(19) DANMARK

(10) **DK/EP 2464943 T3**

Patent- og Varemærkestyrelsen

(12) Oversættelse af europæisk patentskrift

(51) Int.Cl.: ***F 41 G 3/22 (2006.01)*** ***F 41 G 7/00 (2006.01)*** ***F 41 G 9/00 (2006.01)***

(45) Oversættelsen bekendtgjort den: **2020-07-13**

(80) Dato for Den Europæiske Patentmyndigheds bekendtgørelse om meddelelse af patentet: **2020-05-06**

(86) Europæisk ansøgning nr.: **10743212.2**

(86) Europæisk indleveringsdag: **2010-08-10**

(87) Den europæiske ansøgnings publiceringsdag: **2012-06-20**

(86) International ansøgning nr.: **GB2010051323**

(87) Internationalt publikationsnr.: **WO2011018656**

(30) Prioritet: **2009-08-12 GB 0914109** **2009-08-12 EP 09251978** **2009-12-02 GB 0921089**

(84) Designerede stater: **AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO SE SI SK SM TR**

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(54) Benævnelse: **SYSTEMINTEGRATION**

(56) Fremdragne publikationer:
WO-A2-2007/020477
US-A- 4 160 250
D CLARK, A FAUST, A JONES: "Common Launch Acceptability Region Task Group", SAE WORLD AVIATION CONGRESS - PROCEEDINGS OF THE 2001 AEROSPACE CONGRESS, 14 October 2001 (2001-10-14), pages 1-10, XP002562059, Seattle, USA
SINGH A ET AL: "Launch Envelope Optimization of Virtual Sliding Target Guidance Scheme", IEEE TRANSACTIONS ON AEROSPACE AND ELECTRONIC SYSTEMS, IEEE SERVICE CENTER, PISCATAWAY, NJ, US, vol. 45, no. 3, 1 July 2009 (2009-07-01), pages 899-918, XP011277342, ISSN: 0018-9251

DESCRIPTION

[0001] This invention relates to the integration of systems and, more particularly, to the integration of weapons on complex, highly integrated aircraft.

[0002] Integration of a weapon system with the other systems on an aircraft is a complex and lengthy task, as it affects all the major aircraft systems. Accordingly there is a requirement to improve weapon integration time and affordability.

[0003] One of the requirements of weapon integration is to enable the display of information to the aircraft pilot as to whether or not a weapon is capable of successfully engaging a particular target. For this purpose, weapons are usually grouped into two categories, weapons designed to engage targets on the ground (air to ground weapons) and weapons designed to engage targets in the air (air to air weapons). In the case of air to ground weapons, a Launch Acceptability Region (LAR) is calculated, being the region where the probability of successfully engaging or hitting a selected target is above some threshold value. The LAR is calculated in order to provide cockpit displays in the launch aircraft indicating the feasibility of successfully engaging the target, and is a function of the weapon performance characteristics, the relative positions and motions of the aircraft and the target, and often ambient conditions such as wind speed and direction.

[0004] For an air to air weapon, a Launch Success Zone (LSZ) is calculated, indicative of the probability of successfully engaging a selected air target is about some threshold value. Again the LSZ is used to provide a cockpit display indicating whether the weapon is capable of successfully engaging the target. However, calculation of a LSZ is more complicated than the calculation of a LAR, because the relative speeds and directions of travel of the launch aircraft and the target are much greater, and consequently the effects of ambient conditions are greater, and also the physical properties of the weapons in flight are more significant on the calculation.

[0005] The conventional approach has been to create a simple, abstract model of the weapon, which is modified according to the launch conditions (taking into account the aircraft and target conditions (e.g. range, direction and speed of travel, etc.) and the ambient conditions). The model is used on board the aircraft to generate the LAR or LSZ for display to the pilot. A disadvantage of the conventional approach is that each model, for each different weapon type, is different. Storing the data relating to several different implicit models consumes significant storage capacity, and each model has to be comprehensively integrated to ensure that there is no adverse effect on any of the aircraft systems. Further, if there are any changes or modifications made to a weapon (such as an improvement in performance) or if it is necessary to load the aircraft with a completely new weapon, a lengthy and expensive integration process has to be conducted because the weapon model is substantially different to anything previously integrated with the aircraft systems.

[0006] D Clark, A Faust, and A Jones disclose a "Common Launch Acceptability Task Group" in SAE World Aviation Congress - Proceedings of the 2001 Aerospace congress, 14 October 2001, pages 1-10 (XP002562059).

[0007] Singh A et al disclose a "Launch Envelope Optimization of Virtual Sliding Target Guidance Scheme" in IEEE transactions on Aerospace and Electronic Systems, IEEE Service Centre, Piscataway, NJ, US, vol. 45, No. 3, 1 July 2009 pages 899-918 (XP011277342).

