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FAZI EKSPERTSKI MODEL ZA ODREĐIVANJE POLETNO-SLETNE STAZE U UPOTREBI PRIMER: AERODROM CIRIH

FUZZY EXPERT MODEL FOR DETERMINATION OF RUNWAY IN USE CASE STUDY: AIRPORT ZURICH

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Rezime: *Određivanje poletno-sletne staze u upotrebi na aerodromima sa više poletno-sletnih staza je kombinatoran problem sa većim brojem ograničenja. Ovaj problem se rešava u realnom vremenu što dodatno doprinosi složenosti problema. Zbog toga je u radu predstavljen prototip modela za određivanje poletno-sletne staze u upotrebi zasnovan na ekspertskom znanju i fazi logici kojim se maksimizira iskorišćenje kapaciteta i minimizira nivo buke. Model se odnosi na aerodrom Cirih ali se logika i struktura mogu lako primeniti na bilo koji drugi aerodrom.*

KLJUČNE REČI: FAZI LOGIKA, EKSPERTSKI SISTEM, AERODROMI, KONTROLA LETENJA

Abstract: *Determination of runways in use at an airport with multiple runways is a combinatorial problem with many constraints. The problem should be solved in real time, which results in additional difficulties. This, paper presents a prototype of a model for the determination of runways in use based on expert knowledge and fuzzy logic,by means of which the usability of runway capacity is maximized and noise level minimized. The models is designed for Zurich airport but its logic and structure could easily be applied to any other airport.*

KEY WORDS: FUZZY LOGIC, EXPERT SYSTEM, AIRPORTS, AIR TRAFFIC CONTROL

1. INTRODUCTION

The airport traffic control service is responsible for controlling, i.e. monitoring of departing and arriving traffic at a specific airport with aim of securing safe, accurate and expeditious movement of traffic. The traffic controllers who work in this service are located in the airport control tower. They monitor the airport traffic visually (directly through the window or by binoculars) and they communicate with aircraft by radio on a specific frequency.

During their work, the controllers receive information about future planned traffic (for 5 to 10 min in advance) in the form of paper strips (containing necessary information about each flight and which departure or arrival is expected), although they have direct insight into traffic development at the airport. Also, through electronic display, the controllers receive information about changes in wind direction and speed and meteorological forecasts for several hours in advance (information about visibility, ceiling, runway visual range, amount of cloud, precipitation, etc).

One of the controller's duties is to determine runways in use according to meteorological conditions and traffic demand. This decision provides safe aircraft operations (take-off and landings) with fewer delays. In addition, during the decision-making process, they also think about utilization of available airport capacities (particularly at airports with multiple runways) and high noise levels.

2. PROBLEM DEFINITION

At a specific moment of time, depending on meteorological conditions and planned traffic demand, the airport controller determines the runways in use, trying to maximize utilization of available airport capacity, which is presented as hourly number of operations, and minimize noise level. Once the runway in use is determined, the controller's task is to secure safe and punctual traffic movement, until meteorological or traffic demand conditions change so much that a runway change is required.

If we take into account all the mentioned facts, then, at airports with multiple runways, we face a very complex process of decision-making. The reason for this is the large number of feasible combinations of runways in use where each combination produces different capacity and noise level. Because of this, the problem can be characterized as combinatorial. Also, which runway will be used in some specific moment of time depends on the controller's subjective judgments about the meteorological and traffic situation. Their decisions depend on personal experience, age, personality and similar parameters.

During the decision-making process, controllers have available a whole spectrum of data, of different nature and accuracy. Some of this data, although received in an explicit form, may, because of job specificity, be realized subjectively (in linguistic form) and used in that form (e.g. a ceiling of 300ft is realized as a "low" ceiling, visibility of 8600m as "good" visibility, expected number of departures of 37 aircraft as a "large" number of departures, etc.)[3]. On the other hand, some of the data, which is explicit, is used in a same form in the process of decision-making (e.g. wind direction of 340^0).

