MODELING AND OPTIMIZATION OF THE CAPACITY OF AERODROMES

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Abstract:

Nowadays, with the aim of increasing the capacity of the air traffic control system during the formation of the sequence and intervals of movement of aircraft in areas of congested aerodromes, the possibilities of artificially forming groups of arriving and departing aircraft are being considered to increase the total number of serviced aircraft at peak hours.

When servicing the groups of “arriving aircraft” and “departing aircraft”, the resulting throughput of the air traffic control system in the take-off and landing area of a particular aerodrome may increase due to the fact that the formed landing and take-off intervals can be significantly smaller in comparison with the intervals (“take-off-landing-take-off”).Such air traffic control, which consists in artificial manning of arrival and departure groups in the aerodrome area, has not yet been studied and the corresponding analytical models for evaluating the effectiveness and optimization of control processes have not been developed.

Therefore, it seems appropriate to develop appropriate algorithms within the framework of the simulation technique for controlling the flow of arriving and departing aircraft during air traffic control in the area of the aerodrome in order to obtain estimates of efficiency in comparison with the efficiency of traditional procedures.

Key words: aerodrome, flight safety, traffic service dispatcher, dispatcher

provision of an air traffic plan, mission for a flight, boundaries of the transfer of control over the movement of aircraft.

When calculating the airport capacity, defined as the maximum number of aircraft served per hour, the methods of queue theory are used and the sequence of queues is studied, the number of service centers (RWY) determines the movement of which and the characteristics of the services provided.

A simple analogy to this model is the queue for airline tickets, in which each transaction takes a finite period. The number of tickets sold for a fixed time can be increased either by increasing the number of queues (cashiers) or by reducing the time for customer service. Likewise, airport capacity can be increased by increasing the number of RWYs or reducing the time required to take off or land one aircraft by improving the air traffic control service.

To determine the airport capacity, mathematical modeling methods are used on a computer (electronic computer). In the mathematical model of the airport, each aircraft moves in line in accordance with a set of rules for the provision of standard services that determine the speed of the queue. Like the sale of tickets, the number of planes awaiting their turn depends on both planned operations and random circumstances.

The service rules (and therefore the service time) of each aircraft in a complex manner also depend on the air traffic control rules that apply to both the airport device and the aircraft. The calculation of the airport capacity is performed on computers using special mathematical models, which can reflect the interaction of regular and random influences existing in the real operation of the airport.

Using these models, the analyst can estimate the airport capacity with high accuracy. With insufficient airport capacity, delays in aircraft maintenance occur. The analysis of delays using mathematical models is complicated by the fact that the delay time is a nonlinear function of a number of parameters, and small changes (for example, due to errors or errors) in the parameters can cause large (and possibly erroneous) changes in the calculated values of the delay time.

Compliance with the rules for the technical operation of the runway ensures a safe interval between aircraft under adverse weather conditions and reduces the risk of an aircraft entering a zone of strong turbulence in the wake of a previously flying heavier aircraft. These rules establish the maximum permissible intervals between successive take-offs and landings carried out on the same runway, and contain other requirements that guarantee flight safety. As permissible standards become more stringent with deterioration in visibility, airport throughputs using automated take-off and landing systems or only visual landmarks can vary greatly.

When creating complex simulation models, the developer faces a number of problems that are almost impossible to successfully solve at the initial stages of work on a project. So, Yu. N. Pavlovsky points out that “among complex” processes, a significant class is made up of those that are a combination of several simultaneously occurring interrelated, but of different scale in time processes, for the preparation of models, which require characteristic orders of magnitude characteristic scales of averaging over time.

Quite often, there is a situation where among the interacting processes a small number of “main” ones can be distinguished, the characteristics of which we are interested in, and it is precisely for the forecast of these characteristics that a model is developed. The characteristic time scale of the other processes is much smaller, and we are interested in their characteristics insofar as they affect the characteristics of the main processes. Thus, the ongoing processes are divided into “slow”, the development forecast of which we are interested in, and “fast”, the characteristics of which we are not interested in, but their influence on slow ones must be taken into account.”