[0008] Accordingly, the present invention provides a system according to claim 1 for generating in a first aircraft in flight a display indicative of the feasibility of a weapon carried on the first aircraft or a second successfully engaging the other aircraft, the system comprising a first generator, which may be a ground station, configured for generating a database describing a performance envelope of the weapon, a second generator configured for creating coefficients characteristic of that performance envelope using a generic algorithm wherein the generic algorithm has the form of a polynomial, by a) generating candidate polynomials the variables of the polynomials being some or all of a group of weapon or aircraft firing condition parameters, b) for each candidate polynomial, computing coefficients for that candidate polynomial which best fit that candidate polynomial to a characteristic of the performance envelope of the weapon using a criterion of least square error, c) for each candidate polynomial, generating a candidate score according to the quality of the fit of that candidate polynomial to the characteristic of the performance envelope of the weapon, d) applying a genetic algorithm to the candidate polynomials and scores including selecting the best scoring polynomials and discarding the other polynomial(s), thereby identifying a best candidate polynomial and coefficient set , and e) repeating said identifying process until all the required characteristics of the performance envelope have corresponding polynomial models ; an uploader configured for uploading the coefficients to the first aircraft, and a reconstructor on the first aircraft containing the same generic algorithm and configured to select the coefficients for the generic algorithm according to conditions of both aircraft and, using the selected coefficients, generate the feasibility display.

[0009] Such a system significantly improves weapon integration time and cost. A minimal number of generic weapon aiming algorithms are required in order to take account of all weapon types (air to air and air to surface, and powered or unpowered). The generic algorithms can be tailored to different weapons, depending on the weapon aiming methodology adopted, simply by changing the coefficients used in the algorithm. The coefficient can be implemented as loadable data so as to allow accurate and precise weapon behaviour to be implemented within the weapon system. Also, using one or only a few generic algorithms would allow different weapon systems to be cleared or certificated/qualified for use with the aircraft with reduced effort and more quickly than with the extensive testing which is required with conventional approaches. The use of generic algorithms for weapon aiming also enables increases or significant changes in weapon system capability to be integrated with the aircraft systems with significantly less effort then heretofore.

[0010] Preferably the algorithm is a standard polynomial of the form:

$M_{..}$

$$y_n = \sum_{m=1}^{n} \alpha_{mn} x_1^{p_{1mn}} x_2^{p_{2mn}} \ldots$$

where:

α_{mn} represent the m coefficients required to compute output n;

$\{x_1 .. x_{Ni}\}$ represent the normalised inputs; and

$\{y_1 .. y_{Nj}\}$ represent the outputs.

[0011] The invention also provides, in a second aspect, a method according to claim 4 for generating in a first aircraft in flight a display indicative of the feasibility of a weapon carried on the first aircraft or a second aircraft successfully engaging the other aircraft comprising:

generating a database describing the weapon performance envelope of the weapon;

creating coefficients characteristic of that performance envelope using a generic algorithm wherein the generic algorithm has the form of a polynomial, by; a) generating candidate polynomials the variables of the polynomials being some or all of a group of weapon or aircraft firing condition parameters, b) for each candidate polynomial, computing coefficients for that candidate polynomial which best fit that candidate polynomial to a characteristic of the performance envelope of the weapon using a criterion of least square error, c) for each candidate polynomial, generating a candidate score according to the quality of the fit of that candidate polynomial to the characteristic of the performance envelope of the weapon, d) applying a genetic algorithm to the candidate polynomials and scores including selecting the best scoring polynomials and discarding the other polynomial(s), thereby identifying a best candidate polynomial and coefficient set, and e) repeating said identifying process until all the required characteristics of the performance envelope have corresponding polynomial models,

uploading to the first aircraft the generated coefficients; and

selecting, by a reconstructor on the first aircraft containing the same generic algorithm, the coefficients for the generic algorithm according to conditions of both aircraft, and using the selected coefficients, generating, by the reconstructor, the feasibility display.

[0012] The method may comprise generating new polynomials to replace those discarded and repeating steps b) and c) until there is no further significant improvement in candidate scores. Further, the outputs of the selected polynomials may be used to provide the inputs so as to create higher order candidate polynomials. Still further, the method may comprise iterating the steps of the second aspect and generating new polynomials to replace those discarded and repeating steps b) and c) until there is no further significant improvement in candidate scores on the higher order candidate polynomials, and obtaining a final result recursively from the path ending with the best candidate score.

[0013] The aircraft and target conditions may include one or more of their relative positions, distances, directions of movement, speeds and ambient atmospheric conditions.