Due to the nature of the input data, and the subjective opinions about it and also because of the individual differences between controllers, this paper will present a prototype of an expert model for decision-making about runways in use based on fuzzy logic and taking Zurich Airport as its basis. The main idea was that the presented model should be available to airport controllers at this airport starting in 2005 when new operational concepts will be introduced* (Figure 1).

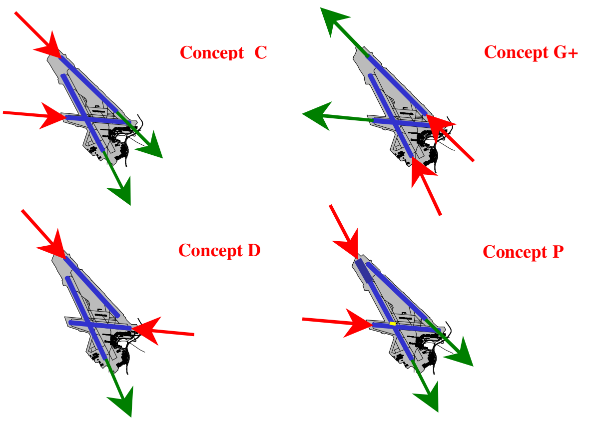

Figure 1. Overview of available Zurich airport operational concepts

The final result of the decision-making process, i.e. of the application of the model, is a possible distribution of traffic on runways in use and aircraft assignment, where for each aircraft category, the available runway is determined.

* operational concept presents specific combination of runways in use (for departures and arrivals)

As a result, the final decision offers a solution, which could provide better utilization of available airport capacities and also, decrease the noise level.

2.1 Conceptual model of determination of runway in use

The process of determination of runway in use consists of several steps (Figure 2):

1. Determination of meteorological conditions depending on visibility and ceiling;
2. Determination of operational concept in use depending on meteorological conditions, wind direction and runway conditions;
3. Aircraft assignment to runways in use based on the operational concept in use and estimated number of departures and arrivals.

The input data necessary for the decision-making process is, because of its nature and controllers opinions, divided into three groups. The first group presents meteorological data, which is here assumed to be lexicographic, and is presented as fuzzy variables. The data is:

- visibility (measured in kilometers) and
- ceiling (measured in feets).

The second group presents meteorological data which is used in explicit form:

- runway condition (wet or dry) and
- wind direction.

The third group consists of planned traffic data, which is also assumed to be lexicographic:

- planned hourly number of departures and
- planned hourly number of arrivals.

Because of all the above-mentioned factors, the process of determination of runways in use is realized through three models:

- ***Fuzzy model 1:*** meteorological conditions are determined depending on visibility and ceiling which are presented as fuzzy variables;
- ***Fuzzy model 2:*** estimated number of departures and arrivals for the next hour are determined depending on the planned number of departures and arrivals and the absolute value of the difference between them; and
- ***Rule base:*** the final decision about the operational concept in use and traffic (aircraft) assignment on runways is determined on the basis of results from Fuzzy models 1 and 2 and additional information about wind direction and runway condition.

Here it should be said that the process of decision-making and the characteristics of the proposed fuzzy models and rule base are the product of engineering expertise. For this reason, the expert model presents a prototype. The value of fuzzy model parameters and combination of rules in rule base, are also the result of engineering expertise and specific meteorological and traffic demand conditions at Zurich airport [2].

