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(54) **System and method to determine OOOI times of an aircraft**

(57) The invention is directed to a method and system to determine the in-time of an airplane. A receiver receives transponder data from the aircraft. The transponder data is parsed in at least coordinate data of the aircraft and speed data of the aircraft. Further, the system verifies if the aircraft coordinates are close to parking

coordinates available in a database and if the speed data of the aircraft is decreasing. The actual processing time is processed as the in-time of the aircraft if the aircraft coordinates are close to the parking coordinates and the speed is zero and the previous speed is higher than zero.

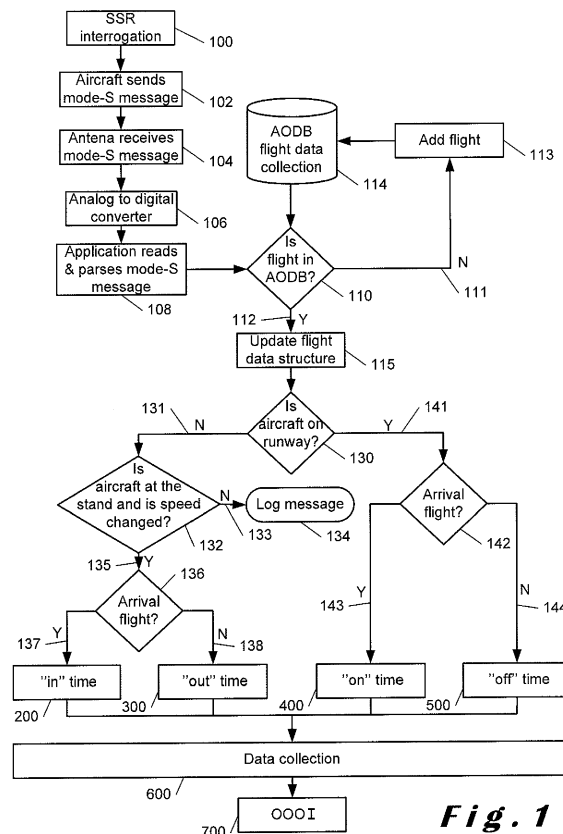


Fig. 1

Description

Field of the invention

[0001] The invention relates to a system to determine the times of an aircraft to touch the runway, to park at a parking position, to leave a parking position and to take off from the runway.

Background of the invention

[0002] Transponders are usually used to identify aircrafts in air traffic control radar and are usually used to avoid collisions between aircrafts. The Secondary Surveillance radar (SSR) depends on an embedded transponder which replies to interrogations of the secondary radar. The interrogation mode of a transponder is the format of a sequence of pulses, referred to as a code used to determine detailed information from the aircraft. There are different types of interrogation modes: modes 1 to 5 are reserved for military use whereas modes A, B, C, D and S are dedicated to civilian use.

[0003] Modes A and C are developed for airframe identification and altitude reporting and this is still widely used in air traffic control and management of air space. However, with the increase of air traffic, the air traffic control radar beacon system (ATCRBS) has nearly become saturated. There are also problems of false replies uncorrelated in time (FRUIT) due to the technology used by modes A and C.

[0004] Mode S technology was developed in the seventies and was widely deployed in the eighties. The advantages of Mode S technology over Mode A and C is that it is addressable, more accurate and reliable and that it can operate with greater capacity. A transponder which receives a valid mode S discrete interrogation replies 128 μ s after reception. The reply is transmitted on 1090 MHz carrier with 56 bit or 112 bit pulse positioning modulation (PPM). Mode-S uses a monopulse SSR, as in modes A and C but it has an increased accuracy. Each mode S interrogation includes an International Civil Aeronautics Organization (ICAO) 24-bit aircraft address, which corresponds to the registration number of the aircraft as a 24-bit parity check for validation. In basic mode S surveillance, the information is limited to altitude reporting, basic airframe information and aircraft identification.

[0005] More and more aircrafts are using today the Automatic dependent surveillance-broadcast (ADS-B). Since radars have a limited precision on the position of aircrafts, the idea behind ADS-B is to use the Global Navigation Satellite Systems (GNSS) to measure the airframe's position and to transmit this position by radio in the mode S message. Aircrafts equipped with mode S, are able to send and receive 56 bits messages. The 1090ES (Extended Squitter) is an extension of the mode S radar transponders which emit at 1090 MHz. This modification allows to send 112 bits messages which include

the position of the aircraft calculated by the GNSS system and eventually to receive them. On the ground, these ADS-B information can be received either by a SSR or by a simple omnidirectional antenna much cheaper. The mode (A, C or S) of the reply is then decoded and the information is demodulated within each mode. Since most of commercial aircrafts are already equipped with transponders, the 1090ES is a very cheap solution for these aircrafts.

[0006] ASDE-X uses data which come different types of radars, sensors and transponders. The merging of all these data allows the ASDE-X to determine the position of aircrafts and to identify aircrafts and vehicles on the airport surfaces, as well as determine aircraft approaching the airport.

[0007] Aircraft travel times and delays often need to be accurately evaluated for a variety of reasons. One of the reasons is to evaluate an air carrier's performance, required by Eurocontrol, the FAA etc. The data used to evaluate the performance include "OOOI" data which corresponds to the operations of an aircraft: Out of the stand, Off the ground, On the ground, and Into the stand. This data along with airline schedules allow for the calculation of route times, stand arrival time delay, stand delay, taxi times etc. for every flight. Another reason is to improve ground operations such as baggage handling, air carrier's refuelling. Late arriving flights may also imply a new stand assignment which drastically complicates the organization of ground operations. Airline's planning and staffing are however planned according to scheduled times and it is therefore important to have realistic scheduled times of departure (STD) and scheduled times of arrival (STA). Realistic STD and STA are also important for passengers in order to meet their expectations.

[0008] OOOI times are significant because these times are used as the basis of predictions and in calculation of delays. For these and other reasons it is important that OOOI data have sufficient completeness and accuracy.

[0009] ACARS, **Aircraft Communications Addressing and Reporting System**, is a digital datalink system for the transmission of messages between an aircraft and a ground station. These messages can be transmitted by satellite or by radio. The main function of ACARS is related to the detection of the major flight phases of an aircraft, the OOOI operations. For planes equipped with ACARS systems, OOOI operations are automatically detected using sensors. 'Wheels "out" of the stand' corresponds to the time an aircraft pushes back from the stand and is measured when the parking brake is released, with the associated change in brake pressure. It corresponds to the Actual time of Departure (ATD). 'Wheels "off the runway' corresponds to the time an aircraft takes-off. 'Wheels "on" the runway' corresponds to the actual time an aircraft lands on the runway. Finally, 'wheels "in"' corresponds to the actual time an aircraft arrives at the stand or in the parking position. It also corresponds to the Actual time of Arrival (ATA).

