AN OBJECTIVE ASSESSMENT TOOL (GOAT) OF HELICOPTER PILOT'S PERFORMANCE

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Abstract

In this research an Objective Assessment Tool (gOAT) is presented. The main idea of the system is to develop a tool that provides more detailed information about the pilots' performance. The gOAT system bases on the Mission Task Elements (MTEs) taken from the Aeronautical Design Standard Performance Specification Handling Qualities Requirements for Military Rotorcraft (ADS-33), and use the data recorded by the flight simulator software. In the ADS-33 document the criteria for tasks are limited and not very complex. The gOAT systems goal is to enlarge the task criteria, so the feedback delivered by the system is wider. That would automatically provide more information and data for postprocessing and evaluation. During simulated flight the gOAT system not only provides an error/deviation compared to the desired pattern, but also has an "assistant" functionality. The developed system could be used as a tool to improve the current flight skills and performance by giving the cues and tips for pilot. The modular architecture of the system allows to implement additional indicators for the pilot, so the task is done with higher precision

1. INTRODUCTION

During the training process of helicopter pilots among many various elements one of the most important is manoeuvring skills. In the literature and from the training documents and procedures the manoeuvring practice training consist of many various tasks. The manoeuvring elements begins from easy ones and ends on difficult ones in various environment conditions (limited visibility, night flights etc.). The list of those exceeds over 350 different tasks [4]. In the official document the list of requirements to pass individual task is limited. In many task the only parameter to be assessed is altitude or speed, in some cases the time is most important parameter. Not only the parameters are limited, but the assessment is done by instructor's subjective rate [8, 9, 10]. Some of the parameters i.e. time is easy to be verified by instructor, but other parameters rate base on the instructor's experience. The repeatability of the instructor's assessment can be questioned. Not only the individual flight might be assessed in different manner by two different instructors but similar task might be assessed different by the same person [11]. Such an approach makes hard to compare the results of individual pilots between each other. The other disadvantage of this method is difficulty of measuring and controlling the pilot's skills progress. The subjective rate could be a subject of various external stimuli such as fatigue or stress so the final assessment might vary [5, 6]. Those aspects makes the actual training rating not stable and vulnerable to factors difficult to control. It would be significantly better to have a system that provides a data instantly during the flight. The result could be used not only by instructor but also by the pilot as a tool to improve the skills. There were research focused on automated rating in flight simulators but it did not cover the subject in presented way [12]. Having the enormous capabilities of collecting and processing the data with the use of onboard systems there is a possibility and need of creating a tool that will provide those data. Such a tool could be used not only to improve the training process but also as a tool to verify and ameliorate the automated systems for helicopter. A good application of such system could be used to assess the autopilot performance and its precession. The presented research shows a developed system that provides a complex assessment of predefined manoeuvring tasks. The Objective Assessment Tool (gOAT) is tested on the helicopter flight simulator. The actual version of the system base on the Mission Task Elements (MTE) adopted from the Aeronautical Design Standard ADS-33D, Handling Qualities Requirements for Military Rotorcraft [1]. The applying the manoeuvres takes from the document used as a reference to assess the handling qualities of rotorcraft was made to ensure that implemented elements are properly defined in terms of requirements and definition. Presented research is done under a grant carried out by Warsaw University of Technology and LEONARDO – PZL Świdnik company. The aim of the project is to adopt the SW-4 helicopter to the maritime operations. One of the tasks in the project is to develop an autopilot and algorithms that will safely perform an autonomous landing on a ship deck. One of the gOAT application will be a verification of the autonomy precision and effectiveness.

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1. HARDWARE

The research results would be difficult to apply in real environment, so the flight simulator was used to test the methodology. However in future step the gOAT could be applied in real flights.

1.1. Hardware

The helicopter flight simulator used as the base for developed system was hardware fully developed at the Faculty of Aeronautical and Power Engineering of Warsaw University of technology. The simulator is a fixed based flight simulator of a PZL SW-4 small helicopter. The flight simulator is a FNPT – Flight Navigation Procedures Trainer class training device. The hardware consists of following components [13]:

- 3-channel visualization system
- Pilot’s station (helicopter cabin)
- Instructor Operator Station (IOS)
- Software

The virtual environment of the simulator is projected on the spherical screen via system of three projectors mounted over the helicopter cabin (Figure 1).

