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Tatyana Shmelova[1]
Yuliya Sikirda[2]
Andriy Zemlyanskiy[3]
Olena Danilenko[4]
Vitalii Lazorenko[5]

ARTIFICIAL NEURAL NETWORK FOR AIR TRAFFIC CONTROLLER'S PRE-SIMULATOR TRAINING

[1,5]National Aviation University
1, Kosmonavta Komarova avenue, Kyiv, 03680, Ukraine
[2,3,4]Kirovohrad Flight Academy of the National Aviation University
1, Dobrovolskiy Street, Kirovohrad, 25005, Ukraine
E-mails: [1]shmelova@ukr.net; [2]sikirdayuliya@yandex.ua; [3]avizofusion@gmail.com;
[4]besingleheart@ukr.net; [5]vitalii.lazorenko@gmail.com

Abstract

Purpose: *to develop the neural network model for evaluating correctness and timeliness of decision-making by specialist of air traffic services during the pre-simulator training.* ***Methods:*** *researchers are based on the basic concepts of threat and error management in air traffic control, for characteristic of situation complexity (threat- error-undesirable condition) the methods of expert estimation and fuzzy sets theory have been used.* ***Results****: stages of the conflict situation developing have been classified and quantitative indicators of complexity level at each stage have been defined. Four layers neural network model for evaluating correctness and timeliness of decision-making by air traffic controller during the pre-simulator training has been built and its parameters have been obtained. The first layer (input) is exercises that perform cadets/listeners to solve potentially conflict situation, the second layer (hidden) is physiological characteristics of learner, the third layer (hidden) is the complexity of the exercise depending on the number of potentially conflict situations, the fourth layer (output) is assessment of cadets/listeners during performance of exercise. Neural network model also has additional inputs (Bias) that including restrictions on calculating parameters. With the help of modelling complex Fusion visualisation of results of educational task implementation by air traffic controller according to specified parameters have been defined.* ***Discussion:*** *taking into account timeliness and correctness of instructor's tasks performance during the pre-simulator education with the help of using artificial neural networks will allow determining the possibility of access of specialist of air traffic services to simulator training. Multimodal system Fusion will give the possibility to improve the process of training of cadet's/listener's – air traffic controllers through automated assessment of their actions.*

Keywords: correctness; fuzzy sets; multimodal system; neural network model; potentially conflict situation; timeliness.

1. Introduction

Statistics data [1-3] show us, that causality of aviation accidents didn't change over the past decade: 70-80% of accidents and disasters happened due human factor, and only 15-20% - through constructive and productive deficiencies of the aircraft. Quality training of aviation experts, including specialists in air traffic services (ATS), occupied important part in reducing influence of the human factor. Simulator training is an important part of training of air traffic controllers.

Simulator training – it's a complex of forms and studying methods, by which the cadet's / listener's can form the practical provisions using of theoretical provisions of several academic disciplines in the way of performing complex tasks and exercises under the guidance of instructor [4]. The aim of training is to improve air traffic controller's *(*ATC's) work and refinement practical skills of ATS in standard situations, potentially conflict situations (PCS), in the special conditions and in the special cases in flight. The quality and number of exercise, objective evaluation of exercise influence on effectiveness of simulator training.

According to the recommendations of Eurocontrol and to optimize effectiveness of simulator training, theoretical and practical training combine from the beginning of the training process preparation using the system pre-simulator training. The process of learning starts with getting skills by cadet's / listeners (SA - skill acquisition), then practice the performance of particular tasks (PTP - part-task practice) and continue simulator training [5].

Types of simulator training include [5]:

– simulator training (SIMUL) - training using the model of air traffic, which responds to cadet's / listener's actions as a real air traffic. This technique accompanies briefing, de-briefing, advice;

– guided simulator training (GSIMUL – Guided SIMUL) – the interaction between cadet / listener and computer in the form of questions, comments, instructions and issue assessments of the cadet / listener interaction in the process. Computer's performance consists of comparing current theoretical model and knowledge of cadet's / listener's in this study [4].

Guided competition skills is an actual at this time (GSA - Guided SA) - gaining skills, accompanied by interactive assessment, comments and control of cadet's / listener's actions.

Guided practice of partial task's performance (GPTP – Guided PTP) is a practical execution of particular tasks, accompanied by comments, display results, assessment of the cadet's / listener's and the ability of feedback [4].

2. Analysis of research and publications

The system of ATC training simulator characterized by low levels of objective evaluation of exercise [4]. It's connected with development of sufficient exercises at a given difficulty level. Increasing the number of exercises leading to significant growth an amount of instructional and methodical staff and requirements for their professional skills as well as time for developing an appropriate exercises of a given complexity. The most time spent on modelling of air situation in accordance with the set of objectives in the exercise, verification of exercise to meet at a given level of difficulty, verification graph to meet a planned workload and the possibility of conflict-free exercises.

