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(72) Inventors:
• **GARAI, Tanushree**
560048 Karnataka (IN)
• **VIRDHE, Srushti**
560048 Karnataka (IN)

(74) Representative: **Gevers & Orès**
Immeuble le Palatin 2
3 Cours du Triangle
CS 80165
92939 Paris La Défense Cedex (FR)

(71) Applicant: **Airbus Operations SAS**
31060 Toulouse (FR)

(54) **METHOD AND SYSTEM FOR AIDING THE LANDING OF AN AIRCRAFT**

(57) - Method and system for automatically determining a list of ranked optimal diversion airports suitable for the landing of an aircraft.

- The system (1) comprises a module (3) for searching by iteration for airports from on-board database (DB1) and on-ground database (DB2). The airports are searched in a circle having a centre corresponding to the current position of the aircraft and a radius that increases from an initial radius by a predetermined increment on each iteration which is carried out until the radius is greater than or equal to a maximum radius. The system (1) further comprises a module (5) for ranking the airports considering a quantity of fuel on board of the aircraft so as to establish a list of ranked airports, a module (6) for transmitting to a user unit (7) a signal representative of the list of ranked airports. The system allows the reduction of the pilot's workload as the system (1) take into account information from on-board and on-ground databases.

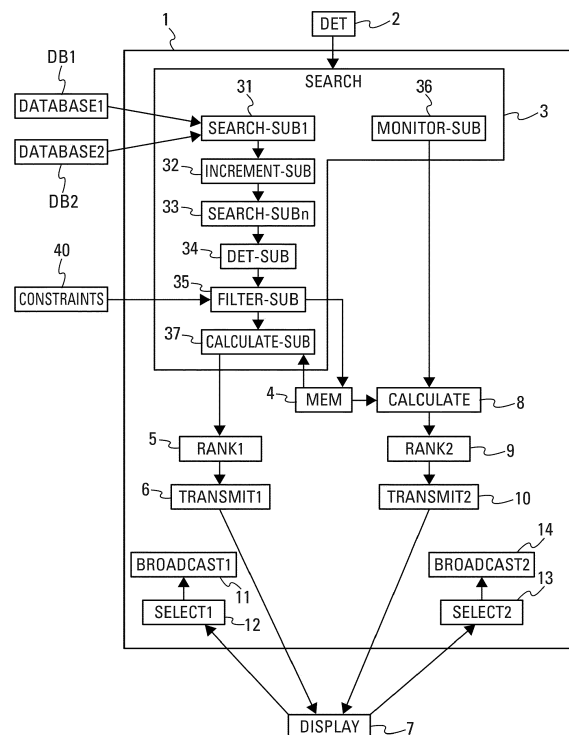


Fig. 1

Description

TECHNICAL FIELD

[0001] The present disclosure relates to a method and a system for automatically determining a list of ranked optimal diversion airports suitable for the landing of an aircraft.

BACKGROUND

[0002] Currently, a diversion operation is a cumbersome process which involves multiple stakeholders such as the Flight Management System (FMS) which provides possible alternate diversion airports; the pilot who considers additional factors as terrain, weather; and Air Traffic Controller (ATC) who adds more information such as traffic in the airspace and possibility of diversion to the airport in terms of current runway conditions, available landing systems, etc. So pilot is required to consider a large number of factors and constraints so as to make a decision by selecting one of the airports for diversion in an emergency situation or otherwise. The pilot also has to communicate with ATC constantly as the decision making process is iterative. Thus, in an emergency situation, the pilot has a large workload.

[0003] Document US 2008/0243318 proposes a method and a device for providing a list of the closest alternate diversion airports for display. The airports listed by the method are determined from an on-board database. So, when the pilot has to decide on the airport, he will have to communicate iteratively with ATC for airports that are not in the on-board database. Thus, the pilot's workload remains large.

SUMMARY

[0004] A purpose of the present disclosure is to overcome this disadvantage by proposing a method and a system allowing the reduction of the pilot's workload by increasing autonomy.

[0005] For this purpose, the disclosure herein relates to a method for automatically determining a list of ranked optimal diversion airport or airports suitable for the landing of an aircraft.

[0006] According to the disclosure herein, the method comprises:

- a step of determining a current position of the aircraft, implemented by a determining module,
- a step of searching for airport or airports, implemented by a search module, comprising searching by iteration for at least one airport from on-board database of airports positions and on-ground database of airports positions, the airport or airports being searched in a circle so as to memorized the airport or airports in a memory, the circle having a centre corresponding to the current position of the aircraft

and a radius that increases from an initial radius by a predetermined increment on each iteration, the iteration being carried out at least until the radius of the circle is greater than or equal to a maximum radius;

if the radius of the circle is greater than or equal to the maximum radius, the method comprising:

- a first step of ranking, implemented by a first ranking module, comprising ranking the airport or airports memorized in the memory, the airport or airports being ranked considering a quantity of fuel on board of the aircraft that can be used for flying a first along-track distance or distances determined from approach and arrival procedures related to the memorized airport or airports so as to establish a first list of ranked airports;
- a first step of transmitting, implemented by a first transmitting module, comprising transmitting to a user unit a signal representative of the first list of ranked airports.

[0007] Thus, thanks to the method, airports information from on-board database as well as from on-ground database can be collated. So, when the pilot decides on airport, his/her decision is based on a global view. This avoids the current iterative decision making process. The method allows the reduction of the pilot's workload and enables the pilot to be in monitoring role rather than control or decision making role.

[0008] Moreover, the step of searching for airport or airports comprises:

- a first sub-step of searching for airport or airports, implemented by a first search sub-module, comprising searching for at least one airport in an initial circle whose centre corresponds to the current position of the aircraft and whose radius is equal to the initial radius;
- a set of sub-steps implemented by iteration until the radius of the circle is greater than or equal to the maximum radius, the set of sub-steps comprising:
 - a sub-step of incrementing, implemented by an incrementing sub-module, comprising incrementing the radius of the circle by a predetermined increment;
 - a second sub-step of searching for airport or airports, implemented by a second search sub-module, comprising searching for at least one airport in a circle whose centre corresponds to the current position of the aircraft and whose radius is equal to the radius incremented in the sub-step of incrementing, the airport or airports being searched from on-board database of airports positions and on-ground database of airports positions;

- a sub-step of determining, implemented by a determining sub-module if airport or airports are found in the second sub-step of searching, comprising determining diversion procedures for the airport or airports found in the second sub-step of searching;
- a sub-step of filtering, implemented by a filtering sub-module if airport or airports are found in the second sub-step of searching, comprising filtering the airport or airports found in the second sub-step of searching by eliminating the airport or airports whose diversion procedures do not meet some constraints and by memorizing in the memory the airport or airports whose diversion procedures meet the constraints,
- a sub-step of calculating along-track distance, implemented by a calculating sub-module, comprising calculating the first along-track distance or distances to the airport or airports memorized in the sub-step of filtering from approach and arrival procedures of the memorized airport or airports.

