The objective of this research is to design and develop tools, layouts, techniques and procedures to aid operators in handling Multiple Operator Multiple UAV (unmanned aerial vehicle) environments. In this paper we describe a study conducted on proficient operators, examining a new tool - 'Maintain Video Quality'. This tool aims to facilitate handoffs and UAV switching among operators. Experimental methodology and preliminary findings are discussed.

Multiple operators controlling multiple UAVs (MOMU) is an operational setup that has been shown to be beneficial for covering areas of interest, particularly in reconnaissance missions, and highly relevant to homeland security and surveillance operations. With the increase in UAVs' self-control tasks requiring less human execution, current UAV systems transit to one operator supervising a team of semi-autonomous UAVs, as opposed to the converse (Brzezinski et al., 2007). However, this mode of operation often increases the cognitive burdens of its operators. Besides the challenge of preventing high operator workload and low situation awareness, caused by the need to attend to multiple sources of information at once, this mode also requires switching of information sources, i.e., tasks, missions, video feeds or camera manipulations, and coordination among operators. Switching is a time-critical and cognitively demanding task. Cognitive costs of switching may be loss of orientation and situation awareness, increase in workload, and decrease in efficient verbal team communication. Consequently, switching between sources can disrupt operator performance (Draper et al., 2008). As the autonomy of the video feed source increases and interfaces improve, switch costs gradually become the bottleneck which limits the number of source feeds that a single operator can manage or be aware of (Hancock et al., 2007).

The aim of this entire research project, which is a US-Israel collaboration, is to identify information, and develop tools and layouts which may facilitate quick and efficient task switching and coordination in MOMU environments, in order to decrease switch-costs and improve mission performance. Previous studies (Porat et al., 2011) have shown that there might be a tradeoff between the screen layout and the number of zoom-related operations that the operator has to perform. As such, the Israeli research team aimed to develop tools that will facilitate a more optimal way for window size changes without affecting the zoom level. Specifically, in the study reported here, experienced UAV operators examined a new tool – the 'Maintain Video Quality' tool. This tool further explored the relationship between zoom operations, window size, layout of multiple video windows, and mission components (e.g., coverage area). In the next section we describe shortly the pre-study examining three different layouts, followed by the methodology and findings of our recent study examining the 'Maintain Video Quality' tool.
Layout Manipulation Preliminary Study

This pre-study dealt with manipulation of window size (Porat et al., 2011). When the operator controls or needs to be aware of multiple video feeds, it is possible that these feeds should be presented to him/her in a way that conveys their importance/relevance to the mission at hand. As such, three display layout configurations were examined: fixed, adaptive (automation-controlled) and 'user control' (see Figure 1). In the adaptive and user controlled layouts, the video feed window which is most in use (e.g., time on window, mouse clicks) enlarges on account of the other windows.

![Figure 1. Fixed layout contained four same sized windows (Left). Adaptive/user control layout, one window enlarges on account of the other two (Right).](image)

Preliminary findings revealed an interesting interaction between the zoom value (the total number of zoom operations) and the layout (F(2, 4)=11.74, p=.021). In the fixed layout, the values of the zoom were significantly higher than in the adaptive and user control layouts. This could imply that having a larger video feed window for the main task could reduce the need for zoom manipulations. Thus, there might be an interesting interaction between the video feed window size, necessity for zoom manipulations and desired target size. Since one of the goals is to reduce operators' workload, reducing the zoom manipulations needed by the operator may reduce the amount of workload he experiences while performing the mission. According to the above, the following "Maintain Video Quality" tool was developed to further examine the relation and interaction between the video feed window size, necessity for zoom manipulations and desired target size.

'Maintain Video Quality' Tool and Study

The Maintain Video Quality tool is a dynamic layout feature which manipulates the relationship between window size, zoom and field of view. It enables operators to define a minimum desired video quality, which is defined as window size (pixels) divided by footprint size (meters) (see Figure 2). The system will preserve this quality, as long as it can, by increasing the available window size or/and changing the zoom. The tool contains two sliders: Zoom value (on the left for display only) and Video quality value (to its right), which serves as an interactive slider. The operator defines the minimum video quality she/he is willing to absorb by clicking on the desired value (a yellow mark will be displayed). This feature is important in surveillance tasks, when the target needs to be seen continuously at a certain level of detail and therefore within a certain size.
Figure 2. Maintain Video Quality tool. Video quality = 1/8 (Left). Video quality = 1/4 (Right).