The correctness is the main criterion for evaluating the quality of the exercises [5, 6]. In modelling the air situation using inverse task of generating dynamic air situation at a given exercise intensity, takes into account the complexity of air traffic, presence and quantity of PCS, occurrence of special cases in flight [6]. The timeliness is another important criterion for evaluating the quality of the exercises. Take into account as correctness as timeliness can be done with the help of artificial neural networks (ANN). Automation of process verification exercise can reduce the time for its preparation (saving up to 80% of the time).

Hybrid neural-expert system is a perspective direction of development of a neuron-information technologies [7]. ANN have many advantages compared to traditions and knowledge-based of diagnostic systems [8, 9]. It can be trained on examples, work in real-time, secure and tolerant to errors. With the help of ANN diagnoses state of the patient, performs the prediction on the stock market and the weather forecast, makes decision on granting the loan, diagnoses condition of equipment, guided operation of the engine, etc [7, 10, 11]. ANN is being created by serial and parallel association of an individual neurons. Neural network is grouped in two classes according to type of connections: straight directional network (which links don't have loops) and recurrent network (with feedback connections) [7-12]. The most common single-layer and multi-layer perceptron, cognitron and network radial basis function (RBF) (among straight directional network); among the recurrent network can be distinguish Hopfield, Boltzmann and Kohonen networks [8, 9].

Using of neural networks and neuro-fuzzy system is appropriate for solutions many exercises of aviation, where it is necessary to process large amount of unclear information; solving tasks (which difficult formalized) and multi-nonlinear problems, namely in the case of: a decision making on flight [13]; using more optimum alternate aerodrome landing [14]; evaluating the effectiveness of alternative completion of the flight in the event of an extraordinary situation [15]; diagnostic erroneous actions of the operator of ergatic aviation system in special cases of flight [16], ect.

It is proposed to use neural network model of evaluation timeliness and correctness of decision making (DM) of air traffic controller in case of PCS during performance of exercises in the simulator training through pre-training studying.

3. Aims of the work

1. Definition of quantitative indicators of the PCS complexity using fuzzy logic.
2. Development of neural network model for evaluation the timeliness and correctness of DM by ATC during the pre-simulator training.
3. Visualization the results of ATC training exercise.

4. Estimation of situation's complexity in case of PCS with the help of fuzzy sets method

There is well known concept of control threats and errors (CTE), consist of threats, errors and undesirable condition, which allows determining links between safety and operability of operator in fleeting difficult operating conditions [17, 18]. Conception has descriptive character and can be used as means of diagnosis both characteristics of human efficiency and effectiveness of the system. Despite in the fact that the CEM was originally developed for using in the cockpit, but it can also be used in various organizations of the aviation industry, including services for ATS.

Regarding ATC, CEM consist of three components:
– threats;
– errors;
– undesirable conditions.

According to CTE, threats and errors are routine part of aviation activity. ATC should control undesirable conditions, because it led to dangerous consequences. One of the main components of CEM is the control of undesirable conditions, and it has the same meaning as factors of threats and errors. Control of undesirable conditions is the last opportunity to avoid dangerous consequences and thus provide maintaining at a given level of aviation safety in ATS.

The concept, according to the problem of determining the timeliness of decision making in solving PCS by air traffic controller, was developed classification stages of conflict situation evolution [19].

The threat of conflict situation is the first stage of the PCS. The threat comes from the moment when the time of remaining to the conflict situation equal time, which needed to perform all elements for solving PCS, taking into account the required buffer time.

Pre-conflict situation is the second stage of the PCS. Pre-conflict situation occurs from the moment when the time of remaining until the conflict situation equal time, which needed to perform all elements to solve the PCS without buffer time. In this situation, the violation of the separation intervals is not yet come, but the probability of resolving situation is extremely small.

The conflict situation is a stage when happens violation of the separation intervals. Since the classification shows, that for determining the timeliness in dealing with DM during PCS should determine when there is a transition stage to the current situation the threat of conflict and pre-conflict situation.

For getting quantitative indicators of the level of situation's complexity in the developing of PCS, was used method of fuzzy sets [20, 21].

There are values of linguistic variable on the scale:
– threat of conflict;
– pre-conflict situation;
– conflict situation.

Minimum level of situation's complexity equal zero (0), maximum – one (1). The resulting range is divided into five intervals.

The degree of membership of linguistic variable at a certain interval defined as the ratio of answers number (where it occurs in this range) to the maximum value of this number for all intervals. There was conducted survey of 30 experts from air traffic service training centre of Kirovohrad Flight Academy of the National Aviation University by Delphi method in two rounds. Getting results shown in tabl. 1.

Membership functions of the situation's complexity μ (threat of conflict, pre-conflict situation, conflict situation) in the case of PCS are in the table.2 and shown in fig. 1.

There is system of transitions between components of CTE concept (stages of development of PCS) in graph of states (fig. 2).

