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Tatyana Shmelova[1]
Vitalii Lazorenko[2]
Anastasiia Bilko[3]

ESTIMATION OF PRE-SIMULATING TRAINING TASKS COMPLEXITY

[1,2,3]National Aviation University
Kosmonavta Komarova avenue 1, 03680, Kyiv, Ukraine
E-mails: [1]shmelova@ukr.net, [2]vitalii.lazorenko@ukr.net, [3]superbelk@ukr.net

Abstract. *In the article we analyzed three different types of simulator training exercises: CTR (Control zone), TMA (terminal control area) and CTA (control area) with various type of complexity. We determined that every zone, where air traffic service is provided, has different technology of work and individual instructions for procedures. Using the algorithm for tasks complexity estimation in the pre-simulator training, with the help of Expert Judgment Method, we found criterion of weighting. According to the results, we built the graph, representing the hard zone of air traffic control. In addition, we analyzed pre-simulation assessment criteria.*

Keywords: control area; control zone; Expert Judgment Method; pre-simulation training; terminal control area.

1. Introduction

Statistical data show that human errors account for up to 80 % of all causes of aviation accidents [1]. Safety in aviation will continue to be highly dependent on the reliability of air traffic service (ATS). This reliability will be directly linked to the ability of ATC (air traffic controllers) planners and managers to incorporate the many lessons of history regarding the impact of human factor on controller performance. According to the list of factors, performance includes: quality of selection criteria, initial and recurrent training, and retention programs for air traffic controllers [2].

Quality of aviation training is important to decrease the influence of the human factor. Simulator practice of ATC is a necessary part of the professional training. Training includes technical subjects, ATC theory and simulator practice. The object of initial training is to prepare an ab initio for training at an ATC unit [3].

2. Analysis of the latest research and publications

ATC Trainee is a set of existing forms and methods by which the experts/trainees (students) under the supervision of an instructor shaped controller skill practical application of theoretical positions of several disciplines, to students through the implementation of the formulated complex tasks and exercises.

Types of ATC Trainee:

– training (SIMUL) – a workout with a model of air traffic, which responds to the audience (students) as a real air traffic . This technique is accompanied by a training briefing, debriefing, and consultation;

– controlled computer training (GSIMUL – Guided SIMUL) – interaction between students and computer in the form of questions, comments, instructions and issue assessments of the listener/student interaction in the process [3].

Many good training programs are ultimately ineffective because of inadequate follow-up. Trainees must be evaluated not only during and upon completion of training, but a continuing process of validating the initial requirements for the training is required to evaluate the effectiveness of the programs and to ensure that training needs are indeed fulfilled [2].

3. Aims of the work

– To develop an algorithm for determining the complexity of task in the pre-simulator training.

– To estimate the complexity of tasks performed by ATC (classification of airspace zones and classes).

– To develop neural network for automated estimation of tasks in the pre-simulation training system.

4. Research results

The organization of the airspace over given area should be arranged so that it corresponds to operational and technical considerations only. In addition, aerodromes where ATC is provided should be designated as controlled aerodromes [4].

States shall select airspace classes which are appropriate to their needs. And also have 3 zones of airspace – very important elements of air traffic management, with individual restrictions, according to Ukraine normative document [5].There are:

Control zone – a controlled airspace extending upwards from the surface of the Earth to a specified upper limit [6].

Terminal control area (TMA) – a control area normally established at the confluence of ATS

routes in the vicinity of one or more major aerodromes [6].

Control area – controlled airspace, extending upwards from a specified limit above the Earth [6]. Control area can be formed by TMAs of sufficient size to contain the controlled traffic around the busier aerodromes, interconnecting airways of a lateral extent, determined by the accuracy of track-keeping of aircraft operating on them, as well as the navigation means available to aircraft and their capability to exploit them; a vertical extent, covering all levels require to be provided with control service; or area-type control areas within which specific ATS routes have been defined for the purpose of flight planning and which provide for the organization of an orderly traffic flow [4].

Analysis of the principles classification of airspace according to requirement ICAO and ATS airspaces shall be classified and designated in accordance with the following classes: *class C and D* ATS [6]. Implementation of airspace classes in Ukrainian airspace in accordance to requirement of normative acts represent in the Table 1.