[0010] However, not all aircrafts use the ACARS sys-

tem. One of the reasons for this is cost. Another reporting option is to use a Docking Guidance System (DGS). DGS employs a technology based on lasers to help pilots to park the aircraft at the stand and the flight crew or the ground personnel transmits the departure and arrival times by radio, electronic or even by written communications.

[0011] When OOOI times are not available they are estimated according to FAA guidelines for US.

[0012] It is therefore an object of the present invention to provide a reliable and simple method to measure OOOI times.

Summary of the invention

[0013] In accordance with one aspect of the present invention, there is provided a method for the determination of an in-time of an aircraft, comprising the steps of

- a) receiving transponder data from the aircraft;
- b) parsing said transponder data in at least coordinate data of said aircraft and speed data of said aircraft;
- c) verifying if speed data is close to zero;
- d) verifying if said aircraft coordinates are close to parking coordinates available in a database;
- e) verifying if said speed data of said aircraft is decreasing;
- f) processing an actual processing time as the in-time of the aircraft if the aircraft coordinates are close to the parking coordinates and the speed is zero and the previous speed is higher than zero.

[0014] The use of the transponder data allows a simple method to accurately determine the in-time of an aircraft. No additional hardware is necessary for the implementation of the proposed method.

[0015] In an embodiment of the present invention, the transponder data is further parsed in at least flight data including data indicating if the flight is an arrival flight or a departure flight, wherein said method further comprises the step of verifying if said flight is an arrival flight, and processing an actual processing time as the in-time of the aircraft if also said flight is an arrival flight.

[0016] This allows a gain in computational time, since only the data indicating an arrival flight is processed to determine the in-time of the aircraft.

[0017] Advantageously, the transponder data is a mode-S message.

[0018] A mode-S message comprises the registration number of the aircraft and preferably its position from the GNSS system. The combination of the mode-S message data and a database allows an accurate computation of the OOOI times of the aircraft.

[0019] Preferably, the method further comprises the step of comparing said parsed transponder data with data available in a flight data database, and adding data from the flight data database to said parsed transponder data

to create more complete flight data.

[0020] Advantageously, the method further comprises the step of verifying if the aircraft is on the runway, and processing an actual processing time as the in-time of the aircraft if also the aircraft is not on the runway.

[0021] In an embodiment of the present invention, said parking coordinates are stand coordinates or parking spot coordinates.

[0022] It is an object of the present invention to provide a system to determine an in-time of an aircraft, comprising

- a) a receiver for receiving transponder data from an aircraft;
- b) a processor for parsing said transponder data in at least coordinate data of said aircraft and speed data of said aircraft, verifying if said speed is close to zero, verifying if said aircraft coordinates are close to stand coordinates, verifying if said speed data of said aircraft is decreasing, and generating as the in-time the actual processing time if the aircraft coordinates are close to the stand coordinates and the speed is zero and the previous speed is higher than zero;
- c) a memory for storing said in-time of said aircraft.

[0023] In another embodiment of the present invention, it is provided a method to determine an on-time of an aircraft, comprising the steps of

- a) receiving transponder data from the aircraft;
- b) parsing said transponder data in at least coordinate data of said aircraft and altitude data of said aircraft;
- c) verifying if said aircraft altitude is close to the airport altitude available in a database;
- d) verifying if said aircraft coordinates are close to runway coordinates available in a database;
- e) processing an actual processing time as the on-time of the aircraft if the aircraft altitude is close to the airport altitude and if the aircraft coordinates are close to the runway coordinates.

[0024] This method allows the determination of the on-time of an aircraft without the need of new special hardware. Only data available in a database and the transponder data are necessary for determining the on-time.

[0025] In an embodiment of the present invention, the method further comprises the step of verifying if a previous on-time is available for said aircraft and processing an actual processing time as the on-time of the aircraft if also there is no on-time available for said aircraft.

[0026] The on-time is only valid if no previous on-time has been previously calculated.

[0027] It is an object of the present invention to also provide a system to determine an on-time of an aircraft, comprising

- a) a receiver for receiving transponder data from an aircraft;
- b) a processor for parsing said transponder data in at least coordinate data of said aircraft and altitude data of said aircraft, verifying if said aircraft altitude is close to the airport altitude available in a database, verifying if said aircraft coordinates are close to runway coordinates available in a database, and generating as the on-time the actual processing time if the aircraft altitude is close to the airport altitude and if the aircraft coordinates are close to the runway coordinates;
- c) a memory for storing said on-time of said aircraft.

[0028] It is an object of the present invention to provide a method to determine an out-time of an aircraft, comprising the steps of

- a) receiving transponder data from the aircraft;
- b) parsing said transponder data in at least coordinate data of said aircraft and speed data of said aircraft;
- c) verifying if said aircraft coordinates are close to parking coordinates available in a database;
- d) verifying if said speed data of said aircraft is increasing; and
- e) processing an actual processing time as the out-time of the aircraft if the aircraft coordinates are close to the parking coordinates and the speed is increasing and the previous speed is zero.

[0029] This method allows the determination of the out-time of an aircraft without the need of new special hardware. Only data available in a database and the transponder data are necessary for determining the on-time.

[0030] It is an object of the present invention to provide a system to determine an out-time of an aircraft, comprising

- a) a receiver for receiving transponder data from an aircraft;
- b) a processor for parsing said transponder data in at least coordinate data of said aircraft and speed data of said aircraft, verifying if said aircraft coordinates are close to parking coordinates available in a database, verifying if said speed data of said aircraft is increasing, and generating as the out-time the actual processing time if the aircraft coordinates are close to the parking coordinates and the speed is increasing and the previous speed is zero;
- c) a memory for storing said on-time of said aircraft.

[0031] It is an object of the present invention to provide a method to determine an off-time of an aircraft, comprising the steps of

- a) receiving transponder data from the aircraft;
- b) parsing said transponder data in at least coordi-

- nate data of said aircraft and altitude data of said aircraft;
- c) verifying if said aircraft altitude is close to the airport altitude available in a database;
- d) verifying if said aircraft coordinates are close to runway coordinates available in a database;
- e) verifying if the previous value of the altitude data is less than the current value;
- f) processing an actual processing time as the off-time of the aircraft if the aircraft altitude is close to the airport altitude, if the aircraft coordinates are close to the runway coordinates and if the current aircraft altitude is lower than the previous.

[0032] This method allows the determination of the off-time of an aircraft without the need of new special hardware. Only data available in a database and the transponder data are necessary for determining the on-time.