Determine the state of the exercise as:

$$y = \begin{cases} 1; t_{01} + t_{02} \le T_2 \\ 0; t_{01} + t_{02} > T_2 \end{cases}.$$

Table 1. Survey results

Meaning of membership functions of the complexity of situation in case of PCS , μ	Interval, units				
	0-0,2	0,2-0,4	0,4-0,6	0,6-0,8	0,8-1,0
Threat of conflict, μ_1	1	1	22	6	0
Pre-conflict situation, μ_2	0	0	8	20	1
Conflict situation, μ_3	0	0	1	12	17

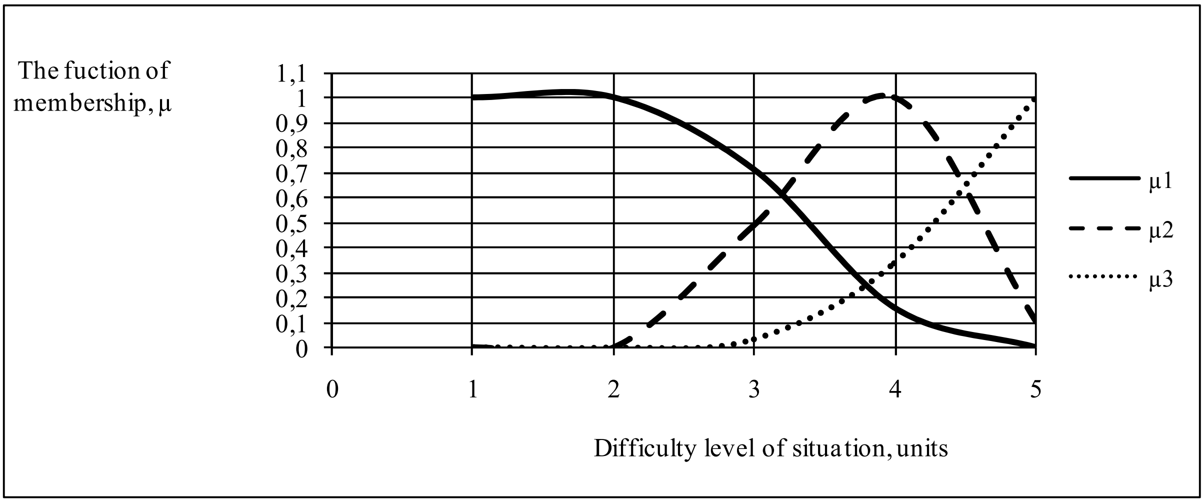


Fig. 1. Membership functions of the situation's complexity in case of PCS

Table 2. Classification of conflict situation by the criterion of timeliness

Classification by the CTE	Classification by timeliness	Description of situation	Level of complexity of situation, units
Threat	Threat of conflict situation	Fixed PCS which requires solving	1-2
Error	Pre-conflict situation	Parry of PCS is difficult or impossible	4
Undesirable condition	Conflict situation	Violation of separation intervals, conflict situation is happened	5

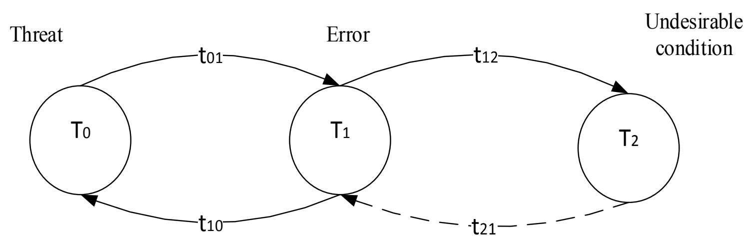


Fig. 2. Transitions between stages of PCS : T_0 – state, characterized by presence of threat in PCS; T_1 – pre-conflict situation, happen in result of erroneous or inaction of operator (cadet/listeners) ; T_2 – conflict situation (violation of separation intervals); t_{01} – transition from T_0 to T_1, characterized by time of parry of PCS and buffer time; t_{12} – transition from T_1 to T_2, characterized by the time of parry of PCS at stage T_1, in case of transition to stage T_2 happen critical situation; t_{10} – transition from T_1 to T_0, characterized by the ability of operator to resolve the PCS; t_{21} – transition from T_2 to T_1, characterized by the appearance of conflict due to T_2 (violations of separation's rules), but in case of successful resolution of problem by operator during allowable time – a return to pre-conflict situation ($T_{sim} = T_2$)

The time to solve conflict depends on the individual characteristics of the operator (cadet / listener) (c), the numbers of PCS (n) and time of PCS (T_s):

$$T_{sc}=T_c \cdot c+T_n \cdot n+T_s,$$

where c – coefficient, which defining the individual characteristics of the operator (cadet / listener);

n – amount of PCS;

T_s – time of developing PCS,

if n=1, c=1, then $T_{sc}=T_c+T_n+T_s$.

5. Development of neural network models of evaluating the timeliness of DM during simulator training and the definition of its parameters

To automate the evaluation of pre-training stage of initial training of air traffic controllers at the stage of learning pre-training studying had been done multilayer perceptron networks (MPN) (fig. 3), which has four layers, two of which are hidden. Each neuron characterized by the input value (dendrite) and output value (axon), weight coefficients (synapses), threshold function. The network has additional inputs, called the Bias (offset) that takes into account additional restrictions on calculating parameters:

$$\sum_{i=1}^{n} w_i x_i - \theta \geq 0 .$$

where w_i – weight coefficients;

x_i – neural network inputs;

$\overline{\theta}$ – Bias (shift).

