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METHOD OF CALCULATING THE AIRCRAFT LANDING BASED ON ROUTING ALGORITHMS

In this paper we propose a method for calculating an aircraft approach path to landing with the engines off, based on use of routing algorithms.

Keywords: routing algorithm, emergency landing, wave algorithm, speed optimization.

Relevance of the research topic. Failure of the aircraft engine is one of the causes of crash, especially at the stage of landing, where altitude and speed do not allow to perform standard maneuvers for approach. This work is dedicated to the calculation of safe emergency landing routes, using the routing algorithm, as one of the best options for pre-calculating the path with the specified criteria.

Problem statement. This is a solution to the problem of choosing the optimal way to reduce the risks of emergency landing.

Analysis of recent research and publications. Several routing algorithms for solving aviation problems were considered. So in [1] was solved the problem of airspace planning using genetic algorithms. In work [2,3] was developed the methods for automated selection-flight aircraft and UAVs.

Appropriation of unexplored parts of the general problem. This article describes the method of calculating the route emergency landing with switched off engine via using the routing algorithm. The research is focused on the construction of the representation of airspace in the form of a mathematical graph and the subsequent finding of optimal routes using a modified routing algorithm.

Setting objectives. The objectives is to develop a way to find the optimal routes for emergency landing of the aircraft with the specified criteria.

Presentation of the main material. Failure of the engine at the stage of landing leads to the problem of the pilot's choice of the ways descend to the runway, which would ensure optimal speed loss and its stock for safe landing.

First of all, to perform this task it is necessary to represent the airspace in the form of a mathematical graph. Since this work is not considered horizontal movement of the aircraft, the airspace is represented as a two-dimensional rectangular graph, where the upper left point is the starting point of the route, and the lower right is the end point. The angles at which the aircraft can move are in the range (-60 °, + 60 °), therefore, the edges of the graph were set in the such way that they are appropriate given angles -

(60 °, 45 °, 30 °, 0 °, -30 °, -45 °, -60 °). Accordingly, each node of the graph has 7 output connections with other vertices. An example of such a graph is shown in Figure 1. Coordinates X and Y indicate the position of the nodes of the graph on the plane.

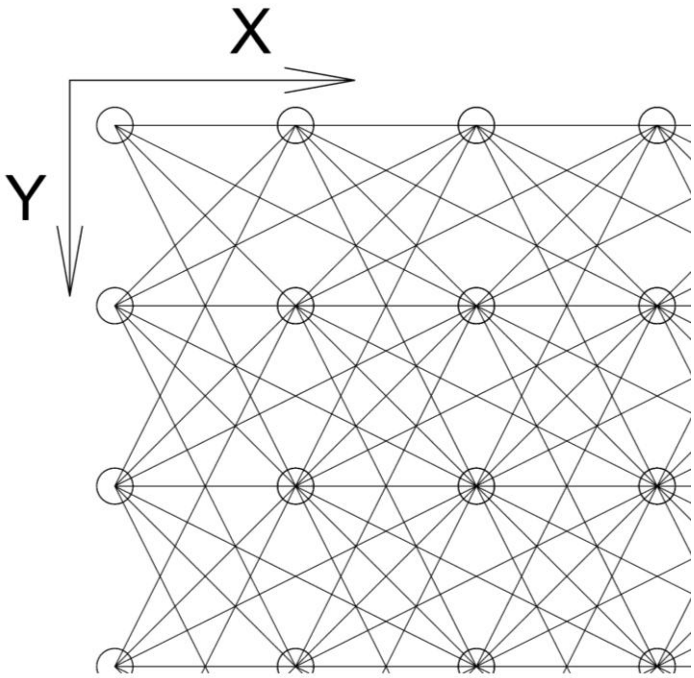

Fig. 1. Image of part of the graph

To organize the calculation of the speed loss of the aircraft and the subsequent selection of the optimal path, the weights of the graph`s edges are given as the coefficients of velocity loss. In order to correctly calculate these coefficients, a series of simulations were performed in the environment of the aviation simulator Microsoft FSX, modeling the flight of the aircraft at the required angles and determining the agnitude of the speed loss for each of them.

$$dV_j = 1 - sign(\propto)\frac{\sum_{i=1}^{5}\frac{\left|Vp_j - Vk_i\right|}{Vp_j}}{5*\frac{3}{l}} \quad (1)$$

Table 1 shows the results of this research.

