were generated, and second signals comprising information on the present position of the second object.

13. Method as claimed in claim 12, characterised in that the second signals are obtained by means of the first sensor.

14. Method as claimed in claim 12, characterised in that the second signals are obtained by means of an electro-optic sensor which is aimed by means of the first signals.

15. Method as claimed in one of the claims 12-14, characterised in that at least during the said time span information on the basis of which control signals are obtained is stored for the purpose of generating the first signals.

16. Method as claimed in one of the claims 12-14, characterised in that the certain time span at least equals the time required by the first object for covering a trajectory from a starting position of the first object up to a position in the vicinity of the second object.

17. Method as claimed in one of the claims 12-15, characterised in that the certain time span equals the time required for covering a part of a trajectory from a starting position of the first object up to a position in the vicinity of the second object.

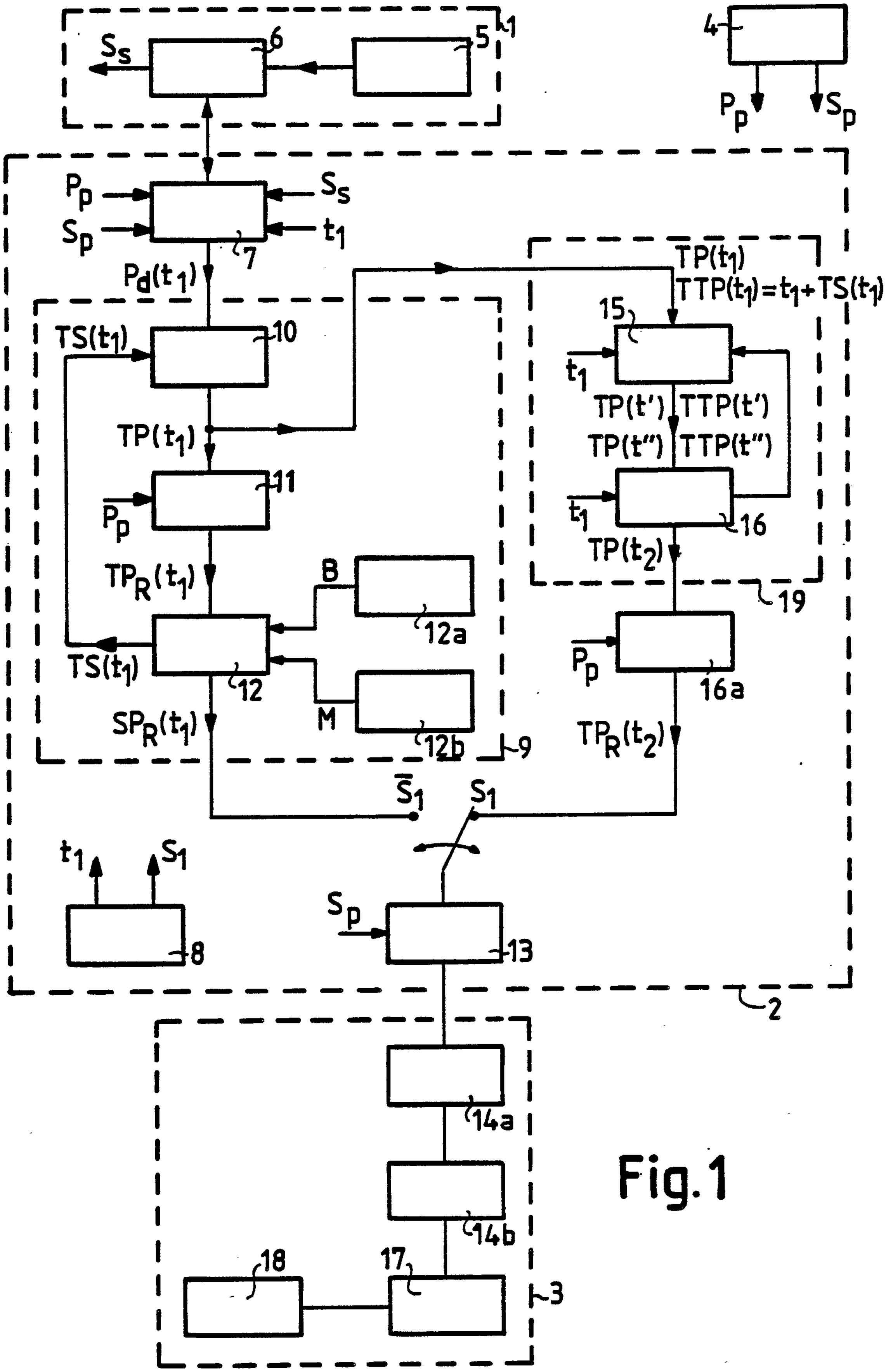
18. Method as claimed in one of the claims 12-17 for application on a moving platform, where use is made of platform signals containing information on orientation, velocity and position of the platform with respect to a reference coordinate system, characterised in that the displacement of the platform is continuously calculated on the basis of the platform signals, and the displacement values are stored at least during the certain time span.