[0009] In a preferred embodiment, the iteration being carried out until the radius of the circle is greater than or equal to the maximum radius or until an emergency is monitored;

if an emergency is monitored, the method comprising:

- a step of calculating along-track distance, implemented by a calculating module, comprising calculating second along-track distance or distances to the airport or airports memorized in the memory before the emergency is monitored, the second along-track distance or distances being determined from the direct distance from the current position of the aircraft to a final approach fix of the airport or airports;
- a second step of ranking, implemented by a second ranking module, comprising ranking the airport or airports memorized in the memory before the emergency is monitored, the airport or airports being ranked considering the time that can be taken for flying the second along-track distance or distances so as to establish a second list of ranked airports;
- a second step of transmitting, implemented by a second transmitting module, comprising transmitting to the user unit a signal representative of the second list of ranked airports.

[0010] Besides, the set of sub-steps is implemented by iteration until the radius of the circle is greater than or equal to a maximum radius or until an emergency is monitored, the set of sub-steps further comprising a sub-step of monitoring, implemented by a monitoring sub-module, comprising monitoring whether there is an emergency, the sub-step of calculating along-track distance being implemented by the calculating sub-module if no emergency is monitored.

[0011] According to one feature, the diversion procedure meets the constraints at least:

- if the aircraft has a current altitude greater than an altitude of the final approach fix at the airport,
- or if the quantity of fuel required for the diversion procedure and safe landing is greater than the quantity of fuel on board of the aircraft at landing airport runway,
- or if the aircraft has a current speed greater than a minimum speed at the final approach fix at airport.

[0012] In addition, the method comprises:

- a step of selecting an airport, implemented by a selecting module, comprising selecting by a pilot one airport amongst the airport or airports of the first list of ranked airports;
- a step of broadcasting, implemented by a broadcasting module, comprising broadcasting the approach and arrival procedure related to the selected airport.

[0013] Moreover, the method comprises:

- a step of selecting an airport, implemented by a selecting module, comprising selecting by a pilot one airport amongst the airport or airports of the second list of ranked airports;
- a step of broadcasting, implemented by a broadcasting module, comprising broadcasting the approach and arrival procedure related to the selected airport.

[0014] The disclosure herein also relates to a system for automatically determining a list of ranked optimal diversion airport or airports suitable for the landing of an aircraft.

[0015] According to the disclosure herein, the system comprises:

- a search module configured for searching by iteration for at least one airport from on-board database of airports positions and on-ground database of airports positions, the airport or airports being searched in a circle so as to memorized the airport or airports in a memory, the circle having a centre corresponding to the current position of the aircraft determined by a determining module and a radius that increases from an initial radius by a predetermined increment on each iteration, the iteration being carried out until the radius of the circle is greater than or equal to a maximum radius;
- a first ranking module configured for ranking the airport or airports memorized in the memory, the airport or airports being ranked considering a quantity of fuel on board of the aircraft that can be used for flying a first along-track distance or distances determined from approach and arrival procedures related to the memorized airport or airports so as to establish a

first list of ranked airports;

- a first transmitting module configured for transmitting to a user unit a signal representative of the first list of ranked airports,

the first ranking module and the first transmitting module being operated if the radius of the circle is greater than or equal to the maximum radius.

[0016] Moreover, the search module comprises:

- a first search sub-module configured for searching for at least one airport in an initial circle whose centre corresponds to the current position of the aircraft and whose radius is equal to the initial radius;
- a set of sub-modules implemented by iteration until the radius of the circle is greater than or equal to a maximum radius, the set of sub-modules comprising:
 - an incrementing sub-module configured for incrementing the radius of the circle by a predetermined increment,
 - a second search sub-module configured for searching for at least one airport in a circle whose centre corresponds to the current position of the aircraft and whose radius is equal to the radius incremented by the incrementing sub-module, the airport or airports being searched from on-board database of airports positions and on-ground database of airports positions;
 - a determining sub-module configured for determining diversion procedures for the airport or airports found by the second search sub-module;
 - a filtering sub-module configured for filtering the airport or airports found by the second search sub-module by eliminating the airport or airports whose diversion procedures do not meet some constraints and by memorizing in the memory the airport or airports whose diversion procedures meet the constraints,
 - a calculating sub-module configured for calculating the first along-track distance or distances to the airport or airports memorized by the filtering sub-module from approach and arrival procedures of the memorized airport or airports.

[0017] In a preferred embodiment, the iteration being carried out until the radius of the circle is greater than or equal to the maximum radius or until an emergency is monitored;

the system further comprising the following modules implemented if an emergency is monitored:

- a calculating module configured for calculating second along-track distance or distances to the airport or airports memorized in the memory before the emergency is monitored, the second along-track dis-

tance or distances being calculated from the direct distance from the current position of the aircraft to a final approach fix of the airport or airports;

- a second ranking module configured for ranking the airport or airports memorized in the memory before the emergency is monitored, the airport or airports being ranked considering the time that can be taken for flying the second along-track distance or distances so as to establish a second list of ranked airports;
- a second transmitting module configured for transmitting to the user unit a signal representative of the second list of ranked airports.

[0018] Besides, the set of sub-modules is implemented by iteration until the radius of the circle is greater than or equal to a maximum radius or until an emergency is monitored, the set of sub-modules further comprising a monitoring sub-module configured for monitoring whether there is an emergency, the calculating sub-module being implemented if no emergency is monitored.

[0019] According to one feature, the diversion procedure meets the constraints at least:

- if the aircraft has a current altitude greater than an altitude of the final approach fix,
- or if the quantity of fuel required for the diversion procedure and safe landing is greater than the quantity of fuel on board of the aircraft at landing airport runway,
- or if the aircraft has a current speed greater than a minimum speed at the final approach fix at airport.