Table 1

j	Pitch angle (α), °	Initial speed (Vp), km/h	Experiment number (*i*)					Speed loss coefficients *(dV), km/h*	The distance between adjacent points of the graph (*l*), *km*
			1	2	3	4	5		
			Speed at the end of the experiment (*Vk*), *km/h*						
1	60°	700	47	36	34	38	50	0,372380952	0,2
2	45°	700	308	322	305	318	304	0,629904762	0,2
3	30°	700	403	400	412	404	405	0,718857143	0,2
4	0°	300	257	254	259	257	253	0,902222222	0,2

Ended table 1

j	Pitch angle (α), °	Initial speed (Vp), km/h	Experiment number (*i*)					Speed loss coefficients (*dV*), *km/h*	The distance between adjacent points of the graph (*l*), *km*
			1				1		
			Speed at the end of the experiment (*Vk*), *km/h*						
5	-30°	200	351	355	349	354	350	1,0506	0,2
6	-45°	200	411	405	410	426	420	1,071466667	0,2
7	-60°	200	535	534	522	521	531	1,109533333	0,2

$$V_k = V_{k-1} * v_j \tag{2}$$

where V_k – the speed of the aircraft at the k-th transition, V_{k-1} – aircraft speed at the (k-1) transition.

Further assignment of edges is performed as follows:

$$t_{(x,y)} \rightarrow \begin{pmatrix} t_{(x+1,y-2)} \\ t_{(x+1,y-1)} \\ t_{(x+2,y-1)} \\ t_{(x+1,y)} \\ t_{(x+2,y+1)} \\ t_{(x+1,y+1)} \\ t_{(x+1,y+2)} \end{pmatrix} = \begin{pmatrix} v_1 \\ v_2 \\ v_3 \\ v_4 \\ v_5 \\ v_6 \\ v_7 \end{pmatrix} \tag{3}$$

where $t_{(x,y)} \rightarrow t_{(x1,y1)}$ – rib assignment, v_j – rib weight for j = [1; 7] pitch angle.

In this problem, the coefficient of loss of velocity depending on the pitch angle, calculated by formula (1), this is the weight of the corresponding edge of the graph (3), $v_j = dV_j$. The calculation of the current speed of the aircraft is performed according to formula (2).

To find the optimal route using a modified wave routing algorithm [4], which introduced certain changes are necessary to perform this task.

Finding optimal landing routes using the routing algorithms has several problems. The first is the simulation of the aircraft`s real flight requires limiting its movement by weeding out impossible transitions for it. For this, the model graph has only unidirectional edges, which directed toward the runway (the ultimate peak route).

The second problem is to maintain and check the speed of the aircraft in the range from minimum to maximum flight speed. To solve this problem in the routing algorithm was entered verification of the aircraft`s flight speed, before moving to the next vertex of the graph. This eliminates unchecked routes at the calculation stage. Also, this solution increases the speed of the developed algorithm, as it reduces the total number of iterations of the algorithm.

Experiments. For experiments was developed the program that searches for routes on the graph of the specified dimension defined above (imitation of the distance to the strip and the height) and displays one or more found paths.

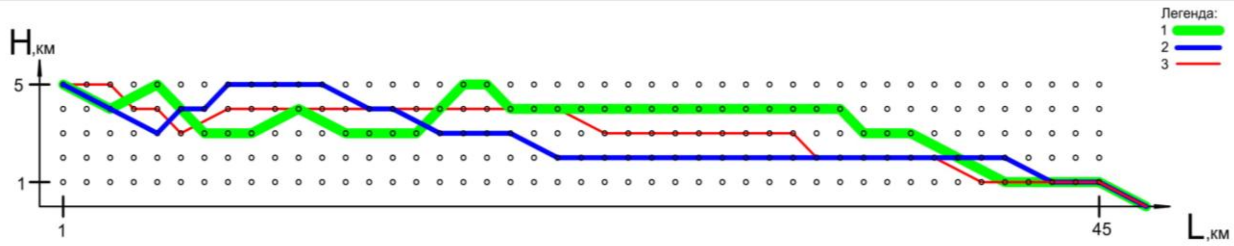

Fig. 2. Searched routes

The developed program found routes with a residual speed in the range (31%; 65%) of the initial simulation speed. The rest of the speed for the route is 1 - 65%, 2 - 51%, 3 - 31%. The number of points of each route is 45. The initial parameters of the experiment are H = 5 km, L = 45 km. All searched routes are similar to each other. The routes found indicate the dependence of the flight altitude of the aircraft on the distance to the runway. The main angles of the trajectory are ± 45 ° and ± 30 °. Since the initial speed of the aircraft is taken as 100%, the criterion for the optimality of the route is the relative value of the landing speed, ie the selected route must provide a safe speed for contact with the runway.

Conclusion. The solution presented in the work fulfills the task and in most cases finds a large number of optimal routes. A large sample allows the pilot to adjust the landing of the aircraft in case of error or unforeseen circumstances. Further improvement of the presented method will allow in the future to better model the behavior of the aircraft, by adding new criteria for plotting and optimizing the path search algorithm.

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