[0014] The coefficients specific to a weapon are preferably uploaded to the aircraft when the weapon is loaded as a weapon store. All that is required when loading a new weapon store to integrate the weapon and aircraft aiming system is at the same time to load the coefficients associated with that weapon into the aircraft system; ideally the coefficient could be stored on a hardware device with the weapon, and the devise connected to the aircraft to upload the coefficient data as the weapon is loaded.

[0015] The database may be generated by defining the range of conditions for which the weapon may be required to be fired, the range of aircraft conditions for which it is feasible for the aircraft to fire the weapon and the range of weapon conditions for which it is feasible to fire the weapon;
generating data indicative of the weapon performance for each weapon firing possibility from within the defined ranges, and creating a database defining the weapon's overall performance envelope.

[0016] In this way the database can be generated on a ground-based system, so that the aircraft system needs the capacity only to store the algorithm and process the coefficients with the aircraft and target conditions in order to generate the feasibility display, thus reducing the amount of data storage/processing capacity required on the aircraft.

[0017] The method may also comprise inputting into the reconstructor coefficients characteristic of the performance envelope of a weapon carried by another aircraft, reconstructing that performance envelope using the generic algorithm and, according to the conditions of both aircraft and the performance envelope, generating a display indicating the feasibility of the aircraft being successfully engaged by the weapon on the other aircraft.

[0018] In this way, the same aircraft system can also display whether or not, or to what extent, the aircraft is at risk of being successfully engaged by a weapon carried by a hostile aircraft, which may be a hostile aircraft which the host aircraft is deciding whether or not to engage. The generic algorithm enables the calculation of opposing LSZs and allows better assessment of air to air engagements. This in turn could lead to confident predictions of advantage and likely outcome of engagements.

[0019] An embodiment of the invention will now be described by way of example and with reference to the accompanying drawings, in which:

Figures 1a and 1b illustrate the Launch Acceptability Region (LAR) for an air to surface weapon;

Figure 2 illustrates the Launch Success Zone (LSZ) for an air to air weapon;

Figure 3 is a schematic illustration of an embodiment of the present invention, and

Figure 4 is a schematic diagram illustrating one embodiment of the coefficient generator technique in accordance with the invention.

[0020] Figure 1a shows the LAR in the plane of flight of a launch aircraft 1 flying along a flight path 3 in respect of a target 5 for an air to surface weapon (not shown) loaded on the aircraft. The LAR is calculated to provide cockpit displays in the launch aircraft 1 concerning the feasibility and firing opportunities for the situation. Figures 1b shows the display generated for the LAR of Figure 1a, which is in the form of a downrange and cross range display (the shaded area), where the weapon flight path 7 coincides with the aircraft flight path 3; to successfully engage the target 5 as shown in the display, the target must fall inside the shaded LAR. As the aircraft 1 moves in the downrange direction, the displayed LAR is bounded by the minimum and maximum ranges, R_{min} and Rmax.

[0021] The LSZ shown in Figure 2 is the region where the probability of an air to air weapon hitting an airborne target T is above a threshold level. Calculation of the LSZ is more complicated than for the LAR, because a greater number of factors are involved, such as the relative velocities and directions of travel of the launch aircraft and the target, and those of the weapon relative to the target. Also, the shape of the LSZ is more complex than that of the LAR; as with the LAR, there are maximum and minimum ranges, R_{max} and R_{min}, between which the target T can be successfully engaged, but there is a zone bounded by R_{min} within which the Target T cannot be engaged successfully because it is outside the capability of the weapon to manoeuvre and hit the target when the launch aircraft is so close to the target, given the speeds and directions of travel of the launch aircraft and the target T.

[0022] As is known in the art, there are two LSZs, one for the launch aircraft to engage the target 7 and the other for the target to engage the launch aircraft.

[0023] It is often a requirement to calculate the LAR or LSZ for an engagement to display to the crew of the launch aircraft information regarding the feasibility, or likelihood of success, of the engagement, and to aid fire control and steering decisions. The traditional approach has been to create a simple, abstract model of the weapon that has parameters defined by the launch conditions; this model is then used on board the launch aircraft to generate the LAR or LSZ and the appropriate display.

[0024] Figure 3 shows the system of the present invention schematically, and is divided between those processes 11 which are carried out on the ground and the processes 13 which are carried out on the launch aircraft. The processes begin with the generation of the data space, which is the range of conditions over which the weapon performance envelope is to be defined; this is effected by a data space generator 15, and depends on the ranges of conditions: for which it is required to fire the weapon (which is defined by the weapon user/operator); for which it is feasible to fire according to the launch aircraft capability, and for which it is feasible to fire according to the weapon capability/performance. The data space generator 15 defines the release, weather and commanded impact conditions for training and verification sets which are run by a truth data generator 17. The truth data generator 17 generates the weapon performance for each firing case in the data space; this depends on the weapon performance model which is usually provided by the weapon manufacturer. The product of the truth data generator 17 is the truth database 19, which is a set of data relating to a number of exemplary weapon firings which is sufficient to define the weapon's performance envelope. The truth data generator 17 produces the training and verification sets which are used by a coefficient generator 21. Conventionally, the truth database is used as a model which can be employed onboard the launch aircraft in order to generate the feasibility of engagement displays (LAR or LSZ, as appropriate).

