Development of Software for Computing of Aircraft’s Takeoff and Landing Characteristics Using Expert System Technology

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Abstract

The principles of expert system are proposed in the development of software application for calculations of rational takeoff and landing characteristics. The modular architecture is developed for the process of takeoff and landing parameters calculations in the system. A prototype of a client-server software application for electronic flight bag based on tablet computer was developed on the example of a specific type of Russian aircraft.

Keywords: take-off and landing characteristics, expert system

1. Introduction

Despite the fact that takeoff and landing are the shortest phases of flight, these are the most difficult and critical in terms of flight safety. At the same time, calculation of takeoff and landing characteristics (which also known as aircraft performance) is of great importance for ensuring safety of these phases. The main purpose of this calculations is to determine maximum allowed takeoff weight of an aircraft, speeds for takeoff (V₅ — the decision speed, i.e. the maximum speed to which takeoff can be safely terminated; Vₓ — the front landing gear lifting speed; Vₛ — the safe takeoff speed) and landing (Vₛₑₑ — the approach speed), maximum landing weight of an aircraft.

Dependencies of flight characteristics are presented in aircraft flight manual (AFM) as nomograms based on mathematical model of a specific aircraft modification and adjusted in accordance with results of flight tests.

The values of takeoff and landing characteristics depend on many operational conditions: the actual takeoff mass of the aircraft, the outside air temperature, the barometric pressure, the characteristics of the runway (declared lengths, slope, condition of its surface), obstacles in the area of the airport, wind’s speed and direction. A significant influence is also exerted by the pilot’s control actions by adjusting such aircraft parameters as engine thrust, flaps position, etc. Also limitations due to presence of permissible deferred defects and deviations of the aircraft configuration (according to MEL — minimum equipment list and CDL — configuration deviation list) or determined by the operator’s policy can be taken into account in calculations.

Currently specialized software applications (such as “Boeing Onboard Performance Tool” for aircrafts manufactured by Boeing Corporation and “FlySmart+” for Airbus aircrafts) become widely used for calculating of takeoff and landing parameters [1, 2]. These applications are intended for use as software of electronic flight bag (EFB) based on tablet computers.
Using the above software allows to speed up aircraft performance computing process significantly and define the rational values of such parameters as thrust, flaps position which increase the economic efficiency of aircraft flight operations (that results in saving engine resources, reducing fuel consumption, increasing of commercial load) while ensuring a high level of takeoff and landing safety. Nevertheless, these software solutions don’t allow operators to implement its own rules for special limitations in aircraft performance calculations in accordance with its policy.

In turn, currently there’s no such software applications for aircrafts produced by russian manufacturers. Pilots of russian aircrafts define takeoff and landing characteristics manually using special nomograms or tables presented in AFM. Performing calculations in accordance with this method is a long process that requires increased attention, and use of incorrect calculation results can lead to an aviation incident or a disaster.

Thus, develop of general principles of the special aircraft performance calculating system for pilots is an actual scientific and technical task.

The scientific novelty of the study is in use of the expert systems technology that provides flexibility in definition of takeoff and landing characteristics by ability of applying special restrictions in the computed results in accordance with the rules based on MEL, CDL or operator’s policy.

Creation of the special language for knowledge description is proposed to manage rules in the expert system. This approach will provide operators with the ease of creating rules and filling the knowledge base of an expert system without the need to make changes to the software code.

2. Task definition

The system for aircraft performance calculations must comply with the requirements for EFB software applications presented in ICAO Doc 10020 guidance material [3]. The experience of using such software for calculations of takeoff and landing performance of foreign-made aircrafts indicates a number of errors associated with the entry and interpretation of data [4, 5]. Therefore, in order to reduce the risk of errors, it’s necessary to take into account ICAO guidance material principles in designing of system’s graphical user interface.

The system being developed consists of blocks is shown in the figure 1.

Dividing of the system into blocks is necessary to ensure its flexibility and extensibility, allowing to take into account the specifics of different types of aircraft.

The filling of the calculation module can be performed either by pre-calculated specific tables of runway analysis for a particular aircraft type, or by electronic data (digitized nomograms) from the flight manual.

The official aeronautical information sources is used to fill the airport characteristics database.