[0020] In addition, the system comprises:

- a selecting module configured for selecting by a pilot one airport amongst the airport or airports of the first list of ranked airports;
- a broadcasting module configured for broadcasting the approach and arrival procedure related to the selected airport.

[0021] Moreover, the system comprises:

- a selecting module configured for selecting by a pilot one airport amongst the airport or airports of the second list of ranked airports;
- a broadcasting module configured for broadcasting the approach and arrival procedure related to the selected airport.

[0022] The disclosure herein also relates to an aircraft, in particular a transport aircraft, which is provided with a system for automatically determining a list of ranked optimal diversion airport or airports suitable for the landing of an aircraft, such as the one described above.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] The disclosure herein, with its features and advantages, will emerge more clearly on reading the description given with reference to the appended drawings in which:

- figure 1 shows a block diagram of a particular embodiment of the system,
- figure 2 shows a block diagram of steps implemented by the system,
- figure 3 shows a plan view of circles around the aircraft in which the airports are searched,
- figure 4 shows an example of display that may be established from the method.

DETAILED DESCRIPTION

[0024] The system 1 for automatically determining a list of ranked optimal diversion airport or airports AP suitable for the landing of an aircraft AC is shown schematically in figure 1. In the rest of the description, said system will be called "system for determining".

[0025] The system for determining 1 may be hosted in ground control or may be on-board as an electronic flight bag (EFB).

[0026] The system for determining 1 further comprises a search module (SEARCH) 3 configured for searching by iteration for at least one airport AP from on-board database (DATABASE1) DB1 of airports positions and on-ground database (DATABASE2) DB2 of airports positions.

[0027] The on-board database DB1 may be comprised by the navigation database of the flight management system (FMS). The on-ground database DB2 may be comprised by the air traffic control (ATC).

[0028] The airport or airports AP are searched in a circle C so as to memorize the airport or airports AP in a memory (MEM) 4. The circle C has a centre CT that corresponds to the current position P of the aircraft AC and a radius Rn that increases from an initial radius R0 by a predetermined increment on each iteration. The iteration is carried out at least until the radius Rn of the circle C is greater than or equal to a maximum radius Rmax. The circle C that has the maximum radius Rmax corresponds to the limit distance which can be flown by the aircraft AC, taking into account the quantity of fuel available on board (figure 3).

[0029] The current position P of the aircraft AC can be determined by a determining module (DET) 2 configured for determining a current position P of the aircraft AC. The determining module 2 may be any usual sensors that are configured for determining the current position P of the aircraft AC.

[0030] In addition, the system for determining comprises a ranking module (RANK1) 5 configured for ranking the airport or airports AP memorized in the memory 4. The airport or airports AP are ranked by considering a

quantity of fuel on board of the aircraft AC that can be used for flying a first along-track distance or distances determined from approach and arrival procedures related to the memorized airport or airports AP so as to establish a first list of ranked airports. A first along-track distance is determined for each of the airport or airports AP. The determination of the first along-track distance takes into account the entire flight plan profile and the approach procedure until the landing of the aircraft AC on the runway of the related airport AP. Then, the distance from the current position P of the aircraft AC to the final approach fix (FAF) via an arrival procedure is determined. Additionally, the distance of the landing procedure is added based on the available landing systems and runway conditions.

[0031] The system for determining 1 also comprises a transmitting module (TRANSMIT1) 6 configured for transmitting to a user unit (DISPLAY) 7 a signal representative of the first list of ranked airports. The user unit 7 may be a display unit that displays at least the first list of ranked airport.

[0032] Figure 4 shows an example of display. On this figure, two tables are displayed: a first table TABLE1 showing the closest airports ranked and a second table TABLE2 showing the optimal diversion airports. On the first table TABLE1, the airports AP are ranked vertically from the closest to the most distant. On the second table TABLE2, the airports AP are ranked vertically from the most optimal for diversion to the least optimal for diversion. For every table, the first column C1 displays identifiers of the airports AP. The second column C2 displays the distance (DIST) between the current position P of the aircraft AC and the position of said airport AP. The third column C3 displays the bearing (BRG). Other columns C4 display other useful indications.

[0033] The ranking module 5 and the transmitting module 6 are operated if the radius Rn of the circle C is greater than or equal to the maximum radius Rmax.

[0034] The search module 3 may comprise a search sub-module (SEARCH_SUB1) 31 configured for searching for at least one airport AP in an initial circle whose centre corresponds to the current position P of the aircraft AC and whose radius Rn is equal to the initial radius R0. The search sub-module 31 allows the initialisation of the search by iteration.

[0035] The search module further comprises a set of sub-modules implemented by iteration until the radius Rn of the circle C is greater than or equal to the maximum radius Rmax.

[0036] The set of sub-modules may comprise an incrementing sub-module 32 (INCREMENT_SUB) configured for incrementing the radius Rn of the circle C by a predetermined increment. The predetermined increment is preferably equal to the initial radius R0.

[0037] The set of sub-modules may further comprise a search sub-module (SEARCH_SUBn) 33 configured for searching for at least one airport AP in a circle whose centre corresponds to the current position P of the aircraft

AC and whose radius R_n is equal to the radius incremented by the incrementing sub-module 32. The airport or airports AP are searched from the on-board database DB1 of airports positions and from the on-ground database DB2 of airports positions.

[0038] The set of sub-modules may comprise a determining sub-module (DET_SUB) 34 configured for determining diversion procedures for the airport or airports AP found by the search sub-module 33. A diversion procedure is determined for the airport or each of the airports AP. The determination of the diversion procedure is based on approach and arrival procedure related to the airport AP for which the diversion procedure is determined.

[0039] The set of sub-modules may comprises a filtering sub-module (FILTER_SUB) 35 configured for filtering the airport or airports AP found by the search sub-module 33. The filtering is done by eliminating the airport or airports AP whose diversion procedures do not meet some constraints (CONSTRAINTS) 40 and by memorizing in the memory 4 the airport or airports AP whose diversion procedures meet the constraints 40.