[0025] In the present invention a coefficient generator 21 receives the true weapon performance envelope represented by the truth database and calculates and generates coefficients according to a generic LAR/LSZ algorithm 23 - the coefficients "fit" the generic algorithm to the weapon performance envelope shape.

[0026] The coefficient generator 21 may generate coefficients by building training and verification footprints (representing the target engagement envelope) from data extracted from the truth database, by fitting a geometric shape to the training footprint and by defining the coefficients for the generic algorithm. The coefficient generator then verifies the coefficients against the verification sets by creating footprints based on the coefficients at the verification set conditions and by confirming that these verification footprints meet the criteria for successful engagement.

[0027] In an alternative method of coefficient generation, illustrated in Figure 4, the number of inputs 27 and the form of each polynomial descriptor, $PD^{\text{Layer, Node}}$, are determined by an optimisation method known as the Genetic Algorithm. In this method the coefficient generator starts by creating an initial set of candidate polynomials whose variables are some or all of the weapon or aircraft firing condition parameters. For each candidate polynomial, the set of coefficients are computed that give the best "fit" to a single characteristic of the required LAR/LSZ using the criterion of least square error; also computed is the quality of the fit in each case, the latter referred to as the candidate "score".

[0028] The Genetic Algorithm is applied to the candidate polynomials and scores. The best polynomials are retained and the worst rejected. New candidates that have similar features to the retained candidates are created to replace the rejected ones. The coefficients giving the least squares fit and the scores are then calculated for this new generation of candidates.

[0029] The Genetic Algorithm is repeated until improvement in the scores of the best candidates ceases. The result is the first layer, Layer 1, of a Self-Organising Polynomial Neural Network (SOPNN) where each node describes a polynomial function that relates the weapon or aircraft firing condition parameters to a characteristic of the required LAR/LSZ.

[0030] The whole process is then repeated with the outputs of the first layer providing the inputs to create a second layer, Layer 2, of the SOPNN. The new layer has the effect of creating higher-order candidate polynomials and coefficients for consideration. The selection of polynomials in the new layer is again governed and optimised by the Genetic Algorithm.

[0031] Layers are added to the SOPNN in this way until improvement in the scores of the best candidates ceases - a completed network comprising two layers is represented in Figure 4. The final network is obtained recursively from the path ending at the output node with the best score in the final generation of candidates (the "Optimum Solution"). Any node with no connection to this path is discarded as shown in Figure 4, where nodes which contribute to the optimal solution are lightly shaded and discarded nodes are black.

[0032] The best single candidate polynomial and coefficient set is identified and stored. This process is repeated until all the required characteristics of the LAR/LSZ have corresponding polynomial models.

[0033] The generic LAR/LSZ algorithm is predetermined, and in the present invention is a polynomial equation of the form:

$$y_n = \sum_{m=1}^{M_n} \alpha_{mn} x_1^{p_{1mn}} x_2^{p_{2mn}} \ldots$$

Where:

α_{mn} represent the *m* coefficients required to compute output *n*;

$\{x_1 .. x_{Ni}\}$ represent the normalised inputs; and

$\{y_1 .. y_{Nj}\}$ represent the outputs.

[0034] Referring again to Figure 3, the output of the coefficient generator 21 is the set of coefficients which is loaded onto the launch aircraft by a data uploader. Following this step, the onboard processes 13 comprises a reconstructor 25, which brings together the generic LAR/LSZ algorithm 23 (which is held in the aircraft systems) and the uploaded coefficients, so as to reconstruct the LAR or LSZ for a particular engagement by selecting the appropriate algorithm and coefficients for the launch conditions. In the present invention, a single algorithm allows the rapid change between different weapons payloads simply by uploading a set of data representing the coefficients applicable to the new weapon. Once the LAR or LSZ has been reconstructed for a particular engagement by the systems onboard the aircraft, the LAR or LSZ is displayed by conventional means onboard the aircraft.

