UDC 004.421(045)

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SOFTWARE IMPLEMENTATION METHODS OF DETECTION AND RESOLUTION OF POTENTIAL CONFLICTS BETWEEN AIRCRAFT

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Abstract. *On a daily basis, on thousands of commercial and military flights, the lives of countless passengers are dependent upon the implementation of safety regulations adopted to protect the public interest. Detecting potential conflict situations – is not only analysis of many factors that occur in a given time, but also a final decision concerning crew of aircraft to change the motion parameters, the timely and proper execution of which will provide a safe distinction aircraft from holding the required minimum separation. A set of algorithms that can identify and resolve a potential conflict situation between the aircraft on counter, trail tracks and intersecting tracks has been developed. The software implementation of methods for the determination and resolution of potential conflict situations between aircraft has been made.*

Keywords: aircraft; algorithm; flight level; potential conflict situation; software implementation; track.

1. Introduction

On a daily basis, on thousands of commercial and military flights, the lives of countless passengers are dependent upon the implementation of safety regulations adopted to protect the public interest. The implications of aviation safety not only save lives while people travel through the air, but ensures the safety of everyone. With more planes in the air and more total time spent in the air during travel, aviation safety is more important than ever. While air safety has been a very important since from the beginning of flight for man, in today's technological world with many complicated systems in operation during a flight paying attention to the details is important. While the aircraft could be a well maintained top of the line flying machine, human error could lead to a crash. Whether it's on the ground (the air traffic controller) or in the air (the pilot or someone else on the plane), one wrong move can equal disaster. Beyond the people controlling and guiding the plane, the actions of the passengers and the rest of the crew can play a big part in airline safety. Detecting potential conflict situations – is not only analysis of many factors that occur in a given time, but also a final decision concerning crew of aircraft to change the motion parameters, the timely and proper execution of which will provide a safe distinction aircraft from holding the required minimum separation.

2. Literature Analysis

Nowadays there exists a great deal of literature and documents concerning a detection and a resolution of potential conflicts between aircraft. Main methods to detect potential conflicts between aircraft are described at the book [Kharchenko, Argunov 2010]. This work deals with annexes 2 "Rules of the air" [Terms…2003], annex 11 "Air Traffic Services" to ICAO Convention [Annex 11…2001], Document 4444" Air traffic management" and the methodological directory "Airspace management [Doc 4444-ATM/501…2007].

3. The goal of the work and formulation of research problems

As a result of the literature analysis, the task concerning developing algorithms for potential conflict situations and creating software, which does not only perform the calculations of the parameters of the situation on the screen and give the results of these calculations, but also provides the necessary hints for the air traffic controller to resolve potentially dangerous situations, have been arisen. This software includes all possible types of conflict situations in the air.

4. The main part

Potentially conflict situation is such sort of situation, where the risk of collision exists. Theoretically there are three types of geographical location of aircraft: on counter tracks, trail tracks and tracks, that intersect. Every of these locations include special calculations.

1) To determine the conflict situation on counter tracks an ATC should know:

a. time required to cross the busy counter flight level (t_d):

$$t_d = \frac{\Delta H}{V_1}; \qquad (1)$$

where ΔH – the difference between the heights of aircraft;

V_1 – vertical speed of one aircraft;

b. distance that both aircraft will pass for descend time (S_{am}):

$$S_{am} = t_d(W_1 + W_2) + S_{zv}; \qquad (2)$$

where S_{am} – the distance measured during communication;

W_1 and W_2 – track speed of the aircraft.

S_{am} depends on total rate of W_1 and W_2:

$$S_{zv} = \begin{cases} 5\,\text{km}, \text{if } W_1 + W_2 \le 600\,\text{km/h}, \\ 10\,\text{km}, \text{if } 600 < W_1 + W_2 < 1200\,\text{km/h}; \\ 15\,\text{km}, W_1 + W_2 \ge 1200\,\text{km/h}. \end{cases} \qquad (3)$$

c. the distance between the aircraft at the time of passing the busy flight level (S_{cr}):

$$S_{cr} = S - S_{zv};$$

d. time of divergence of aircraft (t_p):

$$t_p = \frac{S}{W_1 + W_2};$$

e. altitude of aircraft1 at the moment of divergence ($H_1(t_p)$) is:

$$H_1(t_p) = H_1 - t_p V_1;$$

where H_1 is altitude in the initial moment of time;

f. difference in height between the aircraft at the time of divergence($\Delta H(t_p)$):

$$\Delta H(t_p) = H_2 - H_1(t_p);$$

g. possibility to permit descending: $S_{cr} \ge S_s$, $\Delta H(t_p) \ge H_{v.s}$.

Permission to decrease (climb) can be given if both conditions satisfy the situation. If only one condition is satisfied, controller should use another method:

– Creation of lateral spacing;

– Change the flight level after aircraft divergence.

