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QoE study on drone-mounted camera control

A Goal Document for a Master's Thesis Work

By

Alexander Sandström

Department of Electrical and Information Technology
Faculty of Engineering, LTH, Lund University
SE-221 00 Lund, Sweden

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Student: Alexander Sandström

Civic registration numbers: 19970228-7773

Email address: alexander.h.sandstrom@gmail.com

Company/Foundation Supervisor:

Fredrik Falkman, fredrik.falkman@ssrs.se

Main supervisor:

William Tärneberg, william.tarneberg@eit.lth.se

Examiner:

Maria Kihl, maria.kihl@eit.lth.se

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1. Introduction

The Swedish Sea Rescue Society (SSRS) with its 40 employees along with 2300 volunteers are responsible for around 90% of sea rescues in Sweden. To make these missions more successful and effective SSRS is innovating with new technologies, where one of them is to have drones that will fly out to the location of a reported emergency and get eyes-on-sight before the rescue boat and its' crew arrives.

This thesis aims to compare a few different ways in which a camera onboard of a drone can be controlled in real-time and evaluate the operator's experience with the different controls at different latencies. The different controls are to be evaluated through a *Quality of Experience* (QoE) user experiment, where subjective measurements will be collected from experienced and unexperienced drone operators performing a task with the different controls.

2. Background and Motivation

Currently, SSRS has a drone connected to the mobile network that can fly towards and loiter around a set of waypoints given on a map, while also providing video from the gimbal mounted camera. The drone flies with a hardware module running the autopilot software ArduPilot which also supports camera gimbal control. The mechanical gimbal assembly supports three degrees of freedom, however, the software necessary for remotely controlling the camera gimbal is not implemented.

Furthermore, SSRS does not have an estimate of the latency of the video-feed from the drone, making it difficult to determine how the camera should be controlled, be it by swiping, pressing they arrow-keys or setting a location on a map for it to look at.

In the emerging field of research around drones and remote control there is a clear correlation between latency and the operator's experience. However, a comparison of different types of controls and their effect on the operator at different latencies is, as far as the student's knowledge goes, not documented in the current body of research.

The technical challenges that SSRS face align very well with the challenges that are posed in general so called "Industry 4.0"-applications, and the harsh conditions under which the drone operates, i.e. flying above the sea, makes a strong argument for applying the learning outcomes from previous QoE research.

3. Project Aims

The aim with this master's thesis work is to get insight into which set of remote controls of a camera gimbal that are most appropriate in terms of the operator's experience when there is a varying or high latency.

The main research question that this work aims to answer is:

- How does latency affect different types of controls in a gimbal-mounted camera with three degrees of freedom?

4. Main Challenges

As stated, there is in earlier research a clear correlation between higher latency and worse operator experience. However, adding on another parameter, i.e. set of controls, may result in a more complex relationship between operator experience and latency that may be hard to model.

Furthermore, the result of a user study will also be highly dependent on both the quality of the actual experiment along with the number of participants in it.

5. Approach and Methodology

To begin with, communication must be set up adhering to the ArduPilot interface. Rudimentary communication can be implemented first, and if time allows a more robust software/communication stack can be put in place - having the communication between drone and interface pass through a cloud instance for example.

After achieving basic control of the gimbal, different types of controls can be implemented. Three different ways of controlling the camera have been considered at this point:

- a pair of joysticks

- keystrokes
- setting a GPS-coordinate on a map

Finally, the different controls will have to be evaluated. To do this, user testing is to be carried out to collect subjective measurements, common in the research field known as "Quality of Experience" (QoE), where the user gets a task to perform with the system and then answers forms on how their experience was.

The specific measurements to be taken are not decided yet, but some examples of measurements in previous QoE-research are *perceived fluidity*, *operational safety* and *overall impression*. Usually, the Simulator Sickness Questionnaire (SSQ) is also done by the test subjects right after doing a test. Objective measures can also be taken, such as completion time for a certain task.

The student has had previous contact with Folkuniversitet in Ljungbyhed where they conduct drone operator certification and is planning on contacting them to get more experienced drone operators to participate in the study.

6. Previous work

The supervisor as well as the examiner of this thesis work both have written papers in the fields of *Remote Control* and *Quality of Experience*, and there is currently a PhD working in the lab with another student on remote control of a hoverboard.

