

# Human-Robot Interaction Observations from a Proto-Study Using SUAVs for Structural Inspection

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## Categories and Subject Descriptors

H.5.3 [Information Systems]: Information Interfaces and Presentation (e.g., HCI) - Group and Organization Interfaces - Collaborative computing;

**General Terms:** Human Factors

## Keywords

(S)UAV, Interface, Rescue Robotics, Human Robot Interaction

## 1. INTRODUCTION

Small unmanned aerial vehicles (SUAVs) have been used for post-disaster structural inspection in the aftermaths of disasters such as Hurricane Katrina and the Berkman Plaza II parking garage collapse [Pratt et al. 2008; Murphy 2006; Murphy et al. 2008]. Video and photos captured from SUAVs provided responders with unique vantage points; unfortunately, interpretation and use of the imagery proved difficult for experts both on- and off-site [Pratt et al. 2008]. This was mostly attributed to spatial data confusion and excess, as inconsistent labeling conventions appeared in post-Katrina missions.

An alternative approach we propose to permit responders to annotate imagery with freehand sketching performed on tablet PCs during and post-field data collection. The sketches could serve not only to improve human-human communication of disaster details, but they could also be automatically recognized by the computer to allow for automatic indexing of video, as was done in [Hammond et al. 2002]. This can be combined with the PhotoSynth algorithm to produce a post flight RubbleViewer as a solution to the spatial data confusion. To explore the potential for this interface, a proto-study was organized together with the Texas Engineering Extension Service (TEEX) at Texas A&M University in conjunction with the NIST Responder/Robot Exercise held November 17-20, 2008. Although not an extended formal study, our investigation confirmed previous work on SUAV crew organization and highlighted issues with displays, potential human error due to changes in viewpoint, and mismatched modes of communication between team members.

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HRI'09, March 11–13, 2009, La Jolla, California, USA.  
ACM 978-1-60558-404-1/09/03.

## 2. PROTO-STUDY

Objectives of the proto-study were to (1) observe professional responders using the capabilities of a SUAV in a mission scenario and (2) obtain digital sketch data on a tablet PC from annotations during the process. The end goal of this work was to collect enough ethnographic data to plan a formal study for sketch-based interfaces while giving responders more familiarity with the Center for Robot-Assisted Search and Rescue (CRASAR) cache of robots. Familiarization was accomplished by having a team complete a structural inspection mission similar to that of a post-Hurricane Katrina mission: to use a SUAV, in this case an AirRobot quadrotor autonomous helicopter, to conduct aerial structure inspections of large buildings.

The proto-study was held on the morning of November 21, 2008. The missions consisted of two separate flights surveying the same building, as shown in Figure 1. The flight team consisted of an experienced SUAV Pilot, two Mission Specialists who were trained first responder professionals, and a seasoned Flight Director. Six graduate students served as observers, note takers, and videotaped the Pilot and Mission Specialists. Midway during the exercise, several TEEX observers arrived to watch and, at one point, personnel working in nearby buildings stepped outside and almost entered the SUAV work envelope.

The exercise began with a safety briefing, followed by an introduction session for the Mission Specialists over the capabilities of the SUAV. Operationally, the Mission Specialists were instructed to direct the Pilot to (1) move the SUAV to the positions they needed to specific viewing of the building and (2) to capture still images for future reference.



Figure 1. Study Building.

## 3. FINDINGS

The proto-study produced four salient HRI findings described in the following sections.

*Finding 1: The proto-study confirmed the necessary minimum crew organization of three roles as described in [Murphy et al. 2008]: a Pilot, a Mission Specialist (or Problem Holder), and a*

*Flight Director (or Safety Officer).* The crew organization was mandated during the flight rehearsal and safety brief, but its usefulness was directly observed. The Pilot and Mission Specialist roles, while sharing the same visual display, were unique and distinct. The Pilot was clearly focused on flying the SUAV while the Mission Specialists were focused on information retrieval to complete the inspection. As safety officer, the Flight Director had to alert the Pilot as to the presence of bystanders who might be entering the operational area and that the SUAV was approaching power lines – the Flight Director was never involved with sharing the visual display of the other two members. One significant deviation from Murphy et al. [2008] was two responders serving as Mission Specialists rather than just one. Since the second responder did not add to the process the idea is supported that a 3:1 crew organization for SUAVs should be adopted as the default safe operating practice and that human-robot interaction studies should adopt this as the baseline for considering how to reduce the human-robot ratio. More research is needed into the optimal number of Mission Specialists and how to best coordinate, possibly remote, observers because as noted in Burke et al. [2004], having more than two observers physically co-located, led to poorer mission performance.