[0033] It is an object of the present invention to provide a system to determine an off-time of an aircraft, comprising

- a) a receiver for receiving transponder data from an aircraft;
- b) a processor for parsing said transponder data in at least coordinate data of said aircraft and altitude data of said aircraft, verifying if said aircraft altitude is close to the airport altitude available in a database, verifying if said aircraft coordinates are close to runway coordinates available in a database, verifying if the previous value of the altitude data is less than the current value, and generating as the off-time the actual processing time if the aircraft altitude is close to the airport altitude, if the aircraft coordinates are close to the runway coordinates and if the previous aircraft altitude is less than the current altitude;
- c) a memory for storing said off-time of said aircraft.

[0034] Advantageously, the in-time, the on-time, the out-time and the off-time are used to determine the OOOI time of an aircraft.

[0035] The method allows a simple and accurate way of determining OOOI times of an aircraft. Also, there is no need to provide new hardware in the aircraft for this accurate computation. This is performed using the already existing hardware on board of the aircraft.

Brief description of the drawings

[0036] For a better understanding of the present invention, reference will now be made, by way of example, to the accompanying drawings in which:

Figure 1 shows a flowchart of a system and method to determine the OOOI times.

Figure 2 shows a flowchart of steps in a system or method to determine the in-time and out-time of an aircraft.

Figure 3 shows a further flowchart of steps in a system or method to determine the in-time and out-time of an aircraft.

Figure 4 shows a flowchart of steps in a system or method to determine the on-time of an aircraft.

Figure 5 shows a flowchart of steps in a system or method to determine the off-time of an aircraft.

Description of the invention

[0037] The present invention will be described with respect to particular embodiments and with reference to certain drawings but the invention is not limited thereto. The drawings described are only schematic and are non-limiting. In the drawings, the size of some of the elements may be exaggerated and not drawn on scale for illustrative purposes.

[0038] Furthermore, the terms first, second, third and the like in the description and in the claims, are used for distinguishing between similar elements and not necessarily for describing a sequential or chronological order. The terms are interchangeable under appropriate circumstances and the embodiments of the invention can operate in other sequences than described or illustrated herein.

[0039] Furthermore, the various embodiments, although referred to as "preferred" are to be construed as exemplary manners in which the invention may be implemented rather than as limiting the scope of the invention.

[0040] The term "comprising", used in the claims, should not be interpreted as being restricted to the elements or steps listed thereafter; it does not exclude other elements or steps. It needs to be interpreted as specifying the presence of the stated features, integers, steps or components as referred to, but does not preclude the presence or addition of one or more other features, integers, steps or components, or groups thereof. Thus, the scope of the expression "a device comprising A and B" should not be limited to devices consisting only of components A and B, rather with respect to the present invention, the only enumerated components of the device are A and B, and further the claim should be interpreted as including equivalents of those components.

[0041] A simple, robust and accurate method to calculate OOOI times is described wherein OOOI time calculation refers to Out of the stand, Off the ground, On the ground and Into the stand. The stand is the parking position. It is for example the stand or a parking spot allocated to the aircraft. Therefore, in this description, we refer to this position as the stand position.

[0042] The Runway Thresholds are markings across the runway which define the beginning and the end of the space intended for landing and take-off.

[0043] The Mode S transponder messages include the coordinates of the plane calculated by a Global Navigation Satellite System such as the GPS. The aircrafts are equipped with ADS-B and the mode S messages include

the coordinates of the aircraft.

[0044] The AODB (Airport Operation DataBase) is a resilient, comprehensive central repository for operational data management activities. It delivers the efficiency of an airport's centralized operational database along with guaranteed, consistent and robust operational performance. The AODB stores, distributes and manages all real-time flight data, in addition to all aeronautical and non-aeronautical service data, and it quickly transforms this data into accurate financial figures. The AODB is a multi-tiered application. Interaction between the user interface and service layers, which is designed by utilizing Service Oriented Architecture (SOA), is event-based. The AODB user interface is designed as a RIA, (Rich Internet Application) it takes advantage of cross browser and platform compatibility in addition to taking advantage of the web deployment model's traditional benefits. The AODB is configurable depending on the operation and size of the airport. The AODB is equally well suited for small, medium-sized or large airports. According to the needs of the customer, it can be downsized or dedicated "cost effective" solutions can be tailored. The AODB further includes an interface capable of receiving mode-S messages and interpreting them.

[0045] The definition of "in-time" used in this application is the time that the aircraft arrives in his parking position. The parking position can be a stand position or a parking spot allocated to the aircraft. It should be understood that throughout the application, where stand or parking spot is used, the one can be replaced by the other.

[0046] The definition of "out-time" used in this application is the time that the aircraft leaves his parking position.

[0047] The definition of "off-time" used in this application is the time that the aircraft is no longer in contact with the runway.

[0048] The definition of "on-time" used in this application is the time that the aircraft is touching the runway.

[0049] Referring to Figure 1, Figure 1 illustrates a flow chart of a system that is used to determine OOOI times based on transponder mode-S messages. The method is executed for every mode-S message received. Usually, the transponder of an aircraft sends a mode-S message every few seconds. Preferably, the time interval between two consecutive mode-S messages of an aircraft is lower than 5 seconds.

[0050] The transponder of the aircraft replies to signals from a Secondary Surveillance Radar 100 by transmitting the mode-S messages 102. This mode-S message includes the aircraft identification number, the pressure altitude, the GPS position and the speed of the aircraft. The signal corresponding to the Mode-S message is sent to an SBS receiver (antenna) 104 which decodes the transponder signal from the aircraft, demodulates it and converts the analog signal to a digital message 106. The SBS receiver then sends this digital message to an application, part of a control system, responsible of reading, parsing and processing the digital data 108. In this control

system, another application is responsible for listening to specific ports which receive the converted digital messages. The messages are received byte by byte and the application is able to distinguish each message and its corresponding source. The digital signal corresponding to the analog mode-S message is analysed. The corresponding data is inserted into a predefined flight data structure which comprises the following data fields:

- registration number of the aircraft,
- flight ID,
- coordinates of the aircraft at time t
- pressure altitude at time t
- scheduled time of departure (STD)
- scheduled time of arrival (STA)
- actual time of departure (ATD)
- actual time of arrival (ATA)
- actual time of in-block (AIBT)
- actual time of off-block (AOBT)
- for a given airport if the flight is an arrival flight or a departure flight
- aircraft speed
- OOOI times
- call sign (alternative alphanumeric flight number)
- ...

[0051] This flight data structure is updated and completed during the process, some fields can be empty.

[0052] In step 110, this flight data structure is subsequently compared to the data already available in the AODB 114 from different integrated sources. To find the flight in the AODB, the system can use different search criteria as the flight date and time, the airline and the flight ID, the registration number of the aircraft, the call-sign, etc.

[0053] If the current flight is not yet comprised in the data base (arrow 111 in flow chart), the new flight data is in step 113 added to the database 114. Additional flight data can be added to the AODB 114 from other sources of information such as AFTN, airline-ground handling systems, slot.