[0040] For example, the diversion procedure meets the constraints 40 at least:

- if the aircraft AC has a current altitude greater than an altitude of the final approach fix at airport AP,
- or if the quantity of fuel required for the diversion procedure and safe landing is greater than the quantity of fuel on board of the aircraft AC at landing airport runway AP,
- or if the aircraft AC has a current speed greater than a minimum speed at the final approach fix at airport AP,
- or limits due to constraints related to external factors.

[0041] The external factors may be weather, terrain and obstacles, runway conditions, landing system compatibility, airspace and airlines policies, etc. For example, the diversion procedure meets the constraints 40 if the weather or the runway conditions or the landing system or the airspace and airlines policies allow the landing of the aircraft AC at the airport AP for which the diversion procedure is determined.

[0042] The external factors may be approach and arrival procedures broadcasted by other aircraft in the airspace as well.

[0043] The set of sub-modules may further comprise a calculating sub-module (CALCULATE_SUB) 37 configured for calculating the first along-track distance or distances to the airport or airports AP memorized by the filtering sub-module 35 from approach and arrival procedures of the memorized airport or airports AP.

[0044] The system for determining 1 may also include:

- a selecting module (SELECT1) 11 configured for selecting by a pilot one airport amongst the airport or airports AP of the first list of ranked airports;

- a broadcasting module (BROADCAST1) 12 configured for broadcasting the approach and arrival procedure related to the selected airport.

5 **[0045]** Thanks to the broadcast of the approach and arrival procedure, the system for determining 1 can be applied to several aircraft in an airspace for collaborative diversion.

10 **[0046]** In a preferred embodiment, the iteration is carried out until the radius R_n of the circle C is greater than or equal to the maximum radius R_{max} or until an emergency is monitored.

[0047] In the preferred embodiment, the set of sub-modules is then implemented by iteration until the radius R_n of the circle C is greater than or equal to a maximum radius R_{max} or until an emergency is monitored. The set of sub-modules may further comprise a monitoring sub-module (MONITOR_SUB) 36 configured for monitoring whether there is an emergency. The calculating sub-module 37 is implemented if no emergency is monitored.

20 **[0048]** In the preferred embodiment, the system for determining 1 further comprises the following modules implemented if an emergency is monitored.

- 25 - a calculating module (CALCULATE) 8 configured for calculating second along-track distance or distances to the airport or airports AP memorized in the memory 4 before the emergency is monitored. The second along-track distance or distances is calculated from the direct distance from the current position P of the aircraft AC to the final approach fix of the airport or airports AP;
- 30 - a ranking module (RANK2) 9 configured for ranking the airport or airports AP memorized in the memory 4 before the emergency is monitored. The airport or airports AP are ranked considering the time that can be taken for flying the second along-track distance or distances so as to establish a second list of ranked airports;
- 35 - a transmitting module (TRANSMIT2) 10 configured for transmitting to the user unit 7 a signal representative of the second list of ranked airports.

45 **[0049]** In the preferred embodiment, the system for determining 1 may also include:

- a selecting module (SELECT2) 13 configured for selecting by a pilot one airport amongst the airport or airports AP of the second list of ranked airports;
- 50 - a broadcasting module (BROADCAST2) 14 configured for broadcasting the approach and arrival procedure related to the selected airport.

55 **[0050]** According to one embodiment, the modules and sub-modules are integrated in a central processing unit or a computer.

[0051] By way of example, the modules and sub-modules may correspond to algorithms implemented in a soft-

ware manner in the central processing unit.

[0052] In particular, the modules and sub-modules can be stored in a memory area of the central processing unit.

[0053] The system for determining 1, such as described above, implements the following set of steps of a method for automatically determining a list of ranked optimal diversion airport or airports AP suitable for the landing of an aircraft AC (figure 2).

[0054] The method comprises:

- a step S1 of determining a current position of the aircraft AC, implemented by the determining module 2,
- a step S2 of searching for airport or airports AP, implemented by the search module 3, comprising searching by iteration for at least one airport AP from on-board database DB1 of airports positions and on-ground database DB2 of airports positions, the airport or airports AP being searched in a circle C so as to memorized the airport or airports AP in a memory 4, the circle C having a centre CT corresponding to the current position P of the aircraft AC and a radius Rn that increases from an initial radius R0 by a predetermined increment on each iteration, the iteration being carried out at least until the radius Rn of the circle C is greater than or equal to a maximum radius Rmax.

[0055] As shown on figure 2 with output arrow "Yes" from decision block " $R_n \geq R_{max}$ ", if the radius Rn of the circle C is greater than or equal to the maximum radius Rmax, the method comprising:

- a step S3 of ranking, implemented by the ranking module 5, comprising ranking the airport or airports AP memorized in the memory 4, the airport or airports AP being ranked considering a quantity of fuel on board of the aircraft AC that can be used for flying a first along-track distance or distances determined from approach and arrival procedures related to the memorized airport or airports AP so as to establish a first list of ranked airports;
- a step S4 of transmitting, implemented by the transmitting module 6, comprising transmitting to a user unit 7 a signal representative of the first list of ranked airports.

[0056] The method may comprise:

- a step S8 of selecting an airport, implemented by the selecting module 11, comprising selecting by a pilot one airport amongst the airport or airports AP of the first list of ranked airports;
- a step S9 of broadcasting, implemented by the broadcasting module 12, comprising broadcasting the approach and arrival procedure related to the selected airport.

[0057] Moreover, the step S2 of searching for airport or airports AP comprises:

- a sub-step S21 of searching for airport or airports AP, implemented by the search sub-module 31, comprising searching for at least one airport AP in an initial circle whose centre corresponds to the current position P of the aircraft AC and whose radius Rn is equal to the initial radius R0;

[0058] As shown on figure 2 with output arrow "No" from decision block " $R_n \geq R_{max}$ " the step S2 further comprises a set of sub-steps operated by iteration until the radius Rn of the circle C is greater than or equal to the maximum radius Rmax.

