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OPTIMIZING THE MUTUAL ARRANGEMENT OF PILOT INDICATORS ON AN AIRCRAFT DASHBOARD AND ANALYSIS OF THIS PROCEDURE FROM THE VIEWPOINT OF QUANTUM REPRESENTATIONS

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The purpose of this work is to present the first attempt to provide quantitative analysis and objective justification for designers' decisions that relate to the arrangement of pilot indicators on an aircraft dashboard with the use of video oculography measurements. To date, such decisions have been made only based on the practical experience accumulated by designers and subjective expert assessments. A new method for optimizing the mutual arrangement of the dashboard indicators is under consideration. This is based on iterative correction of the gaze transition probability matrix between the selected zones of attention, to minimize the difference between the stationary distribution of relative frequencies of gaze that are staying in these zones and the corresponding desirable target eye movements that are given for distribution for qualified pilots. When solving the subsequent multidimensional scaling problem, the gaze transition probability matrix that is obtained is considered to be the similarity matrix, the elements of which quantitatively characterize the proximity between the zones of attention. The main findings of this novel work are as follows: the use of oculography data to justify dashboard design decisions, the optimizing method itself, and its mathematical components, as well as analysis of the optimization in question from the viewpoint of quantum representations, all revealed design mistakes. The results that were obtained can be applied for prototyping variants of aircraft dashboards by rearranging the display areas associated with the corresponding zones of attention.

Key words: aircraft dashboard, pilot indicators, zones of pilot attention, video oculography, gaze movement activity, multidimensional scaling, quantum representations

INTRODUCTION

The human factor, along with the effectiveness of professional training, is now recognized as one of the main factors in the emergence of critical situations in civil aviation. According to some expert evaluations, although for the past two decades pilots have been participating in the control process for only several minutes on average during each flight, the number of accidents that result from crew errors is up to 65%.

Clearly, these factors and their impacts on the emergence of critical situations in flight should be taken into account in shaping the information and control field of a crew cockpit. It is therefore topical to determine the relevant methods for assessing the skills of the crew and the conditions in which they operate, as well as for optimizing the aircraft's human-machine interface.

An objective assessment method is needed for estimating the influences that are related to the cockpit information and control field. One of the critical issues involved is the development of both the evaluation criteria and new approaches that can be used to reveal the levels of training as well as the psychophysiological conditions of pilots. The main direction of this activity is the assessment that is based on the results of work on modern simulators and test benches, where it is possible to repeat the special conditions of pilots' work without too much difficulty.

It is important to note that the approaches that require the monitoring of multiple identifiable aircraft parameters are not suitable for practical applications, since the errors in assessment, as well as the generally uncertain sensitivity of the results obtained concerning parameter variations, make these approaches unreliable.

Approaches based on statistical analyses of large data samples allow for the identification of trends, but do not yield certain predictions in particular practical situations, with potential applications being significantly limited. In addition, the transition from one aircraft type to another generally requires an almost complete redesign of the entire calculation model.

As a result, all the methods that have previously been developed have one or more of the above disadvantages. Some of the essential reasons for restricting the practical applications of the relevant results presented in many previous works [2, 8, 10, 16, 19-21], especially in cases of analyzing flight data, are as follows:

- Laborious manual preliminary data processing;
- Lack of rigorous mathematical criteria for selecting abnormal activity;

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- Lack of capabilities to reveal the causes of incorrect activity implementations;
- Inefficient numerical optimization methods;
- The need for very significant computing resources for calculations, and so on.

Certain applications for making projections are available to determine the approach to use through the aid of self-organizing maps (SOM) [4, 9]. However the real capabilities of such maps are limited, essentially because the non-determinism of SOM clustering and its inefficiency in aligning time series analyzed in the time domain with the structural stability of the solutions that are obtained are questionable [17-18].

With regard to the problem of assessing the conditions of the crew, the studies that were performed [13-14, 17-18] have shown that at the present time the most promising and valid methods in this field are non-invasive technologies. These are based on measuring the distribution of visual attention, such as through video oculography and assessment of the parameters of gaze motor activity, with the aid of eye trackers [1]. In terms of the rather complex and difficult problem of optimizing the cockpit interface that is in question, the issue essentially involves the lack of acceptable mathematical models and methods. However, various formulations for addressing problem are under study.

This work presents the first attempt to provide quantitative analysis and objective justification of designers' decisions that relate to the arrangement of pilot indicators on an aircraft dashboard with the use of video oculography measurements. Under consideration are both the mathematical and engineering backgrounds of particular problems of interface optimization, such as that of identifying the best mutual arrangement of the pilot indicators on an aircraft dashboard. A mathematical component of the new approach being presented is based on iterative correction of the transition probability matrix between the selected dashboard zones of attention. This is to minimize the differences between the stationary distribution of the relative frequencies of being in these zones and the corresponding desirable target distribution provided for qualified pilots, with the following multidimensional scaling being performed according to the matrix that is obtained.

To date, the designers' decisions with regard to this question have been made only on the basis of the practical experience accumulated by designers and subjective expert assessments. An important component of this novel work also lies in the accompanying analysis of the optimization procedure that has been developed from the viewpoint of quantum representations, which is of great practical interest due to the possibilities that arise for both interpreting design mistakes and revealing the motivations for the decisions made by the designers. This analysis is also useful to identify optimization trends.

The conclusions made with the aid of the quantum representations cannot be revealed because of the classical approaches for analyzing gaze movement activity.

The results presented differ significantly from the probabilistic methods used in managing systems, predicting technical failures, monitoring the state of the crew, and supporting pilot control actions [11]. These can be applied for prototyping variants of indicator formats by visually rearranging the display areas associated with corresponding zones of attention. Flight experts also perform evaluation and technical adjustments for the resulting arrangements.