REFERENCES CITED IN THE DESCRIPTION

Non-patent literature cited in the description

- **D CLARKA FAUSTA JONES**Common Launch Acceptability Task GroupSAE World Aviation Congress - Proceedings of the 2001 Aerospace congress, 2001, 1-10 [0006]
- Launch Envelope Optimization of Virtual Sliding Target Guidance Scheme**SINGH A et al.**IEEE transactions on Aerospace and Electronic SystemsIEEE Service Centre20090701vol. 45, 899-918 [0007]

Patentkrav

1. System til at generere, i et første luftfartøj (1) under flyvning, en visning, der indikerer muligheden for at et våben, der er båret på det første (1) luftfartøj eller et andet luftfartøj (T), med succes engagerer med det andet luftfartøj, hvor systemet omfatter:

en første generator (17), der er konfigureret til at generere en database (19), der beskriver præstationsegenskaber for våbnet;

en anden generator (21), der er konfigureret til at danne koefficienter, som er karakteristiske for præstationsegenskaber under anvendelse af en generisk algoritme (23), hvor den generiske algoritme har formen af en polynomium, ved

a) at generere kandidatpolynomier, hvor variablerne af polynomierne er nogle af eller alle af en gruppe af våben- eller luftfartøjsaffyringsbetingelsesparametre,

b) for hvert kandidatpolynomium, at beregne koefficienter for det kandidatpolynomium, som bedst passer til det kandidatpolynomium med en karakteristik af præstationegenskaber for våbnet under anvendelse af et kriterium af mindste kvadratafvigelse,

c) for hvert kandidatpolynomium, at generere et kandidatpointtal ifølge kvaliteten af pasningen af det kandidatpolynomium med karakteristikken af præstationsegenskaber af våbnet,

d) at anvende en genetisk algoritme til kandidatpolynomierne og point, der omfatter at vælge de bedst scorende polynomier og at frasortere det eller de andre polynomier, for derved at identificere et bedste kandidatpolynomium og koefficientsæt, og

e) at gentage nævnte identifikationsproces indtil alle de krævede karakteristika af præstationsegenskaber har tilsvarende polynommodeller;

en udlæser, der er konfigureret til at udlæser koefficienterne til det første luftfartøj
(1); og

en rekonstruktør (25) på det første luftfartøj (1), der omfatter den samme generiske algoritme (23) og er konfigureret til at vælge koefficienterne for den generiske algoritme (23) ifølge forholdene for begge luftfartøjer (1, T) og, under anvendelse af de valgte koefficienter, at generere mulighedsvisningen.

2. System ifølge krav 1, hvor den første generator er en landstation.

3. System ifølge krav 1 eller 2, hvor den generiske algoritme (23) er en polynomium af formen:

$$y_n = \sum_{m-1}^{M_n} \alpha_{mn} x_1^{p_{1mn}} x_2^{p_{2mn}} \ldots$$

hvor:

a_{mn} repræsenterer m-koefficienterne, som kræves for at beregne output n;

$\{x_1 \,..\, x_{Ni}\}$ repræsenterer de normaliserede inputs; og

$\{y_1 \,..\, y_{Nj}\}$ repræsenterer outputsene.

4. Fremgangsmåde til at generere, i et første luftfartøj (1) under flyvning, en visning, der indikerer muligheden for at et våben, der er båret på det første (1) eller et andet luftfartøj (T), med succes engagerer med det andet luftfartøj, hvor fremgangsmåden omfatter:

at generere en database (19), der beskriver præstationsegenskaber af våbnet;

at danne koefficienter, der er karakteristiske forn præstationsegenskaber under anvendelse af en generisk algoritme (23), hvor den generiske algoritme har formen af et polynomium, ved at

a) generere kandidatpolynomier, hvor variablerne af polynomierne er nogle eller alle af en gruppe af våben- eller luftfartøjsaffyringsbetingelsesparametre;

b) for hvert kandidatpolynomium, at beregne koefficienter for det kandidatpolynomium, som bedst passer det kandidatpolynomium med en karakteristik af præstationsegenskaber af våbnet under anvendelse af et kriterium af mindste kvadratafvigelse,

c) for hvert kandidatpolynomium, at generere et kandidatpointtal ifølge kvaliteten af pasningen af det kandidatpolynomium med karakteristikken af præstationsegenskaber af våbnet, og

d) at anvende en genertsk algoritme til kandidatpolynomierne og point, der omfatter at vælge de bedst scorende polynomier og at frasortere det eller

de andre polynomier, for derved at identificere et bedste kandidatpolynomium og et koefficientsæt;
e) at gentage nævnte identifikationsproces indtil alle de krævede karakteristika for præstationsegenskaber har tilsvarende polynommodeller;
at udlæse, til det første luftfartøj (1), de genererede koefficienter; og
at vælge, ved hjælp af en rekonstruktør (25) på det første luftfartøj (1), der indeholder den samme generiske algoritme (23), koefficienterne for den generiske algoritme (23) ifølge betingelserne for begge luftfartøjer (1, T), og, under anvendelse af de valgte koefficienter, at generere, ved hjælp af rekonstruktøren (25), mulighedsvisningen.