[0059] The set of sub-steps comprising:

- a sub-step S22 of incrementing, implemented by the incrementing sub-module 32, comprising incrementing the radius Rn of the circle C by a predetermined increment;
- a sub-step S23 of searching for airport or airports AP, implemented by the search sub-module 33, comprising searching for at least one airport AP in a circle whose centre corresponds to the current position P of the aircraft AC and whose radius Rn is equal to the radius incremented in the sub-step S22 of incrementing, the airport or airports AP being searched from on-board database DB1 of airports positions and on-ground database DB2 of airports positions;
- a sub-step S24 of determining, implemented by the determining sub-module 34 if airport or airports AP are found in the sub-step S23 of searching, comprising determining diversion procedures for the airport or airports AP found in the sub-step S23 of searching;
- a sub-step S25 of filtering, implemented by the filtering sub-module 35 if airport or airports AP are found in the sub-step S23 of searching, comprising filtering the airport or airports AP found in the sub-step S23 of searching by eliminating the airport or airports AP whose diversion procedures do not meet some constraints 40 and by memorizing in the memory 4 the airport or airports AP whose diversion procedures meet the constraints 40,
- a sub-step S27 of calculating along-track distance, implemented by the calculating sub-module 37, comprising calculating the first along-track distance or distances to the airport or airports AP memorized in the sub-step S25 of filtering from approach and arrival procedures of the memorized airport or airports AP.

[0060] On figure 2, if airport or airports are not found (output arrow "No" of block S23), the method the radius Rn is incremented for another search.

[0061] According to the preferred embodiment, the iteration is carried out by the set of sub-modules until the

radius R_n of the circle C is greater than or equal to the maximum radius R_{max} (output arrow "Yes" from decision block " $R_n \geq R_{max}$ ") or until an emergency is monitored (output arrow "Yes" from decision block "S26").

[0062] If an emergency is monitored, the method comprises:

- a step S5 of calculating along-track distance, implemented by the calculating module 8, comprising calculating second along-track distance or distances to the airport or airports AP memorized in the memory 4 before the emergency is monitored, the second along-track distance or distances being determined from the direct distance from the current position P of the aircraft AC to a final approach fix of the airport or airports AP; 5
- a step S6 of ranking, implemented by the ranking module 9, comprising ranking the airport or airports AP memorized in the memory 4 before the emergency is monitored, the airport or airports AP being ranked considering the time that can be taken for flying the second along-track distance or distances so as to establish a second list of ranked airports; 10
- a step S7 of transmitting, implemented by the transmitting module 10, comprising transmitting to the user unit 7 a signal representative of the second list of ranked airports. 15

[0063] According to the preferred embodiment, the set of sub-steps is operated by iteration until the radius R_n of the circle C is greater than or equal to a maximum radius R_{max} or until an emergency is monitored. The set of sub-steps further comprises a sub-step S26 of monitoring, implemented by the monitoring sub-module 36, comprising monitoring whether there is an emergency. The sub-step S27 of calculating along-track distance is implemented by the calculating sub-module 37 if no emergency is monitored. 20

[0064] In the preferred embodiment, the method may comprise:

- a step S10 of selecting an airport, implemented by the selecting module 13, comprising selecting by a pilot one airport amongst the airport or airports AP of the second list of ranked airports; 25
- a step S11 of broadcasting, implemented by a broadcasting module 14, comprising broadcasting the approach and arrival procedure related to the selected airport. 30

Claims

1. A method for automatically determining a list of ranked optimal diversion airport or airports (AP) suitable for the landing of an aircraft (AC), **characterized in that** the method comprises: 35

- a step (S1) of determining a current position of the aircraft (AC), implemented by a determining module (2),

- a step (S2) of searching for airport or airports (AP), implemented by a search module (3), comprising searching by iteration for at least one airport (AP) from on-board database (DB1) of airports positions and on-ground database (DB2) of airports positions, the airport or airports (AP) being searched in a circle (C) so as to memorized the airport or airports (AP) in a memory (4), the circle (C) having a centre (CT) corresponding to the current position (P) of the aircraft (AC) and a radius (R_n) that increases from an initial radius (R_0) by a predetermined increment on each iteration, the iteration being carried out at least until the radius (R_n) of the circle (C) is greater than or equal to a maximum radius (R_{max}); 40

if the radius (R_n) of the circle (C) is greater than or equal to the maximum radius (R_{max}), the method comprising:

- a first step (S3) of ranking, implemented by a first ranking module (5), comprising ranking the airport or airports (AP) memorized in the memory (4), the airport or airports (AP) being ranked considering a quantity of fuel on board of the aircraft (AC) that can be used for flying a first along-track distance or distances determined from approach and arrival procedures related to the memorized airport or airports (AP) so as to establish a first list of ranked airports; 45

- a first step (S4) of transmitting, implemented by a first transmitting module (6), comprising transmitting to a user unit (7) a signal representative of the first list of ranked airports. 50

2. Method according to claim 1,

characterized in that the step (S2) of searching for airport or airports (AP) comprises:

- a first sub-step (S21) of searching for airport or airports (AP), implemented by a first search sub-module (31), comprising searching for at least one airport (AP) in an initial circle whose centre corresponds to the current position (P) of the aircraft (AC) and whose radius (R_n) is equal to the initial radius (R_0);

- a set of sub-steps implemented by iteration until the radius (R_n) of the circle (C) is greater than or equal to the maximum radius (R_{max}), the set of sub-steps comprising:

- a sub-step (S22) of incrementing, implemented by an incrementing sub-module (32), comprising incrementing the radius of

the circle (C) by a predetermined increment;

- a second sub-step (S23) of searching for airport or airports (AP), implemented by a second search sub-module (33), comprising searching for at least one airport (AP) in a circle whose centre corresponds to the current position (P) of the aircraft (AC) and whose radius (Rn) is equal to the radius incremented in the sub-step (S22) of incrementing, the airport or airports (AP) being searched from on-board database (DB1) of airports positions and on-ground database (DB2) of airports positions;

- a sub-step (S24) of determining, implemented by a determining sub-module (34) if airport or airports (AP) are found in the second sub-step (S23) of searching, comprising determining diversion procedures for the airport or airports (AP) found in the second sub-step (S23) of searching;

- a sub-step (S25) of filtering, implemented by a filtering sub-module (35) if airport or airports (AP) are found in the second sub-step (S23) of searching, comprising filtering the airport or airports (AP) found in the second sub-step (S23) of searching by eliminating the airport or airports (AP) whose diversion procedures do not meet some constraints (40) and by memorizing in the memory (4) the airport or airports (AP) whose diversion procedures meet the constraints (40),

- a sub-step (S27) of calculating along-track distance, implemented by a calculating sub-module (37), comprising calculating the first along-track distance or distances to the airport or airports (AP) memorized in the sub-step (S25) of filtering from approach and arrival procedures of the memorized airport or airports (AP).