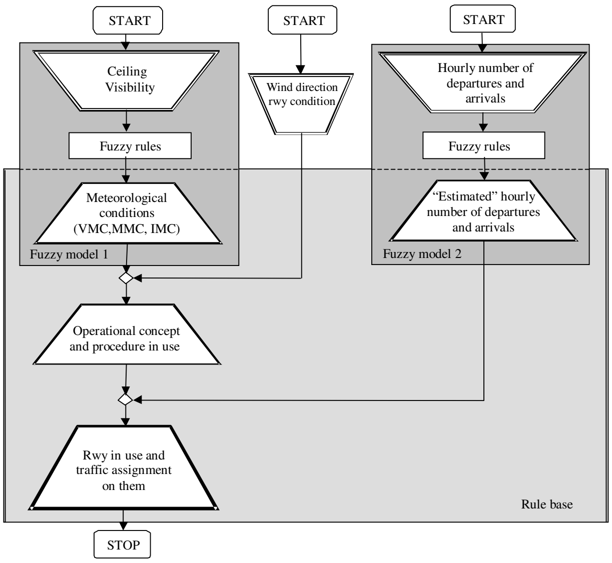

Figure 2. Conceptual model of determination of runway in use

2. 2 Fuzzy model 1

As said before, Fuzzy model 1 serves for the determination of meteorological conditions at a specific time using the fuzzy variable visibility and ceiling. Meteorological conditions at Zurich airport could be defined as:

- visual meteorological condition – VMC;
- marginal meteorological condition – MMC and
- instrumental meteorological condition – IMC.

Visibility is presented as a fuzzy variable which contains 3 fuzzy numbers: small (from 0 to 800m), middle (from 0 to 5km) and large (from 800m) (Figure 3).

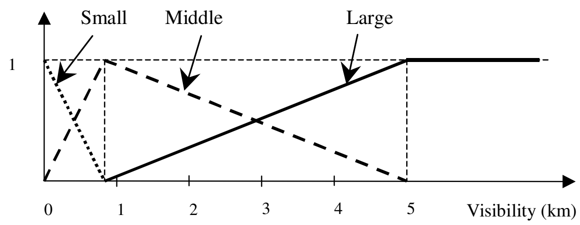

Figure 3. Fuzzy variable "visibility"

Similarly, the ceiling is presented as a fuzzy variable which contains the following 3 fuzzy numbers: low (from 0 to 1000ft), middle (from 0 to 2000ft) high (from 1000ft).

The value of the fuzzy number intervals are defined on the basis of meteorological recommendations and analysis of meteorological conditions at Zurich Airport, for a one-year period [2]. Fuzzy numbers are here presented as triangular and non-symetrical (this assumption is based on engineering expertise).

The output of the model presents the decision about the meteorological conditions which could exist at a specific time. For that reason, output variables are presented in the form of fuzzy variables "preference of VMC (MMC/IMC)". Fuzzy numbers which belong to the mentioned fuzzy variables are also presented as triangular and non-symetrical.

Fuzzy rules, which are used for the determination of preference for a specific meteorological condition, are defined based on the values for the fuzzy variables "visibility" and "ceiling". The example rules for "preference of VMC" are presented in Table 1.

Table 1.Preference of VMC

visibility	small	small	middle	middle
	middle	small	middle	high
	large	middle	high	high
		low	middle	high
		ceiling		

The final decision about the type of meteorological conditions is made according the values of membership function to fuzzy variables "preference of VMC (MMC/IMC)" in such a way that the chosen type of meteorological condition has the highest (maximal) value of membership function for specific input variable values.

2. 3 Fuzzy model 2

Fuzzy model 2 using fuzzy variables "planned hourly number of departures (arrivals)" and "absolute difference" determines the "estimated" number of departures and arrivals.

Planned hourly number of departures (arrivals) is presented as a fuzzy variable containing 3 fuzzy numbers: small, middle and large number of departures (arrivals). The absolute value of the difference between the planned hourly number of departures and arrivals is presented as a fuzzy variable containing 3 fuzzy numbers: small, middle and large difference. It was assumed that fuzzy numbers are triangular and non-symetric. The values of fuzzy numbers intervals are defined based on analysis of traffic planned for Zurich Airport, for a one-month period [2].

Output from Fuzzy model 2 presents the linguistic "estimation" of numbers of arrivals and departures. Because of that, output variables are presented in the form of fuzzy variables "preference that number of departures (arrivals) is small (middle/large)". Fuzzy numbers, which belong to the mentioned fuzzy variables, are presented as triangular and non-symetrical.

