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# PILOTS' PERFORMANCES IMPROVING IN DUAL STREAM ENVIRONMENT: VERTICAL COMPONENT OF VIRTUAL FLIGHT AND PHYSIOLOGICAL PROFILE

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***Abstract:*** *The main goal of this paper is to provide the latest developments in high level integrating of two different sides of pilots' performances improving. First one focuses on the assessment of the contribution of the vertical component of the virtual flight in the performance optimizing process. The other one is oriented to model the contribution of physiological profiling data in performance improvement. This goal is a complex one, meaning that two different approaches need to be considered: one concerning the dedicated system able to carry out the all the tasks required by performances improving and other in charged with modeling the data showing the contribution of the vertical component of the virtual flight assisted by physiological data in performance improving process. The main source for all acquired and processed data is an entirely new specially designed expert system for high precision assessments of aircraft piloting abilities. It is based on a multi-stream data acquisition and processing system, able to integrate the simulated flight environment with virtual flights and physiological and behavior data. As a direct result of these integrated improving processes, new models of the piloting abilities are implemented. Even more, a solid basis for the decision-making process for setting the pilots' and candidates' hierarchy for admittance to specific flight training programs is provided. Data analyzed and results emerge from the system recorded performance parameters based on measuring the differences between vertical components of the ideal trajectories according to assigned missions and the real trajectories in simulated flights.*

***Keywords:*** *pilot's performance improvement, flight simulators, virtual flight environment*

## 1. GENERALITIES

As a general approach, the expert adaptive system is intended to perform as a complex and parametric set of tools. The engine of the assessment process is also dual: a hierarchical set of specific flying stimulus and a complex physiological profile, both weighted in the pilot's performances models. The virtual environment hosts not only all the subjects' flights, where specific visual, sound and tactile information are provided in a cockpit specific form. It also hosts the frame necessary to acquire the physiological data used to build the profile. A library of basic and generic tasks is the basis for generating the dynamic complex scenarios acting as mission assignment, according to the pilots' training level; each flight situation is enriched by considering the stimulus hierarchies (one stimulus category at one time – visual, flight, navigation and environment integration) and the associated physiological profile. The main tasks are distributed in few well defined sub-systems: the simulation sub-system for the virtual environment management, the flight simulation sub-system and the multi-stream data acquisition sub-system for data integration in simulated flight and for physiological and behavior data management. Separate, a sub-system for processing, structuring and correlative analysis of all the information provides the decision making sub-system with all profiling data. The data acquisition stream rate is variable, but for academic purposes the rate of 2 samples per second proved to be satisfactory. Each of these variables is processed afterwards so that a set of performance data can be synthesized (e.g.: average values, symmetry and form of distributions). All the information operated by the expert adaptive system is stored in secured relational databases: the basic scenario database, the complex scenario database, the subjects' database and the results database.

## 2. ASSESSMENT FRAME

The current requirements of the flight security challenges need a direct answer. Alongside with the quality of pilots' training process, the intelligent system [1] comes to provide this particular answer: approaching of high precision assessments of aircraft piloting abilities by taking into account two different streams: vertical component of flying in virtual environments and physiological data. It can also provide the specialized staff with assistance in the decisional processes of pilots' selection.

The subjects' performances improving process is based on a hierarchical structure in a staged approach: subject identification; subject accommodation with the session requirements; subject's theoretical training module; subject's theoretical knowledge assessment; simulator controls training module; main simulation session; optimization module; data processing; final decision stage.

The expert system implements few important capabilities: building the specific flying stimulus set [2]; building the stimulus hierarchy; weighting the stimulus types in flying performances [3]; building the different flight simulations based on the current stimulus hierarchies; building the flying tasks set, so that the most important psychical processes involved to be covered [4]; the simulation's scenarios manipulation; the relevant parameters set elaboration for the flying capacity optimization; building the relevant psycho-physiological set of parameters (EEG, EKG, FC, pressure on the controls, brain signals, visual focus, pulse, blood pressure, local temperature and local resistance – see Fig.1) which best describes the tested subjects general panel; working with complex models for the acquired data, aiming to minimize the dimension of the information universe without losing content.