3. Method according to claim 1,

characterized in that the iteration being carried out until the radius (Rn) of the circle (C) is greater than or equal to the maximum radius (Rmax) or until an emergency is monitored;

if an emergency is monitored, the method comprising:

- a step (S5) of calculating along-track distance, implemented by a calculating module (8), comprising calculating second along-track distance or distances to the airport or airports (AP) memorized in the memory (4) before the emergency is monitored, the second along-track distance or distances being determined from the direct distance from the current position (P) of the aircraft (AC) to a final approach fix of the airport or

airports (AP);

- a second step (S6) of ranking, implemented by a second ranking module (9), comprising ranking the airport or airports (AP) memorized in the memory (4) before the emergency is monitored, the airport or airports (AP) being ranked considering the time that can be taken for flying the second along-track distance or distances so as to establish a second list of ranked airports;

- a second step (S7) of transmitting, implemented by a second transmitting module (10), comprising transmitting to the user unit (7) a signal representative of the second list of ranked airports.

4. Method according to any one of claims 2 or 3,

characterized in that the set of sub-steps is implemented by iteration until the radius (Rn) of the circle (C) is greater than or equal to a maximum radius (Rmax) or until an emergency is monitored, the set of sub-steps further comprising a sub-step (S26) of monitoring, implemented by a monitoring sub-module (36), comprising monitoring whether there is an emergency, the sub-step (S27) of calculating along-track distance being implemented by the calculating sub-module (37) if no emergency is monitored.

5. Method according to claim 2,

characterized in that the diversion procedure meets the constraints (40) at least:

- if the aircraft (AC) has a current altitude greater than an altitude of the final approach fix at the airport (AP),

- or if the quantity of fuel required for the diversion procedure and safe landing is greater than the quantity of fuel on board of the aircraft (AC) at landing airport runway (AP),

- or if the aircraft (AC) has a current speed greater than a minimum speed at the final approach fix at airport (AP).

6. Method according to any one of claims 1 to 5,

characterized in that the method comprises:

- a step (S8) of selecting an airport, implemented by a selecting module (11), comprising selecting by a pilot one airport amongst the airport or airports (AP) of the first list of ranked airports;

- a step (S9) of broadcasting, implemented by a broadcasting module (12), comprising broadcasting the approach and arrival procedure related to the selected airport.

7. Method according to any one of claims 1 to 5,

characterized in that the method comprises:

- a step (S10) of selecting an airport, implement-

ed by a selecting module (13), comprising selecting by a pilot one airport amongst the airport or airports (AP) of the second list of ranked airports;

- a step (S11) of broadcasting, implemented by a broadcasting module (14), comprising broadcasting the approach and arrival procedure related to the selected airport.

8. A system for automatically determining a list of ranked optimal diversion airport or airports (AP) suitable for the landing of an aircraft (AC), **characterized in that** the system comprises:

- a search module (3) configured for searching by iteration for at least one airport (AP) from on-board database (DB1) of airports positions and on-ground database (DB2) of airports positions, the airport or airports (AP) being searched in a circle (C) so as to memorized the airport or airports (AP) in a memory (4), the circle (C) having a centre (CT) corresponding to the current position (P) of the aircraft (AC) determined by a determining module (2) and a radius (Rn) that increases from an initial radius (R0) by a predetermined increment on each iteration, the iteration being carried out until the radius (Rn) of the circle (C) is greater than or equal to a maximum radius (Rmax);

- a first ranking module (5) configured for ranking the airport or airports (AP) memorized in the memory (4), the airport or airports (AP) being ranked considering a quantity of fuel on board of the aircraft (AC) that can be used for flying a first along-track distance or distances determined from approach and arrival procedures related to the memorized airport or airports (AP) so as to establish a first list of ranked airports;

- a first transmitting module (6) configured for transmitting to a user unit (7) a signal representative of the first list of ranked airports, the first ranking module (5) and the first transmitting module (6) being operated if the radius (Rn) of the circle is greater than or equal to the maximum radius (Rmax).

9. System according to claim 8, **characterized in that** the search module (3) comprises:

- a first search sub-module (31) configured for searching for at least one airport (AP) in an initial circle whose centre corresponds to the current position (P) of the aircraft (AC) and whose radius (Rn) is equal to the initial radius (R0);

- a set of sub-modules implemented by iteration until the radius (Rn) of the circle (C) is greater than or equal to a maximum radius (Rmax), the

set of sub-modules comprising:

- an incrementing sub-module (32) configured for incrementing the radius of the circle (C) by a predetermined increment,
- a second search sub-module (33) configured for searching for at least one airport (AP) in a circle whose centre corresponds to the current position (P) of the aircraft (AC) and whose radius (Rn) is equal to the radius incremented by the incrementing sub-module (32), the airport or airports (AP) being searched from on-board database (DB1) of airports positions and on-ground database (DB2) of airports positions;
- a determining sub-module (34) configured for determining diversion procedures for the airport or airports (AP) found by the second search sub-module (33);
- a filtering sub-module (35) configured for filtering the airport or airports (AP) found by the second search sub-module (33) by eliminating the airport or airports (AP) whose diversion procedures do not meet some constraints (40) and by memorizing in the memory (4) the airport or airports (AP) whose diversion procedures meet the constraints (40),
- a calculating sub-module (37) configured for calculating the first along-track distance or distances to the airport or airports (AP) memorized by the filtering sub-module (35) from approach and arrival procedures of the memorized airport or airports (AP).

10. System according to claim 8, **characterized in that** the iteration being carried out until the radius (Rn) of the circle (C) is greater than or equal to the maximum radius (Rmax) or until an emergency is monitored; the system (1) further comprising the following modules implemented if an emergency is monitored:

- a calculating module (8) configured for calculating second along-track distance or distances to the airport or airports (AP) memorized in the memory (4) before the emergency is monitored, the second along-track distance or distances being calculated from the direct distance from the current position (P) of the aircraft (AC) to a final approach fix of the airport or airports (AP);

- a second ranking module (9) configured for ranking the airport or airports (AP) memorized in the memory (4) before the emergency is monitored, the airport or airports (AP) being ranked considering the time that can be taken for flying the second along-track distance or distances so as to establish a second list of ranked airports;

- a second transmitting module (10) configured for transmitting to the user unit (7) a signal representative of the second list of ranked airports.