General view of the ANN shown in fig. 3:

$$\overline{Y} = f(\overline{net} - \overline{\theta}),$$

where f – non-linear function (active function);

$\overline{net}$ – weighted sum of inputs.

Characteristics of ANN's layers:

1 layer (input) - exercises that perform cadets / listeners to solve PCS ($\overline{X}$);

2 layer (hidden) - defines the physiological characteristics of cadets / listeners ($\overline{H}$);

3 layer (hidden) - the complexity of the exercise, which is determined by the number of PCS ($\overline{D}$);

4 layer (output) – assessment of cadets / listeners during performance of exercises ($\overline{Y}$).

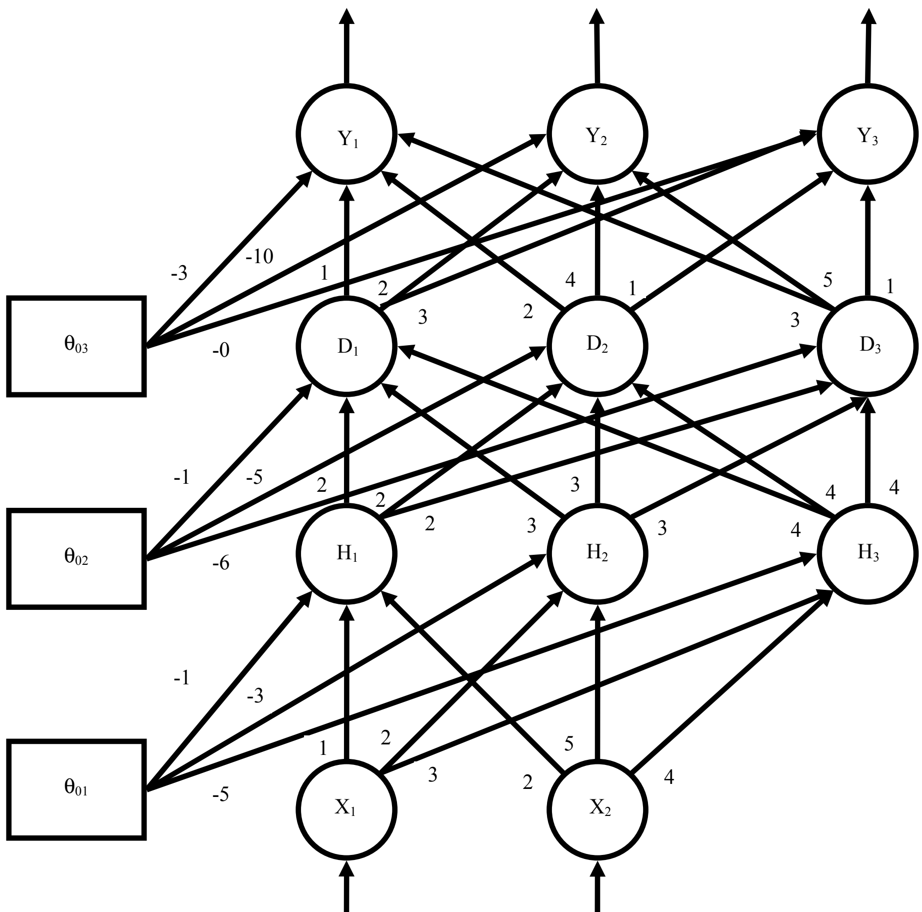


Fig. 3. Example of ANN when three cadets / listeners perform two tasks

Consider in more detail the topology of the neural network as an example, if three cadets / listeners (Y_1, Y_2, Y_3) perform two tasks (X_1 and X_2):

1 layer (input) – inputs x_1, x_2, ..., x_n - meet the objectives that perform by cadets / listeners to solve PCS ($\overline{X}$).

2 layer (hidden) – defines the physiological characteristics of cadet / listener ($\overline{H}$) using additional input Bias, which specifies limits on individual solving exercises (T_{01}).

The output vector layer:

$$\overline{H} = f(\overline{W}_1, \overline{X}) = f(\overline{net}_1 - \overline{\theta}_{01}),$$

where $\overline{net}_1 = \overline{W}_1 \overline{X}$;

$\overline{W}_1$ – weight coefficients, for example for studying situation when two exercises doing by three cadet's / listener's (fig. 4):

$$\overline{W}_1 = \begin{pmatrix} w_{01} & w_{11} & w_{21} \\ w_{02} & w_{12} & w_{22} \\ w_{03} & w_{13} & w_{23} \end{pmatrix};$$

$\overline{\theta}_{01}$ – time to solve individual training exercises.

3 layer (hidden) – the complexity of the exercise, which is determined by the number of PCS ($\overline{D}$) and characterized by dynamic air situation. Auxiliary input Bias indicates the total limit time for resolving PCS (T_{02}).