Based on the values of the fuzzy variables "hourly number of departures" ("hourly number of arrivals") and "absolute difference", fuzzy rules for the determination of preference of estimated number of departures and arrivals are defined.
The final decision about the estimated number of departures (arrivals) is made according the values of membership function to fuzzy variables "preference that

number of departures (arrivals) is small (middle/large)" in such a way that the estimated number of departures (arrivals) which has the highest (maximal) value of membership function for specific input variable values, is chosen.

2. 4 Rule base

The rule base, based on results from Fuzzy Model 1 and using additional information on wind direction and runway conditions, as a result gives us the operational concept in use. Also, using that result and the results from Fuzzy Model 2, the rule base can give us the final result: distribution of traffic (by aircraft category) on runways in use (traffic pattern). The Rule base is developed wholly on the basis of engineering expertise.

The final decision contains the solution, which could provide better utilization of available airport capacities and also, decrease noise level (Figure 4).

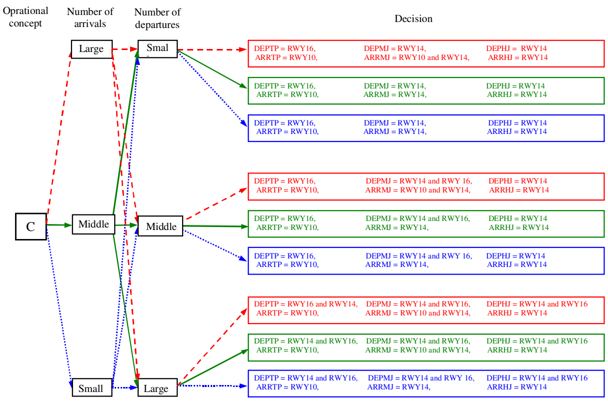

Figure 4. Traffic distribution in case when operational concept C is in use

Figure 4. contains an example for operational concept C in use. Here it can be seen that the final result depends on a combination of the operational concept in use and the estimated number of departures and arrivals. The result obtained for a specific combination of variables, contains information about the runway in use for specific aircraft types. Aircraft are divided into three categories (depending on engine type and wake turbulence category): Turbo Prop, Medium Jet and Heavy Jet.

3. PROGRAMMING

The programming of the fuzzy models (mentioned in earlier chapters) was done using the software UNFUZZY 1.2 [1]. Using this software three programs were designed:

- ***Meteo Conditions*** based on Fuzzy Model 1, which serve for determination of meteorological conditions;
- ***Departures*** based on Fuzzy Model 2, which serve for determination of number of departures;
- ***Arrivals*** based on Fuzzy Model 2, which serve for determination of number of arrivals.

Rule Base was realised through the programme "Runway in Use" written in programming language Borland Pascal.

The expert model is conceived as interactive, where input data is entered in three steps. The final result presents the distribution of different aircraft categories into runways according to rules from previous chapters.

4. CONCLUSION

This paper presents a real problem, which exists at airports with multiple runways – determination of runways in use and aircraft assignment on those runways. In reality airport traffic controllers solve this problem. The process of determination of runway in use is realized through several steps. Most of the input data necessary for this process is fuzzy. Because of the mentioned facts, a fuzzy expert model for determination of runways in use, which could serve controllers for evaluation of their own solutions or for suggestions of new solutions, has been developed. This model is based on usage of two fuzzy "sub" models.

The model has been developed for the case study of Zurich airport but could easily be applied to any other airport. Application of mentioned programs give us final results, which are presented in the form of runways in use and distribution of different aircraft category on those runways. These results present a solution to the mentioned problem, which simultaneously enable "maximization" of available airport capacity and "minimization" of noise levels in the airport vicinity. As a result, this kind of fuzzy expert model could be of benefit in reality.

In conclusion, it should be emphasized that the developed fuzzy expert model is a prototype and has not been verified yet. The reason is that the mentioned solutions to the problem (operational concepts) are still not used at Zurich airport. As a result, verification is, together with fine-tuning of the models, the goal for further research.

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