11. System according to any one of claims 9 or 10, 5
characterized in that the set of sub-modules is implemented by iteration until the radius (R_n) of the circle (C) is greater than or equal to a maximum radius (R_{max}) or until an emergency is monitored, the set of sub-modules further comprising a monitoring sub-module (36) configured for monitoring whether there is an emergency, the calculating sub-module (37) being implemented if no emergency is monitored. 10
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12. System according to claim 9, 15
characterized in that the diversion procedure meets the constraints (40) at least:
 - if the aircraft (AC) has a current altitude greater than an altitude of the final approach fix, 20
 - or if the quantity of fuel required for the diversion procedure and safe landing is greater than the quantity of fuel on board of the aircraft (AC) at landing airport runway (AP), 25
 - or if the aircraft (AC) has a current speed greater than a minimum speed at the final approach fix at airport (AP).
13. System according to any one of claims 8 to 12, 30
characterized in that the system comprises:
 - a selecting module (11) configured for selecting by a pilot one airport amongst the airport or airports (AP) of the first list of ranked airports; 35
 - a broadcasting module (12) configured for broadcasting the approach and arrival procedure related to the selected airport.
14. System according to any one of claims 8 to 12, 40
characterized in that the system comprises:
 - a selecting module (13) configured for selecting by a pilot one airport amongst the airport or airports (AP) of the second list of ranked airports; 45
 - a broadcasting module (14) configured for broadcasting the approach and arrival procedure related to the selected airport.
15. Aircraft, 50
comprising a system (1) for automatically determining a list of ranked optimal diversion airport or airports (AP) suitable for the landing of an aircraft (AC), as specified in any one of the claims 8 to 14. 55

