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Assessing Human Factors for Drone Operations in a Simulation Environment

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ABSTRACT

Small drones are use more and more by civilian and military users for all kinds of applications. However, this technology also bears a risk: novice or ill-trained users often cause incidents with drones, leading to dangerous situations. While the drone industry is investing massively in technological responses to this threat, it has been shown that most of the drone incidents can be attributed to a human error. For this reason, it is important to know what are the exact human factors that play an important role during operations with small drones. This paper responds to this need by the introduction of a novel concept to provide a qualitative and quantitative assessment of the performance of the drone operator. We thereby focus specifically on the use case of military operators of small drones. The methodology is based on two key constituents: a series of standardized test methods & scenarios and a highly realistic simulation environment.

Keywords: Human factors, Drones, Performance assessment

INTRODUCTION

As the amount of drone operations rises each year, so does the number of incidents with these systems (Chow et al., 2016). Research has shown that the large majority of these drone incidents are caused by human error (Shively, 2015). In order to avoid all these incidents, it is therefore required to investigate what are the root causes for these errors, with the aim to learn from these mistakes for improving the training procedures of future drone pilots.

However, assessing the human factors that play a role in the occurrence of incidents is not a trivial problem. In general, two types of approaches can be distinguished. On the one hand, a detailed incident report analysis can be performed in order to investigate the causes of the incident. However, for operations with small drones, incident reporting is very often missing, meaning that the input data required for performing the analysis is missing or not abundant enough to allow for statistically relevant processing. On the other hand, there are the approaches that make use of simulation environments to observe pilots in a controlled environment. This is a common practice within manned aviation, where pilots for regular aircraft or for larger (typically military) drones generally follow extensive simulator training before engaging in any real flight. However, for operations with small drones, this is much less the case, mainly because it is very difficult to convey a realistic representation to the human sensory system for these kinds of operations. Moreover, both for rotary wing and fixed wing systems, a major problem with present-day simulators is that they are limited to simplistic scenarios (typically executing a predefined pattern or practicing landing or take-off maneuvers). The output of such a simulation system does not providing a high-quality feedback to the trainee or the mentor.

To tackle the issues identified above, we propose in this paper a drone operator performance assessment tool, which measures the performance of drone operators in both a qualitative and a quantitative manner. The ultimate goal is then that these metrics are used by the trainers to iteratively optimize the training curricula to guarantee a maximum safety level.

For any simulation system, the level of realism is a key aspect that must be carefully considered in order to achieve the desired result. For the proposed simulation framework, we make use of a highly realistic environment, including realistic operational conditions (wind, weather effects, etc.). Another important aspect of any qualification assessment procedure is furthermore the definition of the test methods and scenarios. Present-day simulators geared at drone pilot training are very often very limited with respect to the type of scenarios covered. Most often, they only provide the possibility to train some simple take-off & landing operations or to practice executing simple patterns in the air. However, many of the human factors related to operating drones only arise in much more complex scenarios, such as working in adverse environmental or operational conditions. Pilots operating drones in tough operating conditions (e.g., military, police, firefighters, civil protection units encounter such complex scenarios, etc.). For these users, the simplistic scenarios are hardly relevant. Therefore, this paper also introduces a standard test methodology which is specifically oriented towards the assessment of the performance of drone operators working in the security sector.

PREVIOUS WORK & MAIN CONTRIBUTIONS

The modelling of drone operator human performance is not a new subject. Already in 2006, the US Air Force developed a human performance model (Deutsch, 2006). However, as this research focused on operations with large and remotely operated military drones, these operator performance modeling approaches focus solely on operator workload analysis, with the aim of optimizing the (remote) crew composition. For smaller drone systems, this is not very relevant, as the 'crew' for these systems is in general very limited.

On the other hand, (Bertuccelli et al, 2010) proposed a new formulation for a single operator performing a search mission with multiple drones in a time-constrained environment. (Wu et al., 2016) expanded on this idea by proposing a multi-operator multi-drone operator model.

A major criticism with respect to the methods that are discussed above, is that they all rely heavily on aspects such as attention and fatigue modeling and neglect other aspects that are paramount for operations in the security sector, such as mission stress, enemy counter-measures, varying operator skill levels, etc.

To tackle these issues, this paper presents a methodology to develop a drone operator performance model, which is specifically geared to operators of drones in the security sector.