2) To determine the conflict situation on trial tracks it is obligatory to:

a. calculate time reduction is required for crossing busy passing flight level (formula 1);

b. calculate the distance will pass both aircrafts during reduction (formula 2):

If $W_1 > W_2$ then S_{am} be increased by S_{zv} that takes into account the communication to the team crew. S_{zv} is determined from the expression and depends on the velocity difference $W_1 - W_2$:

$$S_{zv} = \begin{cases} 5\text{ km, if } W_1 - W_2 \le 300\text{ km/h}, \\ 10\text{ km, } W_1 - W_2 > 300\text{ km/h}; \end{cases} \qquad (4)$$

c. calculate the distance between aircrafts at the time of crossing the busy passing level (S_{cr}):

$$S_{cr} = S - S_{am};$$

If $W_1 < W_2$, S_{cr} will be increased over the initial distance between aircrafts, as

$$S_{cr} = S + S_{am};$$

d. determine the ability to permit the reduction:

$$S_{cr} \ge S_s.$$

Permission to decrease (climb) may be issued if the condition is performed, otherwise the controller should use another method for crossing busy passing level:

– Creation of lateral spacing;

– Speed limit flight;

– Changes in the level flight.

3) To determine the conflict situation on tracks, that are intersected an ATC should know:

a. the time of flight (in minutes) of each aircraft from the point of intersection of the tracks (routes) (t_1 and t_2):

$$t_1 = \frac{S_1}{W_1}60;$$

$$t_2 = \frac{S_2}{W_2}60,$$

where S_1, S_2 – the distance from the point of intersection of lines under the first and second aircraft, km.

b. the actual time interval passing of aircraft:

$$\Delta t = |t_1 - t_2|;$$

c. the separation distance of aircraft (in kilometers). Necessary to notice that regardless of what the aircraft goes into the intersection first (more or less speed), the smallest interval of the difference will be in the moment at the point of crossing the tracks is a high-speed aircraft.

It follows that the minimum distance between the aircrafts (actual line spacing differences) is determined by the speed with less speed aircraft:

$$d_{cr} = \frac{\Delta t W_l}{60}.$$

Velocity of the less speed aircraft defined by the formula:

$$W_l = \begin{cases} W_1, \text{if } W_1 \le W_2, \\ W_2, \text{if } W_1 > W_2. \end{cases}$$

Given separation distance of aircraft is defined as:

$$d = S_s + S_{zv},$$

where S_s – minimum safe interval.

Corrections S_{zv} determined by the formulas:

– in the case of flights to oncoming tracks (formula 3);

– in the case of flights passing tracks (formula 4).

Decisions to regulate the movement of aircrafts, which fly to the point of tracks intersection are made by comparing the actual separation distance of aircraft with a given:

a) if $d_{cr} \ge d$ – it is enough to control holding aircrafts set flight mode;

b) if $d_{cr} < d$ – controller must apply one type of traffic control and to ensure their separation on the established interval d as possible, ensuring the regularity of flights.

To control the movement of aircrafts it is necessary to determine the difference of the actual and the desired separation intervals (Δd):

$$\Delta d = d - d_{cr}.$$

It is necessary to correct the velocity (ΔV):

$$\Delta V = \frac{\Delta d}{t_1}.$$

The time to fly by the aircraft which comes to the point of intersection firstly (t_1) is:

$$t_1 = \begin{cases} t_1, \text{if } t_1 \le t_2, \\ t_2, \text{if } t_1 > t_2. \end{cases}$$

It is necessary to reduce the aircraft speed on the value ΔV, if it comes second to the intersection point, thus:

if $t_1 \le t_2$, then $W_3 = W_1 - \Delta V; W_4 = W_2$;

if $t_1 > t_2$, then $W_3 = W_1; W_4 = W_2 - \Delta V$,

where W_3 and W_4 are speeds of the 1st and 2nd aircrafts after correction.

If ΔV is large, it is possible to change speed for both aircrafts for $\Delta V/2$ (less speed can be reduced for $\Delta V/2$, more speed – increased for $\Delta V/2$).

Software implementation of the considered conflict requires the development of algorithms for each of the possible types of conflicts. Is suggested a set of algorithms that allow for the known characteristics of the situation (time required to cross the busy counter flight level, the difference between the heights, distance that both aircraft will pass for descend time, the distance measured during communication, the distance between the aircraft at the time of passing the busy flight level, time of divergence of aircraft, altitude of aircraft1 at the moment of divergence, difference in height between the aircraft at the time of divergence) not only to calculate key parameters and to determine the conflict, but also predetermine further actions of controller.

There were created algorithms for all three types of tracks. The algorithm for counter tracks is presented below (Fig. 1) as an example.