Table 1. Implementation of airspace classes in Ukrainian airspace

№	Class of airspace	Zones of airspace	Restrictions
1.	D	Control zone	1500-2900 m
2.	D (except Boryspil TMA, where class C is applied due to high traffic volumes)	Terminal control area	D (1500-2900 m) and C (2900m – Fl 660)
3.	D and C	Control area	D (1500-2900 m) and C (2900m – Fl 660)

Complexity of zone (CTR, TMA and CTA) was obtained with a help of Expert Judgment Method [7]. The experts are Air Traffic Controllers, who operated in training course.

An algorithm was developed for determining the complexity of task in the pre-simulator training.

Algorithm of estimation of complexity tasks in the pre-simulator training with the help of Expert Judgment Method.

1. Questionnaires for experts (m – number of experts, $m \geq 30$).

2. Matrix of individual preferences. Obtained – R_i, $i = \overline{1, m}$, where m – number of expert; R_i – system of preference of i-expert.

3. Matrix of group preferences obtained R:

$$R = R_j = R_{gr} = \frac{\sum_{i=1}^{m} R_i}{m},$$

where R_j – the experts' group opinion of complexity of j-zone, $j = \overline{1,n}$; n - quality of zones; m – number of expert; R_i – system of preference of i-expert.

4. Coordination of expert's opinion.

4.1. Calculation of dispersion D:

$$D = \frac{\sum_{i=1}^{m} \left(R_{gr} - R_i\right)^2}{m-1}.$$

4.2. Calculation of square average deviation σ:

$$\sigma = \sqrt{D}.$$

4.3. Obtained coefficient of the variation ν:

$$v = \frac{\sigma}{R_{gr}} 100\ \%.$$

If $\nu_{CTR,TMA,CTA} \leq 33$ %, opinion coordinated, and obtained system of preference of expert group. If $\nu_{CTR,TMA,CTA} > 33$ %, we need Kendal's coordination coefficient:

$$W = \frac{12S}{m^2(n^3 - n) - m\sum_{i=1}^{m} T_i},$$

$$S = \sum_{j=1}^{n} \left(\sum_{i=1}^{m} R_{ij} - \overline{R}\right)^2,$$

$$T_i = \sum_{i=1}^{m} \left(t_i^3 - t_i\right),$$

$$\overline{R} = \frac{1}{n} \sum_{j=1}^{n} \left(\sum_{i=1}^{m} R_{ij}\right).$$

where S – is generalized dispersion; t_i – is the number of the same ranks in the i-th row, and fixed the i-th expert.

Within the limits $0{,}7 < W \leq 1$. If $W < 0{,}7$, we need repeated interrogation.

5. Compare system of preference R_{gr} (X) and R_i (Y), $i = \overline{1, m}$, with the help of rating correlation coefficient R_s (Spearman's coefficient):

$$R_s = 1 - \frac{6\sum_{j=1}^{n}(x_j - y_j)^2}{n(n^2-1)}.$$

6. Significance of the calculations.

6.1. The significance of the calculations W, criterion – χ^2:

$$\chi_f^2 = \frac{S}{\frac{1}{2}m(n+1) - \frac{1}{12(n-1)}\sum_{i=1}^{m}T_i} > \chi_t^2,$$

where χ_f^2 – factual value of variable; χ_f^2 – table value of variable.

6.2. The significance of the calculations R_s (Spearman's coefficient) for using Student's t – criterion:

$$t_{critical} = r_s\sqrt{\frac{n-2}{1-R_s^2}} > t_{st},$$

where n – quality of zones; t_{st} – tabulated, while number of degrees of freedom $f = n–2$ and error $\alpha = 5$ %.

7. Weight coefficient w_j of complexity j-zone:

$$w_j = \frac{C_j}{\sum_{j=1}^{n}C_j}, \quad \sum_{j=1}^{n}w_j = 1,$$

where n – quality of zones; C_j – estimates.

$$C_j = 1 - \frac{R_j - 1}{n}; \quad j = \overline{1,n}.$$

8. Graphical presentation of weight coefficients.

For estimation complexity of an exercise in system of pre-simulation training needed to find weight coefficient, which characterize complexity of airspace zones. Estimation complexity of airspace zones was obtained for using algorithm of estimation of complexity tasks in the pre-simulator training:

1. Questionnaires for experts – ATC with working experience.

2. Matrix of individual preferences. Evaluation of complexity of airspace zones (CTR, TMA and CTA). Obtained – R_i, $i = \overline{1,m}$, where m – number of expert; R_i – system of preference of i-expert.

For example,

$R_i = R_{iTMA} \succ R_{iCTA}, R_{iCTR}$.

3. Matrix of group preferences obtained, for CTR:

$$R_{grCTR} = \frac{\sum_{i=1}^{m}R_{iCTR}}{m} = 2{,}64.$$

Average value R_{gr} for TMA and CTA have the similar calculations (table 2).