Accordingly, the complex system under investigation is usually presented as some “slow” model, whose behavior depends on the behavior of one or more “fast” models. The influence of “fast” processes on “slow” ones in a model can be taken into account in two ways: either consider the fast process in detail at the appropriate time scale and, in fact, build a separate model for it, or refuse detailed modeling and replace the corresponding process characteristics with random variables.

The second method, obviously, is much simpler, but does not always provide the required level of accuracy, and in some cases it is simply impossible to obtain distribution functions of random variables that describe the effect of fast processes on slow ones.

Thus, complex systems are characterized by the presence of such an embedded hierarchy of fast and slow processes, that is, by the presence of several levels of abstraction. Accordingly, the developer of the simulation model faces a difficult problem: at what level of abstraction should you stop when creating the model to ensure the necessary modeling accuracy, but at the same time not make the system unnecessarily complicated. At the initial stages of development, it is rather difficult and far from always possible to precisely determine this boundary. In fact, defining the boundaries of modeling is one of the main and most complex problems facing the developers of the model.

Basic requirements for the software package

The development of any simulation model requires a detailed study of the subject area. As for modeling the ground movement of aircraft, the development of the substantive part depends primarily on the conditions under which the performance of the airport will be evaluated. In this case, these conditions include the following design decisions for the reconstruction of the airport: the construction of high-speed taxiways; construction of new passenger terminals; construction of a new runway; taxiway repair.

In addition, the model should make estimates both under normal conditions and in cases of failures caused by weather conditions or repair work on the airfield transportation network. It should also be noted that not only the operating conditions of the model are diverse, but also the airport performance indicators: airport capacity in terms of ground movement, indicators (criteria) of taxiing processes, criteria for choosing optimal taxiing conditions.

It follows that the software package will have to simulate the operation of the ground-based complex in a wide range of possible technical conditions. A mathematical apparatus must be created and implemented in software that allows scientifically based assessments of the impact of various options for control decisions on the processes of ground movement and the placement of aircraft on platforms, at telescopic racks and at parking lots.

It should be noted that the detailed requirements for the software package are themselves an object of study. The list of requirements in the process of analyzing the subject area, building, implementing and using the simulation model was repeatedly updated, new requirements were formed, and previously put forward requirements were changed, replaced by others or deleted altogether.

Ultimately, the following basic requirements were put forward to the software package.

Using various flight schedule options. The work of the airport should be modeled for various options of schedules, both for existing and for forecast, obtained as a result of modification of existing ones. The software package should provide:

• implementation of any existing schedule;

• implementation of any existing schedule with the addition of an arbitrary number of departures and arrivals;

• implementation of any forecast schedule compiled by the user in the accepted format;

• implementation of forecast schedules on the basis of some schedule adopted as the basis.

Support for simulation scenarios. Since the software package should simulate various options for design decisions, at least it is necessary to implement in the software package a list of typical scenarios for the operation of the airport, the parameters of which (for example, failures, weather conditions, etc.) will vary by the user during the operation of the model. The composition of these variable parameters for each of the typical scenarios should be justified at the stage of developing a mathematical model. Accordingly, the software package should provide:

• implementation of scenarios of design options, as well as existing airport operating conditions (for example, to assess the adequacy of the model);

• the ability of the user to select a specific scenario for conducting experiments;

• the ability to change the user model parameters of the script in the specified ranges;

• the possibility of expanding the list of scenarios.

Formalized presentation of airport performance indicators. Bandwidth indicators are used to assess the quality of airports. However, there is no unified interpretation of these indicators, especially as applied to throughput in terms of ground traffic. Thus, the developed software package should include a formalized presentation of indicators and have the function of calculating these indicators. But this is not enough, because, as will be shown below, a number of parameters of the calculated indicators can be finally established only in the process of practical use of the model.