The software implementation of the developed algorithms have been performed. Programming language C++, a programming environment Microsoft Visual Studio 2010 has been used to write the program. The program has an interactive interface that allows the user to enter the initial characteristics of potentially conflict situations, such as: horizontal, vertical velocities, distance between aircraft and altitude of both of them.

Then the program will calculate the time required to cross the busy counter flight level. Afterwards the distance that both aircraft will pass for descend time will be calculated, depending on the sum of vertical speeds of aircraft, which is equal to 5, 10 or 15 km. Next it will calculate the distance between the aircraft at the time of passing the busy flight level, time of divergence of aircraft, altitude of aircraft at the moment of divergence, using data about altitude in the initial moment of time. After this it is obligatory to measure difference in height between the aircraft at the time of divergence.

Finally, the program will compare the further horizontal and vertical distance between aircrafts. If both distances are bigger than safe constant distance, the window “Descend permitted”. If one of these two conditions, or both of them are not satisfied, there will be message about warming of potentially conflict situations and the sequence of actions to perform to avoid collision.

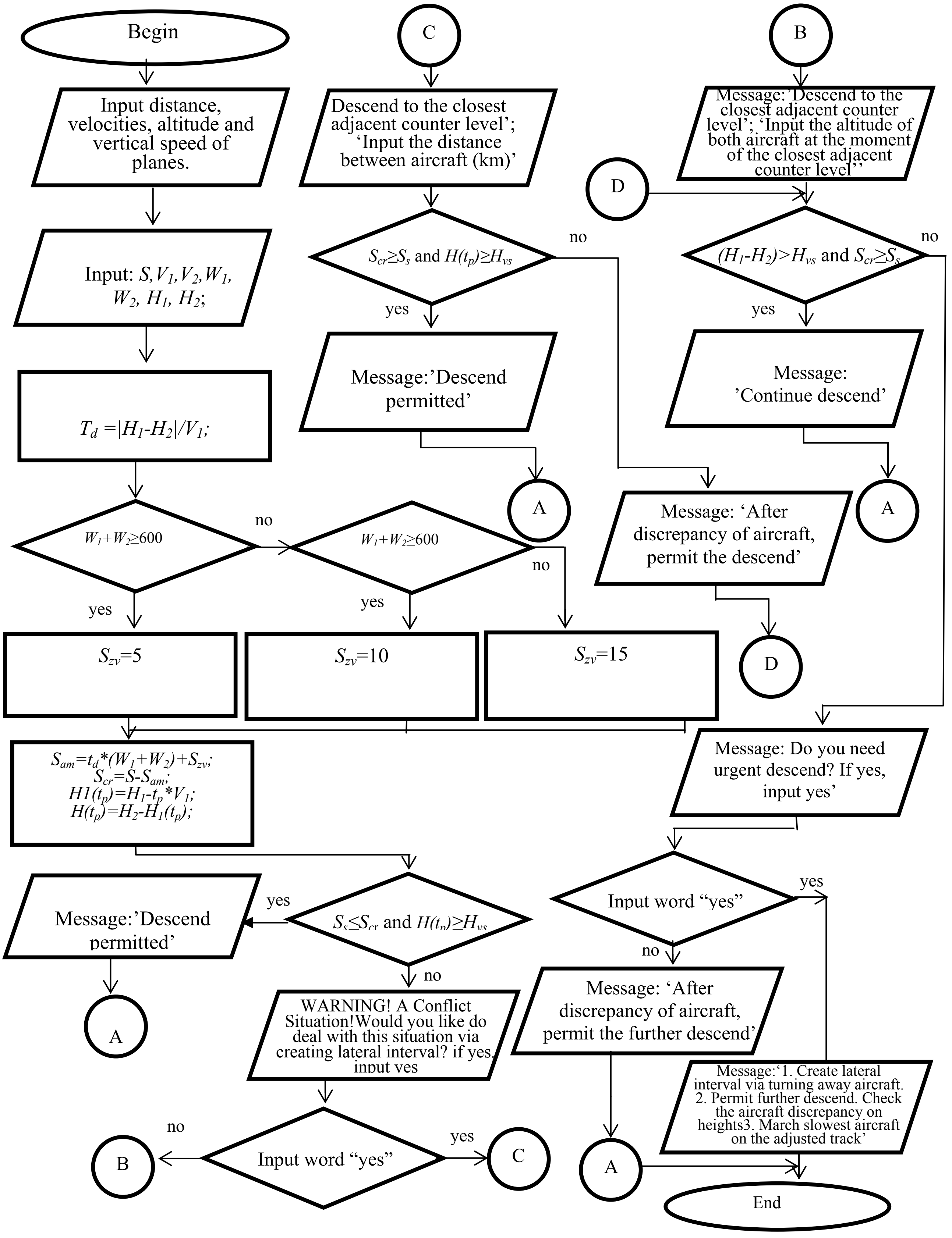


Fig. 1. The algorithm of the program

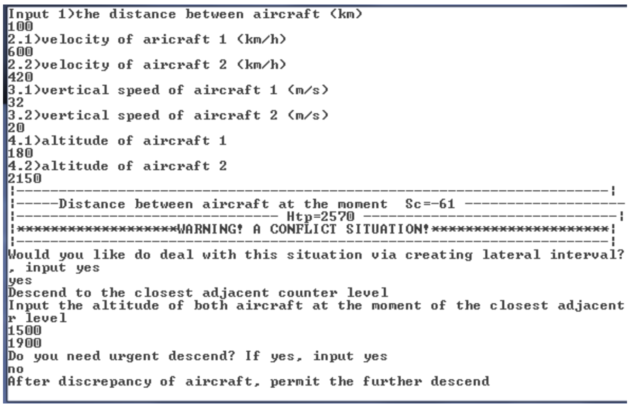
Also, in case of conflict, the user-controller is displayed the information in the form of suggestions of further possible solutions of the potential conflict. And when one of the proposed solutions is chosen, the potential user will see a list of commands, using which it is possible to solve a conflict situation and prevent a collision of aircraft.

Below there are presented examples of program implementation and tables with input data to demonstrate the functionality of the program:

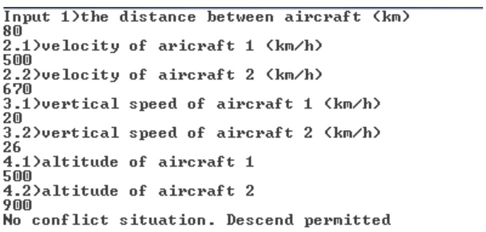
a) there is PCS with the conflict between aircrafts. Initial data to investigate are at the Table 1, the result of the program, with PCS is at the Fig. 2, *a*.

Table 1. Data to investigate a PCS

FL_1/H_1	FL_2/H_2	V_1, km/h	V_2, km/h	W_1, km/h	W_2, km/h	S, km
180	2150	600	420	32	100	100



a



б

Fig. 2. The result of the program:
a – with PCS;
b – no PCS

b) there is PCS without the conflict between aircrafts. Initial data to investigate are at the Table 2, the result of the program, with PCS is at the Fig. 2, *b*.

Table 2. Input data, no PCS

FL_1/H_1	FL_2/H_2	V_1, km/h	V_2, km/h	W_1, km/h	W_2, km/h	S, km