THEORETICAL CONTRIBUTION: CALCULATION OF THE OPTIMAL MUTUAL ARRANGEMENT OF ATTENTION ZONES REPRESENTING VARIOUS DISPLAY ELEMENTS

The calculation of the optimal mutual arrangement of attention zones, representing various display elements, is based on the quantitative assessments determined by this arrangement. These assessments are determined by the degree of distribution consistency of relative stay periods in the attention zones and frequencies of reciprocal transitions between them, with similar reference characteristics of qualified pilots' gaze movements measured during their various flight maneuvers or using their expert recommendations.

In order to represent the dynamics of gaze movements on attention zones, *Markovian processes with discrete states and discrete time (Markovian chains)* are used. In these models, the specified zones correspond to certain states, forming a complete system (i.e., these states cover all admissible areas where the gaze can be directed). Staying in the state is determined by the gaze being in its corresponding attention zone.

The discrete time tact – depending on the amount of accumulated empirical data – is either specified by certain, and usually small, time interval, or corresponds to the time interval defining the transition from one gaze fixation to another. The probabilities of transitions between states are model parameters.

Gaze movements are characterized by sequences of passed attention zones which, in terms of this model, are interpreted as sequences of states.

The dynamics of the probability distribution of staying in the model states as a function of discrete time is defined by the following matrix equation:

$$\mathrm{p}(t+1)=\mathrm{Mp}(t) \tag{1}$$

where t–discrete time; $0 \leq t \leq T$; $t, T \in N$; T–final time; N–set of natural numbers; vector $\mathrm{p}(t)=((p_1(t),\ldots,p_n(t))^T$ represents the probabilities of being in the model states at the time t; n–the number of states of the Markovian process equal to the number of attention zones under study; $\mathbf{M}=\|m_{ij}\|$ – stochastic transition probability matrix between states of the Markovian chain of the order n, in which m_{ij} is the probability of transition from state j to state i for the representative set of flight maneuvers under consideration. This matrix is considered an integral characteristic representing *the frequencies of mutual transitions between attention zones*. The identification of matrices **M** for the considered representative set of flight maneuvers is performed using experimental data on the frequencies of transitions from one attention zone to another.

As a characteristic representing *the relative stay periods in the attention zones* for the considered representative set of flight maneuvers, the stationary distribution of the probabilities of staying in the specified zones, defined by the p^* solution of the following equation, is used: $p^*=Mp^*$.

Obviously, p^* is an eigenvector of matrix **M** corresponding to eigenvalue *1*. As it is known, stochastic matrices always have an eigenvalue equal to *1*, and this number is the spectral radius of these matrices [15]. In the general case, matrices **M** are asymmetric, and their eigenvalues are complex numbers.

Since the elements of vectors p^* are interpreted as probabilities, their values require normalization:

$$\sum\nolimits_{k=1}^{n} p_k^*=1, p_k^* \geq 0(k=1,\ldots,n) \tag{2}$$

In the subsequent solution of the multidimensional scaling problem [3, 6], the transition probability matrix **M** is regarded as a similarity matrix in which m_{ij} quantifies the degree of proximity between the *j*-th and *i*-th attention zones. Thus, as a result of scaling, the attention zones with a higher probability of mutual transition will be located closer to each other on the display panel.

Such mutual arrangement of attention zones is essentially caused by higher efficiency of flight information reading. The high frequency of mutual transitions indicates the necessity of simultaneously receiving information from the corresponding indicators and transitioning between geometrically close zones is performed faster. In addition, the proximity of the attention zones makes it possible, when reading the information from one indicator, to control. Using peripheral vision, another indicator, provides simultaneous control of the information necessary for performing the maneuver.

To quantify the distribution proximity of relative frequencies of stays in the attention zones, represented by the above considered stationary probability distribution p^* and the reference distribution, $\{F_k\}_{k=1,\ldots,n}$ of the total observed number of gaze hits F_k of qualified pilots into the specified zones, determined directly by empirical data or indirectly by expert data, the Pearson statistics is applied:

$$X^2=\sum\nolimits_{k=1}^{n} \frac{\left(p_k^* N-F_k\right)^2}{p_k^* N} \tag{3}$$

where $N=\sum_{k=1}^{n} F_k$, $p^*=(p_1^*,\ldots,p_n^*)^T$. Under some general conditions, its values are described by χ^2 distribution with *n*-1 degrees of freedom [7]. This allows us to use the above statistics to test the hypothesis that the desired distribution of frequencies of staying in the attention zones, is consistent with the reference, one.

Taking into account the abovementioned perceptions related to the pilots' gazes in the attention zones, the formal problem statement of calculating the optimal mutual arrangement of display elements comes down to two subproblems:

1. To determine the transition probability matrix **M** between attention zones, which provides the extreme value of the abovementioned Pearson statistics χ^2 used in these calculations as an optimization criterion to be minimized.
2. To calculate the desired mutual arrangement of the display elements as a result of multidimensional scaling of the resulting matrix **M** considered as a similarity matrix in this subtask.

It is important to note that the observed transition probability matrix of qualified pilots cannot be used immediately as a part of the optimization criterion in question due to significant individual differences between gaze movements of pilots with matching qualifications. The total observed numbers of gaze hits into the attention zones, which are presented in the given X^2 criterion, are much more indicative, meaningful and stable in this sense.