For example, the concept of throughput is closely related to the permissible delay times for aircraft departures and, of course, these parameters will not only be refined during the operation of the model, but will also vary depending on unknown conditions at the development stage. Therefore, the software package should cover:

• calculation of throughput indicators and other indicators;

• variation (by the user of the model) of parameters and algorithms for calculating indicators, depending on the problem being solved and the conditions;

• the ability to refine the model to introduce new formalization of indicators (if necessary) without significant changes in the model scheme itself.

Adequacy assessment. The software package should provide verification of the adequacy of the simulation results. By checking, the adequacy is understood the establishment of the consistency of the model and the consistency of the simulation results with the available evidence estimates of experts and managers.

The adequacy check can be carried out both by formal methods based on a quantitative analysis of modeling results, and with the help of expert assessment.

Using a universal programming language in combination with a specialized

Modeling Library

Often when creating software related to a well-formed and well-developed subject area, such as simulation, the question arises of choosing between specialized and universal development tools (languages, software environments and systems). Considerable attention is paid to this issue in the literature on simulation modeling. Usually, the main advantage of specialized modeling languages 75 is the lesser complexity of development in relation to universal programming languages.

However, you have to pay for it with a loss of conceptual expressiveness and a loss of flexibility in the development process and the final software product - the simulation model. The consequences of this are manifested already directly in the process of developing a simulation model, and in the future, with the development of the model, with the repeated use of the found successful solutions in other tasks. However, these two approaches do not necessarily have to be opposed to each other. One of the most famous and illustrative examples is the programming language Simula 67, where the means of creating simulation models were implemented in the form of a library that extends the capabilities of a universal programming language. Such a solution made it possible to provide a simple and quick solution to specialized tasks while maintaining the expressive capabilities of the language, its flexibility and versatility.

To date, a number of modeling libraries have been created for universal languages (SimPack, CSIM, C ++ SIM, JavaSIM, SSF, CppSIM, MOOSE, etc.), as well as specialized modeling systems where a universal programming language is used as the base language (AnyLogic, VisSim, Simplex 3, OMNeT ++, etc.). Such a wide selection of development tools makes it possible to choose tools that implement the most favorable combination of expressiveness of the programming language, versatility, flexibility with the required level of productivity and efficiency of the programs being created on the one hand, and the convenience and speed of constructing a simulation model, preparing source data, and conducting simulation experiments and analyzing their results on the other hand.

When constructing a simulation model of the ground movement of aircraft in practice, this approach was used. The C ++ programming language was taken as a basis, and its capabilities were expanded using a class library that supports the development of models using simulation processes.

However, development experience and further research showed that Smalltalk would be the best choice of a basic programming language, which provides the best combination of expressive power, flexibility, usability, and simplicity of the language and the development system as a whole.

Development process

Since it is not possible to consider in detail the entire process of developing a real simulation system in the framework of this paper, the main practical aspects of using the test-driven simulation method will be analyzed using several iterations as an example, namely:

1. Simplest model.

The airport is simulated as a single-channel queuing system, providing landing aircraft, considered as transactions.

This model is too primitive and not very suitable for solving real tasks of managing a real airport, but it is a good basis for establishing contact with the customer during the development process, represents the necessary basis for starting work on creating a software package: implementing the main subsystems and ensuring interaction between them (visualization , preparation of input data and processing of simulation results).

2. Taxi network.

As one of the main subsystems of the airport, responsible for providing takeoff and landing operations and servicing the aircraft, a taxiway network is singled out. To provide the ability to simulate the movement of aircraft along various routes, the taxiway network of the airport is divided into separate sections. "Unit of partition" is called a location. At this iteration, a location means a section of a taxiway network with the only possible trajectory of movement. Locations are combined in a graph, providing the ability to assign the aircraft-taxiing route and simulate movement along this route.