[0054] If the current flight is in the AODB 112, then the method continues with step 115. The flight data structure is checked and updated if necessary depending on the mode-S transponder message data. The most important data being the identification number because it allows identification of the aircraft.

[0055] Step 130 consists in checking whether the aircraft is already on the runway. This step is performed with a comparison of its coordinates, available in the flight data structure, to the runway coordinates. If the aircraft is not on the runway (arrow 131), the next step 132 consists in determining if the aircraft is in the stand position and if its speed has recently changed. A negative reply 133 leads to perform the "Log message" step 134, which consists in saving an appropriate message, to be used later on. In case of a positive reply 135, the method verifies at step 136 if the flight is an arrival flight. If it is (arrow

137), the system performs the "in" time determination method 200.

[0056] If it is not an arrival flight (arrow 138), the system performs the "out" time determination method 300. The sequence of operations used to determine these "in" and "out" times are described in more detail later in this description.

[0057] However, if at step 130 the outcome is that the aircraft is on the runway (arrow 141), it means the aircraft is about to take off or that it has just landed. Therefore, step 142 checks if the current flight is an arrival flight. In case of a positive reply 143, the system performs the "on" time determination method 400. In case of a negative reply 144, the system performs the "off" time determination method 500. The sequence of operations used to determine these "on" and "off" times are described in more detail later in this description.

[0058] When these four outcomes 200, 300, 400 and 500 have all been determined, the data is collected at step 600 and the OOOI times 700 of the aircraft are available for further use..

[0059] Referring now to Figure 2, Figure 2 illustrates the method to determine the "in" time 200. The method includes the following steps and starts after step 136 of Figure 1. All the data of the aircraft are available in the flight data structure. Step 220 consists in checking whether the speed is close to zero.. Theoretically, the speed should be zero. However, sometimes transponders may send incorrect speed values. These incorrect values are found by comparing the speed values of the previous and the next messages. Each airport has its own regulation regarding the speed limit for which a plane is assumed to be in its parking position. Usually, this speed limit value is around 3 knots.

[0060] If it is not the case, the system logs the available data in step 225 for further use. If the speed is close to zero, the method compares the aircraft coordinates to the stand coordinates in step 230. If the coordinates do not lie in a range corresponding to the stand coordinates, the method stops and performs logs the data in step 235 for further use. While the coordinates lie in the range of the stand coordinates, the next step consists in checking whether a previous "in" time has been saved in step 240. While no previous "in" time is available, the current time corresponds to an actual "in" time and the "in" time is set to the current time. The stand coordinates which correspond to the current GPS coordinates of the aircraft saved in the flight data structure are also set as "stand" coordinates. This is performed in step 245 where the "in" time and the "stand" coordinates are set. However, if a previous "in" time has already been stored, the method verifies if there is a previous "out" time with step 250. While there is no previous "out" time, the method sets the "out" time to the current time with step 255. If a previous "out" time has been saved, the method verifies if the speed of the aircraft was higher than zero in the previous data with the verification step 260. If it is not the case, the plane is about to leave and the "out" time can

be updated with step 265. However, if the aircraft was moving in the previous data, it implies that the plane has just arrived in the gate and a new "in" time can be saved. The coordinates of the stand position are also stored from the available GPS data saved in the flight data structure. The "in" time and the stand coordinates are saved in step 270..

[0061] Referring to Figure 3, Figure 3 illustrates the flow chart corresponding to the processing of the "out" time. Pilots may turn the transponders off. However they should be turned on before leaving the stand. Once a transponder is turned on it starts sending messages. The method actually compares the coordinates of the aircraft with the stand coordinates and checks the speed. If the speed is different from zero and/or the coordinates are different from those of the allocated stand, it means that the aircraft is about to leave the stand. The method includes the following steps and starts after the arrival flight verification 136 step of Figure 1. In this case, the flight is a departure flight. The aircraft coordinates are available and the speed is available from the transponder Mode-S message.. The first step consists in checking whether the speed of the aircraft is close to zero with step 320.. If it isn't, or if it is moving fast, the data is logged in step 325 for further use. If it is moving slowly, the method verifies whether the aircraft coordinates lie in the range corresponding to the allocated stand. If they don't, the next step is to log the data 335 for further use. If it is, the method checks if the speed in the previous data is higher than zero in step 340. If it isn't, the method performs the step of determining the "out" time in step 345. If the plane was previously moving, the method performs the step of adding a new "in" time as well as a new stand coordinate in step 350.

[0062] Referring now to Figure 4, Figure 4 illustrates the sequence of events used to determine the "on" time 400. The aircraft coordinates are compared with coordinates corresponding to the runway thresholds coordinates. If the aircraft coordinates (longitude and latitude) lie in this zone and if the altitude corresponds to that of the runway, the current time is stored as an actual "on" time candidate. For validation, the method continues to verify whether or not the next messages support this "on" time candidate. When the below conditions are met, then the time becomes a real "on" time:

the next coordinates of the plane must correspond to the coordinates of a point in the runway and/or taxiway further away in the moving direction of the plane,
the altitude must correspond to the previous one (small differences are tolerated based on a given threshold),
the plane must be decelerating.

[0063] While these 3 conditions are not met, it means that the current flight can be either a training flight, that pilots may train to approach the runway, or it could be any technical problem which has lead the pilot to cancel landing. However, in these scenarios, the data is stored as "on" approach time for further reporting in AODB.

[0064] The method includes the following steps and

starts after the arrival flight verification step 142. The first condition concerns the altitude of the aircraft and the method verifies if the altitude of the aircraft is close to the altitude of the runway in step 420. If it isn't the method stops by storing the flight data structure in memory and performs the step of logging the data in 425. If the altitude of the aircraft is close to that of the runway, the method continues with step 430 where the coordinates of the aircraft are compared to the runway thresholds coordinates. While the coordinates of the aircraft don't lie in a range corresponding to the runway thresholds coordinates, the method stops and the flight data structure is logged in step 435. However, if the coordinates lie in that particular range, the method then verifies if there is any other "on" time previously saved 440. If there isn't, the current time corresponds to the actual "on" time and the method performs the step of setting the "on" time in step 445. Step 445 also comprises the setting of the thresholds. "Set "on" time & threshold" 445. If the actual "on" time is not valid, the method needs to verify whether the speed of the aircraft is increasing with the condition 450. If it isn't, the method stops and logs the data in step 455. If the speed of the aircraft is increasing, it means that the plane has taken off again and the method stops with the status "Set Touch and Go" 460.

