Improving Human Interfaces for Commercial Camera Drone Systems

Brian D. Hall
University of Wisconsin-Stevens Point
Stevens Point, WI 54481, USA
brian.hall@uwsp.edu

Nicolaus Anderson
University of Wisconsin-Stevens Point
Stevens Point, WI 54481, USA
nicolaus.anderson@uwsp.edu

Kierstan Leaf
University of Wisconsin-Stevens Point
Stevens Point, WI 54481, USA
kierstan.leaf@uwsp.edu

CHI'17 Extended Abstracts, *May 06-11, 2017, Denver, CO, USA*
ACM 978-1-4503-4656-6/17/05.
http://dx.doi.org/10.1145/3027063.3048428

Abstract
This project reports on a pilot study investigating both the opportunities for improvement, and the dangers present, in the currently available human interfaces used to operate commercial camera drones. Nine participants completed flight operation missions in six experimental configurations, using two different drones, operated using line of sight, live camera-feed on a tablet, and through a first-person view headset designed for use by drone racers. Qualitative and quantitative methods explore the risks for damage and injury posed by current system design, and identify areas of potential improvement.

Author Keywords
Camera drones; quadcopters; human factors; augmented reality; first-person view; commercial unmanned aerial systems; human-in-the-loop.

ACM Classification Keywords
H.5.1 Multimedia Information Systems - Artificial, augmented, and virtual realities

Introduction
The recent explosion in the popularity of drones is not without danger. Researchers have warned that control systems for drones had "less-than-adequate human-system interfaces", and failure to improve these

systems could result in loss of human life and public acceptance of drone systems [5]. While existing advice on cockpit design could have helped in some settings, it was noted that drones pose unique challenges not covered by any previous research. Further, nearly all UAS research in the past decade has focused on large craft and teams of trained operators, which excludes the most common use cases of civilian operators [9].

In this pilot study, we seek to address the existing gap in research that relates to an area of great public interest. Future designers of cyber-physical systems involving drones will need to know more about the novel human factors considerations necessary with civilian operators. Institutions and businesses considering deploying drones could greatly benefit from guidance on important factors for safety and efficacy in drone operation, especially in situations where automation proves difficult or unreliable. The problems considered here are issues of how to design and develop novel human computer interfaces used to control next generation devices, and represents a potentially fertile area of future research for the HCI community.

Background and Related Work

The commercial drone market has grown exponentially faster than predicted by the Federal Aviation Administration (FAA). In 2010, the FAA forecasted that there would be 15,000 drones flying in US national airspace by 2020, assuming "no significant technological or extraordinary demand" [7]. Per public FAA datasets, by May 2016 there were already 461,420 registered drone owners. This unanticipated growth has occurred even though commercial use of drones is still illegal without a special Section 333 exemption.

Commercial drone operators often control their craft using a personal mobile device, or using controller sticks adapted from radio control model aircraft. First Person View (FPV) headsets, which use a hybrid of augmented reality (AR) and virtual reality (VR) techniques, have also become available. FPV use amongst drone racers is especially common, though legally questionable [8], but no identified research has examined their safety or efficacy.

Novel control methods for drones have previously been explored in a variety of contexts [10]. Physical gestures have been explored as a potential control method for personal drones primarily through elicitation studies [2]. Gaze-based control, including mixed modalities combining gaze and keyboard control, have also been explored with potentially promising results for use in head-mounted displays, though current commercial headsets do not support this [4].

Methods

Participants

Nine participants were recruited from an undergraduate class in Unmanned Aerial Systems, at a medium-sized University in the American Midwest (2 females, 7 males). Participants were compensated $20 US for their time. One participant reported nausea when attempting to operate using the FPV headset, and thus did not complete three of the conditions.

Equipment

Two drones were used in this experiment: Phantom 3 Professional, manufactured by DJI, and the Bebop 2 (Red Edition), manufactured by Parrot. The Phantom 3 was controlled using the standard remote provided with the system, while the Bebop 2 was controlled using the

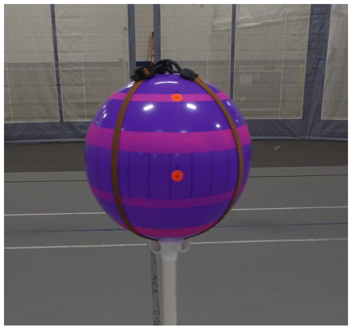

Figure 1: Example of the target ball, as photographed by the DJI Phantom 3.

Skycontroller (Red Edition) by Parrot. An Apple iPad Mini was used for the tablet condition, and a HeadPlay HD FPV headset was used for the FPV condition. Each model of drone handles in its own way, and it is unclear how the multitude of unique design decisions that differ between each drone may matter in their operation.