3. The discipline of taxiing on locations.

At this iteration, aircraft movement is modeled taking into account taxiing rules, which include both numerical parameters (permissible speeds, intervals, etc.) and the organization (discipline) of movement (for example, the possibility of simultaneously finding only one aircraft at the intersection). Since different rules may apply in individual sections of the taxi network, locations are divided by type in accordance with the accepted discipline. Thus, the concept of location is specified: each location must correspond to one general discipline of movement.

4. Simulation of movement with varying speed and compliance with the destination between the aircraft.

In the model, it is necessary to reflect the fact that overtaking when the aircraft moves along the taxiway network is impossible. To do this, it is necessary to track the distance between successively moving aircraft and adjust their speed, preventing them from approaching a dangerous distance.

The listed iterations are only part of the entire development of the model. The real process also included the solution of the following tasks:

• Modeling take-off operations.

Here you must take into account the rules for using the runway. Managing the use of this component is the responsibility of the take-off manager. At this stage of development, his actions are simulated to control the access of the aircraft to the executive start, the implementation of take-off operations.

• Simulation of landing operations.

At this iteration, changes are introduced into the model that provide correct modeling of landing operations in accordance with the rules of flight organization. Here, in particular, allowable time and space intervals between take-off and landing operations must be taken into account. The operation algorithm of the dispatching services (takeoff and landing manager) should take into account the priority of landing operations, accordingly organizing access to the runway.

• Alignment on the glide path.

Here, the actions of air traffic control services are simulated, providing the necessary intervals between the aircraft landing.

• Route Assignment.

For correct modeling, it is necessary to ensure the correct on-value of taxi routes for individual aircraft. At this stage, it is necessary to introduce the corresponding structural elements (terminals, parking places of the landing point, take-off, etc.), as well as implement algorithms for selecting the starting and ending points of the route, searching for the route on the taxi network graph.

• Maneuvering in the terminal area.

The movement of aircraft near parking lots is usually organized in a special way. Clinch situations should be excluded here, adequately (depending on the take-off and landing course) to simulate the direction of aircraft movement, blocking the movement of individual locations as necessary.

A description of such details should be part of the data describing a single simulation experiment. Their change should not concern the description of the infrastructure of the entire airport. For this, the concept of a simulation scenario is introduced, which includes the initial data describing the current configuration of the airport and necessary for conducting a series of simulation experiments.

• Modeling aircraft after landing.

Taxiing of arriving aircraft ends at the designated parking place. Here passengers are disembarked, after-flight service of the vessel. Some of the planes are then towed to another place, and some remain here awaiting departure. These aspects should also be adequately reflected in the model.

These tasks form the basis of a real model of ground movement of the aircraft. Moreover, many requirements were identified only during the operation of intermediate versions of the model. Using the model to solve a different range of tasks may require refinement of the model, processing of its individual components, etc. The method of test-driven simulation allows you to make the introduction of such changes controlled and, therefore, less "painful", reducing material and time costs

Taxi network model

The taxiway network model is one of the most important components of the airport simulation model, which ensures the correct reproduction of almost all other aspects of aircraft taxiing. Therefore, we will begin the consideration of individual subsystems precisely with this component.

The transport (taxiing) network is an integral part of the airport infrastructure, providing the opportunity for aircraft to take off and land operations, as well as their passage from the parking place to the start point and from the end point of the run after landing to the parking place. The airport taxi network model includes the following types of elements:

- taxiways (regular and main)
- intersections
- runways
- parking places (platforms)
- preliminary start
- executive start
- fictitious elements representing entities that in reality are not related to the taxi network, but are used in the modeling process; fictitious locations, for example, include airport complexes (terminals) of the airport, the air zone of the airport ("pre-landing" and "take-off" locations), etc.

Aircraft model

Aircraft model objects contain and provide other objects of the model with the following information about themselves.

Aircraft identifier - an internal name that allows you to identify an aircraft in the simulation model, as well as in other modules of the software package (flight schedule editor, visualization subsystem).

