

Adaptive Ground Control System of Multiple-UAV Operators in a Simulated Environment

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- INTRODUCTION:** In the present study, an Adaptive Ground Control System for Multiple-UAV Operator Workload Decrement (AGCS) has been developed and the effectiveness of the system has been analyzed using eye-tracking and task performance data. The AGCS contained four more functions than the conventional GCS (CGCS) functions. The functions were based on real-time operator gaze information, multiple UAV operational state, and mission state information to help safe and efficient multiple UAV operation.
- METHODS:** A total of 30 volunteers participated in the human-in-the-loop experiment to compare the performances of the newly developed AGCS and CGCS while executing reconnaissance and strike missions by operating multiple UAVs.
- RESULTS:** According to the results, the AGCS demonstrates a statistically significant increase in mission performance, such as the mission completion rate ($M = 97.3$ vs. $M = 95.4$; $SD = 3.1$ vs. $SD = 4.9$) and mission success rate ($M = 90.4$ vs. $M = 88.4$; $SD = 5.7$ vs. $SD = 5.6$). In addition, the subjects' pupil diameter and gaze indicator show significant differences in the direction of workload reduction ($\alpha = 0.05$). The subjects expressed positive opinions about using the AGCS.
- DISCUSSION:** The originally developed AGCS showed a promising future extension based on the experimental data. After completion of the experiment, domain experts were interviewed and the next version will reflect their opinion.
- KEYWORDS:** mental workload, eye movement, target detection, surveillance, military.

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With the advancement of unmanned aerial vehicle (UAV) automation technology, recent studies have focused on how a single operator can take supervisory control of multiple UAVs simultaneously.^{1,3,21} In this regard, it is worth mentioning that if the number of UAVs assigned to a single operator increases, the amount of information to process may exceed the maximum work capacity of that operator.^{7,15,16} For this reason, an adaptive ground control system needs to be developed which can check the workload status of a multiple-UAV operator and help reduce it.^{4,19,22} Unfortunately, such studies are insufficient in Korea. Against this backdrop, the present study aimed to develop an adaptive ground control system capable of decreasing the workload of multiple-UAV operators and experimentally compare the proposed Adaptive Ground Control System for Multiple-UAV Operator Workload Decrement (AGCS) with the conventional GCS (CGCS). The effectiveness of the proposed AGCS was evaluated based on the results of the human-in-the-loop experiment conducted herein.

There are several UAV ground control systems (GCS) for UAV operation in the world. Among them, we will introduce

some examples to help the readers understand the present status of UAV GCS. Supervision of Unmanned Vehicles Mission Management by Interactive Teams (SUMMIT) and Multirobot Operator Control Unit (MOCU) are introduced to show examples of configurable GCSs. Research Environment for Supervisory Control of Heterogeneous Unmanned Vehicles (RESCHU) and Multi-Autonomous Vehicle Insertion Extraction System (MAVIES) are mentioned to introduce research examples of estimating operator workload.

SUMMIT was developed by Lockheed Martin jointly with the U.S. Navy and was designed to move beyond the present model where systems are assigned to each operator to control,

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