The output vector layer:

$$\overline{D} = f(\overline{W}_2, \overline{H}) = f(\overline{net}_2 - \overline{\theta}_{02}),$$

where $\overline{net}_2 = \overline{W}_2 \overline{H}$;

$\overline{W}_2$ – weight coefficients, which taking into account the complexity of dynamic air situation (fig. 4):

$$\overline{W}_2 = \begin{pmatrix} d_{01} & d_{11} & d_{21} \\ d_{02} & d_{12} & d_{22} \\ d_{03} & d_{13} & d_{23} \end{pmatrix};$$

$\overline{\theta}_{02}$ – time to solve training exercise that takes into account the complexity of the dynamic air situation.

4 layer (output) – directly assessment of cadet / listener during performance of exercises ($\overline{Y}$). Auxiliary input Bias limits the number of attempts for solving the PCS (T_{03}).

The output vector layer:

$$\overline{Y} = f(\overline{W}_3, \overline{D}) = f(\overline{net}_3 - \overline{\theta}_{03}),$$

where $\overline{net}_3 = \overline{W}_3 \overline{D}$;

$\overline{W}_3$ - weight coefficients, taking into account the quality of the exercise by the timeliness (fig. 4):

$$\overline{W}_3 = \begin{pmatrix} y_{01} & y_{11} & y_{21} \\ y_{02} & y_{12} & y_{22} \\ y_{03} & y_{13} & y_{23} \end{pmatrix};$$

$\overline{\theta}_{03}$ – attempts to solve exercises.

As a result, we have:

Provides the following outputs vectors layers of neurons $\overline{H}$, $\overline{D}$, $\overline{Y}$:

$$H_i D_k Y_m = \begin{cases} 1; f(x) > 0 \\ 0; f(x) \le 0 \end{cases}$$

where f- non-linear function of activation.

Consider the following set of values of weight coefficients ($\overline{W} = \overline{W}_1, \overline{W}_2, \overline{W}_3$), that take into account the performance of individual training exercises by cadet / listener depending on the physiological characteristics, complexity dynamic air situation, the quality of the exercise according to the timeliness:

$$\begin{cases} H_1 = f(1x_1 + 2x_2 - 1) \\ H_2 = f(2x_1 + 5x_2 - 3) \\ H_3 = f(3x_1 + 4x_2 - 5) \\ D_1 = f(2d_1 + 2d_2 + 2d_3 - 1) \\ D_2 = f(3d_1 + 3d_2 + 3d_3 - 5) \\ D_3 = f(4d_1 + 4d_2 + 4d_3 - 6) \\ Y_1 = f(1y_1 + 3y_2 + 2y_3 - 3) \\ Y_2 = f(2y_1 + 4y_2 + 1y_3 - 10) \\ Y_3 = f(3y_1 + 5y_2 + 1y_3 - 0) \end{cases}$$

Present an example in vector form:

$$\begin{cases} \begin{pmatrix} 1 \\ H_1 \\ H_2 \\ H_3 \end{pmatrix} = f\left[\begin{pmatrix} 1 & 0 & 0 \\ 1 & 2 & -1 \\ 2 & 5 & -3 \\ 3 & 4 & -5 \end{pmatrix} * \begin{pmatrix} 1 \\ X_1 \\ X_2 \end{pmatrix}\right] \\ \begin{pmatrix} 1 \\ D_1 \\ D_2 \\ D_3 \end{pmatrix} = f\left[\begin{pmatrix} 1 & 0 & 0 & 0 \\ 2 & 2 & 2 & -1 \\ 3 & 3 & 3 & -5 \\ 4 & 4 & 4 & -6 \end{pmatrix} * \begin{pmatrix} 1 \\ H_1 \\ H_2 \\ H_3 \end{pmatrix}\right] \\ \begin{pmatrix} Y_1 \\ Y_2 \\ Y_3 \end{pmatrix} = f\left[\begin{pmatrix} 1 & 0 & 0 & 0 \\ 1 & 3 & 2 & -3 \\ 2 & 4 & 1 & -10 \\ 3 & 5 & 1 & 0 \end{pmatrix} * \begin{pmatrix} 1 \\ D_1 \\ D_2 \\ D_3 \end{pmatrix}\right] \end{cases}$$

The result of the functioning with different initial data (X = (0;0), (0;1), (1;0), (1;1)), taking into account the coefficients and conditions of performed exercises (time, attempts, characteristics of cadet / listener), are as follows (table 1).

Table 1. Results of functioning ANN

X_1	X_2	H_1	H_2	H_3	D_1	D_2	D_3	Y_1	Y_2	Y_3
0	0	0	0	0	0	0	0	0	0	0
0	1	1	1	0	1	0	0	0	1	1
1	0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1	0	1

In general, ANN can be represented as follows:

$$\overline{H} = f(\overline{W}_1, \overline{X});$$

$$\overline{D} = f(\overline{W}_2, \overline{H});$$

$$\overline{Y} = f(\overline{W}_3, \overline{D}).$$

From the equations, we've get definition of 4-leyer ANN:

$$\overline{Y} = f(W_1 f(W_2 f(W_3(\overline{X})))),$$

where $\overline{X}$ – network input vector (exercises);

$\overline{W}$ – coefficient of individual cadet's/listener's characteristics. For example, for vector $\overline{H}$, which determines the physiological characteristics of cadet / listener, we have:

H_1 №1 – w_{11}, w_{21} – coefficient, which characterized by ability of cadet / listener №1;

H_2 №2 – w_{12}, w_{22} – coefficient, which characterized by ability of cadet / listener №2;

H_3 №3 – w_{13}, w_{23} – coefficient, which characterized by ability of cadet / listener №3.