5. Fremgangsmåde ifølge krav 4, omfattende at generere nye polynomier til at erstatte disse frasorterede og gentage trin b) og c) ifølge krav 4 indtil der ikke er nogen yderligere signifikant forbedring i kandidatpointtal.

6. Fremgangsmåde ifølge krav 5, hvor outputsene af de valgte polynomier anvendes til at tilvejebringe inputsene for at danne kandidatpolynomer med højere orden.

7. Fremgangsmåde ifølge krav 6, yderligere omfattende at gentage trinnene ifølge krav 4 og 5 på kandidatpolynomierne med højere orden, og at opnå et slutresultat rekursivt fra baneenden med det bedste kandidatpointtal.

8. Fremgangsmåde ifølge et hvilket som helst af kravene 4 til 7, hvor den generiske algoritme (23) er et polynomium af formen:

$$y_n = \sum_{m=1}^{M_n} \alpha_{mn} x_1^{p_{1mn}} x_2^{p_{2mn}} \ldots$$

hvor:

a_{mn} repræsenterer m-koefficienterne, som kræves for at beregne output n;
$\{x_1 .. x_{Ni}\}$ repræsenterer de normaliserede inputs; og
$\{y_1 .. y_{Nj}\}$ repræsenterer outputsene.

9. Fremgangsmåde ifølge et hvilket som helst af kravene 4 til 8, hvor luftfartøjs-(1, T) betingelserne inkluderer en eller flere af deres relative positioner, distancer, bevægelsesretninger, hastigheder og omgivende atmosfærebetingelser.

10. Fremgangsmåde ifølge et hvilket som helst af kravene 4 til 9, hvor koefficienterne, der er specifikke for et våben, udlæses til det første luftfartøj (1), når våbnet lastes som et luftfartøjslager.

11. Fremgangsmåde ifølge et hvilket som helst af kravene 4 til 10, hvor databasen (19) er genereret af:

at definere området af betingelser, for hvilke våbnet kan kræve at blive affyret, området for luftfartøjsbetingelser, for hvilke det er muligt for luftfartøjet at affyre våbnet og området for våbenbetingelser, for hvilke det er muligt at affyre våbnet;

at generere data, der indikerer våbenpræstation for hver våbenaffyringsmulighed inden for de definerede områder; og

at danne en database (19), der definerer våbnets samlede præstationsegenskaber.

DRAWINGS

Fig.1a.

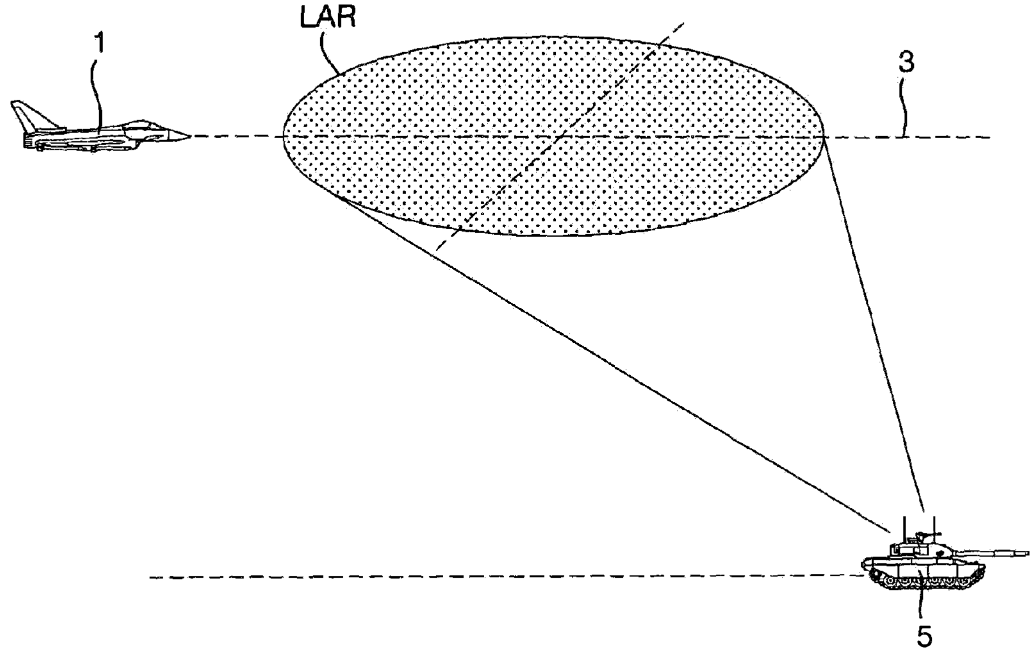


Fig.1b.