4. Coordination of expert's opinion.

4.1. Calculation of dispersion D.

$$D = \frac{\sum_{i=1}^{m}\left(R_{gr} - R_i\right)^2}{m-1} = \frac{\sum_{i=1}^{m}\left(R_{grCTR} - R_{iCNT}\right)^2}{m-1} = 0{,}401099.$$

Calculations for TMA and CTA would be the same variant (table 2).

4.2. Calculation of square average deviation σ:

$$\sigma = \sqrt{D} = \sqrt{D_{CTR}} = 0{,}633324.$$

Calculations for TMA and CTA would be the same variant (table 2).

4.3. Obtained coefficient of the variation ν:

$$v = \frac{\sigma}{R_{gr}}100 = \frac{\sigma_{CTR}}{R_{grCTR}}100 = 23{,}9636\ \%.$$

Variation for TMA and CTA have the similar calculations (table 2).

If $\nu_{CTR,TMA,CTA} \leq 33$ %, opinion coordinated, and obtained system of expert group. For example,

$R_{gr} = R_{TMA} \succ R_{CTR} \succ R_{CTA}$.

Table 2. Matrix of group preference

Coordination of expert's opinion	CTR	TMA	CTA
	x_1	x_2	x_3
R_{gr}	2,64286	1,14286	2,21429
D_i	0,40110	0,13186	0.33516
σ_i	0,63332	0,36313	0,57893
v_i %	23,9636	31,77445	26,14542

Calculations shows that opinion was coordinated and necessary obtain weight coefficients of complexity for airspace zones.

Weight coefficient of complexity:

$$w_j = \frac{C_j}{\sum_{j=1}^{n}C_j},$$

where n – quality of zone; $j = \overline{1,n}$; C_j – estimates:

$$C_j = 1 - \frac{R-1}{n}, \quad \sum_{j=1}^{n}w_j = 1,$$

$w_1 = w_{CTR}$ – weight coefficient for CTR zone;

$w_2 = w_{CTR}$ – weight coefficient for TMA zone;

$w_3 = w_{CTR}$ – weight coefficient for CTA zone.

Table 3. The results of obtaining weight coefficient

№	Zone	Ri rg	Cj	wi
1	CTR	2,64286	1,12222	0,22619
2	TMA	1,14286	1,21229	0,47619
3	CTA	2,21428	1,14035	0,29762

5. Graphical presentation of weight coefficients of CTR, TMA and CTA.

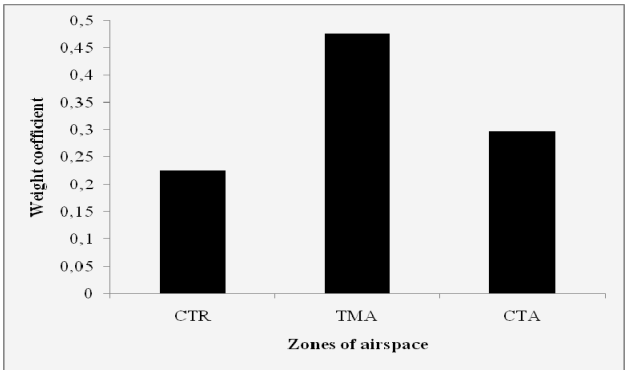

Fig. 1. Weight coefficient of zone's importance

Calculations was obtained for using program MSExcel.Integrated estimate Q_{jl} of tasks with j-th level of complexity in air traffic control for n-zones:

$$Q_{jl} = \sum_{j=1}^{n} \sum_{l=1}^{L} w_j q_l,$$

where Q – estimate for task with given complexity and types of airspace zone (CTR, TMA and CTA); Q_{jL} – mark according to task; w_j – weight coefficient (complexity of airspace zone), $j = \overline{1,n}$; $L = \overline{1,l}$; l – level of task.

So, we can see that the most difficult zone of airspace, based on the opinions of experts is Terminal control area (w_{TMA}= 0,47619). In the future ATC instructor would take into account this expert's opinion for definition of a task, according to difficulty.

Integrated estimation for implementation of task with complexity characteristic air control zone was calculated with the help of methods such as additive (multiplicative) aggregation.

For automate estimation of pre-simulation training on initial stage built neural networks – multilayer types [7; 8]. Fig.2 represents the neural network admission student to simulator training by the number of hours and level of training. It is neural network with type multilayer perceptron in which one layer is hidden:

– first layer – calculation of hours on theoretical training in accordance with the evaluation of student's knowledge;

– second layer – restrictions on given number hours (hidden layer);

– third layer – restrictions on passing mark hours (hidden layer).