The table 1 shown, that during performance of exercise №2 (X_2 = 1) cadet / listener №2 and №3 completed the task on time (№1 – not complied).

During resolving of exercise №1 – nobody completed the task.

During simultaneously performing of 2 tasks (X_1 = 1, X_2 = 1) completed the task cadets / listeners №1 i №3, and №2 – not coped with the task.

6. Visualization of result's performance of training exercises' execution by ATC

Computer program was developed according to visualization of state of exercise's performance by cadet's / listener's under timeliness. The instructor has information about ATC's stage of solving problem: threats, pre-conflict or conflict. Threats should be seen as a warning that it is necessary to take immediate measures to resolve the PCS. Pre-conflict stage shows that to avoid conflict is difficult or impossible. Displays information about the origin of these steps will allow those who are taught to pay attention to necessary taking actions to resolve PCS.

To increase the effect is proposed to duplicate the information data on those aircraft, between which is predicted PCS. For instructor, such information will help draw the attention of the learner on need for measures to resolve the PCS. In conducting group sessions, such information will help the instructor to know who cadet / listener can not cope with the task.

The Institute of Air Navigation of Kirovograd Flight Academy of National Aviation University is developed modelling complex (MC) Fusion, which provides multimodal system of predicted PCS (fig. 4).

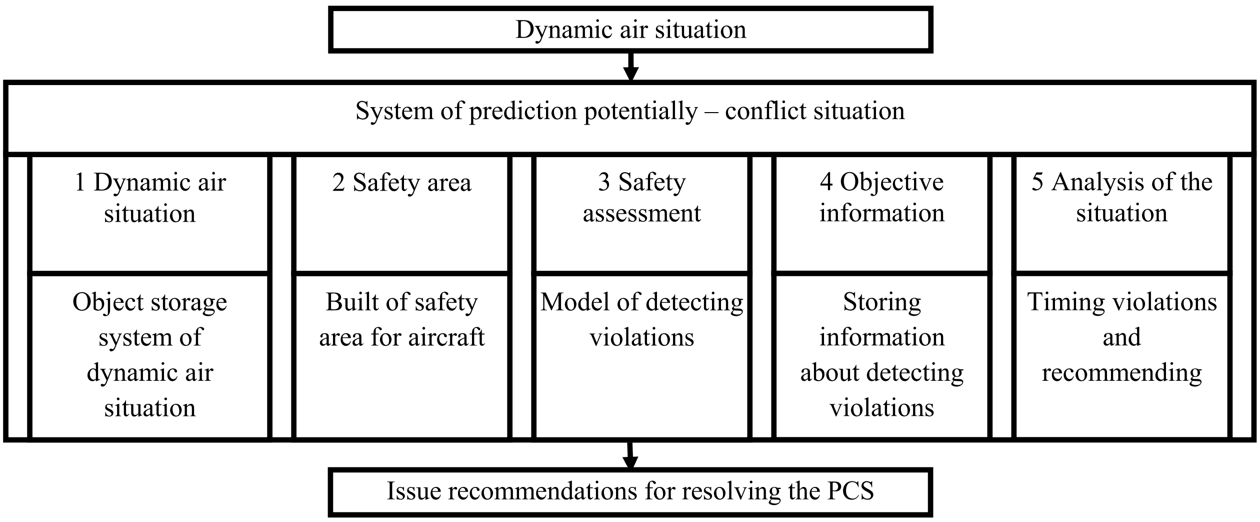


Fig. 4. The block scheme and algorithm of advanced modelling MC Fusion

Information from display of dynamic air situation, with regularity in one second (t = 1 s), transmitted to the objective system for storage information as to dynamic air situation. Then, considering parameters of aircraft's movement and its relative positions, can determine the type of PCS.

After determining the type of PCS, this information comes to the module of construction safety zone of aircraft. Security zones in MC Fusion is built in compliance with the regulations to maintain separation intervals (longitudinal, lateral and vertical) [22]. The size of the security zone depends on airspace structure and the relative position of the aircraft (for which the calculation is performed). Security zone is built along the motion vector of aircraft at each time when provide recalculation of the relative position of the aircraft. Ingestion the aircraft in the security zone of another aircraft clearly regarded as a violation of separation intervals and recorded as violation.

The module of detection violation's system, including type of conflict and an active situation of security zone defines the fact of violation of the intervals.