The development of quantitative evaluation methodologies for the evaluation of the performance of drones and their operators is something that has already been researched before by the National Institute of Standards and Technology (NIST), specifically in the framework of urban search and rescue (USAR) operations (Jacoff et al., 2017). Within this research, NIST develops standardized test methods and test infrastructure to quantitatively evaluate the performance of drone operators. The resulting standard test methods enable any user to generate statistically relevant performance data to evaluate airworthiness, maneuvering, sensing, payload functionality, etc. While extremely valuable, these standard test methodologies developed by NIST heavily focus on urban search and rescue operations and are not generically useable for all types of security operations.

Within our previous work (Doroftei et al., 2020), we therefore initiated a concept of using a set of standardized test methodologies for human performance modelling in the domain of security operations, based upon the existing NIST framework for urban search and rescue operations. In this paper, we build further upon this work, by comparing its performance to a commercial state–of–the–art solutions. Before making this comparison, the following section introduces the overall concept of the proposed methodology.

CONCEPTUAL OVERVIEW OF THE APPROACH

To assess the relationship between human factors and the human operator performance, we follow a user-centered design approach (Doroftei et al., 2017) to come to the methodology which is graphically depicted in Figure 1, and which can be summarized as follows:

1. In a first step, we identify which human factors could potentially influence the performance of drone pilots, via a set of interviews with expert drone operators. From this set of interviews, it appears that the most relevant human factors to include are: Task Difficulty, Pilot Position, Stress, Fatigue and Pressure. Each of these identified parameters is re-identified with the test subjects during an intake questionnaire to assess the state of the pilot when she or he starts the simulation exercise.
2. Via a set of interviews with expert drone operators working in the security sector, we identify which operational scenarios and environmental conditions potentially affect the performance of drone pilots. From this set of interviews, a set of 22 standard operational scenarios were compiled that cater to the needs of as many end-users (i.e., drone operatives in the security sector) as possible. These scenarios consider complex target detection, tracking, observation & identification missions in urban and rural environments.

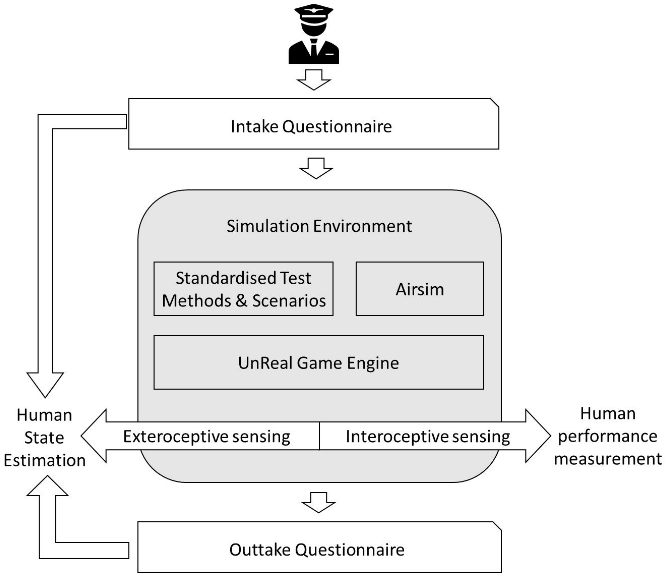

Figure 1: Schematic overview of the test procedure where the pilots are subjected to. After taking an intake survey, the pilots have to perform a complex mission in a simulation environment. While doing this, their performance parameters and physiological state are assessed. After completing the mission, they perform an outtake survey.

3. We developed and extensively documented a highly realistic simulation environment, where drone operators can perform complex drone operations (Doroftei et al., 2020). In summary, it is based upon the Microsoft AirSim simulation engine (Shah et al., 2017), which is an open-source simulator for drones, built on the Unreal Engine (Epic Games, 2022). This simulation environment is completely open and customizable, which enables us to incorporate the standard test scenarios, to multiple customizable drones and to quantitatively measure the performance of the pilots on-line while executing the mission. Within this simulator, 22 standard operational scenarios are defined within two environments (urban/rural). In these scenarios, the operators need to deal with large-scale dynamic environments, changing environmental conditions and time pressure in order to deliver quality data in a minimal amount of time. These are all factors that can lead to human errors and can have an impact on the performance of the operator.
4. When having finished their scenario within the simulation environment, the physiological state of the drone operators is assessed by means of a questionnaire. This questionnaire also serves to assess whether there are changes in the physiological state of the drone operators with respect to the moment of performing the intake survey. A typical example for this would be the pressure level, which is typically perceived as quite low before a trial (as it concerns 'only' a simulation trial), but is generally perceived much higher due to the time pressure induced in the trial scenarios.