Thus, the procedure for calculating the optimal mutual arrangement of the given display elements consists of the following steps, which have either pure engineering or mathematical content:

Step 1 Estimation of the stationary target frequency distribution of stay in the attention areas is based on empirical data with qualified pilots’ participation or using their expert recommendations (results of this step are determined by either experimental measurements or expert estimations).

Step 2 Calculating the transition probability matrix providing the minimum value of the abovementioned Pearson statistics used as an optimization criterion, employing the assessment resulted from experiments with the first variant of indicator layout developed by cockpit dashboard designers as a rough initial approximation (i.e., the optimization problem is solved by a numerical method at this step);

Step 3 Determination of the optimal mutual arrangement of the given display elements using the multidimensional scaling procedure, considering the transition probability matrix calculated at the previous step as the similarity matrix quantitatively characterizing the required relative proximity indices between pairs of display elements (one of the multivariate statistical techniques is performed numerically at this step);

Step 4 Performing rotations and mirror images relative to the given axes for the calculated optimal mutual arrangement of the given display elements to ensure the perceptual convenience and limitations imposed by the design requirements (pure engineering step based on design considerations);

Step 5 Converting the obtained optimal mutual arrangement of the given display elements from relative to absolute distance scale that is consistent with the real dimensions of the dashboard in use (technical step).

The specified matrix **M** when performing numerical optimization at Step 2 of the aforementioned procedure is calculated as a result of an iterative numerical procedure at each step of which the rows of the current approximation to the desired matrix whose numbers are determined by the maximum and minimum differences between the same order elements of vectors $(p_1^*,\cdots,p_n^*)^T$ and $1/N\,(F_1,\cdots,F_n)^T/N$ are multiplied and divided, respectively, by $(1+r)$, where $0<r<1$ is the procedure parameter followed by normalization of the modified matrix that restores its stochasticity. As a rough initial approximation to the desired matrix, it is convenient to use its assessment obtained as experimental results with the first variant of indicator layout developed by cockpit dashboard designers. The specified procedure has shown its effectiveness in practice. Details of Step 2 are presented in Fig. 1 in the form of a diagram depicting their components and internal connections using notation of graphical programming language G of the LabVIEW environment [5], which is one of the most convenient means for compact rigorous representation of computational algorithms.

In order to ease the perception and ensure that the optimal mutual arrangement of display elements obtained as a result of multidimensional scaling with the constraints imposed by design requirements at the discretion of specialists, orthogonal transformations including rotations and mirror images relative to the given axes are applied.

In the case of constructing an initial approximation to the transition probability matrix based on already adopted design solutions, the analysis of the dynamics and results of the presented optimization procedure is of great practical interest both in terms of interpretation of design errors and their causes and motivation of the decision-making.

This approach to the study of the optimization process contains significant elements of novelty. This paper presents an example of such an analysis based on quantum models. This paper presents an example of such an analysis based on quantum models.

RESULTS: VIDEO OCULOGRAPHY MEASUREMENTS AND THEIR IMPLICATIONS TO PRACTICE

To optimize the format of the screen display based on the analysis of the movements of the pilot's gaze on the attention zones, five zones were selected on the stimulus material. These zones contained indicators of altitude, attack angle, indicated airspeed, aircraft spatial position, and vertical speed, which are designated further, respectively, by attitude, a Angle, ind Speed, pos Indication, and vrt Speed. Anything not covered by these zones was considered a conditional sixth zone, designated as