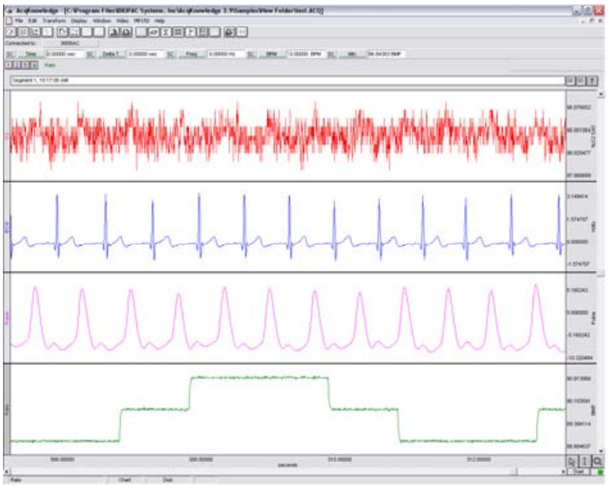

Fig. 1: Physiological stream data processing

Block scheme of physiological stream data acquisition and processing is shown in Fig.2.

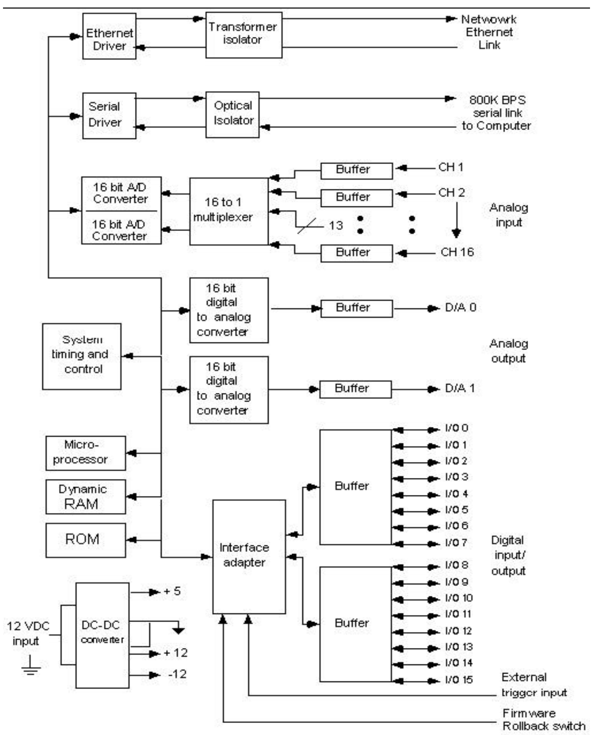


Fig. 2: Physiological stream block scheme

The acquired data processing models are statistic. The deviations are acquired in the simulated flight process, in the form of differences between the vertical components of the real trajectory and the imposed specific mission trajectory (see Fig. 3). Also, an analysis of the candidate behavior related to the statistical group to which he belongs can be performed. Three-dimensional viewing models of the real and imposed trajectories are implemented both at mission assembly level and primary components level, with the possibility to dynamically modify the observer's position related to the trajectory. In addition, all relevant deviations are displayed, too. The statistic analyzing models are also applied to all candidate controls (stick, rudder and throttle).

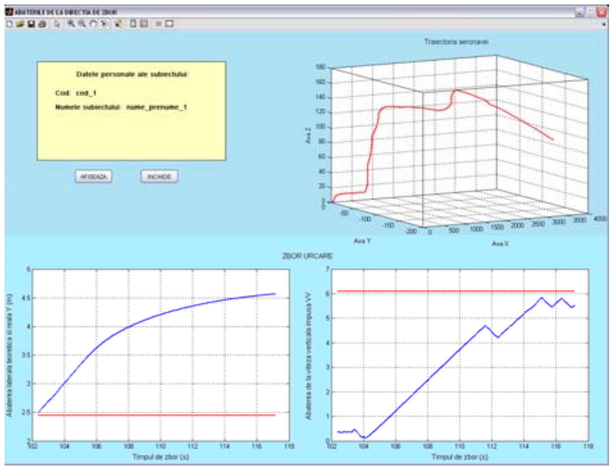

Fig. 3: Post flight global and vertical component contribution to flying performance

## 3. METHOD AND RESULTS

The current release used entered the operational stage of the Integrated Adaptive System for pilot performance assessment in a standard flight scenario: climbing or descending flight, with fixed flight path data (initial flight altitude, final flight altitude, glide/slope angle, indicated speed). In order to provide the new dimension in pilots' performances hierarchy, all subjects hold the same experience on training aircrafts. There also exist recordings of pilot performance assessments in real flights for each one.

The system recorded the performance by measuring the differences between the vertical components of the ideal trajectories according to the assigned missions and the vertical components of the real trajectories in simulated flights. These differences were measured actually in 3D space, but for this paper will be retained only the data of vertical channel – Oz axis. The data acquisition stream rate is 2 samples per second. Each of these variables is processed afterwards so that a set of performance data can be synthesized (e.g.:

average values, symmetry and form of distributions).

