Information Management for Multiple Entities in a Remote Sensor Environment

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Abstract. Current remote piloted aircraft (RPA) operations typically have one sensor operator dedicated to a single sensor, but this may change in the future. To maintain a clear line of sight, the operator must know which sensor to switch to, especially for a moving target. We researched whether using augmented reality and presenting obstruction information helped operators maintain good situational awareness about sensor target relationships. This study had two independent variables: predictive interface (three levels—none, predictive only, and predictive with rays) and interface configuration (two levels—with and without dedicated sensor screens). The results of this study showed that the predictive interface did not increase the operators' performance; however, their performance did increase when we added the dedicated screens.

Keywords: augmented reality, sensor management, RPA, control station.

1 Introduction

Advances in sensor technology have allowed smaller and smaller remotely piloted aircraft (RPA) to capture full motion video. Ground forces have desired this relatively new capability, and the military expects them to continue to need the technology for some time. To meet this need, the military expects sensor use to increase, making more and more information available to the troops in the field. As the amount of video data increases, the military can conduct more comprehensive and efficient surveillance, but this will require the operator to make more decisions.

In an effort to better understand the impact of multiple RPAs, we chose a persistent stare mission as the experimental task. The persistent stare mission requires the participant to maintain a sensor line of sight on a designated target at all times. One of the main challenges with this task is that terrain features sometimes occlude the sensor view, especially in urban environments. One way to overcome this problem is to fly high and stay directly overhead of the target. Unfortunately, smaller RPAs do not fly very high and are slow, so a fast moving target (such as a car) could out run the RPA. Also, the lower-flying RPA is more likely to be detected.

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One strategy to maintain constant eyes on a target with smaller RPAs would be to employ multiple RPAs around an area. Most likely no one RPA will have a clear line of sight to the target at all times, but at least one of them should. The key is for the operator to understand which RPA has the clear line of sight. The purpose of this line of experiments is to investigate interface technology that can help operators gain this understanding.

2 Background

We are not the first to use augmented reality and obstruction information. Israeli researchers (Porat, 2010) have previously experimented with using augmented reality. They used augmented reality to help two people maintain persistent stare of a moving target in an urban environment. Figure 1 shows an example of the 'Castling Rays' developed by Porat. The Castling Rays provided an operator with information about the elevation of the sensor, the RPA affiliation, and obstruction information (whether or not the sensor could see the desired stare point). The results from Porat showed that these measures increased operators' performance and situation awareness. The researchers at the Air Force Research Laboratory (AFRL) wanted to follow up the concept of using augmented reality for aiding in decision making. In particular, the AFRL researchers wanted to know what information to encode in the rays.

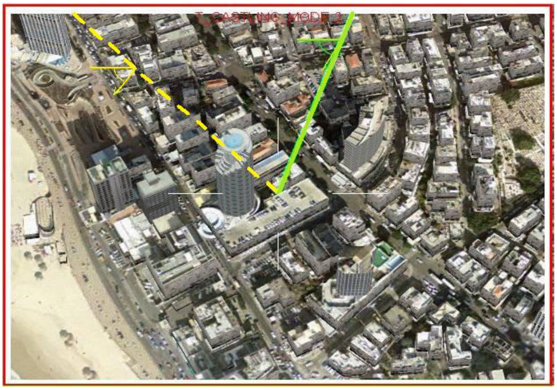

Fig. 1. Sample of the 'Castling Rays' augmented reality

The AFRL research consisted of three studies that investigated different aspects of line-of-sight rays and target conditions. In the first study, AFRL required participants to monitor the front door of a building in an urban environment and indicate when persons of interest entered the building. Then, in phase two of the study, a person of interest (POI) leaves a building and participants were to maintain a clear line of sight to the moving target. For the first study, we auto-tracked the moving target. The task for the second and third studies focused only on the moving target task. We told the participants that they were providing support to a customer who was behind enemy lines and had a small screen with only a single view (like a smart phone or tablet). The customer was relying on them (the participant) to provide constant line of sight of the target. All four sensors would move together, so if the participant changed the stare point, the stare points for the other sensors would move as well. The interface used for all the studies consisted of a map, master sensor screen (the external customer's screen), and multiple dedicated sensor screens.