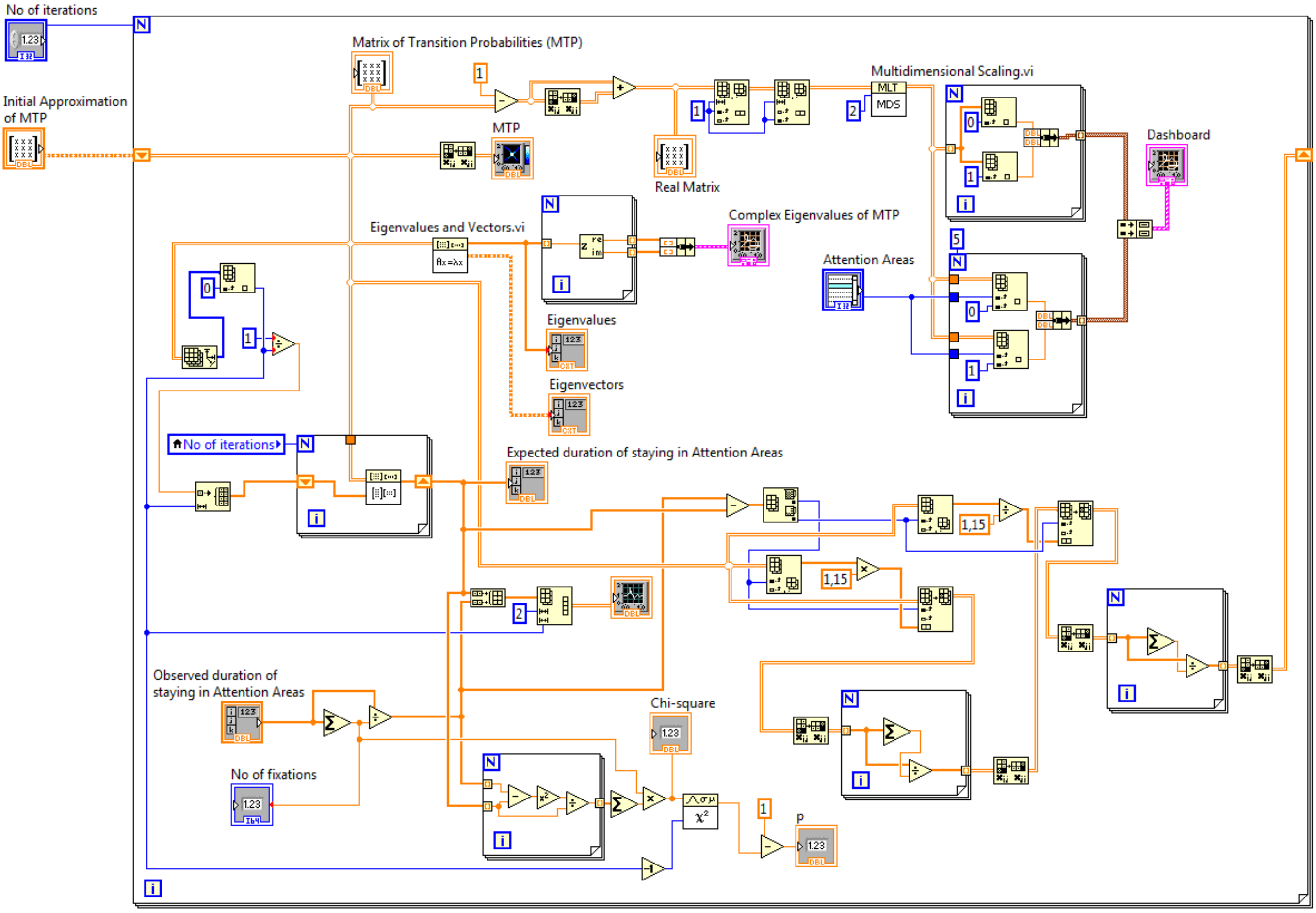


Figure 1: Step 2 of the Procedure for Calculating Optimal Mutual Arrangement of the Display Elements: Diagram Depicting Numerical Optimization Components and Their Internal Connections in Notation of Graphical programming language G

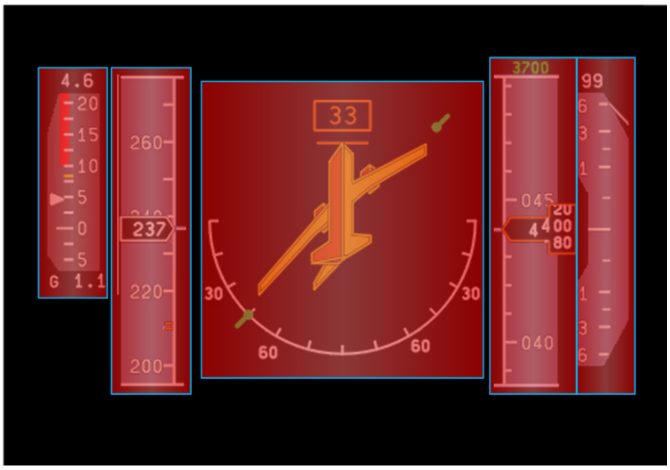


Figure 2: The Initial Arrangement of Attention Zones in the Flight Screenshot

Figure 3: The Aircraft Cockpit Universal Prototyping Bench of GosNIIAS

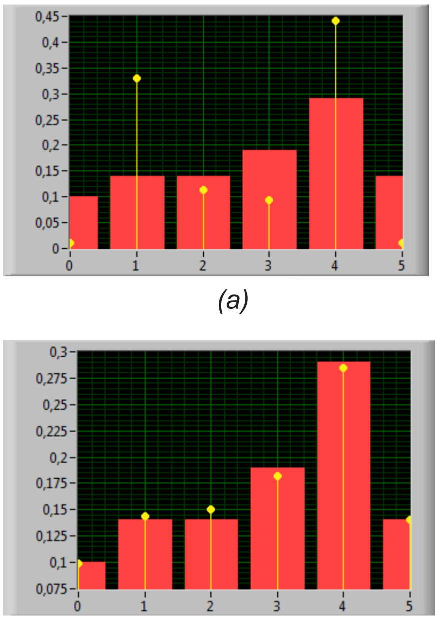
Figure 4: The eye tracker used for recording video oculography data

Out. The initial arrangement of these display elements is shown in Figure 2.

The experiments were carried out at the Aircraft Cockpit Universal Prototyping Bench of the State Research Institute of Aviation Systems (GosNIIAS) (Fig. 3). Video oculography data were recorded using the eye tracker shown in Fig. 4.

Using the results of experiments with the participation of experienced pilots, a reference assessment of the stationary frequency distribution of staying in the attention zones was obtained. Based on this assessment and the initial approximation to the transition probability matrix obtained as a result of experiments with the first variant of indicator arrangement proposed by the designers, the transition probability matrix, which provides the minimum value of the above Pearson statistics, was numerically determined.

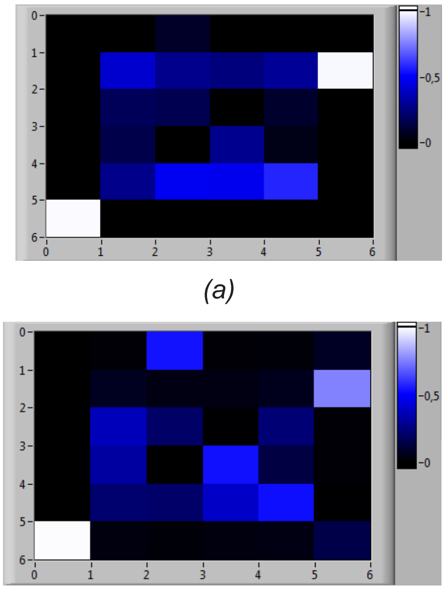
As an illustration, Fig. 5 shows the reference and calculated stationary distributions of frequencies of staying in the attention zones before and after the optimization procedure, Fig. 6 shows their corresponding transition probability matrices between the attention zones in the