Threshold functions activation building according with requirements of hours and level of marks task (discipline) in compliance with criterion of estimation of task.

5. Tasks' assessment criteria

5.1. General principles to assess tasks

All positions of assess criteria are prescribed and have to be used in a proper way as given below:

1. To take a duty and work place preparation.
2. An ability to follow the prescribed standard phraseology (excepting tasks with emergency and urgency situations).
3. Coordination with adjacent ATC units and other kinds of aerodrome service provision units.
4. Handling of procedural control.
5. Handling of visual control.
6. Daily flight plan conduction.
7. Execution of traffic massages timesheets.
8. Timeliness and accuracy of decision-making in ATC.
9. Compliance with safety in ATC.
10. Performing of console operations.

Some of the criteria might not be used in order to which are chosen by a supervisor before training.

5.2. Application of necessary criteria values and adaptation to pre-simulation training

If we are talking about pre-simulation training we have to take into account, that we evaluating abilities and skills of ATCO' feedback.

We can not apply general assessment criteria as they exist for the time of operation actions evaluation. However, some of them might be useful to apply. So, pre-simulation assessment criteria are:

– Retelling of given situation;
– Phraseology to be used;
– Taking a duty and work place preparation;
– Information about traffic;
– Level change proposal;
– Vectoring and heading guidance.

Retelling of given situation and expected phraseology is a fully individual criterion for supervisors. They must define elements which are necessary to be retailed as well as to evaluate proposed phraseology.

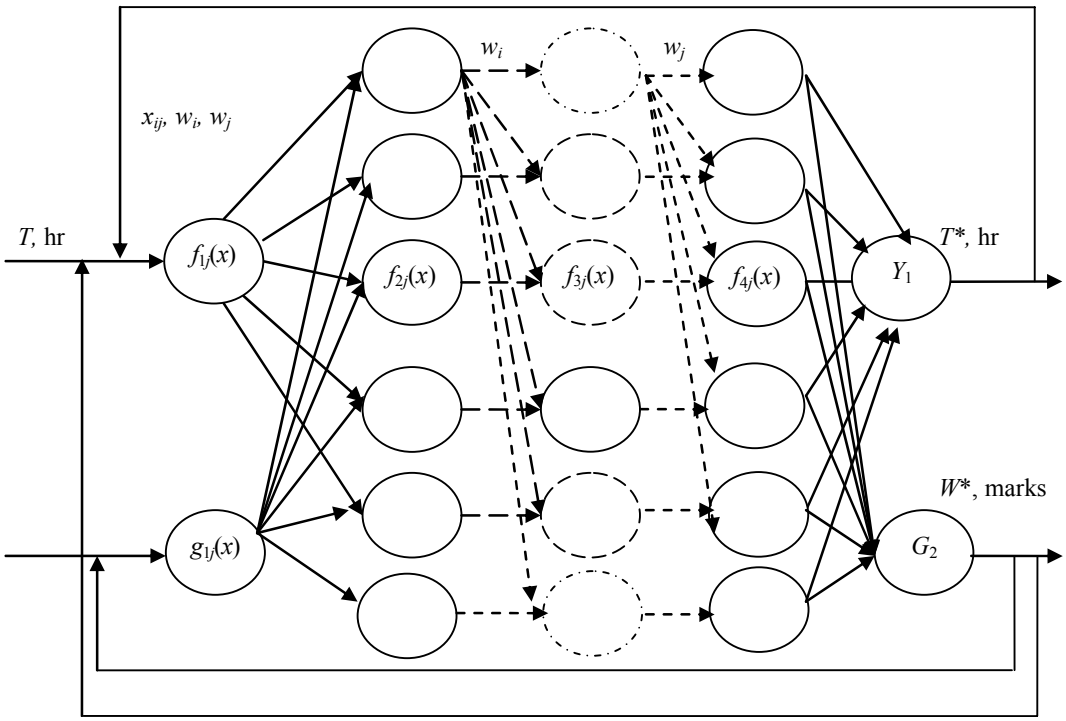

Fig. 2. Neural network admission student to simulator training by the number of hours and level of training

Information about traffic must be a reflection of an ability of a student to define/detect through the plan all conflict situations. Evaluation of this element depends on the whole number of conflicts regarding to the number of aircrafts.