A fragment of the database logical structure is shown in the figure 2. The "Airport data" includes tuples of ICAO airport codes, airport names and their elevations. The "Runway data" table includes tuples related to the characteristics of the runways: their identifiers, declared distances (TORA — Takeoff Run Available — available takeoff distance, TODA — Takeoff Distance Available, ASDA — available Accelerate-Stop Distance Available, LDA — Landing Distance Available) and slopes values. The table "Obstacles data" includes tuples of obstacle identifiers, their types, distance from the end of the runway, the values of lateral offsets and heights.

The specified database is subject to frequent updates. Its relevance, integrity, accuracy and quality are critical in the process of aircraft performance computing.

The knowledge base of the expert system contains rules describing the limitations imposed by the operator and affecting take-off and landing performance.
3. EFB platform selecting task

According to ICAO Doc 10020 [3], EFB hardware is divided into 2 classes: portable and installed (i.e. integrated into the aircraft). Hardware of portable EFB is an electronic device such as a tablet computer.

Tablet computers become widely used in aviation as portable EFB devices [6, 7] because of their lower cost (in comparison of installed EFB), the technology of operations with portable EFB is not limited to use only in the cockpit, and this equipment is approved by aviation authorities. Currently market presents a large number of different models of tablet computers that can be used as EFB. With the development of this market and the regulatory framework governing the approval and use of tablet computers in aviation as an EFB, aircraft operators are faced with the challenge of choosing the most rational device model for them.

The task of selecting a rational model of tablet computer was considered in [8].

Taking into account the existing variety of electronic tablets, and to ensure the operation of the software on the domestic element base to minimize dependence on foreign manufacturers, the main goal is to create a universal system for aircraft performance calculating without referencing to a specific hardware platform.

The achievement of this goal is possible both by adapting the software-algorithmic prototype of the system to existing platforms, which is a simple technical task, and by developing using universal programming systems that translate the code for the corresponding virtual machines, that provides the ability to use the system on the whole variety of existing devices, without need of developing individual version for each of them. Currently such universal solutions are React Native and Flutter programming systems. Despite the fact that these systems are developed mainly by foreign developers, they are free and distributed with open source code, that reduces the risks of termination of support and allows to independently modify the system libraries and minimizes the likelihood of malicious “bookmarks” in the code.

4. The software prototyping

As the first stage of the software application developing is the task of creating a software-algorithmic prototype, the choice of the initial hardware platform and operation system is not critical. Therefore, in order to simplify the testing of the developed prototype and for possibility of rapid adaptation to other platforms due to the simplicity of the language syntax, its development is carried out in the Xcode programming environment with use of Swift language.

Figure 3 shows the interface of the software prototype.

The algorithm of aircraft takeoff performance calculations is built on performance data in the aircraft flight manual and consists of two stages: determining of the maximum take-off weight and determining the characteristic speeds.

To automate the calculation, nomograms were digitized and their mathematical models were built. For example, in accordance with the constructed mathematical model, the takeoff mass limited by the normalized climb gradient is presented as the function:

$$m_{10} = f(T, H_{aer})$$

(1)

where $T$ — air temperature at the aerodrome, $H_{aer}$ — the aerodrome height that corresponding to the actual barometric pressure at the aerodrome.
Depending on the values that the parameters \( T \) and \( H_{\text{aer}} \) takes, the take-off mass limited by the climb can be determined in 12 different ways. For example, if \( 15 \leq T \leq 20 \) and \( 1800 \leq H_{\text{aer}} \leq 2000 \), \( m_{\text{to}} \) is determined in accordance with the formula:

\[
m_{\text{to}} = (4 - 0.2T)\left[[118061 - 8.48485H_{\text{aer}}] - (119430 - 10.596H_{\text{aer}})\right] + (119430 - 10.596H_{\text{aer}}).
\]

(2)

The algorithm of landing performance calculations also consists of two stages: determining of the maximum landing weight and the approach speed \( V_{\text{app}} \).

For the database of airport characteristics, information from AIP (Aeronautical Information Publications) is used. AIP is a publication issued by or with the authority of a state and containing aeronautical information essential to air navigation.

5. Conclusion

The use of expert system technology in the developed software provides flexibility in determining takeoff and landing characteristics and simplifies the process of filling the knowledge base with rules without need of making changes in the program code.

The practical utility of the proposed system is in improving efficiency and safety of flight operations of aircrafts in large-scale and increase the competitiveness of these by providing the proposed software as a related service that improves the flight operations technology.

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