In cases where the system has detected a violation of safe intervals, this information comes in system of storage information about violations. Storage information system about violations is able to keep three types of information about the conflict that took place, namely:

– call signs of couples aircraft, between which there was conflict;

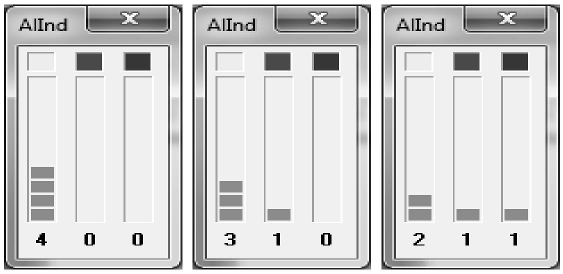
– time of conflict;

– type of conflict.

Visual form of information presentation is the most appropriate form about occurrence phases of PCS for understanding by cadet's / listener's or instructor's.

According to developed classification, proposed to output the formula of three elements, each of which will show the number of potentially conflicting situations at each stage of development. Fig. 5 shown us exterior form of output of such information.

There are elements which colored yellow, crimson and red correspond to stages of conflict situation (shown in fig. 5). The yellow element corresponds to stage "The threat of a conflict situation," crimson - "Pre-conflict situation," Red - "Conflict situation".



a) b) c)

Fig. 5. Forms of indication: a – projects four PCS (identified by yellow - the first column); b – one of the PCS has passed the stage of "pre-conflict situation" (identified by the crimson - the second column), c – one of the PCS has passed the stage of "conflict" (violation of separation intervals), one of the PCS - the stage of "pre-conflict situation" (crimson identified (second column) and red (third column) colours

Indicators, which are located under the colour elements are designed to display information about the number of PCS at an appropriate stage of development.

The use of the proposed indicators stages of the PCS at the workplace of future ATS specialist recommended at the stages of training, which will allow cadets / listeners gain the necessary skills to identify and resolve PCS.

The similar indication at the workplace of instructor (teacher), can done the group sessions with cadets / listeners is more ease , because that will promptly identify problems in the detecting and resolution of PCS during performance of training exercises.

7. Conclusions

The correctness and timeliness are the main criterions for evaluating the quality of performance simulator exercises. With the help of using artificial neural networks it take into account.

For building ANN according to the provisions of the basic concepts of control factors of threats and errors, classified stages of the developing conflict situation and defined quantitative indicators of the complexity level at each stage using fuzzy logic.

Developed neural network models of assessment the timeliness and correctness of the decision-making by specialist of ATS in the simulator training and defined its parameters.

Presented the block diagram of MC Fusion with the ability to display phases of PCS, which simplifies the process of training of cadets / listeners

- air traffic controllers, as well as evaluating their actions in the performance of educational tasks by instructor.

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Т.Ф. Шмельова[1], Ю.В. Сікірда[2], А.В. Землянський[3], О.М. Даниленко[4], В.А. Лазоренко[5]

Штучна нейронна мережа для передтренажерної підготовки авіадиспетчера

[1,5]Національний авіаційний університет, Київ, Україна
[2,3,4]Кіровоградська льотна академія Національного авіаційного університету
вул. Добровольського, 1, Кіровоград, 25005, Україна
E-mails: [1]shmelova@ukr.net; [2]sikirdayuliya@yandex.ua; [3]avizofusion@gmail.com; [4]besingleheart@ukr.net;
[5]vitalii.lazorenko@gmail.com

Мета: Розробити нейромережеву модель оцінювання своєчасності та безпомилковості прийняття рішень спеціалістом з обслуговування повітряного руху в процесі передтренажерної підготовки. **Методи:** Дослідження базуються на основних положеннях концепції контролю факторів загроз та помилок при управлінні повітряним рухом, для характеристики складності ситуації (загроза-помилка-небажаний стан) використано методи експертних оцінок та теорії нечітких множин. **Результати**: Класифіковано етапи розвитку конфліктної ситуації та визначено кількісні показники рівня складності на кожному з етапів. Побудовано чотирьохшарову нейромережеву модель оцінювання своєчасності та безпомилковості прийняття рішень авіадиспетчером в процесі передтренажерної підготовки та отримано її параметри. Перший шар (вхідний) нейронної мережі представляє собою вправи, які виконують курсанти/слухачі, другий шар (схований) визначає психофізіологічні характеристики того, хто навчається, третій шар (схований) враховує складність вправи залежно від кількості потенційно конфліктних ситуацій, четвертий шар (вихідний) – оцінка курсанта/слухача при виконанні вправи. Нейромережева модель також має додаткові входи (зсув), що включають обмеження на обчислювальні параметри. За допомогою моделюючого комплексу Fusion отримано візуалізацію результатів виконання навчальної вправи авіадиспетчером за вказаними критеріями. **Обговорення**: Врахування критеріїв безпомилковості та своєчасності виконання поставлених інструктором завдань в процесі передтренажерного навчання за допомогою використання штучних нейронних мереж дозволить визначати можливість допуску спеціаліста з обслуговування повітряного руху до тренажерної підготовки. Мультимодульна система Fusion дасть можливість удосконалити процес професійної підготовки курсантів / слухачів – авіадиспетчерів завдяки автоматизації оцінювання їхніх дій.

Ключові слова: безпомилковість; мультимодульна система; нейромережева модель; нечіткі множини; потенційно конфліктна ситуація; своєчасність.