(a)

(b)

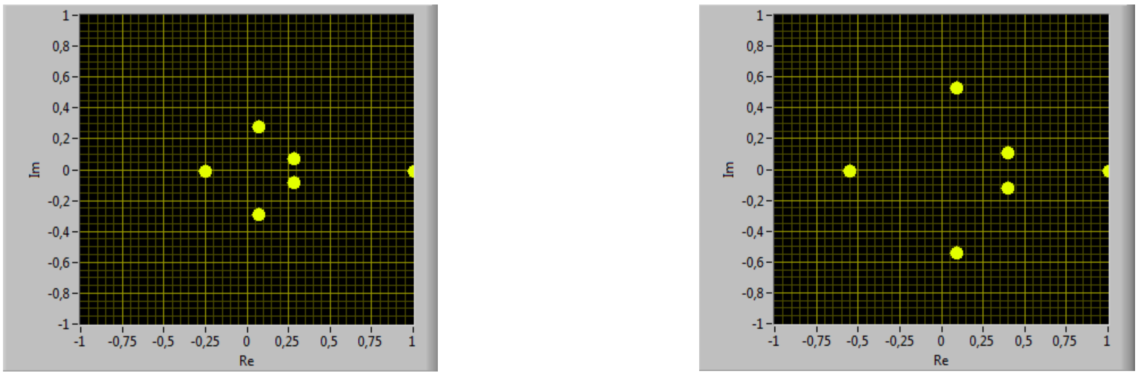
Figure 5: Reference and calculated stationary distributions of frequencies of staying in attention zones before and after performing the optimization procedure. The Pearson statistic X^2 can be used as a goodness-of-fit measure to evaluate the distribution fit: (a) X_5^2=275,97,p<0,0001; (b) X_5^2=0,374,p=0,996



(a)

(b)

Figure 6: Transition probability matrices between attention zones on a color scale



(a) *(b)*

Figure 7: Eigenvalues of transition probability matrices between attention zones

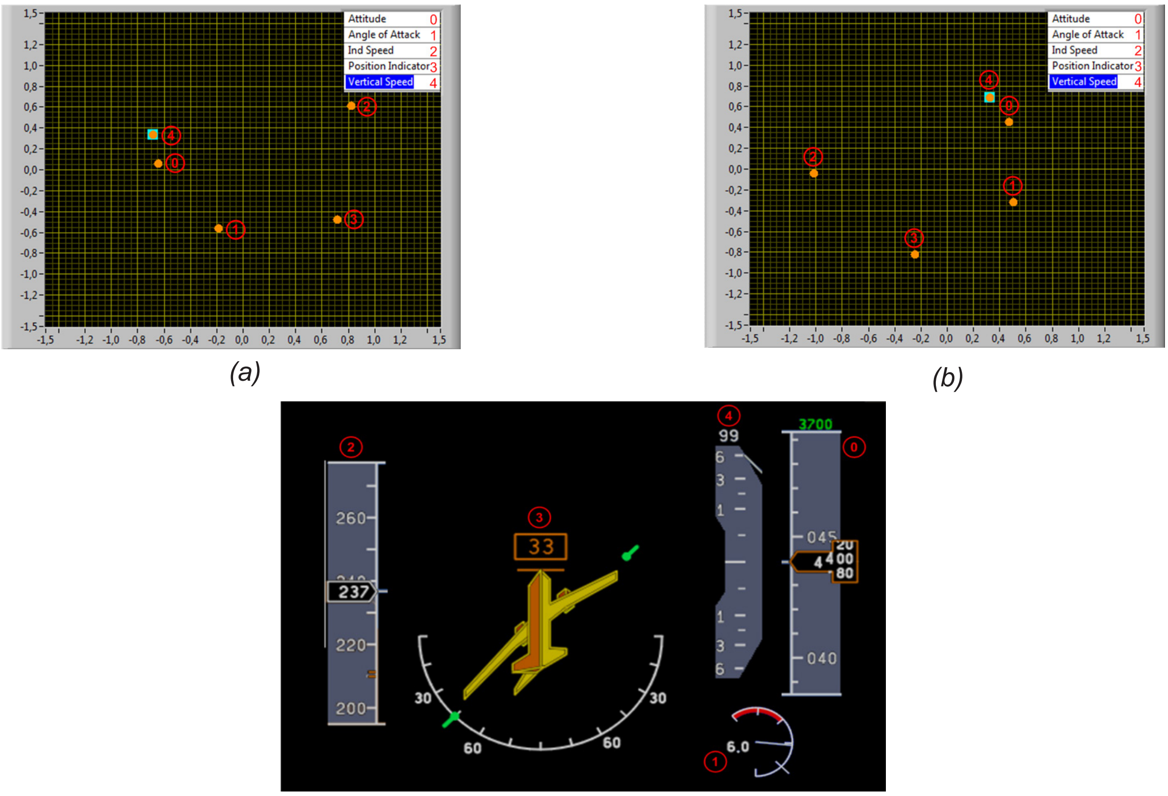
color scale, and Fig. 7 shows the eigenvalues of these matrices. The following numbering of the areas of interest is used: (0) "Attitude", (1) "Out", (2) "a Angle", (3) "ind Speed", (4) "pos Indication", (5) "vrt Speed."

Fig. 8 shows the optimal mutual arrangement of the given display elements before and after performing rotations and mirror images relative to the given axes, including the final arrangement of display elements.

Basing on the optimized arrangement of the display elements under consideration, a frame synthesis was carried out, with the requirements of aesthetics and designer's regulatory documents being taken into account (see Fig. 8c). For this, the display elements associated with the corresponding attention zones were arranged according to the obtained optimization results. The attention area associated with the angle of attack and previously had a ribbon type has been replaced by a dial, giving a complete and aesthetically pleasing look for the final layout.