Fig. 1. A flight simulator with the screen and the helicopter cabin

The visualization system consists of spherical screen (FOV - 180 degrees horizontally, and 40 degrees vertically), on which an image is displayed. The visualization is projected by three projectors mounted over the helicopter cabin. Images are synchronized automatically by the system. The simulator environment is written in C++ language and built in HLA architecture standards. The main advantage of this flight simulator is that its architecture is fully open. Such an architecture allows to change and improve every single element of the software. The modification could be applied to change the scenario by implementing new virtual elements to existing environment. Also the dynamic models of aircraft can be changed as well as the hardware – new cabins and cockpits. The pilot’s stand uses a real size helicopter cabin in which a minor modifications were done so the cockpit could be adopted to simulated flights. The flight instruments are displayed with the use of LCD screens under the mask. The instructor’s operator station is placed outside the pilot’s FOV. It consists of four 17” monitors, displaying state of the helicopter, map of the terrain, current state of the dials inside cockpits, and several other parameters necessary for appropriate oversight of the exercise performed. The instructor can modify the flight conditions and change the state of the helicopter i.e. apply some emergency situations. For the gOAT purpose there was done a slight modification of the cabin - a tripod was mounted to the passenger seat, so the pilot’s personal tablet could be fixed. On the tablet the additional data - the gOAT interface is displayed.

2. SOFTWARE

2.1. Virtual environment

The scenario of the flight simulator is fully configurable. This software feature allows to introduce various elements into the virtual environment. The procedure regarding the adding new elements is defined (dimensions, element cog, etc.). Every element modelled in 3D software could be transferred and placed in specified position to the simulator environment. This feature allowed to implement a set of Mission Task Elements defined in [1] report. Some of the MTEs were selected for the gOAT tests. Firstly modelled in 3DsMax Autodesk software and finally implemented to the scenario using the ivu format. An example of the implemented slalom is presented on the figure 2.

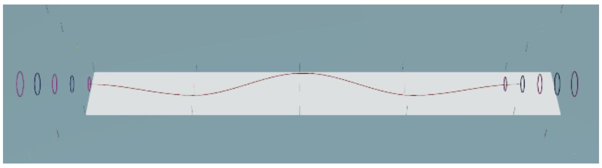

Fig. 2. A slalom virtual trajectory model

For the first gOAT tests the set of 6 various MTEs have been implemented. The MTEs were chosen so the flight parameters are interesting in the meaning of the assessment aspect. – various flight parameters, interesting trajectories etc. The set of maneuvers was chosen in a way that tests

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a variety of skills possessed by trainee, from agility and quick response to sophisticated and delicate tasks. The selected MTEs are as follows:

- Slalom
- Obstacle avoidance in forward flight
- U-Turn
- Carrier landing
- Carrier landing with vertical descent
- Pirouette maneuver

All 6 elements were placed together as one training scenario an implemented at once into the virtual environment. The reason of using the tasks from ADS report was that the presented tasks are used in helicopter testing, so they are realizable and there are defined criteria and reference trajectories. Thus they are perfect baseline for testing the systems and pilot's maneuvering skills. Despite numerous use of those MTEs the desired performance for each tasks is limited (figure 3).

	GVE	DVE
DESIRED PERFORMANCE		
• Maintain an airspeed of at least X knots throughout the course	60	30
• Accomplish maneuver below reference altitude of X ft:	Lesser of twice rotor diameter or 100 ft	100 ft
ADEQUATE PERFORMANCE		
• Maintain an airspeed of at least X knots throughout the course	40	15
• Accomplish maneuver below reference altitude of X ft:	100 ft	100 ft

Fig. 3. A desired performance for slalom maneuver.

For some of the tasks the requirements are limited to maintain the forward velocity or altitude on certain level. It is clear that the same task could be finished meeting those criteria, but other flight parameters could significantly change the instructor's assessment (i.e. roll angle, or acceleration rates). One of the gOAT characteristic is to expand the list of flight parameters that are subject of assessment. Providing an additional flight parameters assessment will allow to customize the final instructor's result. The list of criteria form the ADS were used as a base and the list of additional requirements derives form this baseline. In most cases the trajectory is crucial flight parameter from which the helicopter angles and accelerations are derived from. The use of MTEs allowed to use a proper dimensions of the tasks assuring its feasibility. The first set of the implemented MTEs are presented on the figure 4.