Level change proposal. Level change proposal is a kind of a feedback that defines a degree of suitably given flight levels or altitudes by a student. Evaluation of this element is performed in percentage terms. Deviation of each level is equal to losing of 1 point.

Vectoring and heading guidance. Accuracy of a heading designation is a 3° deviation from desired direction. If we are out of limits we are losing 1 point within a criterion.

Every element has a five-point system basis. Evidently, missing all points of procedural elements by a student, should be considered as non-completed element and non-completed task correspondingly. Positively given marks are output into the mean value.

6. Conclusion

With the help of Expert Judgment Method determined difficulty of Air Traffic Control operations (tasks). Using expert's opinion and criterion of weight coefficient, we defined hard zone for operation on initial training, such as simulator practice.

According to interrogation, we built the graph, based on preliminary calculation. Analyzed graph from which we can see terminal control area have first position according to complexity of operation and procedure in air traffic control.

Built the neural network admission student to simulator training by the number of hours and level of training.

Automation of estimation of pre-simulator training on phase of initial training specialists of Air Traffic Control increases the efficiency of simulator training through interactive evaluation of the performance of students' tasks. Performance of partial assignments, accompanied by comments, displaying results, assessments of the student and the possibility of feedback.

In future we plan to evaluate pre-simulating phase of training for the other methods of aggregation.

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Т. Ф Шмельова[1], В. А. Лазоренко[2], А. П. Білько[3]. Розрахунок складності вправ передтренажерної підготовки
[1,2,3]Національний авіаційний університет, просп. Космонавта Комарова, 1, Київ, Україна, 03680
E-mails: [1]shmelova@ukr.net, [2]vitalii.lazorenko@ukr.net, [3]superbelk@ukr.net

Проаналізовано три різні типи вправ тренажерної підготовки: CTR (диспетчерська зона), TMA (термінальний диспетчерський район) та CTA (диспетчерський район) з різними видами складності. Встановлено, що кожна з зон, де проводиться обслуговування повітряного руху, має різну технологію роботи та робочі інструкції. Використовуючи алгоритм для розрахунку складності вправ передтренажерної підготовки, за допомогою методів експертних оцінок, ми обчислили вагові коефіцієнти. Відповідно до результатів побудували графік, який презентує найважчу зону управління повітряним рухом. Крім того, проаналізували передтренажерний критерій оцінювання.

Ключові слова: диспетчерська зона; диспетчерський район; методи експертного оцінювання; передтренажерна підготовка; термінальний диспетчерський район.

Т. Ф Шмелева[1], В. А. Лазоренко[2], А. П. Билько[3]. Расчет сложности упражнений предтренажерной подготовки
[1,2,3]Национальный авиационный университет, просп. Космонавта Комарова, 1, Киев, Украина, 03680
E-mails: [1]shmelova@ukr.net, [2]vitalii.lazorenko@ukr.net, [3]superbelk@ukr.net

Проанализировано три разных типа упражнений тренажерной подготовки: CTR (диспетчерская зона), TMA (узловой диспетчерский район) and CTA (диспетчерский район) с разными видами сложности. Установлено, что каждая из зон, где предоставляется обслуживание воздушного движения, имеет разную технологию работы и рабочие инструкции. Используя алгоритм для расчета сложности упражнений в предтренажерной подготовке, с помощью метода эксперных оценок, мы вычислили весовые коэффициенты. Основываясь на результатах, построили график, который демонстрирует самую сложную зону управления воздушным движением. Кроме того, проанализовали предтренажерный критерий оценивания.

Ключевые слова: диспетчерская зона; диспетчерский район; методы экспертного оценивания; предтренажерная подготовка; терминальный диспетчерский район.

Shmelova Tetyana (1961). Doctor of Engineering. Professor.
Air Navigation Systems Department, National Aviation University, Kyiv, Ukraine.
Education: Kirovograd Institute of Agricultural Engineering, Kirovograd, Ukraine.
Research area: decision making in air navigation systems.
Publications: 69
E-mail: shmelova@ukr.net

Lazorenko Vitaliy (1982). Lecturer.
Air Navigation Systems Department, National Aviation University.
Education: State academy of Ukraine, Kirovograd, Ukraine.
Research area: air traffic management, air traffic service, ATCO's simulator training, radiotelephony phraseology, human factors, human resources.
Publications: 9
E-mail: vitalii.lazorenko@gmail.com

Bilko Anastasiia (1993). Student.
National Aviation University, Kyiv, Ukraine.
Research area: decision making in air navigation systems.
Publications: 1
E-mail: superbelk@ukr.net