In the first study (Rowe, 2012), we varied four different aspects of the rays. The ray thickness varied with distance or sensor resolution. We showed obstruction information by using dashed rays when the target was obstructed. For sensor identification, we assigned each RPA a different color. We also varied whether or not the rays were selectable. The results of the first study indicated that the optimal condition for both the stationary and moving target conditions was solid rays that showed sensor identification and were selectable. Contrary to what we would have thought, operators did not perform better when the rays showed obstruction information. We think this outcome was mainly due to the auto slewing of the sensors.

The second study had two independent variables: ray configuration (three levels—rays with obstruction information, rays without obstruction information, and no rays) and interface configuration (two levels—with and without dedicated sensor screens). The results again showed that operators performed better when we did not provide obstruction information on the rays. The dedicated sensor views did not significantly increase operators' performance, but they did reduce operators' workload and were more desirable to the operators.

From the first two studies, it seemed clear that the rays were useful and did improve operators' performance. The dedicated sensor screens also were valuable because they reduced operators' workload. Following these studies, we had several questions that we wanted to investigate in the next study: 'Does adding more sensors make the rays less useful?', 'Can we display the obstruction information in a different way to make it more useful?', and 'Will the dedicated screens increase operators' performance with an increased number of RPAs?'

The third study again had two independent variables: predictive interface (three levels—none, predictive only, and predictive with rays) and interface configuration (two levels—with and without dedicated sensor screens). The results of this study showed that operators did not perform better with the predictive interface; however, they did perform better when we added the dedicated screens.

2.1 Hypotheses

The first hypothesis for this paper (h1) is that conditions with the timeline will outperform the conditions without it. The second hypothesis (h2) is that there will be an interaction between the interface configuration and presence of the timeline, meaning the timeline will replace the need for the dedicated screens. Finally, the third hypothesis (h3) is that the conditions that provide obstruction information will outperform the conditions that don't.

3 Methods

3.1 Participants

We used a total of 24 (21 males, 3 females) participants for the study. All of the participants were subject matter experts (SMEs) and had experience with using or exploiting remote sensors. Twelve of the participants were from the Springfield Air National Guard (SPANG), and the other twelve participants were from distributed ground station -Indiana (DGS-IN).

3.2 Apparatus

This study used eight computers running the Windows 7 operating system, and all computers were connected to a local network. Six computers ran individual instances of a virtual environment that we developed in-house (Subr Scene). Subr Scene rendered a digital representation of Sadr City in Iraq. We used these computers as sensor feeds for the Vigilant Spirit Control Station (VSCS) (Rowe & Davis 2009) and had their desktops duplicated and streamed digitally for VSCS to consume. We used FFmpeg for both decoding and encoding the video stream in H.264. A fifth computer ran the Vigilant Spirit Simulation and Vigilant Spirit's Zippo. Zippo controls Ternion's Flames Simulation Framework, which we used to send distributed interaction simulation (DIS) packets to control the four computers running Subr Scene. Each participant used a sixth computer running the VSCS in conjunction with two, 24-inch monitors set to a resolution of 1920x1200 pixel, and a Dell laser, 6 button, wired mouse. We permitted each user to adjust their distance from the monitors as desired. Figure 2 shows the participant control station.

Fig. 2. Desktop system that participants used

3.3 Task

Similar to what we had done in previous studies, we told the participants to provide the best possible sensor feed to a notional joint terminal area controller (JTAC) who was equipped with a small hand-held computer (similar to an Apple iPad) that can only consume one video at a time. In this scenario, the JTAC was relying on the participant to maintain a constant view of a high value individual (HVI). The HVI moved through an urban environment for approximately eight minutes, stopping twice per trial to converse with associates. The trial ended when the HVI entered a building. We randomly placed six RPAs in one of six predetermined starting positions, and they flew a predetermined route. Due the path of the target and the route of the RPAs, no one RPA had a clear line of sight to the target at all times.