DISCUSSION: ARRANGEMENT OF DISPLAY AREAS FROM THE VIEWPOINT OF QUANTUM REPRESENTATIONS

Based on the quantum representations presented in an article [12], a probabilistic structure represented by qubits is used, with a process in question being at one and only one of the states under consideration at any time point. Each qubit representation is considered as a formal quantum structure, which evolution in the closed mode is described by some orthogonal transform (see [12] for the



(a) *(b)*

(c)

Figure 8: Obtained Optimal Mutual Positions of the Given Display Elements Before (a) and After (b) Performing Rotations and Mirror Images Relative to the Given Axes, including the final arrangement of display elements (c)

reasons to select the orthogonal transform instead of the unitary one as well as for the other foundations).

The applied normalization transformations make the given qubits entangled by measuring (EM), therefore the whole set of the presented qubits is referred to as the EM-quantum system.

Complete qubit system undergoes a series of measurements at certain time points. Every measurement converts each of the current qubit representations into one of the corresponding basic vectors. Due to the principles of quantum computing, it is impossible neither to determine probability amplitudes, which are defined in the closed system by measuring nor to re-measure the system. As shown in [12], the identified qubit representation quantities to be determined are parameters of the closed qubit system ensuring the best fit with observations. The relevant fitness criterion of least squares to be minimized is described ibid.

For the EM-quantum system in question, both frequency values and the observed numbers of getting into states, which are referred to as the amplitudes, are considered as a corresponding process spectrum. Such spectra are determined to clarify the hidden cyclicities of being in the given states during the observation period and reveal the system behavior structure in this way.

Within a framework of the approach under consideration, staying in each display zone of attention is represented by a qubit included at the EM-quantum system. The Nyquist frequency determined via the maximum frequency of the pilot's saccades should be taken equal to 2.5 Hz, with the sampling frequency being assumed to be 5 Hz. To keep acceptable computation duration, zones “Out” and “vrtSpeed” were combined in analyzing.

The spectra representing selected iterations of the optimization procedure under study, obtained by the method of exhaustive search, are presented in Fig. 9. Stabilization of spectra is observed after 30 iterations.

Stabilization of spectra is observed after 30 iterations.

An increase with optimization iterations in the number of actively used display zones (i.e. with relatively high frequencies) is clearly visible with the proper extension of the reading area.

If the designer's variant is under consideration, the highest reading rates are observed for zones “*Out* + v*rt Speed*” and “*pos Indication*“. In the case of the optimized variant, they occur for zones “*Out + vrt Speed*”, “*ind Speed*”, and “*pos Indication*”.

The distribution of reading rates for different zones of attention evolves from a heterogeneous one in the case of the first designer's variant to an approximately homogeneous one in the case of optimal zone arrangement. This result meets the iteration dynamics of the relative Shannon entropy shown in Fig. 10 concerning the uniform case, which characterizes the measure of the uncertainty of gaze stay in the zones of attention.

The conclusions presented above cannot be revealed based on the classical approaches for analyzing gaze movement activity as experimental measurements can-

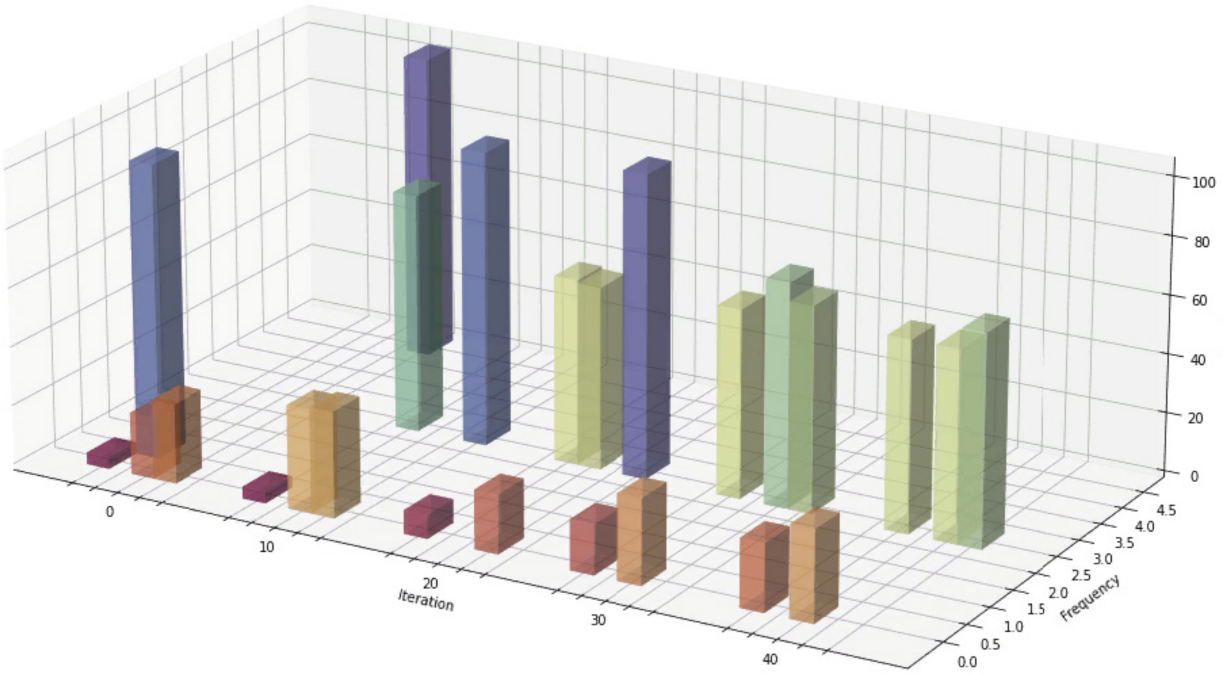


Figure 9: Obtained spectra which correspond to the EM-quantum systems representing the iterations of the optimization procedure under study. Qubit rotation frequencies and amplitudes are given as the functions of both number of iterations and Qubit numbers. Each depicted iteration is represented by 5 Qubits corresponding to zones “Attitude”, “Out+vrt Speed”, “a Angle”, “ind Speed”, and “pos Indication“. Frequency is given in Hz with overall frequency step 0.5 Hz