Type of aircraft: (3 - heavy aircraft, 2 - medium aircraft, 1 - light aircraft). Depending on the type of aircraft, some of its characteristics (such as the path length during landing, taxiing speed in various sections, etc.), as well as taxiing parameters (for example, the intervals between aircraft during landing, take-off, taxiing).

The type of flight (arrival or departure) is assigned at the time of creation of the object representing the aircraft, in accordance with the information indicated in the schedule.

The route of movement is presented as an ordered set of locations. The route is assigned at the time of creation of the facility representing the aircraft.

Current location - the location on which the aircraft is currently located.

The current speed of movement in a location.

Airspace Manager Model

In reality, the task of the air zone dispatcher is to provide the required longitudinal distances between aircraft going to land. It is convenient to simulate this aspect within the framework of solving the more general problem of calculating the time of arrival of arriving aircraft in the system. In this case, the following shall be taken into account:

• Scheduled arrival or departure times for aircraft. These values are the input parameters of the model.

• Random deviation of arrival time from the schedule

• Time for which it is necessary to notify the runway manager of the upcoming landing.

At a real airport, the landing manager receives information about the approaching aircraft in advance. This is necessary, in particular, in order to ensure that there are no obstacles on the runway that could interfere with the landing. The value remains constant and is set as the input parameter of the model.

• Time intervals between landing operations in accordance with safety requirements.

Start and Landing Controller

The launch and landing manager provides control of the use of the runway. Dispatchers are responsible for making the following decisions related to takeoff and landing operations.

Landing permit

Safe landing is only possible under a number of conditions. The most important conditions in this case are:

• The absence of aircraft on the runway at the time of the passage of the near beacon by the aircraft landing

• The absence of aircraft and vehicles on the pre-landing line and in the critical zone of the radio beacon landing system at the time of passage by the plane approaching the landing point at the glide path under meteorological conditions of I and II category ICAO or before the start of the fourth turn under meteorological conditions of III category ICAO.

Thus, the landing control process from the start and landing manager is modeled as follows.

Table 1.

The distance of the aircraft making the landing from the runway threshold necessary to permit landing (depending on weather conditions)

	Weather conditions		
	Simple	I and II categories of ICAO	ICAO Category III
Decision line on landing permission	Inner beacon	Glide path entry point	4th turn start point
Distance (km)	1	8	18
Time (s) based on a speed of 300 km/h	12	100	220

In accordance with table 1.3, when simulating an aircraft landing, the moment of time is selected when a final decision must be made on whether to allow or cancel this operation. Now, an event is planned whose processing is associated with sending a request to an object representing the launch and landing manager. When processing the request, the busy flag is checked for all locations related to the runway where this operation is performed. If for some reason by this moment the aircraft is in the landing zone, which impedes its implementation, the situation of canceling the landing operation is simulated.

The requirement is also taken into account that when flying from one runway and parallel runways, the distance between the axes of which is less than 1000 meters, the time interval between successive takeoff and landing should be at least 1 minute.

It should be noted that the cancellation of the landing is a rather dangerous operation and is considered as an emergency. Therefore, one of the main tasks of the dispatcher is to ensure the conditions for the successful completion of all landing operations, that is, the absence of PA on the runway of other aircraft.

Literatures:

1. ICAO doc 9426-FN/924 Air Traffic Services Planning Manual
2. Vysotskiy V.Z. Scientific Bulletin of MSTU GA №99 – 2006
3. Pechenezhsky V.K., Sazonova A.M. Scientific Bulletin of MSTU GA No. 209 - 2014
4. Guidelines for the organization of air traffic in the Republic of Uzbekistan (PSK / TSUAN / OVD-01).
5. Flight operations manual Tashkent
6. Doc 9976 Flight Planningand Fuel Management Manual (First Edition) – 2015
7. Евстигнеев Д.А. Авиационная психология для авиадиспетчеров, Учебное пособие Ульяновск – 2005г.