Procedure

Participants completed informed consent forms, and were given a 30-minute operations briefing to review the basics of flight, control principles for the drones, and safety rules. Each participant then completed approximately 10-15 minutes of basic practice in flying each drone, to familiarize themselves with the controls and task directions. Once comfortable, the participants then flew their missions under all experimental conditions in a randomized partially counterbalanced order. A fully counterbalanced (Latin square) design was initially planned, but there were too few participants available to fill all potential condition orderings. This partial counterbalancing was thus a compromise, to reduce the impact of training effects on the results with the limited number of participants.

Flight Mission

Operators were tasked to fly a mission based on the use of drones to collect photographic data for the 3D modeling and inspection of physical structures, such as a communication tower. This mission was developed from informal interviews with Civil Engineering and Geographic Information Systems subject-matter experts, to identify practical needs for drone use.

For the mission, each participant was assigned to have the drone take off and fly to a ball mounted on top of a pole, approximately 25 feet away. They were to then take a photograph from a total of 8 designed points, with 4 photos to be taken at a 45-degree downward angle from the drone to the ball, and 4 points to be taken at approximately the same height as the ball (less than 10 degrees of angle). Photos were recorded on the drone itself for later analysis.

The participants then completed the mission again using a different drone and control scheme. A total of 6 conditions were completed: Phantom 3 using Line of Sight only, Phantom 3 using a tablet display mounted on the controller, Phantom 3 using FPV headset, Bebop 2 using Line of Sight only, Bebop 2 using a tablet display mounted on the controller, and Bebop 2 using FPV headset. The same drone-specific remotes were used to operate the drones in all conditions.

Measures

Time to complete the mission was measured from the time between when first photo was taken, to the time the final photo was taken. We continually observed the participants and made notes on their comments and flight behavior. Once the missions were complete, we interviewed the operators to better understand their subjective experience of challenges in operating the drones throughout the various experimental conditions.

Results

An ANOVA was run to determine if there were statistically significant differences in the time to complete the mission under the 6 experimental conditions. The ANOVA results are summarized in Table 1, and Table 2 shows descriptive statistics for each condition. The results show no evidence that there is an effect for any experimental condition on time to complete the mission in this experiment.

Source	df	F	Sig.
Drone	1	.170	.682
Mission	2	.149	.862
Drone * Mission	2	.042	.959
Total	51		

Table 1: ANOVA results, showing no significant differences in time to complete mission.

Drone	Mission	Mean	Std. Deviation	N
Bebop	LOS	200.778	47.853	9
	Tab	213.778	72.457	9
	FPV	202.625	44.165	8
Phantom	LOS	214.000	47.964	8
	Tab	216.333	71.547	8
	FPV	206.875	51.377	9

Table 2: Descriptive statistics of time to complete mission, measured in seconds.

Observation of flight behavior, on the other hand, showed clear differences between the experimental conditions. In the FPV condition, a researcher had to act as a visual observer for the participant, warning them if they attempted to go too high or got too near any of the safety nets around the perimeter of the experimental area. The FPV headsets obscure all natural vision of the drone, while only providing a view directly in front of the drone. Movements to the side, backwards, or vertically, must be made blindly by the operator. This resulted in three near misses during the experiment, with one participant nearly hitting the experimental structure (ball), and two participants nearly running into the nets more than 20 feet away from the target. All participants reported uneasiness in ascending, as they could not determine if they were near the ceiling or near a vertical obstruction.

Interviews with the operators and manual review of the photos taken during the experiment also showed considerable differences in the conditions. All operators expressed difficulty when lining up photos by line of sight only, as they had difficulty determining if the ball was appropriately centered in the camera's viewing area. Five participants reported, unsolicited, that they had trouble determining the drone's position relative to the ball, especially in terms of positioning the drone directly behind or in front of the ball. Review of the photos taken during line of sight operation revealed that one participant took a photo where the ball was not fully within the frame of the camera, and four participants took photos with the ball at the extreme edge of the photo (nearly out of frame). No such errors were seen in FPV or tablet conditions.

Operators expressed the most confidence about the quality of the photos they took in FPV mode, though at least 5 participants expressed nervousness at some point during the experiment while in this. One participant explained that they felt it was easy to perfectly center the target directly in the center of their vision while using the headset, while in all other modes they felt that they had to split their attention between watching the craft and trying to line up the photograph. An initial review of the photographs captured supported the operator's assessments of superior accuracy during FPV-aided flight, but qualitative accuracy measurement would be needed in future work to confirm this.

It must be noted that one participant found the FPV headset unusable, as within 20 seconds of wearing the device they reported becoming nauseous and unable to continue. The participant was permitted to immediately remove the headset, and sat for approximately 15 minutes to rest before they reported they no longer felt sick. The symptoms they reported seemed similar to "virtual reality sickness" [1,3,6]. We cannot attempt to estimate how common this is in the general population, but this could be a major concern for prospective drone operators.