3.4 Procedures

We gave the participants an introduction to the program, and they reviewed and signed the informed consent form. They then completed three training trials that we had designed to familiarize them with the task and the different aspects of the control station. After they had completed the training trials, they completed 12 data collection trials. After each trial, we administered questionnaires that assessed workload and situation awareness.

3.5 Independent Variables

The experiment had two independent variables: obstruction information presentation (OIP) and interface configuration. The OIP independent variable describes how we presented the obstruction information to the participant. The OIP independent variable had three levels: none (no obstruction information presented), timeline only (obstruction information presented through the timeline only), and timeline with rays (obstruction information presented through timeline and the vantage rays). The interface configuration independent variable determined whether or not the operator had dedicated screens for each of the sensors. Figure 3 shows an example of the map (A), master sensor screen (B), timeline (C), and the six dedicated sensor screens (D).

3.6 Dependent Variables

We collected objective and subjective measures to assess the participants' performance. We collected the following objective measures: percent unoccluded, average unoccluded time span, total number of transitions, and number of good transitions. The percent unoccluded was the amount of time the HVI was actually visible in the master sensor screen divided by the amount of time the HVI was potentially able to be seen in the master sensor screen. The average unoccluded time span was the average length of time the HVI was in the master sensor screen. The total number of transitions was a count of the number of times the participant switched sensors in the master sensor screen. The number of good transitions was a count of the number of times the participant switched sensors and was able to see the HVI in the new sensor. We also collected subjective measures for the operators' situation awareness and workload.

Fig. 3. Sample interface with map (A), master sensor screen (B), timeline (C), and six dedicated senor screens (D)

4 Results

We observed significant differences in only two of the objective measures. Neither of the subjective measures showed any significant differences. For *transition count*, we observed significant effects ($p < .001$) for ray condition (no rays: 16.59; timeline only: 21.86; timeline with rays: 25.44) and interface configuration (master sensor screen only: 24.46; master sensor screen with six dedicated screens: 18.12). A significant interaction ($p < .05$) existed between ray condition and interface configuration when the difference between interface configuration levels was smaller under the no ray condition.

For *user percent unoccluded*, there was a significant main effect ($p < .05$) for interface configuration (master sensor screen only: 84.5%; master sensor screen with six dedicated screens: 86.7%) and an interaction between ray condition and interface configuration.

5 Discussion

The underlying belief behind the hypotheses was that the obstruction information would be beneficial; however, the data does not support that theory. When considering the performance metric *user percent unoccluded*, the main factor that improved operators' performance was the dedicated sensor screens. This data does not support hypothesis h1or h3 (obstruction information would improve operators' performance). Hypothesis h2 postulated that the timeline would remove or reduce the need for the dedicated screen, but we did not see that at all. When looking at the transition counts, which may be an indication of the operators' workload, we see no benefit of providing the participants with the obstruction information; in fact we see an opposite effect. The question is 'Why did we see this?'

We think that the main reason providing obstruction information did not help operators is that the database for our environment contained noisy information. In order to determine if a sensor is being blocked or not, the operator needs a detailed database of the environment. In our experiments we had such a database; however, it did not account for architectural details (e.g., awnings) or other attributes in the environment such as trees or vehicles. These minor omissions from the database would cause the obstruction information driving the timeline to be incorrect, which would in turn lead the participants to not trust the timeline.

6 Conclusion

In conclusion, the data from previous and current research suggests augmented reality rays improve operators' performance when maintaining persistent stare with multiple sensors. One caveat to this research is that all of the tasks took place in an urban environment with straight and either parallel or perpendicular streets, possibly helping the operators in unforeseen ways. The number of RPAs an operator is controlling also influences the utility of augmented reality. In addition, the data suggests that providing obstruction information is not beneficial. Future researchers will examine the appropriate size for the dedicated sensor screens and begin to look at how to employ this technology on mobile devices.

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