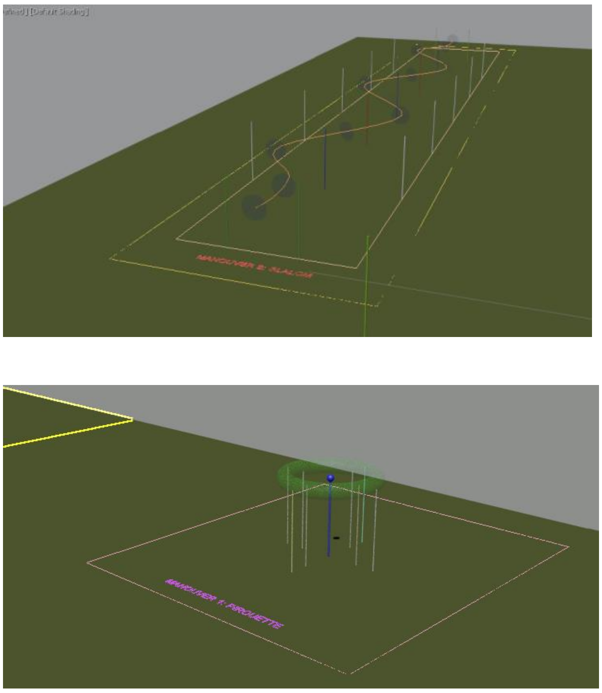

Fig. 4. An example of various Mission Task Elements implemented to the virtual environment (up – slalom, down – pirouette)

2.2. Goat software

The core of the gOAT system was done in Labview. This software has a intuitive interface to create a customized Graphical User Interfaces (GUI). There is a wide list of various indicators, gauges, sliders, and plot types so the GUI can be individually modified to fit the system requirements. It can be also modified quickly so the process of tests and system improvement is easy. The other advantage of the system is that it allows a simple communication with hardware (flight simulator) and other softwares software (MatLab). This Labview feature allowed to evaluate part of the system in MatLab as external functions. This approach allowed to keep Labview structure fixed and the individual MTEs parameters and definitions could be applied as separate functions. This solution allows to implement new MTEs faster. The reference trajectories and all other individual flight parameters and definitions have been defined and fixed as separate functions so there is no need to interfere in the main system structure.

3. AN OBJECTIVE ASSESSMENT TOOL – GOAT STRUCTURE

The gOAT system main feature is to provide a new information for instructor and a pilot during a

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flight so the pilot's performance could be improved. And the training becomes more effective. The part of the data is provided instantly during the flight and the more advanced analysis could be done after the flight. The gOAT structure is presented on the figure 5. The general idea of the system is to use the reference data and compare them with the actual flight parameters using a proper algorithms and functions.