500	900	20	26	32	100	80

5. Conclusions

The software implementation is particularly useful in the training on future air traffic controllers to practice their decision-making skills during the conflict. Further research in this area will develop a program visualization conflict on the terminals creen for the possibility of anadequate perception of the actual air situation and decision-making to the air traffic controller.

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Received 12 September 2013.

С.М. Креденцар[1], М.О. Чорна[2]. Програмна реалізація методів виявлення та вирішення потенційно конфліктних ситуацій між повітряними кораблями
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Показано, що кожен день під час тисяч комерційних і військових польотів життя багатьох пасажирів залежать від реалізації правил техніки безпеки, прийнятих для захисту суспільних інтересів. Розглянуто потенційно конфліктні ситуації, які виникають в конкретний момент часу, рішення екіпажу літака про зміну параметрів руху, своєчасне та належне виконання яких забезпечить безпечний рух, дотримуючись мінімуму ешелонування. Розроблено комплекс алгоритмів, що дозволяють визначити і вирішити потенційно можливу конфліктну ситуацію між повітряними кораблями на попутних, зустрічних треках та треках, що перетинаються. Виконано програмну реалізацію методів виявлення та вирішення потенційно конфліктних ситуацій між повітряними кораблями.
Ключові слова: алгоритм; ешелон; повітряний корабель; потенційно конфліктна ситуація; програмна реалізація; трек.

С.М. Креденцар[1], М.А. Черная[2]. Программная реализация методов определения и решения потенциально конфликтных ситуаций между воздушными суднами
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Показано, что каждый день во время тысяч коммерческих и военных полетов жизни многих пассажиров зависят от реализации правил техники безопасности, принятых для защиты общественных интересов. Рассмотрены потенциально конфликтные ситуации, возникающие в конкретный момент времени, решения экипажа самолета об изменении параметров движения, своевременное и надлежащее выполнение которых обеспечит безопасное движение, придерживаясь минимума эшелонирования. Разработан комплекс алгоритмов, позволяющих определить и решить потенциально возможную конфликтную ситуацию между воздушными суднами на попутных, встречных и пересекающихся треках. Выполнена программная реализация методов определения и решения потенциально конфликтных ситуаций между воздушными суднами.
Ключевые слова: алгоритм; воздушное судно; потенциально конфликтная ситуация; программная реализация; трек; ешелон.

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