[0065] Referring now to Figure 5, Figure 5 illustrates the sequence of operations for determining the "off" time 500. In step 520, the coordinates of the aircraft are compared with the runway thresholds coordinates. If the aircraft coordinates (longitude and latitude) lie in the corresponding range of the runway coordinates, it means that the aircraft is ready for take-off and the system continues to monitor the movements of the aircraft until it passes the take-off zone on the runway and the altitude of the aircraft becomes higher than the altitude of the runway. Once the above condition is met, the time is saved as actual take-off time. The method includes the following steps and starts after the arrival flight verification 142 step. In this case, the flight is a departure flight and the first verification step of the method concerns the comparison of the coordinates of the aircraft with respect to the runway thresholds coordinates (step 520). If the position of the aircraft is not in the zone of the runway thresholds coordinates, the method stops with logging the data in step 525. Otherwise the method continues with an altitude check in step 530: is the altitude of the aircraft increasing with respect to previous data? A negative reply leads the method to stop and to log data in step 535. However, a positive reply means that the aircraft is taking off. Subsequently, step 540 verifies whether there is a previous "off" time set. With a negative reply, the method can save the actual time as the "off" time in step 545. With a positive reply, the method stops and logs the data in step 550.

[0066] In Figures 2, 3, 4 and 5, the sequences of operations for determining the "in" 200, "out" 300, "on" 400 and "off" 500 times have respectively been described.

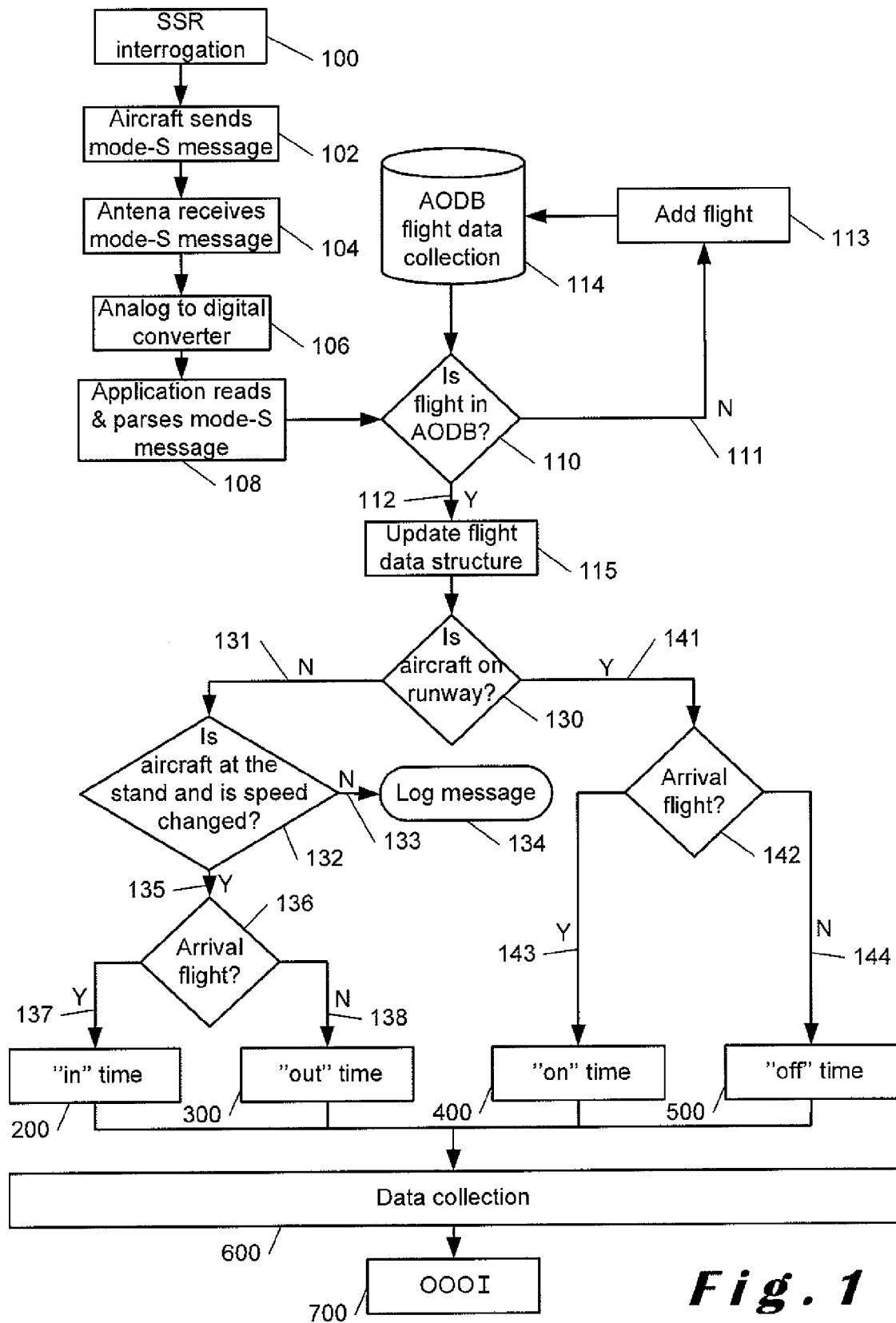
[0067] Referring now to Figure 1, step 600 is dedicated