	Proposed methodology	DRL Sim 3.0 Drone Racing Simulator	DJI Drone Simulator	Zephyr Drone Simulator	droneSim Pro Drone Flight Simulator	RealFlight RF9.5 Drone Simulator
Graphics	Unreal Engine High Definition graphics which can be augmented with own models	OK	OK	OK	OK	OK
World size	Large-scale environments	Small-scale race tracks	Large-scale environments	Medium-scale	Medium-scale	Medium-scale
Remote Control compatibility	Limited number of RC's compatible with AirSim	Relies on USB controllers	Only compatible with selected DJI controllers	Multiple	Few compatible controllers (no real drone RC)	Mostly geared towards RCs
Complex scenarios	Yes, possibility to freely encode complex scenarios	No, only racing	Limited number of scenarios, which offer a limited degree of complexity	Limited	Limited	Limited
Drone models	Possibility to encode any drone model desired (given that you have the model)	Yes, advanced built-in physics models	Selection of DJI drone models built-in. No possibility to include others.	Yes, advanced built-in physics models	Very few models	Multiple
Environmental effects	Yes, weather, wind, snow, …	No	Yes, wind	Yes, customizable weather	Yes	Yes
Operator Performance logging	Yes, automatic logging of all operator inputs and mission statistics	No	No	Yes, flights statistics are logged and used for training	No	No
Drone Performance logging	Yes, automatic logging of all MavLink messages	No	No	No	No	No
Application training	Yes, open architecture to encode multiple applications. Focus on security applications.	No, only racing	Limited number of applications built-in (search & rescue, powerline inspection)	No	No	No

Figure 2: Comparison of the features of the proposed methodology related to the training of drone operators to existing commercial solutions.

5. A repeated execution of the 22 test scenarios over enough drone operators as test subjects entails that statistically relevant data is obtained related to the physiological state prior to beginning the mission, during the mission, and after completing the mission. Furthermore, the simulation engine quantitatively measures human performance data, like e.g. the time required to perform mission objectives.

Using this data, a mathematical model is built up between on the one hand the human factors and the human physiological state and on the other hand the human performance. This model enables us to predict human performance given a certain input state and it can be used for drone pilot performance assessment.

VALIDATION & COMPARISON

A direct comparison to state of the art systems is not straightforward, as there are not many existing tools for the assessment of the human factors for drone operations. Therefore, in this section, we concentrate on the validation of the drone pilot training tool, for which there are multiple competing possible solutions. Referring back to the conceptual scheme of the proposed architecture (section 3), the validation focuses on steps one to three, while discarding steps four and five.

Figure 2 shows a comparison of the features of the proposed architecture related to drone pilot training with existing commercial solutions in the same domain. Here we will discuss each of these features:

- In terms of *graphics*, the presented tool relies on the UnReal rendering engine (Epic Games, 2022), which is capable of recreating highly realistic environments. Most of the existing commercial solutions also use some form of the UnReal engine (or the competing Unity engine) under the hood. However, the advantage of our method is that it is possible to add own models and thereby build up the level of realism.
- The world size is important, as real complexity can only be achieved in feature-rich large-scale open-world environments. Only our method and the DJI Drone Simulator provide this capability.
- The *compatibility with remote controllers* is also a key aspect for our research, as the remote controller is the human-machine interface. Optimizing its choice is one of the underlying goals of the program. The proposed methodology is somewhat limited with this respect, because it relies on AirSim for making the link to the remote controller and the list of AirSim-compatible remote controllers is somewhat limited. In contrast, the Zephyr and RealFlight solutions are compatible with a very wide range of remote controllers.
- Human errors mostly appear when executing *complex scenarios*. It is therefore very surprising to notice that most commercial solutions really focus on scenarios with a relatively low degree of complexity, in contrast to the method we use.
- The number of *drone models* that are incorporated into the simulator determines the versatility and modularity of the tool. Most of the solutions have a very good offering in this domain. Our solution relies on AirSim, which enables to freely incorporate drone models. However, this does imply that the drone model needs to be known.
- Dealing with non-standard *environmental effects* like rain, wind, snow, etc., is a typical cause for human error. Most of the solutions therefore also incorporate these features as training models.
- In order to use the training data effectively, it is required to *log the operator performance* during flights. Interestingly, only our solution and the Zephyr simulator provide this functionality.
- Next to the operator performance, the *status and performance of the drone needs to be logged* during flight, in order to be able to correlate the effect of human pilot action with the drone performance. To our knowledge, our approach is the only one which does this.
- Going beyond individual scenarios towards full-scale *application training* is a feature that very few simulators provide. The DJI simulator offers application training for search & rescue and for powerline inspection applications. Our solution provides application training for security applications (detection, tracking, identification of persons) in multiple scenarios.