Figure 3 shows several use-examples of the 'maintain video quality' tool. In the first example (Figure 3; top-left), the operator defines a minimum video quality constraint in the upper left window. While performing the task the user zooms-out in this window, an action which is threatening to break the defined constraint. The system automatically increases the window, to its maximum possible size (top-right). The second example (Figure 3; mid-left) shows that if a video is defined with a quality constraint for example on the bottom-right window and the size of the window decreases, which threatens to break the constraint, the system will zoom-in in order to maintain the constraint up to the possible maximum zoom-in (mid-right). The third example (Figure 3; bottom-left) shows the advantage of the tool when switching payloads. The work assumption is that the operator would like to view the target from a different point of view, but maintain the defined video quality. Therefore, when switching payloads, the system will make the necessary adjustments (zoom and window size) to the switched payload video, to maintain the desired video quality (bottom-right).

Methodology

Participants
Four highly experienced male UAV operators with similar skills and experience. Their age ranged from 25 to 28.

Operational Mission
To force switching of attention among payloads, the mission took place in two separate geographical locations: airport and city. The operator guarded a house and an airport utilizing 3 UAVs. The operator had to report upon the occurrence of 6 types of events, 5 events occurred in the city (vehicle exit, vehicle enter, vehicle framed, caravan exit, caravan framed) and one event in the airport (plane take-off). Events differed in their
importance and caravan events were valued as most important. The aim of the mission was to identify maximum real events, ignore distracters and avoid false events.

Figure 3. Example 1 (top): user defines a quality constraint on the upper left video (yellow line) (left). Window grows to maintain quality constraint (right). Example 2 (mid): bottom-right window has a quality constraint (left). Bottom-right window size decreases, system automatically zooms-in to maintain constraint (right). Example 3 (bottom): The operator desires to switch between the top-left payload (green) to the bottom-right payload (blue) (left). The video quality of the blue payload (zoom and window size) changes to maintain the quality definitions (right).

**Procedure**

Figure 4 describes the study procedure for each operator in each layout. Operators commenced with the fixed layout and then proceeded to the dynamic layout. The total duration of the study for each participant was 3 hours (1 hour training and 2 hours experiment). Each scenario contained 18 events (11 real and 7 false) and lasted 15 minutes.
Performance measures

Objective performance included success rate and detection time. Operational metrics indicating on the quality of payload utilization, zoom-value, double-clicks (manual following of a target), and locks of the payload on target were also collected. These measures evaluate the task-switching and payload manipulation efficiency. In addition, subjective assessment of workload was assessed using SWAT (Reid et al., 1988).

Results

Participants thought that the task was difficult and would normally not be performed by a single operator. This was also reflected in the relatively low Success rate - 62%. Preliminary results revealed no significant differences in success rate between the fixed (.63) and the dynamic (.61) layouts, in neither scenario nor per events analysis (see Figure 5). However, for both layouts, a learning curve was found and performance on the third scenario was always better than on the first and second ones. SWAT results also did not differ among layouts. Operators felt that the dynamic layout was not beneficial over the fixed layout. Operators were instructed to use the 'maintain video quality tool' as much as possible but were not forced to maintain it throughout the experiment. Overall 85% of the time the quality maintenance tool was on (hence, 15% of the time operators turned it off), and 50% of the time, operators specified a different value than the default minimum value.

Figure 5. Scenario by Layout interaction for success rate (Left). Event by Layout interaction for success rate (Right).

Conclusions

The results indicate the need to further examine the utility of the 'maintain video quality tool', as this tool did not reveal superiority for the dynamic layouts in the examined scenarios. Future studies should examine
tool features more specifically, while controlling layout and environment. To illustrate, in this study, the use of the 'maintain video quality tool' is inseparable from the dynamic layout and, perhaps, removing the dynamic change of window size, which operators felt was not beneficial in the current context, would have influenced the results and allowed the operators to utilize it more efficiently. In addition, the learning curve from the first to the third scenario could imply that operators need more time to learn and get used to such complex tools before improvements in their performance occur (as they also indicated in their subjective feedback).

Structured interviews with experienced operators strengthen the necessity and importance of layouts and tools in reducing operators' workload and improving mission performance. These studies mentioned here are only two of the many studies performed within the framework of this research project. The results of the study, although preliminary, revealed interesting concerns regarding fixed versus adaptive window size and the interaction between zoom and window size. Proposed future studies should, for example, examine automatic changes of zoom while switching or castling payloads (Porat et al., 2010); fitting the zoom to the task; examine the interaction of target size by zoom and window size and enable the operators to define manually the optimal window size for performing the task. Hopefully, results of the current and future studies will encourage researchers in the MOMU community to further develop decision support tools and layouts aimed to reduce operators' workload, increase situation awareness and improve mission performance, specifically for facilitating video-feeds switching tasks.

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References