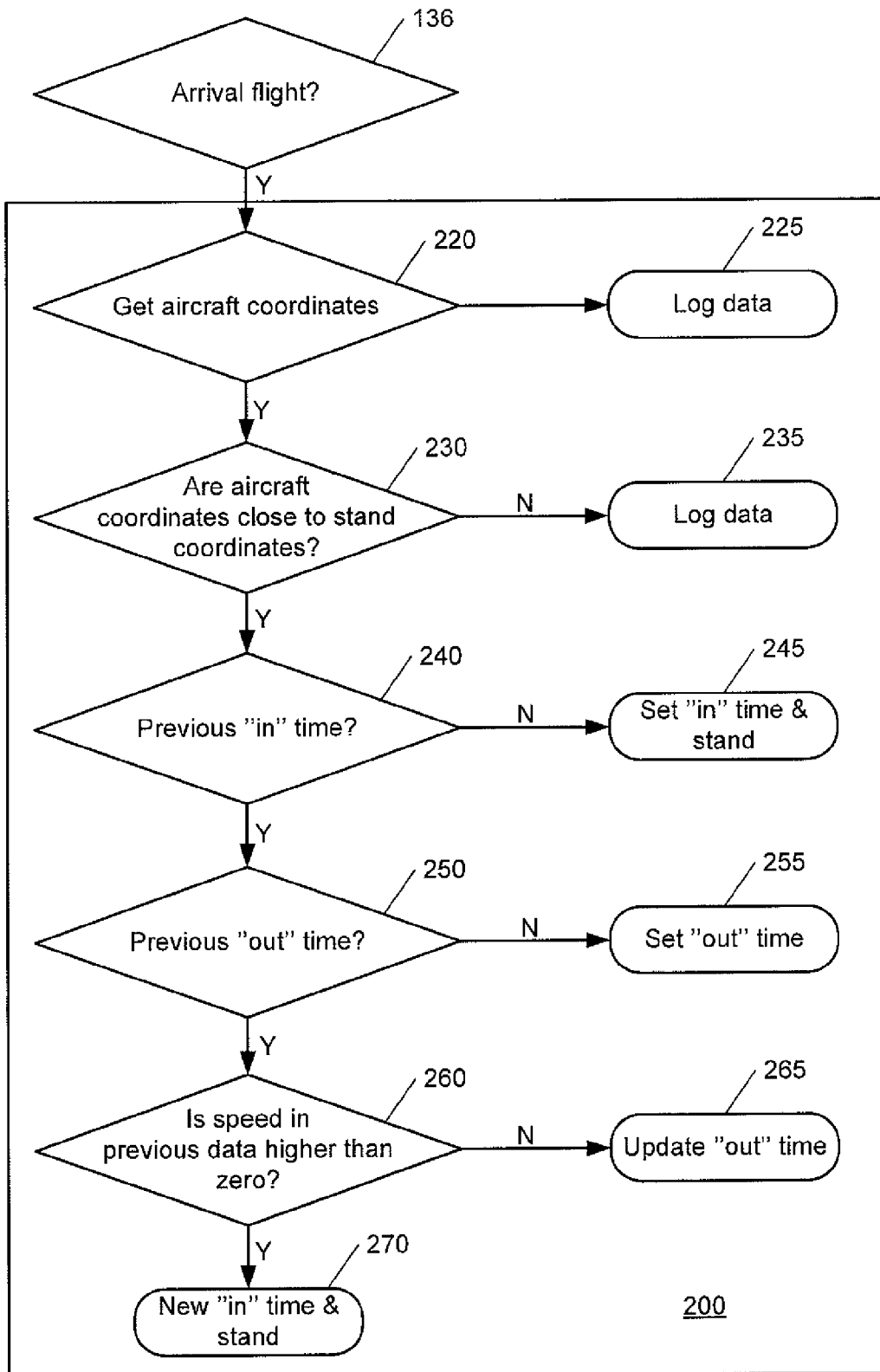
to collect the four times acquired in steps 200, 300, 400, 500. Step 700 accurately calculates the OOOI time of an aircraft from the "in", "out", "on" and "off" times.