Here follows a table of some research papers that have been relevant in defining the aims and methods of this thesis work:

Title	Date	Author(s)	Content of interest
Towards Intelligent Industry 4.0 5G Networks: A First Throughput and QoE Measurement Campaign	2020	Tärneberg, William and Hamsis, Omar and Hedlund, John and Brunnström, Kjell and Fitzgerald, Emma and Johnsson,	Thorough QoE experiment; methodology and measurement techniques; most interesting latencies: 0, 66, 132, and 264 ms;

		Andreas and Berggren, Viktor and Kihl, Maria and Rao, Akhila and Steinert, Rebecca and Kilinc, Caner	
Quality of Experience (QoE) and Quality of Service (QoS) in UAV Systems	2019-02-28	Laghari, A	Definition and relationship of QoS and QoE, subjective vs objective measurements
QON: QUALITY OF EXPERIENCE (QOE) FRAMEWORK FOR NETWORK SERVICES		ASIF ALI LAGHARI, ASIF ALI LAGHARI, MUHAMMAD IBRAHIM CHANNA, TIAGO H.FALK	Framework for QoE testing
Quality of Experience Evaluation of Remote Reality Based Applications: Case of FPV Drone Piloting	2021	Matko Sili ˇ c, Mirko Su ´ znjevi ˇ c, Lea Skorin-Kapov	QoE user-study FPV-drone using simulator.
FlyCam: Multitouch Gesture Controlled Drone Gimbal Photography	2018	H. Kang, H. Li, J. Zhang, X. Lu and B. Benes	Interesting evaluative method of video control: make the user adjust a picture to a reference, measure pixel distance to reference and completion time.
Control Architecture for a UAV-Mounted Pan/Tilt/Roll Camera Gimbal	2005	Ole C. Jakobsen and Eric N. Johnson	Software/Hardware-in-the-loop testing; camera gimbal control
Latency impact on Quality of Experience	2020	Kjell Brunnström,	QoE in VR/AR; History of QoE; Simulator Sickness;

in a virtual reality simulator for remote control of machines		Elijs Dima, Tahir Qureshi, Mathias Johanson, Mattias Andersson, Mårten Sjöström	Varying both display and input delay in user tests; Big impact of screen delay, not so much for joystick delay;

7. Advancements and Outcome

The thesis work aims to contribute to the current body of QoE-research both with answering the research question along with the novelty of the environment (i.e. naval drone) for which it is to be done. It also aims to conduct a user test which will contribute to the uniqueness of the work.

8. Resources

The thesis work will be carried out in the 5/6G lab of the EIT faculty using their network hardware such as radio base stations and cloud infrastructure. SSRS will provide an assembled camera gimbal as well as a rover that runs the same software stack as their drone.

9. Project plan

Figure 1 describes the planned thesis work divided into sub-parts. In figure 2 the plan is visualized in a Gantt chart.

Task 1: 23^{rd} Jan – 3^{rd} Feb:

- Literature study
- Introduction to the lab environment
- Introduction to the SSRS hardware

Task 2: 6^{th} Feb – 17^{th} Feb:

- Rudimentary camera interface with video
- Camera control through software
- Measure and control latency

Task 3: 20^{th} Feb – 17^{th} March:

- Mapping to keystrokes
- Mapping to joysticks
- Possible room for other sets of controls

Task 4: 27^{th} Feb – 3^{rd} March:

- Review other report

Task 5: 20^{th} March – $7th^{th}$ April:

- Develop user experiment

Task 6: 17^{th} April – 29^{th} April:

- Conduct user experiment

Task 7: 1^{st} May – 12^{th} May:

- Evaluation and interpretation of results

Task 8: 30^{th} Jan – 3^{rd} Feb, 13^{th} March – 17^{th} March, 3^{rd} April – 7^{th} April, 8^{th} May – 9^{th} June:

- Report writing (more intensely)

Task 9: 5^{th} June – 16^{th} June:

- Presentation

Fig. 1. The project plan for the thesis work.

Tasks/Weeks	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1: Lit. study & intro	■	■																			
2: Interface & basic control			■	■																	
3: Control mapping					■	■	■	■													
4: Review other report						■															
5: Develop user experiment									■	■	■										
6: Conduct user experiment													■	■							
7: Interpret results															■	■					
8: Report		■						■			■					■	■	■	■	■	
9: Presentation																				■	■

Fig. 2. A Gantt chart over the project plan from Fig. 1.

This goal document is approved by:

Main Supervisor

Examiner

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William Tärneberg

Maria Kihl