3.1. Task implementation

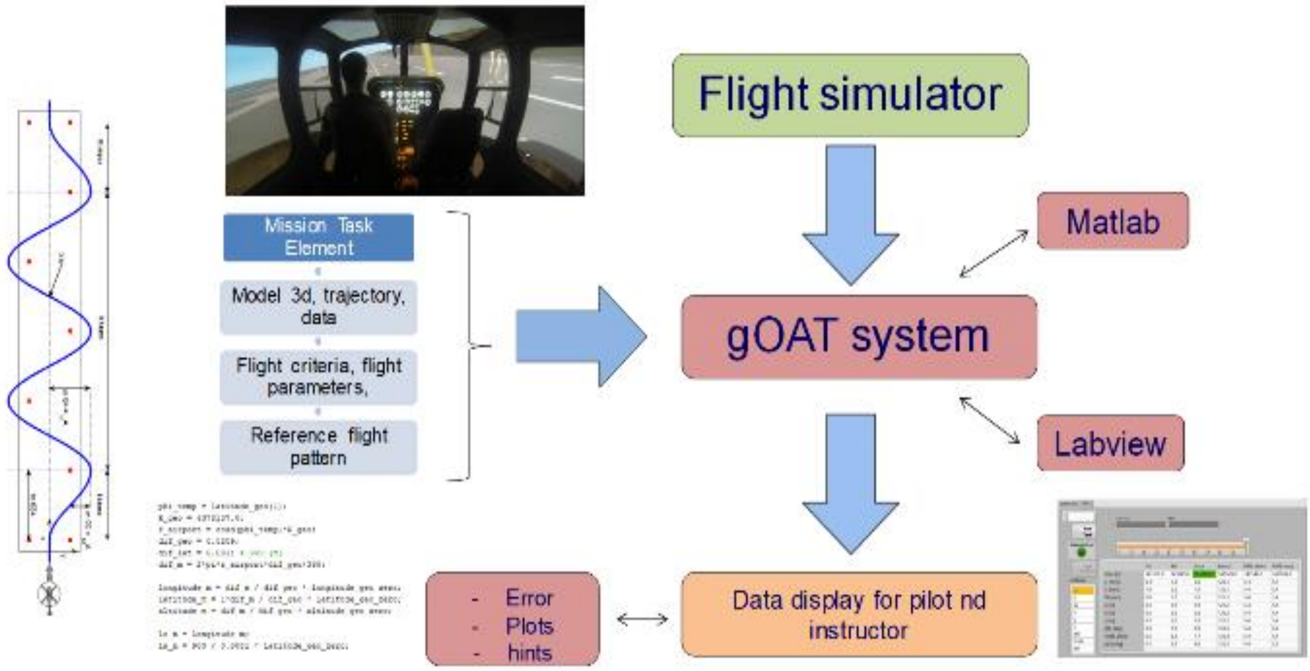

Fig. 5. gOAT structure

As it was mentioned above, the main part of the tool was written in Labview were both GUI for instructor and for the pilot were developed. Each of the implemented task has its model prepared in 3dsmax software. Along with the structural model the reference trajectory and other flight parameters functions are delivered. Those are written as separate functions in Matlab software. An example of the trajectory for a slalom maneuver is presented in the Figure 6. And the reference trajectory is presented as a function [2] defined by the equation 1.

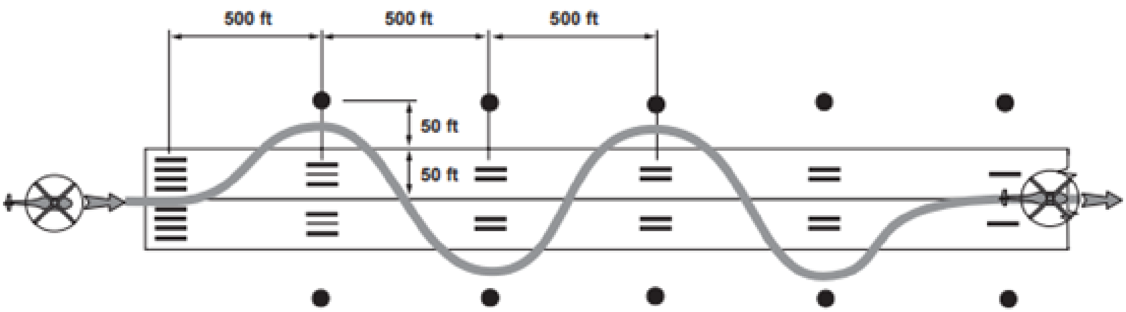

Fig. 6. Slalom manoeuvre dimensions

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$$(1)\qquad \begin{cases} -23*(2*(x/(0.3048*500))^3-3*(x/(0.3048*500))^2 & for\ x<0,150> \\ 23*(1-6*(x/(0.3048*500))^2+4*(x/(0.3048*500)-1)^3 & for\ x(150,600> \\ -23*(1-2*((x-1000)/(0.3048*500)-2)^3+3*((x-1000)/(0.3048*500))^2 & for\ x<600,750> \end{cases}$$

From the ADS report the desired performance is to maintain the forward speed not higher than 60 knots and keep the altitude not higher than 100 ft. The additional requirement was to maintain the coordinated turn passing by the pylons. However this criterion is not presented in any measurable way. Base on those and adding additional criteria the rest of flight parameters could be defined. All from the 9 flight parameters: position, velocities and helicopter orientation angles were defined as a function of position (translation along the x axis). The matrix of flight parameters included as a reference is presented in equation 2.