For a thorough analysis of the data issued by the system, the following concepts were used:

- central trend (typical values), representative for the whole data distribution;
- variation pointers, pointing to the modeling of the distribution displacements;
- distribution shape pointers, pointing to the modeling of the distribution shapes.

Behind the first concept stands the mathematic formula of averaging a data distribution:

$$m = \frac{\sum_{i=1}^{N} X_i}{N} \quad (1)$$

X denotes the focus variable (differences between the vertical components of the ideal trajectories data according to the assigned missions and the vertical components the real trajectories data in simulated flights – for each chart the variable X is defined), N denotes the number of variable entries in current distribution.

Behind variation and distribution shape pointers stand:

Dispersion $s^2$:

$$s^2 = \frac{\sum_{i=1}^{N} (X_i - m)^2}{N} \quad (2)$$

Standard deviation s:

$$s = \sqrt{\frac{\sum_{i=1}^{N} (X_i - m)^2}{N}} \quad (3)$$

Skewness:

$$\frac{\sum_{i=1}^{N} (X_i - m)^3}{(N-1)s^3} \quad (4)$$

Kurtosis:

$$\frac{\sum_{i=1}^{N} (X_i - m)^4}{(N-1)s^4} \quad (5)$$

The following charts show the results of analyzing the contribution of vertical component of the virtual flights on subjects' performances (on Oz axis):

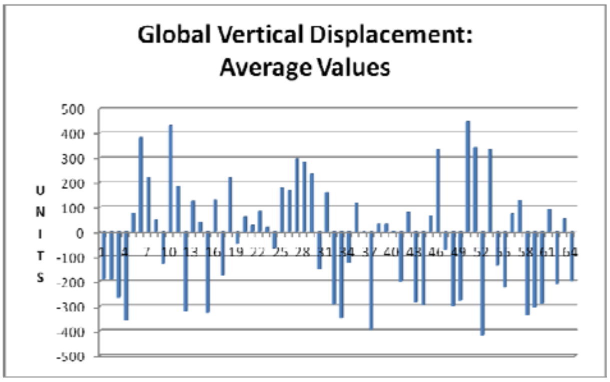


Fig. 4: Global vertical displacement (on Oz axis): average values

Average values of global vertical displacement (on Oz axis) is the part of the mechanism which models the subjects' ability to maintain a proper position in the flight plan, according to the mission assigned, focusing on the average values issued by the system during the differences generation between the real and the theoretical trajectories. This type of data offers a global vision of how close the subjects respect the vertical component of the flight plan (exposing the extreme points of the path envelope). Ideally, the envelope should be as tight as possible. Small variations around zero are acceptable (the sign is irrelevant in performance, showing only the side of the ideal vertical trajectory – above or below – the current subject keeps the aircraft during the flight).

In this chart (Fig. 4) units represent the performance indicator of virtual distances, based on the metrics of the virtual space where the simulated flight takes place. Lower values are better.

In this population of subjects, numbers 4, 6, 10, 12, 15, 33, 37, 46, 50, 51, 52, 53, 58 and 59 show large variations in average differences, which draw special attention to their low performance level. A possible future exclusion of these subjects from the flight training program can be expected. A definite trend to exclusion goes to subjects 10, 37, 50 and 52, who are far from the flight plan.

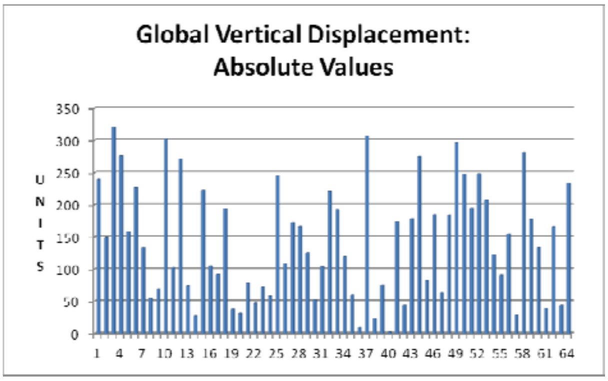


Fig. 5: Global vertical displacement (on Oz axis): absolute values

For a local analysis of global vertical displacement the system uses absolute values of this variable. In this population of subjects, numbers 3, 4, 10, 12, 37, 49 and 58 show large variations in absolute differences, which draw special attention to their low performance level. A possible future exclusion of these subjects from the flight training program can be expected. A definite trend to exclusion goes to subjects 3, 10 and 37, who are far from the flight plan.