*Finding 2: The role of Mission Specialist appeared to need a separate monitor with different display functionality from the Pilot.* As shown in Figure 2, one monitor was not sufficient, as all three crew members could not effectively use the monitor simultaneously. The Pilot took precedence over the display/control panel, while the Mission Specialists had to position adjacently for a better viewing angle. The need for role-specific display functionality was evidenced by the fact that the Mission Specialists requested a second flight after discovering several key photos were blurry during the post-flight closer inspection of images on the ground. “Cockpit-oriented” displays are not well-suited for the Mission Specialist’s image collection task, who needed the capability to inspect the imagery mid-flight to reduce the need for additional flights, without competing for the display with the Pilot.



**Figure 2. Display Viewing.**

*Finding 3. The Pilot did not use line of sight (LOS) to direct the SUAV until it was moving through a cluttered environment.* The Pilot had his back to the SUAV during the majority of flight time in order to avoid staring into the Sun. The Pilot also appeared to be completely focused on the display until the Flight Director warned of the SUAV’s proximity to power lines. Nine seconds after the warning, the Pilot asked out loud, apparently as a comment to himself, whether something on his screen was a power line. He then switched to LOS flight until the SUAV returned to a less cluttered volume of the operations envelope. This suggests that there is a potential for human error in switching viewpoints and in maintaining broader situational awareness of the envelope of operations.

*Finding 4. Mission Specialists attempted to transmit directives to the Pilot using responder jargon and hand gestures.* The Mission Specialists had difficulties numerous times in conveying their intentions about the flight path to the Pilot. As was recorded in the video, the use of language was unclear and hand gestures were often unseen as the Pilot was visually captured by the

display or used LOS with the robot. In the end the Mission Specialists, after they trained the Pilot during flight, resorted to responder mapping jargon, to guide the Pilot. This emerged naturally as a possible solution for communicating the Mission Specialist’s intention to the Pilot. This finding suggests that more attention is needed for team processes and “hasty training” of ad hoc teams in order to clarify terminology and practice interaction. Perhaps a sketch interface would have been helpful: the mission might have gone more smoothly if the Mission Specialists had been able to draw on the shared image to indicate intent (e.g., “look here”, “go this way”). In addition: important lessons can be learned from iSearch by Voshell and Oomes [2005] a software interface utilizing virtual position and orientation indicators to alleviate perceptual ambiguities and navigation problems experienced by robot handlers and Mission Specialists.

## 4. ACKNOWLEDGMENTS

This work was supported in part by the National Science Foundation 0757557 and EIA-0224401. The authors thank TEEX personnel Steven Sparks and Duane Frederick for serving as Mission Specialists and Clint Arnett and Bob McKhee for arranging the facilities, and Thomas Meyer of AirRobot GmbH. The authors are grateful for the funding provided by the University Fund Delft, the TU Executive Board Fund, and the EWI Travel Fund.

## 5. REFERENCES

- Burke, J.L., Murphy, R.R., Coovert, M.D., Riddle D.L. 2004. Moonlight in Miami: An Ethnographic Study of Human-Robot Interaction in USAR. *Human-Computer Interaction* 19, 1.
- Hammond, T., Gajos, K., Davis, R., Shrobe, H. 2002. An Agent-Based System for Capturing and Indexing Software Design Meetings. In *Proceedings of 2002 International Workshop on Agents in Design* (Cambridge, MA, USA, August 28-30, 2002), WAID '02
- Murphy, R.R. 2006. Fixed- and Rotary-Wing UAVs at Hurricane Katrina, *IEEE International Conference on Robotics and Automation* (Orlando, FL, USA, May 15-19, 2006)
- Murphy, R. R., Pratt, K. S., and Burke, J. L. 2008. Crew roles and operational protocols for rotary-wing micro-uavs in close urban environments. In *Proceedings of the 3rd ACM/IEEE international Conference on Human Robot interaction* (Amsterdam, The Netherlands, March 12 - 15, 2008). HRI '08. ACM, New York, NY, 73-80. DOI= <http://doi.acm.org/10.1145/1349822.1349833>
- Pratt, K. S., Murphy, R. R., Burke, J. L., Craighead, J., Griffin, C., and Stover, S. 2008. Use of Tethered Small Unmanned Aerial System at Berkman Plaza II Collapse. *IEEE/RSJ 2008 International Conference on Intelligent Robots and Systems* (Nice, France, September 22-26, 2008).
- Voshell, M., Oomes, A.H.J. 2005. Coordinating (Shared) Perspectives in Robot Assisted Search & Rescue. In *Proceedings of the 3rd International ISCRAM Conference* (Newark, NY, USA, May 13-17, 2006). ISCRAM '05.