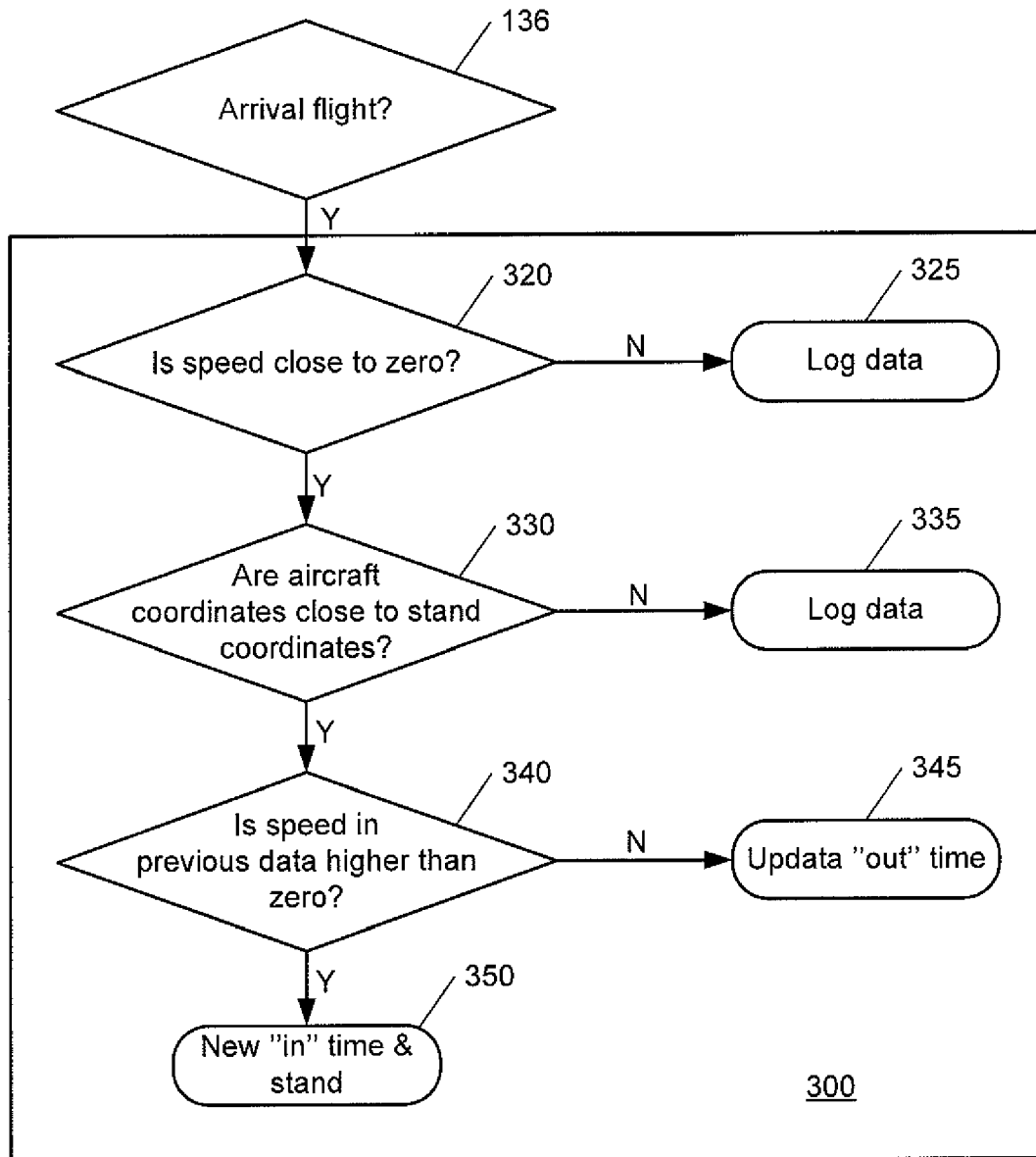
Claims

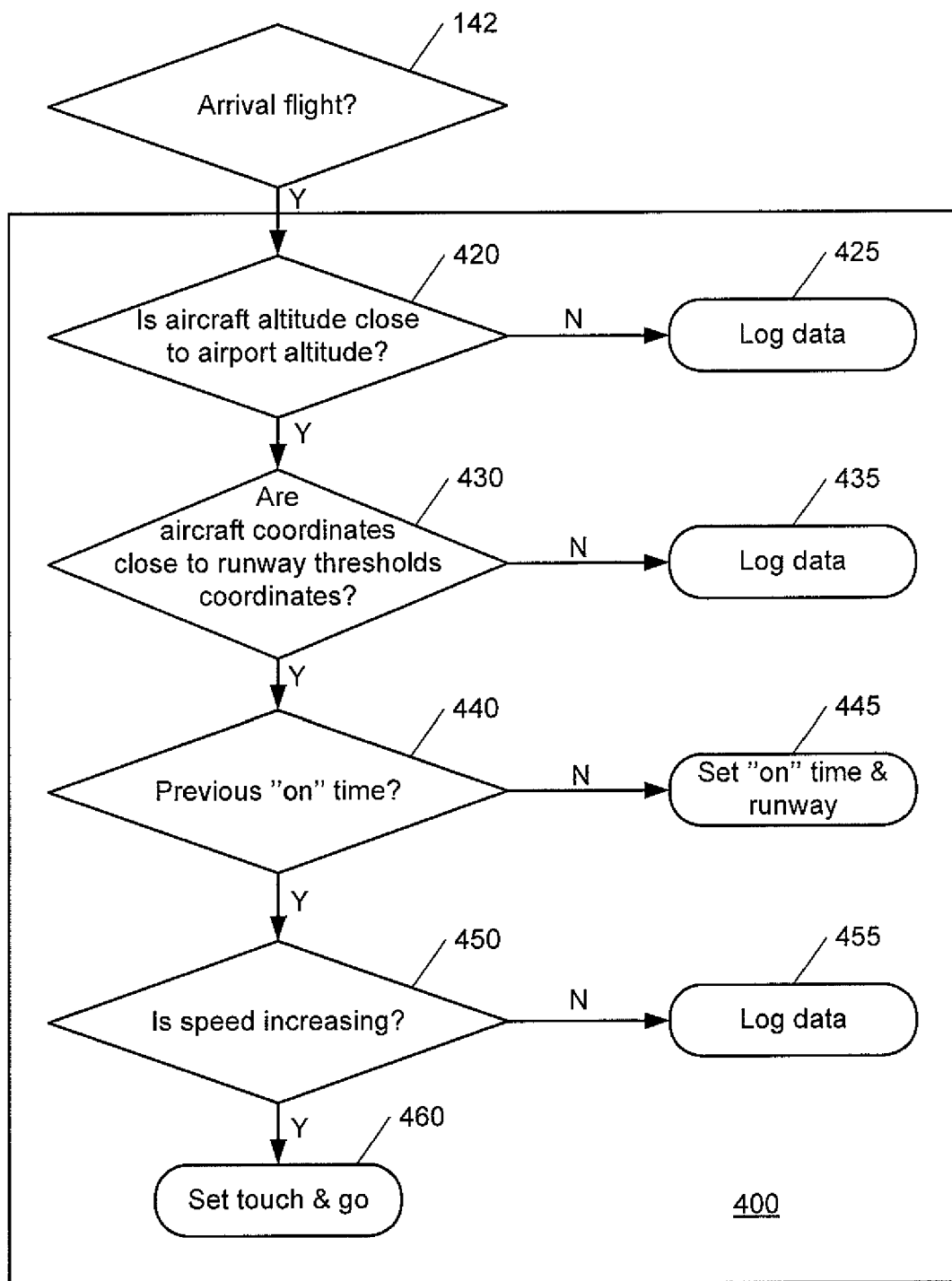
1. A method to determine an in-time of an aircraft, comprising the steps of
 receiving transponder data from the aircraft;
 parsing said transponder data in at least coordinate data of said aircraft and speed data of said aircraft;
 verifying if speed data is close to zero;
 verifying if said aircraft coordinates are close to parking coordinates available in a database;
 verifying if said speed data of said aircraft is decreasing;
 processing an actual processing time as the in-time of the aircraft if the aircraft coordinates are close to the parking coordinates and the speed is zero and the previous speed is higher than zero.
2. A method according to claim 1, wherein said transponder data is further parsed in at least flight data including data indicating if the flight is an arrival flight or a departure flight, wherein said method further comprises the step of verifying if said flight is an arrival flight, and processing an actual processing time as the in-time of the aircraft if also said flight is an arrival flight.
3. A method according to any one of the preceding claims, wherein said transponder data is a mode-S message.
4. A method according to any one of the preceding claims, wherein said method further comprises the step of comparing said parsed transponder data with data available in a flight data database, and adding data from the flight data database to said parsed transponder data to create more complete flight data.
5. A method according to any one of the preceding claims, wherein said method further comprises the step of verifying if the aircraft is on the runway, and processing an actual processing time as the in-time of the aircraft if also the aircraft is not on the runway.
6. A method according to any one of the preceding claims, wherein said parking coordinates are stand coordinates or parking spot coordinates.
7. A system to determine an in-time of an aircraft, comprising
 a receiver for receiving transponder data from an aircraft;
 a processor for parsing said transponder data in at least coordinate data of said aircraft and speed data
- of said aircraft, verifying if speed data is close to zero, verifying if said aircraft coordinates are close to stand coordinates, verifying if said speed data of said aircraft is decreasing, and generating as the in-time the actual processing time if the aircraft coordinates are close to the stand coordinates and the speed is zero and the previous speed is higher than zero;
 a memory for storing said in-time of said aircraft.
8. A method to determine an on-time of an aircraft, comprising the steps of
 receiving transponder data from the aircraft;
 parsing said transponder data in at least coordinate data of said aircraft and altitude data of said aircraft;
 verifying if said aircraft altitude is close to the airport altitude available in a database;
 verifying if said aircraft coordinates are close to runway coordinates available in a database;
 processing an actual processing time as the on-time of the aircraft if the aircraft altitude is close to the airport altitude and if the aircraft coordinates are close to the runway coordinates.
9. A method according to claim 8, further comprising the step of verifying if a previous on-time is available for said aircraft and processing an actual processing time as the on-time of the aircraft if also there is no on-time available for said aircraft.
10. A system to determine an on-time of an aircraft, comprising
 a receiver for receiving transponder data from an aircraft;
 a processor for parsing said transponder data in at least coordinate data of said aircraft and altitude data of said aircraft, verifying if said aircraft altitude is close to the airport altitude available in a database, verifying if said aircraft coordinates are close to runway coordinates available in a database, and generating as the on-time the actual processing time if the aircraft altitude is close to the airport altitude and if the aircraft coordinates are close to the runway coordinates;
 a memory for storing said on-time of said aircraft.
11. A method to determine an out-time of an aircraft, comprising the steps of
 receiving transponder data from the aircraft;
 parsing said transponder data in at least coordinate data of said aircraft and speed data of said aircraft;
 verifying if said aircraft coordinates are close to parking coordinates available in a database;
 verifying if said speed data of said aircraft is increasing; and
 processing an actual processing time as the out-time of the aircraft if the aircraft coordinates are close to the parking coordinates and the speed is increasing and the previous speed is zero.