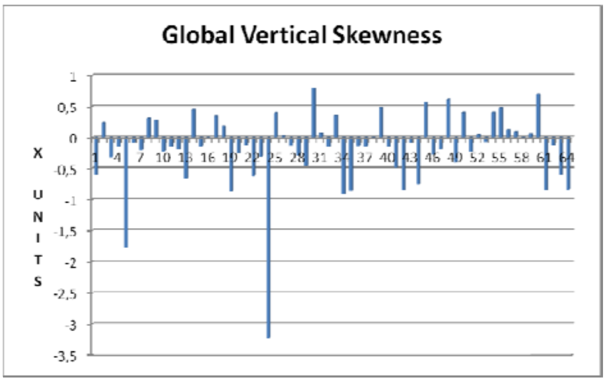


Fig. 6: Global vertical Skewness (on Oz axis)

The vertical component of the global skewness (on Oz axis) is a part of the mechanism pointed to model the contribution of the distribution shape pointers in the decision making process. The sign of this component provides information about the density of the distribution data related to the average values. The chart in Fig. 6 shows the fact that the distribution is quite even related to the flight plan, meaning that the deviations in the vertical plane show two main data: first – the subjects position the plane relatively symmetrical above and below the ideal trajectory, meaning that the subjects hold the same experience in flight; second – there are subjects in this population with lower performances: 1, 5, 13, 19, 22, 24, 30, 34, 35, 42, 44, 45, 48, 60, 61, 63 and 64. A definite trend to exclusion goes to subjects 5 and 24, who are far from the flight plan. The symmetry of the distribution is affected: four subjects keep the plane above the imposed trajectory; 13 subjects keep the plane below the ideal trajectory.

In this chart (Fig. 6) X units represent the non-dimensional performance indicator which encodes the data distribution shape of the computed parameter of the differences between the theoretical and the real trajectories on Oz axis, based on the metrics of the virtual space where the simulated flight takes place. Lower values are better, meaning that a narrow distribution shape shows better performances.

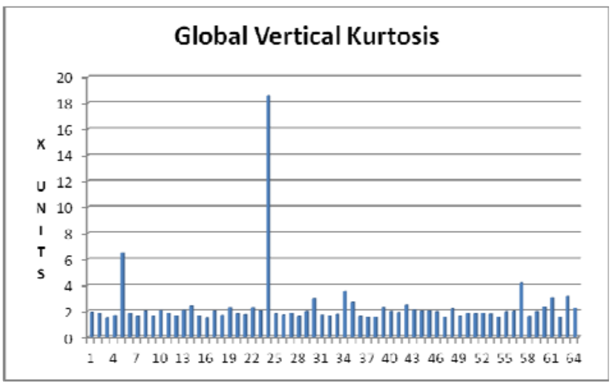


Fig. 7: Global vertical Kurtosis (on Oz axis)

The global vertical Kurtosis is another important part of the distribution shape pointers pointed to assess the symmetry of the data distribution. It is a component of the global kurtosis which is the part of the mechanism charged with modeling the contribution of the distribution shape pointers in assessing the behavior of population of subjects concerning the flight plan. The sign is not relevant. The important thing is the consistency of the distribution shape, the chart above showing that most subjects behave symmetrically related to the average values. Subjects 5, 24 and 57 are exceptions, showing abnormally high values. These data are to be correlated with the variation pointers.

In this chart (Fig. 7) X units represent the non-dimensional performance indicator which encodes the symmetry of the data distribution shape of the computed parameter of the differences between the theoretical and the real trajectories on Oz axis, based on the metrics of the virtual space where the simulated flight takes place. Lower values are better, meaning that asymmetrical data distributions with lower Kurtosis values show better performances. In flight terms, the subjects control the aircraft mostly by applying only one type of corrections to the real trajectory (ascends or descend), not evenly distributed corrections (up and down).

## 4. CONCLUSIONS

The performance parameters exposed by intelligent system indicators were correlated with real in flight performance and with the results of coordination in multi-tasking test (Double Maze Bonnardel).

The results of Kendall correlations confirmed a significant association for differences between ideal and real trajectories on Oz axis (differences in horizontal plane), in all three stages of flight: first third ($r = +0.45$, $p = 0.025$), middle third ($r = +0.55$, $p = +0.005$) and final third ($r = +0.64$, $p = +0.002$). Also, the average global variation on Oz axis positively correlated with real in flight performance ($r = +0.61$, $p = +0.0006$). The multiple regression coefficient calculated for the four predictors is $R = 0.81$ ($F = 7.68$, $p = 0.002$).

The correlation with performance in Bonnardell shows moderate associations, taking values around 0.3÷0.4, with the ones between performance at simulator indicators and the number and duration of test errors [5, 6].

All results are thoroughly analyzed, as well as their psychological meanings and consequences for future releases of intelligent system.

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