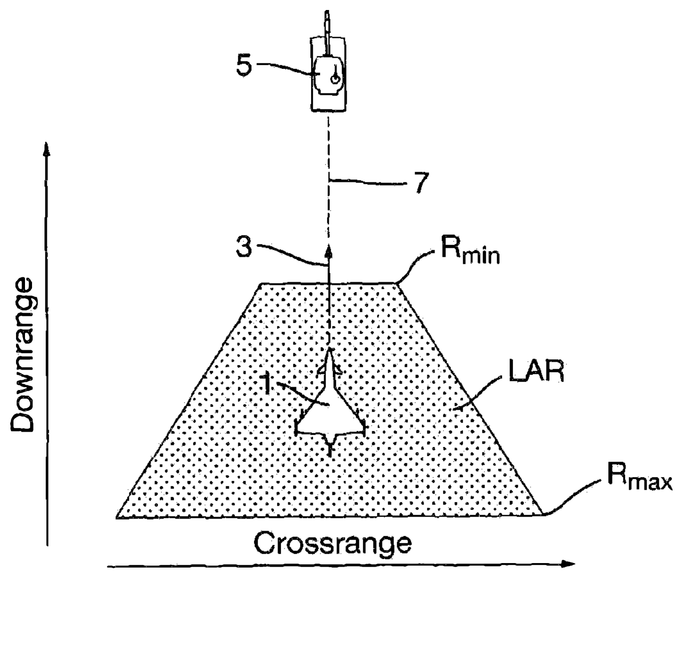
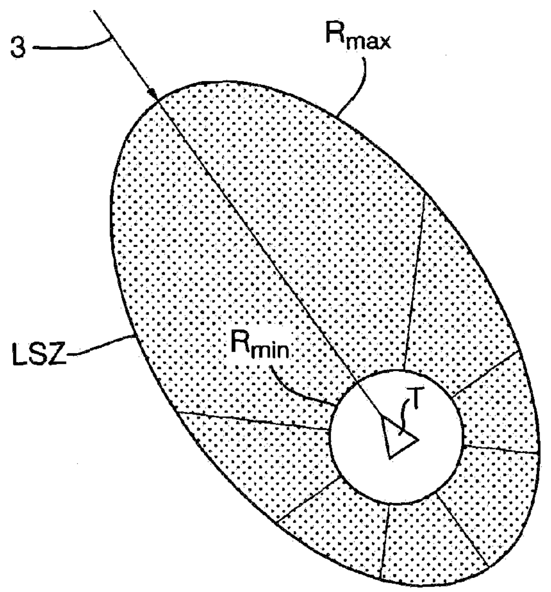


Fig.2.