Discussion

This pilot study is the first identified study to focus on the practical concerns of safety and efficacy of commercial camera drone operation by civilians. The time to complete a data collection mission of this nature does not appear to be dominated by drone design or camera-viewing method, but the use of FPV glasses proved to have great potential to improve accuracy of the photographs taken by drones. Unfortunately, FPV systems also present serious safety concerns, due to the limitations of the view provided by current cameras and headsets.

Further inspection of the FPV headsets themselves, and questioning operator experience with them, revealed many challenges that need to be addressed. The combination of a single drone camera and single display design within the headset, presents only monocular vision that makes depth perception difficult compared to natural human binocular vision. The interface design shown within the headset provided few instruments to assist the operator, providing rough and slow to update height and ground-speed indicators. No sensors or indicators were available to indicate if the drone was near to an object, or on a collision course with an object (in or out of direct camera view). Drone flight controls allow (or require) movement into blind spots during FPV control, with no panning or "peek" ability to allow the operator to check for obstructions without rotating the drone towards the direction of movement.

Future Work

The combination of qualitative and quantitative methods in this study has allowed us to identify multiple potential avenues for future research. An especially valuable area for future research could be extending research on virtual reality and augmented reality systems to improve FPV headsets. Drone FPV systems may even require its own dedicated line of research, due to the unique constraints and opportunities presented by this emerging class of cyber-physical systems.

The current experiment included the capturing of over 400 photos, and there is potential for coding each imagine to determine various measures of accuracy. Accuracy is particularly difficult to measure in 3-dimensions, with only a single 2-dimensional photograph. Triangular distance could be used to attempt to measure accuracy in terms of distance from the ball, and target distance from dead-center could be used to estimate side-to-side or vertical accuracy. It is unclear if these methods would provide sufficient accuracy, so considerable testing would be required.

Finally, the Bebop 2 drone uses a 180-degree fisheye lens. It could be possible to live-stream full 180-degree images and convert them to a partial 3D environment. If this could be done in near-real time, general purpose virtual reality headsets could utilize head-tracking to allow more natural operator vision of their environment. This is an intriguing possibility, but one that will require extensive further work.

Acknowledgements

The authors would like to extend special thanks to Professor Tim Krause and Professor Tim Kennedy; without their dedication and support, this research would not have been possible.

References

1. Frank Biocca. 1992. Will Simulation Sickness Slow Down the Diffusion of Virtual Environment Technology? *Presence: Teleoperators and Virtual Environments* 1, 3: 334–343. https://doi.org/10.1162/pres.1992.1.3.334

2. Jessica R Cauchard, L E Jane, Kevin Y Zhai, and James A Landay. 2015. Drone & me: an exploration into natural human-drone interaction. *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing*: 361–365. https://doi.org/10.1145/2750858.2805823

3. Ajoy S Fernandes and Steven K. Feiner. 2016. Combating VR sickness through subtle dynamic field-of-view modification. In *2016 IEEE Symposium on 3D User Interfaces (3DUI)*, 201–210. https://doi.org/10.1109/3DUI.2016.7460053

4. John Paulin Hansen, Alexandre Alapetite, I Scott MacKenzie, and Emilie Møllenbach. 2014. The use of gaze to control drones. *Proceedings of the Symposium on Eye Tracking Research and Applications - ETRA '14*: 27–34. https://doi.org/10.1145/2578153.2578156

5. Alan Hobbs and R Jay Shively. 2014. Human Factor Challenges of Remotely Piloted Aircraft. *31st EAAP Conference*: 5–14.

6. Randy Pausch, Thomas Crea, and Matthew Conway. 1992. A Literature Survey for Virtual Environments: Military Flight Simulator Visual Systems and Simulator Sickness. *Presence: Teleoperators and Virtual Environments* 1, 3: 344–363. https://doi.org/10.1162/pres.1992.1.3.344

7. Randy Babbitt. 2010. FAA aerospace forecast fiscal years 2010 – 2030. Retrieved from http://www.faa.gov/data_research/aviation/aerospace_forecasts/2009-2025/media/FAA Aerospace Forecasts FY 2009-2025.pdf

8. David Schneider. 2015. Is U.S. drone racing legal? Maaaaybe. *IEEE Spectrum* 52, 11: 19–20. https://doi.org/10.1109/MSPEC.2015.7335890

9. David Shultz. 2015. Game of drones. *Science* 347, 6221: 497–497. https://doi.org/10.1126/science.347.6221.497

10. Dennis A. Vincenzi, Brent A. Terwilliger, and David C. Ison. 2015. Unmanned Aerial System (UAS) Human-machine Interfaces: New Paradigms in Command and Control. *Procedia Manufacturing* 3, Ahfe: 920–927. https://doi.org/10.1016/j.promfg.2015.07.139