Т.Ф. Шмелева[1], Ю.В. Сикирда[2], А.В. Землянский[3], Е.Н. Даниленко[4], В.А. Лазоренко[5]

Искусственная нейронная сеть для предтренажерной подготовки авидиспетчера

[1,5]Национальный авиационный университет, Киев, Украина
[2,3,4]Кировоградская летная академия Национального авиационного университета
ул. Добровольского, 1, Кировоград, 25005, Украина
E-mails: [1]shmelova@ukr.net; [2]sikirdayuliya@yandex.ua; [3]avizofusion@gmail.com; [4]besingleheart@ukr.net;
[5]vitalii.lazorenko@gmail.com

Цель: разработать нейросетевую модель оценивания своевременности и безошибочности принятия решений специалистом по обслуживанию воздушного движения в процессе предтренажерной подготовки. **Методы:** Исследования базируются на основных положениях концепции контроля факторов угроз и ошибок при управлении воздушным движением, для характеристики сложности ситуации (угроза-ошибка-нежелательное состояние) использованы методы экспертных оценок и теории нечетких множеств. **Результаты**: Классифицированы этапы развития конфликтной ситуации и определены количественные показатели уровня сложности на каждом этапе. Построена чотырехслойная нейросетевая модель оценивания своевременности и безошибочности принятия решений авиадиспетчером в процессе предтренажерной подготовки и получены ее параметры. Первый слой (входной) нейронной сети представляет собою упражнения, которые выполняют курсанты/слушатели, второй слой (скрытый) определяет психофизиологические характеристики обучаемого, третий слой (скрытый) учитывает сложность упражнения в зависимости от количества потенциально конфликтных ситуаций, четвертый слой (выходной) – оценка курсанта/слушателя при выполнении упражнения. Нейросетевая модель также имеет дополнительные входы (сдвиг), которые включают ограничения на вычисляемые параметры. С помощью моделирующего комплекса Fusion получена визуализация результатов выполнения учебного упражнения авиадиспетчером за указанными критериями. **Обсуждение**: Учет критериев безошибочности и своевременности выполнения поставленных инструктором задач в процессе предтренажерного обучения с помощью использования искусственных нейронных сетей позволит определять возможность допуска специалиста по обслуживанию воздушного движения к тренажерной подготовке. Мультимодульная система Fusion даст возможность усовершенствовать процесс профессиональной подготовки курсантов/слушателей – авиадиспетчеров благодаря автоматизации оценивания их действий.

Ключевые слова: безошибочность; мультимодульная система; нейросетевая модель; нечеткие множества; потенциально конфликтная ситуация; своевременность.

Shmelova Tetyana. Doctor of Engineering. Associate Professor.
Air Navigation Systems Department, National Aviation University, Kiev, Ukraine.
Education: Kirovohrad Institute of Agricultural Mechanical Engineering, Kirovohrad, Ukraine (1983).
Research area: development the evaluation system of decision-making efficiency by a human-operator of socio-technical air navigation system in the expected and unexpected operating conditions of an aircraft with the influence of the professional and non-professional factors.
Publications: 210.
E-mail: shmelova@ukr.net

Sikirda Yuliya. Candidate of Engineering. Associate Professor.
Vice-Dean of the Management Faculty, Kirovohrad Flight Academy of the National Aviation University, Associate Professor of the Management, Economy and Law Department, Kirovohrad Flight Academy of the National Aviation University, Kirovohrad, Ukraine.
Education: State Flight Academy of Ukraine, Kirovohrad, Ukraine (2001).
Research area: evaluation and improving the efficiency of decision-making by a human-operator of air navigation system.
Publications: 130.
E-mail: sikirdayuliya@yandex.ua

Zemlyansky Andrew. Senior Lecturer
Faculty of Air Traffic Services, Kirovohrad Flight Academy of the National Aviation University, Kirovohrad, Ukraine.
Education: Faculty of Air Traffic Services, State Flight Academy of Ukraine, Kirovohrad, Ukraine (1995).
Research area: development the intelligent modelling complexes for automation of air traffic controller simulator training.
Publications: 30.
Aviation University.
E-mail: avizofusion@gmail.com

Danilenko Olena.
Cadet of Kirovohrad Flight Academy of the National Aviation University, Kirovohrad, Ukraine.
Education: National Aviation University, Kiev, Ukraine (2015), Kirovohrad Flight Academy of the National Aviation University, Kirovohrad, Ukraine (2016).
Research area: identifying and minimizing the impact of threats and errors on the activity of air traffic controller.
Publications: 15.
E-mails: leax_l@mail.ru;besingleheart@ukr.net

Lazorenko Vitaliy. Lecturer.
Air Navigation Systems Department, Institute of Information-Diagnostic Systems, National Aviation University.
Education: State Flight Academy of Ukraine, Kirovohrad, Ukraine (2004).
Research area: research on improving air traffic controller training simulator Traffic Service of Civil Aviation.
Publications: 10.
E-mail: vitalii.lazorenko@gmail.com