19. Method as claimed in claim 18, characterised in that the first signals are continuously corrected by the present orientation and the displacement of the platform during the certain time span with respect to the reference coordinate system.

20. Method as claimed in one of the claims 12-19, where the first object is fired by a gun at the second, moving object, where the gun is aimed by the control signals and, for the purpose of generating the control signals, the control device continuously calculates, by means of a prediction of a projectile trajectory and a trajectory of the second object, future hitting points and corresponding times of impact of the second object and the first object, characterised in that the first signals concern the present hitting points and times of impact calculated the certain time span ago and relating to the present.

21. Method as claimed in one of the claims 12-19, where the first object is correctable by control signals, characterised in that a future maximum interception area is calculated of the first object with the second object and the first signals concern the present interception are calculated the certain time span ago and relating to the present.

22. Method as claimed in claims 14 and 20, characterised in that the electro-optic sensor is fitted on the gun.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12a
12b
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14b
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17
18
19
S_s
P_p
S_p
t_1
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TS(t_1)
TP(t_1)
TP_R(t_1)
SP_R(t_1)
B
M
TTP(t_1)=t_1+TS(t_1)
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TTP(t')
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TTP(t'')
TP(t_2)
TP_R(t_2)
S̄_1
S_1

Fig.1

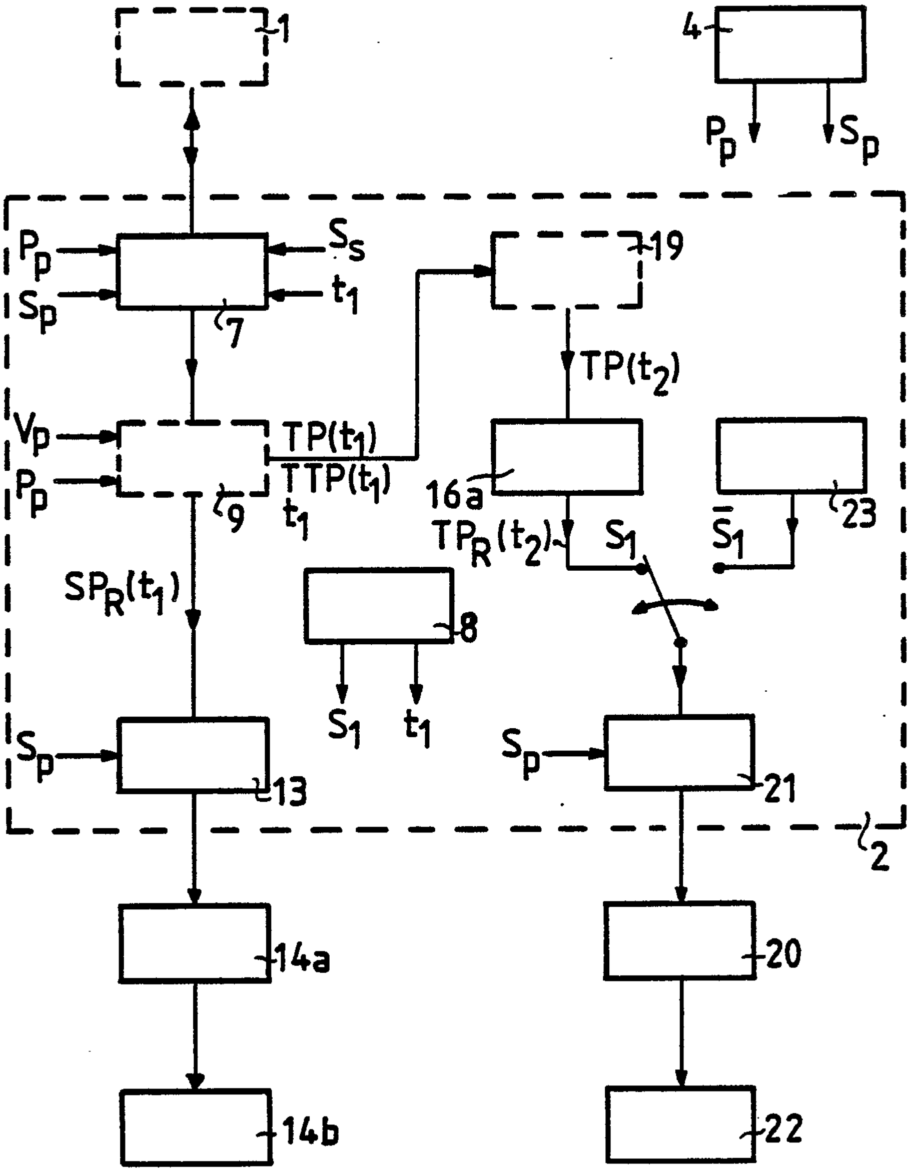
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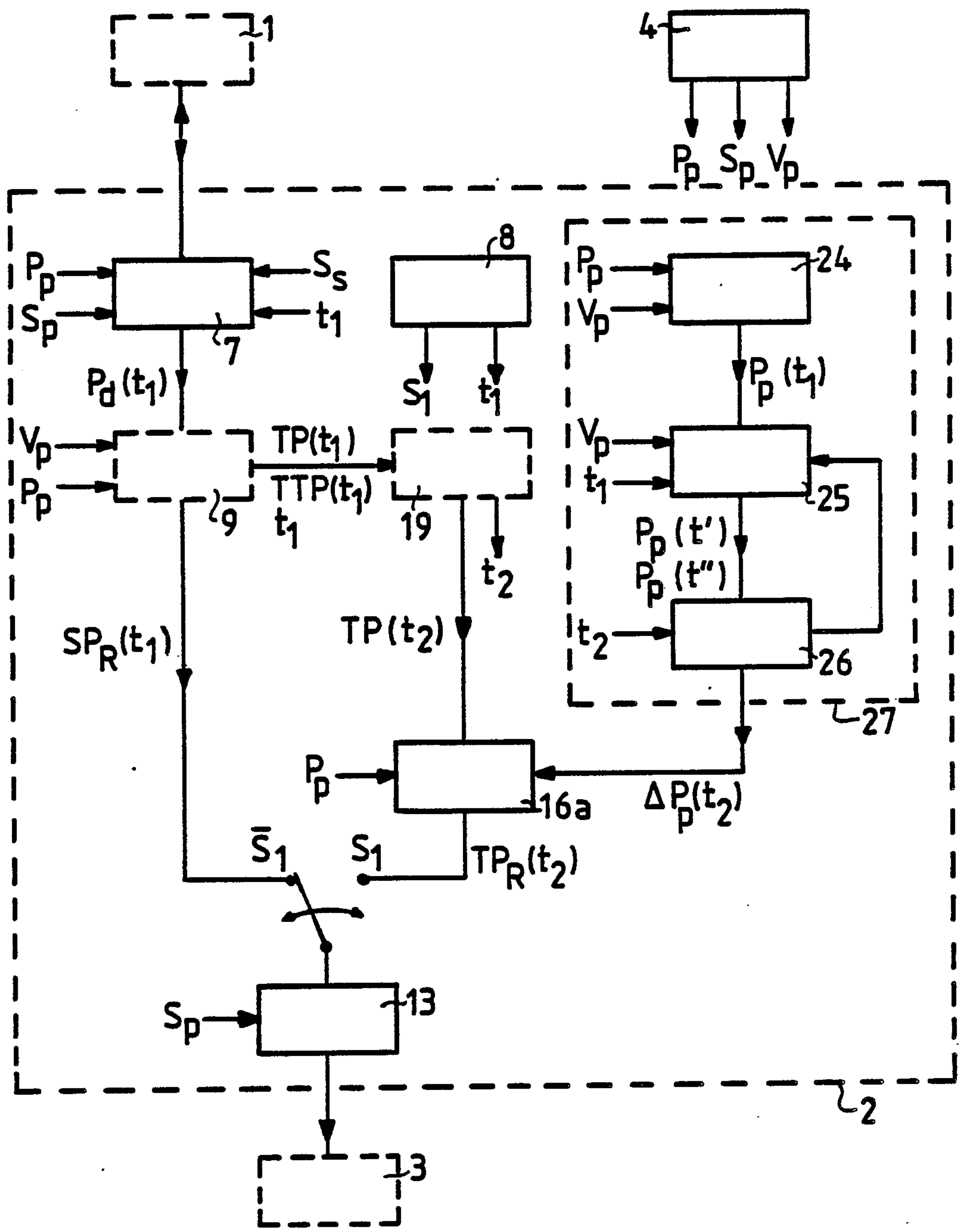
Fig. 2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13
2
3

Fig. 3

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 89 20 1478

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
X	US-A-4 320 287 (H.C. RAWICZ) * Whole document *	1-4,6,9,12-15,17,20	F 41 G 5/08 F 41 G 5/14 F 41 G 7/30
X	WO-A-8 100 149 (HOLLANDSE SIGNAALAPPARATEN) * Figure 1; page 2, line 24 - page 4, line 14; page 8, lines 9-19 *	1,2,4,5,7-9,12,13,15,16,18-20	
A	EP-A-0 207 521 (CONTRAVES) * Whole document *	1	
A	EP-A-0 070 541 (SIEMENS) * Figure 1; page 4, line 10 - page 5, line 14 *	1,2,4,9,12,13	
A	FR-A-2 378 318 (THOMSON-CSF)	1,7,12,18	
A	US-A-4 647 759 (R.H. WORSHAM et al.)		TECHNICAL FIELDS SEARCHED (Int. Cl.4)
A	US-A-3 848 509 (R.J. CORN)		F 41 G
A	GB-A-2 095 799 (H. BAASCH)		

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	04-09-1989	CHAIX DE LAVARENE C.P.H.

CATEGORY OF CITED DOCUMENTS

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