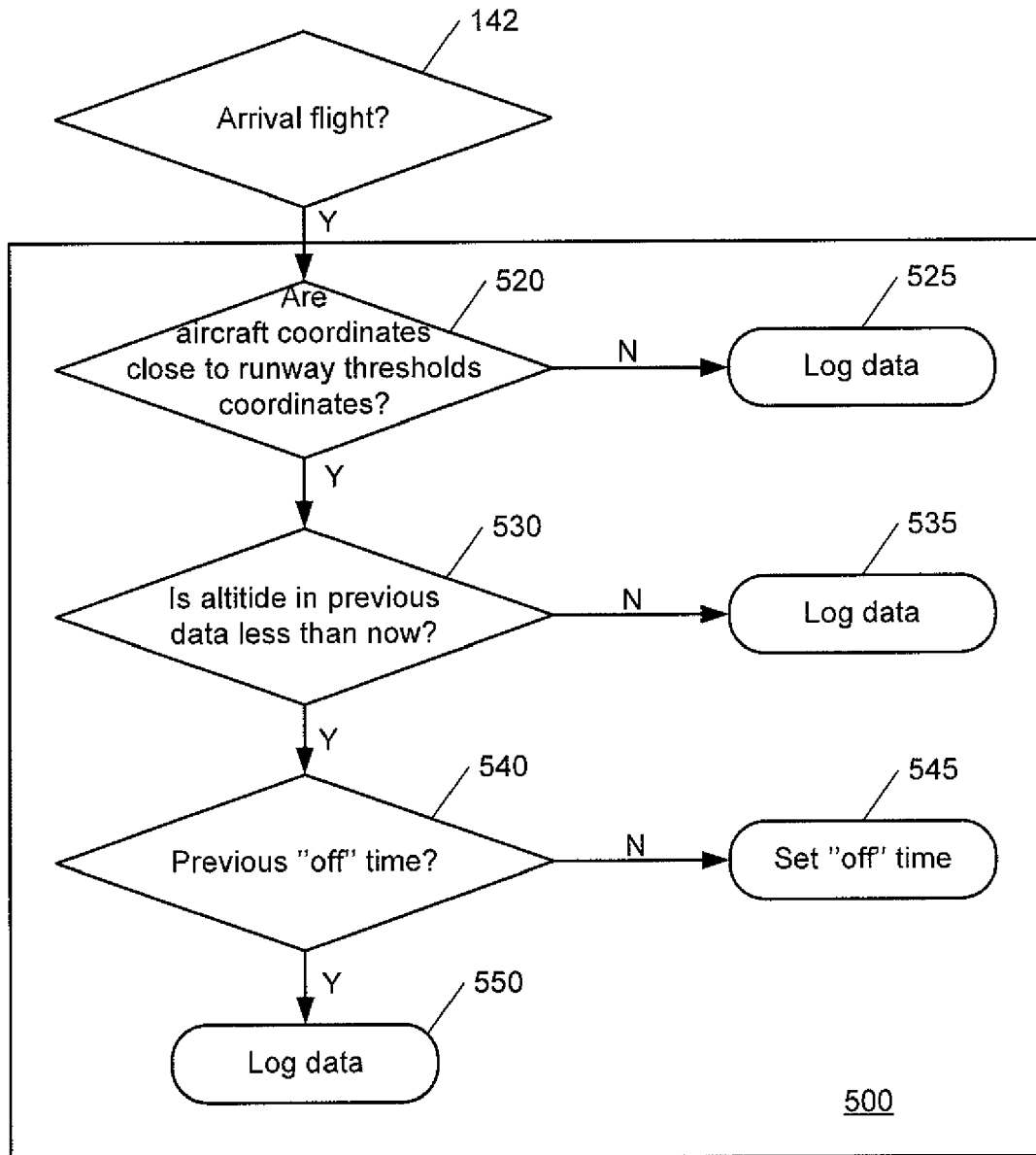
12. A system to determine an out-time of an aircraft, comprising
 a receiver for receiving transponder data from an aircraft;
 a processor for parsing said transponder data in at least coordinate data of said aircraft and speed data of said aircraft, verifying if said aircraft coordinates are close to parking coordinates available in a database, verifying if said speed data of said aircraft is increasing, and generating as the out-time the actual processing time if the aircraft coordinates are close to the parking coordinates and the speed is increasing and the previous speed is zero;
 a memory for storing said on-time of said aircraft.
13. A method to determine an off-time of an aircraft, comprising the steps of
 receiving transponder data from the aircraft;
 parsing said transponder data in at least coordinate data of said aircraft and altitude data of said aircraft;
 verifying if said aircraft altitude is close to the airport altitude available in a database;
 verifying if said aircraft coordinates are close to runway coordinates available in a database;
 verifying if the previous value of the altitude data is less than the current value;
 processing an actual processing time as the off-time of the aircraft if the aircraft altitude is close to the airport altitude, if the aircraft coordinates are close to the runway coordinates and if the previous aircraft altitude is lower than the current aircraft altitude.
14. A system to determine an off-time of an aircraft, comprising
 a receiver for receiving transponder data from an aircraft;
 a processor for parsing said transponder data in at least coordinate data of said aircraft and altitude data of said aircraft, verifying if said aircraft altitude is close to the airport altitude available in a database, verifying if said aircraft coordinates are close to runway coordinates available in a database, verifying if the previous value of the altitude data is less than the current value, and generating as the off-time the actual processing time if the aircraft altitude is close to the airport altitude, if the aircraft coordinates are close to the runway coordinates and if the previous aircraft altitude is less than the current altitude;
 a memory for storing said off-time of said aircraft.
15. A method according to claims 1 to 14, wherein the in-time, the on-time, the out-time and the off-time are used to determine the OOOI time of an aircraft.

**Fig. 1**

**Fig. 2**

**Fig. 3**

**Fig. 4**

**Fig. 5**



EUROPEAN SEARCH REPORT

Application Number
EP 14 18 7838

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	LEVY B S ET AL: "Objective and automatic estimation of excess taxi-times", INTEGRATED COMMUNICATIONS, NAVIGATION AND SURVEILLANCE CONFERENCE, 2008. ICNS 2008, IEEE, PISCATAWAY, NJ, USA, 5 May 2008 (2008-05-05), pages 1-10, XP031283424, ISBN: 978-1-4244-2303-3 * page 1, right-hand column, lines 3-6 * * page 2, right-hand column, line 11 - page 4, right-hand column, line 27 * * page 10, right-hand column, lines 30-33 * -----	1-15	INV. G08G5/00 ADD. G08G5/06
			TECHNICAL FIELDS SEARCHED (IPC) G08G
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
The Hague		17 April 2015	Fagundes-Peters, D
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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