Overall, it can be concluded that, while the DJI and Zephyr drone simulator also provide some very good features & concepts, our proposed solution provides capabilities beyond the feature set of state of the art commercial solutions in the domain.

CONCLUSION & FUTURE WORK

This paper presented a methodology for the qualitative and quantitative assessment of the performance of drone pilots. The methodology is based upon a set of standard test methods and a virtual training environment. The proposed methodology enables the development of a comprehensive human performance drone model, which helps us to make a link between the human factors and the physiological state on the one hand and the human performance on the other hand. This will not only help us to understand the relationship between these parameters, it also would, in a later stage, support completely pilot-agnostic qualitative (Doroftei et al., 2015) and quantitative (De Cubber et al., 2017) evaluation of drones and drone pilots.

However, before this can be accomplished, it is required to achieve a number of research goals. In a first phase, the proposed methodology will be validation-tested by real expert military drone pilots. This will not only allow us to qualitative and qualitative assess the performance of these pilots, but also to build up the human performance model. In a second phase, this human performance model will then be used, on the one hand as a reference for drone pilot performance testing and on the other hand for assisting with the accreditation of new drone designs, as it would allow to eliminate the human pilot from the test process.

REFERENCES

Bertuccelli, L.F., Beckers, N.W.M., Cummings, M.L. (2010). Developing operator models for UAV search scheduling. In Proc. of AIAA Guidance, Navigation, and Control Conference, Toronto, Canada.

Chow, E., Cuadra, A., Whitlock, C. (2016). Hazard Above: Drone Crash Database - Fallen from the skies. The Washington Post.

De Cubber, G., Doroftei, D., Balta, H., Matos, A., Silva, E., Serrano, D., Govindaraj, S., Roda, R., Lobo, V., Marques, M., Wagemans, R. (2017). Operational Validation of Search and Rescue Robots. In: De Cubber, G., Doroftei, D. (eds.) Search and Rescue Robotics - From Theory to Practice.

Deutsch, S. (2006). UAV Operator Human Performance Models. BBN Report 8460.

Doroftei, D., De Cubber, G., De Smet, H. (2020) "Reducing drone incidents by incorporating human factors in the drone and drone pilot accreditation process," in: Advances in Hu-man Factors in Robots, Drones and Unmanned Systems, San Diego, USA, p. 71–77.

Doroftei, D., De Cubber, G., Wagemans, R., Matos, A., Silva, E., Lobo, V. Cardoso, G., Chintamani, K., Govindaraj, S., Gancet, J., Serrano, D. (2017). User-Centered Design. In: De Cubber, G., Doroftei, D. (eds.) Search and Rescue Robotics - From Theory to Practice. InTech.

Doroftei, D., Matos, A., Silva, E., Lobo, V., Wagemans, R. De Cubber, G. (2015). Operational validation of robots for risky environments. In: Proc. 8th IARP Workshop on Robotics for Risky Environments. Lisbon, Portugal.

Epic Games, Inc., 2022, accessed 13 February 2022, Website: https://www.unrealengine.com/

Jacoff, A., Saidi, K. (2017). Measuring and Comparing Small Unmanned Aircraft System Capabilities and Pilot Proficiency Using Standard Test Methods. NIST report.

Shah, S., Dey, D., Lovett, C., Kapoor, A. (2017). AirSim: High-Fidelity Visual and Physical Simulation for Autonomous Vehicles. Field and Service Robotics.

Shively, J. (2015). Human Performance Issues in Remotely Piloted Aircraft Systems. in: ICAO Conference on Remotely piloted or piloted: sharing one aerospace system.

Wu, Y., Huang, Z., Li, Y., Wang, Z. (2016). Modeling Multioperator Multi-UAV Operator Attention Allocation Problem Based on Maximizing the Global Reward. In: Mathematical Problems in Engineering.