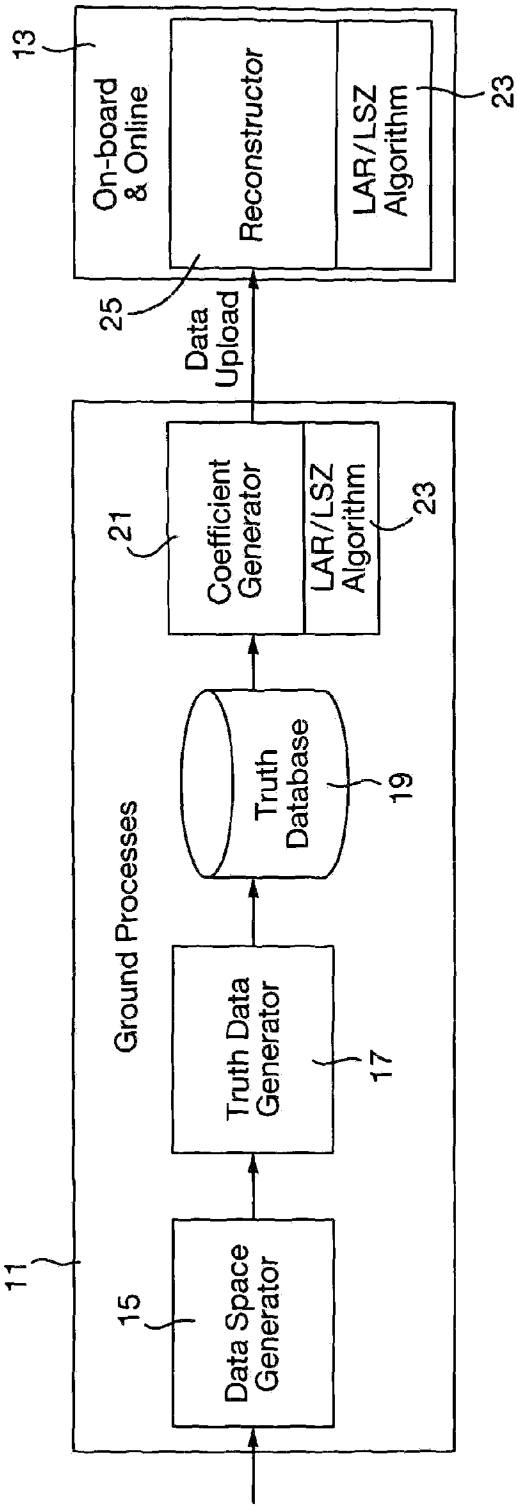
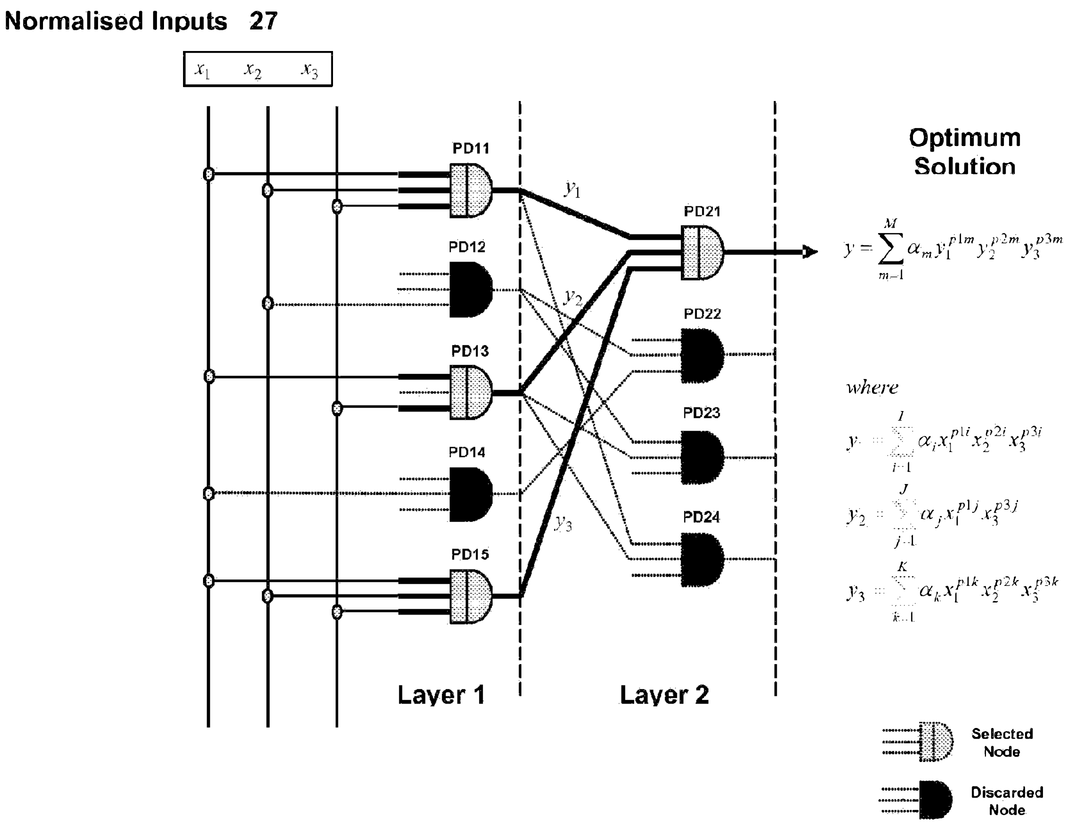

13
On-board
& Online
Reconstructor
LAR/LSZ
Algorithm
23
25
Data
Upload
21
Coefficient
Generator
LAR/LSZ
Algorithm
23
Truth
Database
19
Ground Processes
Truth Data
Generator
17
11
15
Data Space
Generator

Fig.3.

Fig. 4


Normalised Inputs 27
x_1 x_2 x_3
PD11
PD12
PD13
PD14
PD15
y_1
y_2
y_3
PD21
PD22
PD23
PD24
Optimum Solution
$y = \sum_{m=1}^{M} \alpha_m y_1^{p1m} y_2^{p2m} y_3^{p3m}$
where
$y_1 = \sum_{i=1}^{I} \alpha_i x_1^{p1i} x_2^{p2i} x_3^{p3i}$
$y_2 = \sum_{j=1}^{J} \alpha_j x_1^{p1j} x_3^{p3j}$
$y_3 = \sum_{k=1}^{K} \alpha_k x_1^{p1k} x_2^{p2k} x_3^{p3k}$
Layer 1
Layer 2
Selected Node
Discarded Node