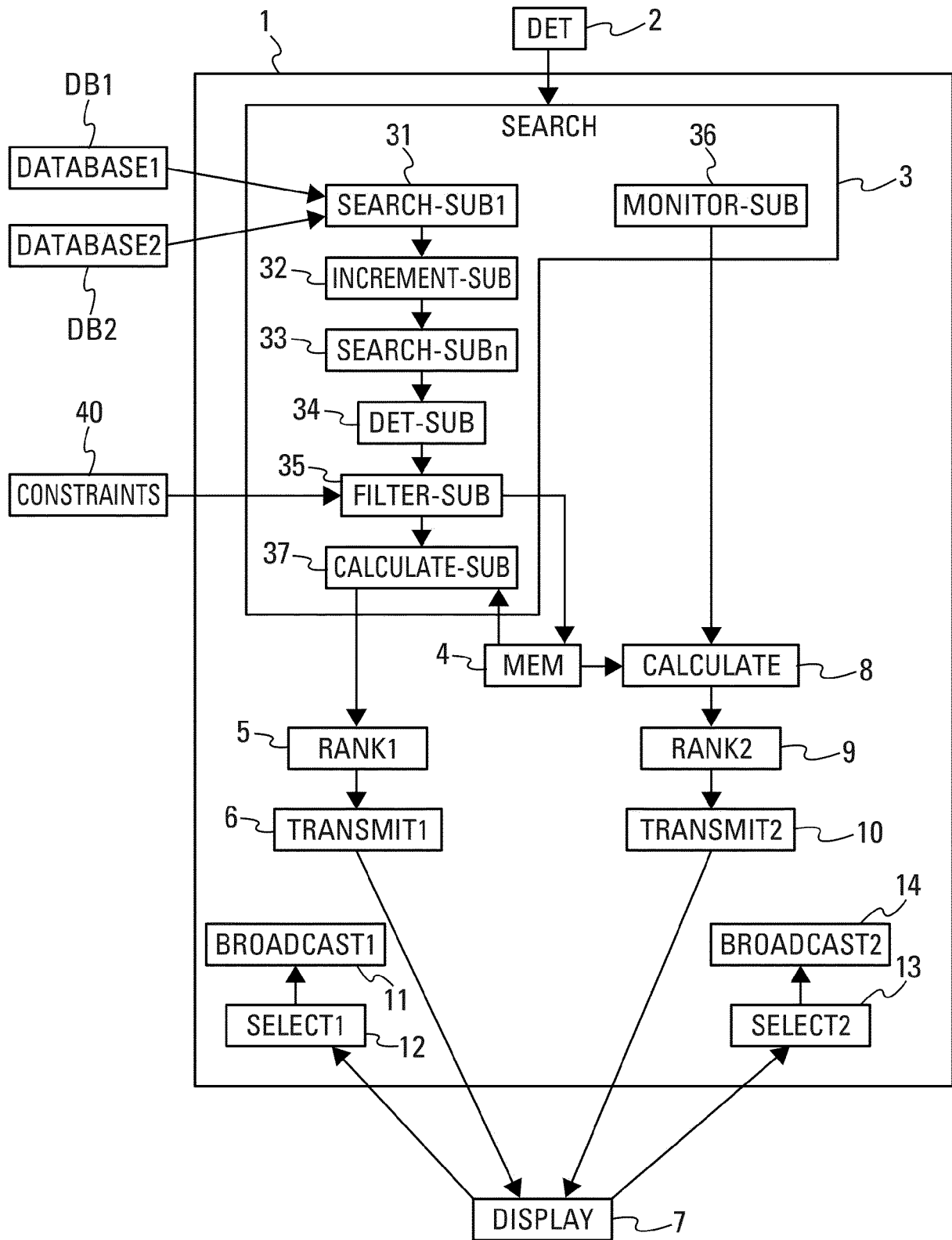


Fig. 1

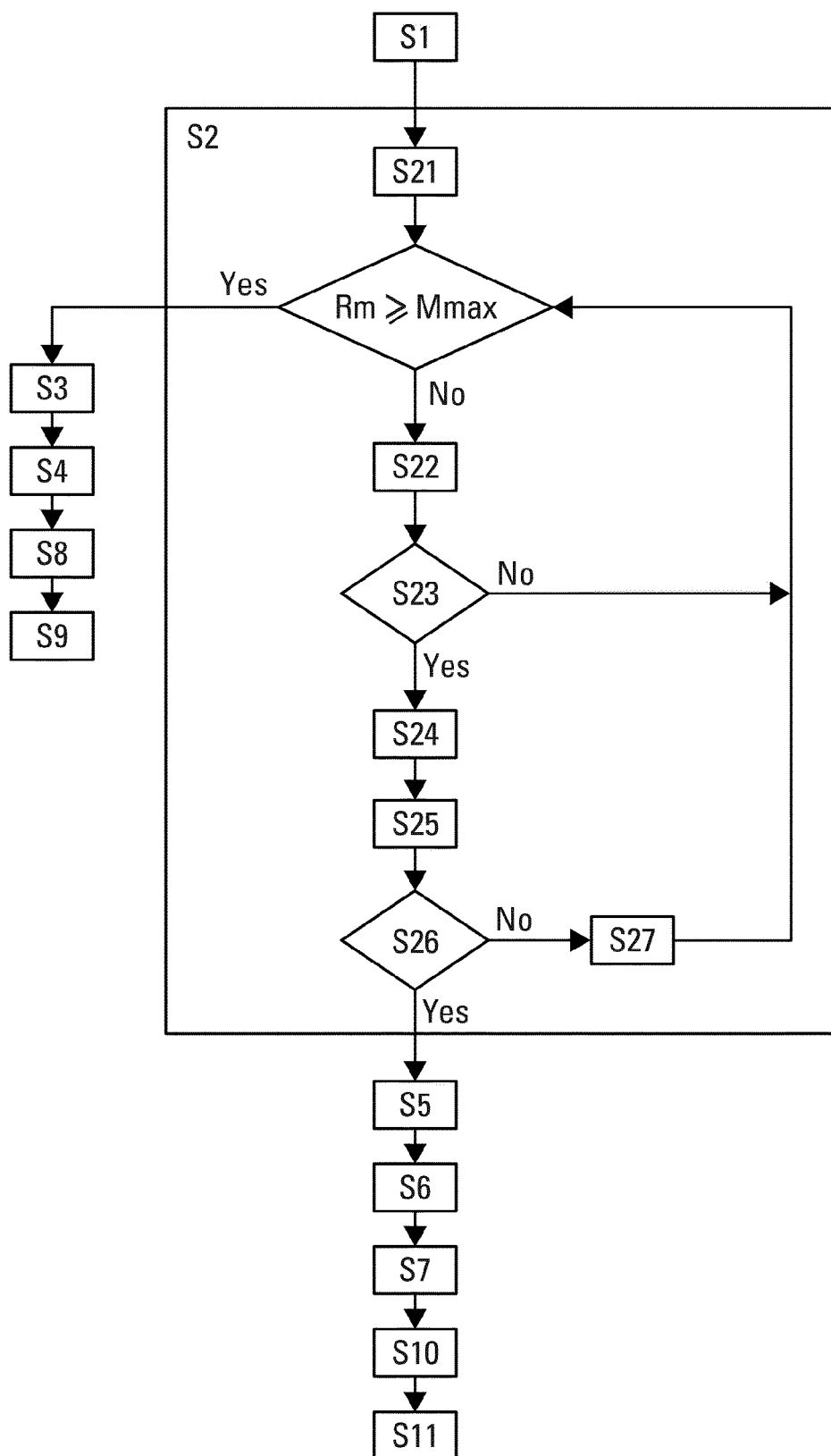


Fig. 2

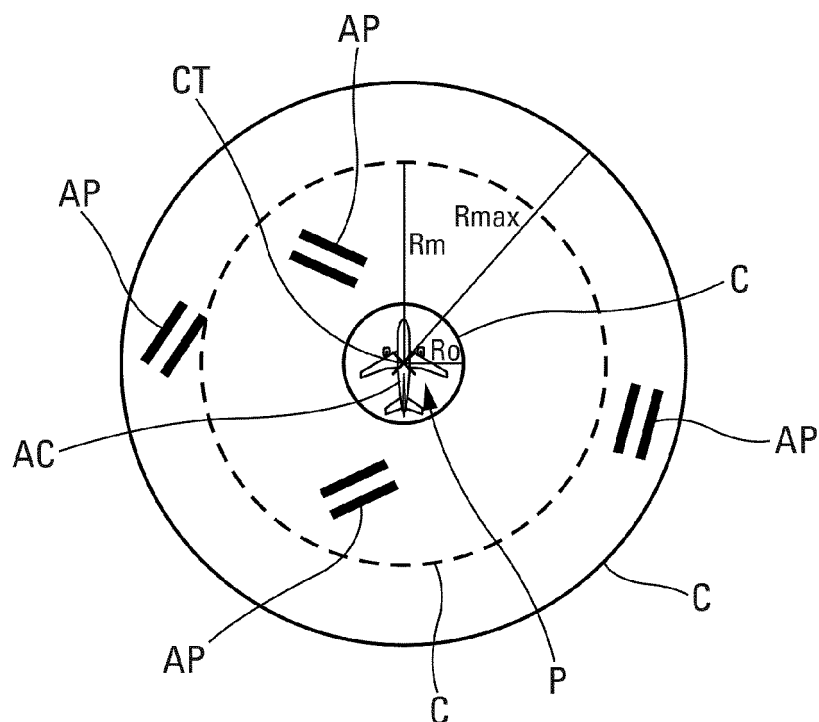


Fig. 3

ACTIVE/F - PLN/CLOSEST AIRPORTS							
DATA FROM P.POS iO ARPTS							
		DIST	BRG	TIME	EFOB	EFF	WIND
CLOSEST ARPTS							
TABLE1	LFB�▶	26NM	330	• 15 : 56	16 . 6 T		HD000
	LFBÜ▶	30NM	113	• 15 : 56	16 . 5 T		HD000
	LFBX▶	41NM	228	• 15 : 56	16 . 3 T		HD000
	LFBV▶	62NM	13	• 15 : 56	16 . 1 T		HD000
TABLE2	OPTIMAL ARPTS						
	LFOB▶	50NM	16	• 15 : 58	15 . 0 T		HD000
	LFCM▶	45NM	153	• 16 : 00	13 . 8 T		HD000
	LFBZ▶	41NM	208	• 16 : 01	13 . 5 T		HD000

Fig. 4



EUROPEAN SEARCH REPORT

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Place of search The Hague		Date of completion of the search 6 May 2020	Examiner Pariset, Nadia
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