$$(2)\qquad M_{ref} = \begin{bmatrix} x \\ y \\ z \\ V_x \\ V_y \\ V_z \\ \Theta \\ \Phi \\ \Psi \end{bmatrix} = \begin{bmatrix} - \\ f(x) \\ const. \\ const. \\ 0 \\ 0 \\ f(x) \\ f(x) \\ f(x) \end{bmatrix}$$

Mostly, those reference values are represented as functions or a constant values, depends on task complexity. For each task the set of reference trajectory is described as it was done in [3]. But in this case the rest of the parameters and functions have been derived. Having both: 3D model and the reference flight parameters the implementation of the task was possible. Each of the MTE has its own model and the set of criteria for pilot to follow during the task evaluation. There is no limit in number of flight parameters that are within the matrix (2). It could be extended to more parameters if necessary.

3.2. gOAT data process

The actual version of the system provides 2 various information:

- an overall error for each parameter
- temporary error from the defined time period

The overall error for each parameter is expressed as the criterion commonly used in automation:

$$(3)\qquad J = \int_{x_p}^{x_k} e(x)^2\, dx$$

This parameter will be used to calculate the overall score that uses the weight for each parameter. It is clear that in individual task not all flight parameters has the same importance. The instructor would have an possibility to set proper scales for each parameter so the final result takes into account its importance. This error however for individual parameter is not the most suitable, since it keeps the “error value” until the end of the task even if the pilot performed perfectly part of the task. To avoid the mislead in displaying this as an error the other – temporary error is displayed for the pilot and instructor. The temporary error is calculated in the same manner but from the limited period of time of 5 [sec]. So the pilot could monitor his performance in a shorter period.

3.3. System display – GUI

There are two separate GUI consoles: one for the instructor and the second one for the pilot. The main console allows to set the proper task for the pilot, set the tolerances and all important parameters before the flight (Figure 7).

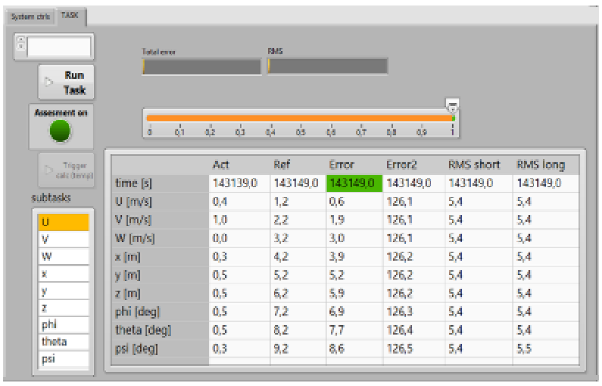

Fig. 7. A GUI for instructor

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In the instructor's GUI there is a option to monitor the individual flight parameters on plots, as well as numerical form. The final form of the GUI is not established yet. The process of improving the indicators and gauges will be done in later part of the project. The second console – for pilot – is mounted inside the cabin. The data displayed for the pilot is limited so the pilot is not overwhelmed with the data. There is no sense to distract the pilot with additional set of information. The main idea behind the inside console is to provide a brief information so the pilot knows his/her performance at the moment (Figure 8).

Fig. 8. A cockpit view with a pilot's additional panel

4. FIRST TESTS

The system could be tested also as a tool to verify and compare various settings of autopilot. In the research some of the gOAT elements will be used to assess the autopilot efficiency during the approach on the ship deck [3]. The flight parameters on autopilot mode could be than treated as a pilot's performance and compared as the helicopter would be piloted automatically.

5. CONCLUSION

The presented research is focused on a developing a new tool to increase the training efficiency by providing a new set of information for an instructor and pilot. The presented research can be developed and used not only for helicopter training but also as a tool for any other aircraft. The dynamic model, individual MTEs and their requirement would be changed but the methodology stays the same. Not only it can be applied to other aircraft types but also it could be used for the training in real environments. Providing the measurable rates for individual pilot would increase the training process significantly and make the recruitment process more complex. The gOAT could also be used as a tool to assess the pilot's performance skills among the longer time period. Finally, the system could be expanded with the biofeedback systems. The integration of the multiple data from psychophysiological measurements would provide additional information for instructor. Not only the performance would be assessed objectively but the pilot's effort and engagement would cover a full pilot's status during the training.

Acknowledgements

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