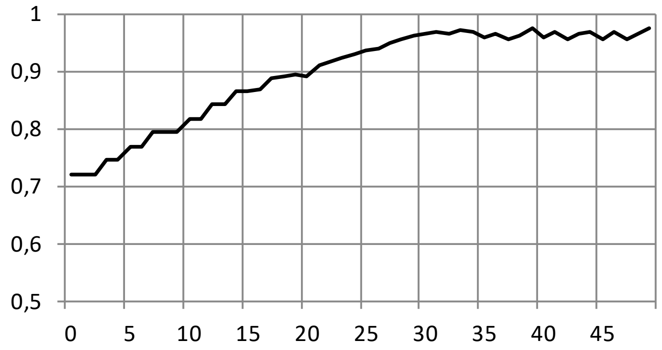


Figure 10: Relative Shannon entropy with respect to the uniform case as a function of the number of optimization iterations

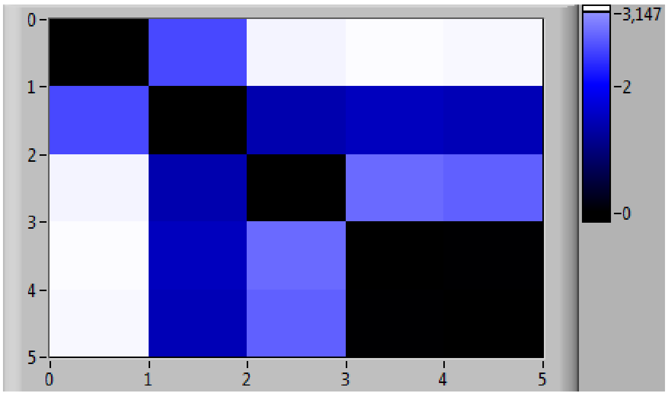


Figure 11: The matrix of mutual differences between iterations no 1, 10, 20, 30 and 40 of the optimization procedure, which were calculated in the spectral metric, in a color scale

not accompany the numerical optimization. Even if these experiments could be available, analyzing the primary indicators obtained by eye-tracking yields a very poor base for such an investigation. Thus, these classical tools are not applicable to find out optimization trends.

The matrix of mutual differences between iterations No 1, 10, 20, 30, and 40 of the optimization procedure (Fig. 11), calculated in the spectral metric presented in [12], shows the fast accumulation of indicator arrangement changes on the first steps with their subsequent stabilization of changes on the last steps.

CONCLUSIONS

1. Presented is the method for optimizing the mutual arrangement of pilot indicators on an aircraft dashboard, based on iterative correction of the transition probability matrix between the selected zones of attention. This is intended to minimize the difference between the stationary distribution of relative frequencies within these zones and the given corresponding target distribution required for qualified pilots, with the following multidimensional scaling for the obtained matrix being performed.
2. When resolving the multidimensional scaling problem, the transition probability matrix between the zones of attention is considered as the matrix of similarities, elements of which quantitatively characterize the proximity between the zones of attention. As a result of scaling, the higher the probability of transition between attention zones, the closer their location on an aircraft dashboard. It was shown that such an arrangement results in significantly higher efficiency in reading flight information. It is essential that the proximity of the attention zones allows reading information from one indicator and at the same time to checking another one in peripheral vision, thus providing simultaneous monitoring the information required to perform a maneuver.
3. When constructing an initial approximation for the transition probability matrix based on the already-adopted design decisions, the analysis of dynamics and the results of the optimization procedure are of great practical interest in both the interpretation of the faults in the design and the reasons for the decisions made by the designer. Such analysis contains significant unexpected elements.
4. Analysis of the optimization procedure from the perspective of quantum representations revealed that distribution of reading rates for different zones of attention evolved from heterogeneous, in the case of the first designer's variant, to approximately homogeneous, in the case of the optimal zone arrangement, as well as an increase, with optimization iterations, in the number of actively used display zones with the correct extension of the reading area.
5. Each qubit representation is considered a formal quantum structure which, when evolving in the closed mode, is described as an orthogonal transform. The applied normalization transformations show that the qubits are entangled by measuring. For the quantum system in question, both frequency values and the observed numbers of getting into states, referred to as the amplitudes, are considered a corresponding process spectrum. Such spectra are used to clarify the hidden cyclicities within the given states during the observation period and reveal the system behavior structure in this manner.
6. In the case of the simplest rotation, to provide the most reliable information about the system behavior, the rotation frequencies are identified to yield the best-fit between the evolution of the qubit representations, in the case of the closed system, and the available observations, with the relevant fitness criterion of least squares being applied.
7. The conclusions from the quantum representations cannot be determined based on traditional approaches for analyzing gaze movement activity as it has not been possible to use experimental measurements alongside the numerical optimization. These traditional tools are not applicable to find out optimization trends.
8. Novelty components include the usage of oculography data to justify dashboard design decisions,

the optimizing method itself and its mathematical components as well as analyzing the optimization in question from the viewpoint of quantum representations revealed the interpretation of design mistakes.

9. The results obtained can be applied for prototyping formats of aircraft dashboard indicators.

REFERENCES

1. Barabanschikov, V.A., Zhegallo, A.V. (2013). Registration and analysis of the orientation of a person's gaze. Institute of Psychology of the Russian Academy of Sciences, Moscow.
2. Bastani, V., Marcenaro, L., Regazzoni, C. (2014). Unsupervised trajectory pattern classification using hierarchical Dirichlet Process Mixture hidden Markov model. IEEE International Workshop on Machine Learning for Signal Processing, p. 1-6, DOI: 10.1109/MLSP.2014.6958916
3. Borg, I., Groenen, P.J.F. (2005). Modern multidimensional scaling: Theory and applications. Springer, New York, DOI: 10.1007/0-387-28981-X
4. Cottrell, M., Faure, C., Lacaille, J., Olteanu, M. (2019). Anomaly detection for bivariate signals. Rojas, I., Joya, G., Catala, A. (Eds.), Advances in Computational Intelligence. IWANN 2019. Lecture Notes in Computer Science, vol. 11506. Springer, Cham, p. 162—173, DOI: 10.1007/978-3-030-20521-8_14
5. Bress, T.J. (2013). Effective LabVIEW programming. National Technology & Science Press, Austin, Texas.
6. Cox, T.F., Cox, M.A.A. (2001). Multidimensional scaling. 2nd ed. Chapman & Hall/CRC, Boca Raton, Florida.
7. Cramer, H. (1999). Mathematical methods of statistics. Princeton University Press, Princeton, New Jersey.
8. Eerland, W.J., Box, S. (2016). Trajectory clustering, modelling and selection with the focus on airspace protection. AIAA Infotech@ Aerospace, p. 1-14, DOI: 10.2514/6.2016-1411
9. Faure, C., Olteanu, M., Bardet, J.M., Lacaille, J. (2017). Using self-organizing maps for clustering and labelling aircraft engine data phases. 12th International Workshop on Self-Organizing Maps and Learning Vector Quantization, Clustering and Data Visualization, p. 1-8, DOI: 10.1109/WSOM.2017.8020013
10. Hung, C., Peng, W., Lee, W. (2015). Clustering and aggregating clues of trajectories for mining trajectory patterns and routes. The VLDB Journal - The International Journal on Very Large Data Bases, vol. 24, no. 2, 169-192, DOI: 10.1007/s00778-011-0262-6
11. Krasilshchikov, M.N., Evdokimenkov, V.N., Bazlev, D.A. (2011). Individually adapted on-board systems for monitoring the technical condition of the aircraft and supporting the pilot's control actions. MAI, Moscow.
12. Kuravsky, L.S. (2021). Modeling dynamical behavior of stochastic systems: spectral analysis of qubit representations vs. the mutual Markovian model likelihood estimations. Lobachevskii Journal of Mathematics, vol. 42, no. 11.
13. Kuravsky, L.S., Yuryev, G.A., Zlatomrezhev, V.I., Yuryeva, N.E. (2020). Assessing the aircraft crew actions with the aid of a human factor risk model. Eksperimental'nayapsikhologiya = Experimental Psychology, vol. 13, no. 2, 153-181, DOI: 10.17759/exppsy.2020130211
14. Kuravsky, L.S., Yuryev, G.A., Zlatomrezhev, V.I., Greshnikov, I.I., Polyakov, B.Y. (2021). Assessing the aircraft crew activity basing on video oculography data. Eksperimental'nayapsikhologiya = Experimental Psychology, vol. 14, no. 1, 204-222, DOI: 10.17759/exppsy.2021140110
15. Lancaster, P. (1969). Theory of matrices. Academic Press, New York.
16. Laxhammar, R., Falkman, G. (2014). Online learning and sequential anomaly detection in trajectories. IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 36, no. 6, 1158-1173, DOI: 10.1109/TPAMI.2013.172
17. Report on applied research on the topic "Development of human factor risk models and recommendations for creating a human-machine interface for the aircraft crew cabin" (intermediate), stage 1, State program of the Russian Federation "Development of the aviation industry for 2013-2025", grant agreement dated 21.10.2019. No. 075-11-2019-018, state registration no. RFMEFI62819X0014.

18. Report on applied research on the topic "Development of human factor risk models and recommendations for creating a human-machine interface for the aircraft crew cabin" (final), stage 2, State program of the Russian Federation "Development of the aviation industry for 2013-2025", grant agreement dated 21.10.2019. No. 075-11-2019-018, state registration no. RFMEFI62819X0014.
19. Rintoul, M., Wilson, A. (2015). Trajectory analysis via a geometric feature space approach. Statistical Analysis and Data Mining, vol. 8, no. 5-6, 287-301, DOI: 10.1002/sam.11287
20. Wei, J., Sciandra, V., Hwang, I., Hall, W.D. (2014). Design and evaluation of a dynamic sectorization algorithm for terminal airspace. Journal of Guidance, Control, and Dynamics, vol. 37, no. 5, 1539-1555, DOI: 10.2514/1.G000345
21. Wilson, A., Rintoul, M., Valicka, C. Exploratory trajectory clustering with distance geometry. Schmorrow, D., Fidopiastis, C. (Eds.), Foundations of Augmented Cognition: Neuroergonomics and Operational Neuroscience. AC 2016. Lecture Notes in Computer Science, vol. 9744. Springer, Cham, p. 263-274, DOI: 10.1007/978-3-319-39952-2_2

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