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Integrating the First Person View and the Third Person View Using a Connected VR-MR System for Pilot Training

Chang-Geun Oh
Kent State University - Kent Campus, coh1@kent.edu

Kwanghee Lee
Dankook University, kwanghee0124@gmail.com

Myunghoon Oh
Dankook University, snt2426@gmail.com

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Background

Virtual Reality, Augmented Reality, and Mixed Reality Technology for Aviation

Virtual reality (VR) and augmented reality (AR) have emerged as innovative human–computer interaction technologies. They have been considered cost-effective training schemes to enhance human performance (Farrell, 2018). The aviation industry can apply VR and AR effectively because this sector requires significant costs and complicated structures in its training materials in order to educate aircraft pilots, air traffic controllers, and aircraft maintenance staff. Recently VR, AR, and mixed reality (MR; a mixture of VR and AR) have been pervasively applied to aviation fields (Eschen, Kötter, Rodeck, Harnisch, & Schüppstuhl, 2018; Regenbrecht, Baratoff, & Wilke, 2005). VR has been used in military pilot training (Losey, 2018). Using VR-based flight simulators, pilots experience a closer approximation to reality with a wider field of view, and they can train with many realistic and challenging flight conditions that are difficult or impossible to create in real conditions, such as engine fire.

Researchers have evaluated VR, AR, and MR's effectiveness in aviation. Macchiarella, Liu, Gangadharan, Vincenzi, and Majoros (2005) and Macchiarella and Vincenzi (2004) found that AR can improve human long-term memory for task procedures, allowing to recall over a longer timeframe. The AR has also been tested in aircraft maintenance training support (Eschen et al., 2018; Jo et al., 2014; Macchiarella & Vincenzi, 2004; Wang, Anne, & Ropp, 2016).

Generating effectively perceivable 3D graphics is an advantage of AR and MR. For route planning and spatial navigation, people perceive qualitative judgments better with 3D than with 2D, whereas 2D is superior for quantitative judgment (Dixon, Fitzhugh, & Aleva, 2009). Liu et al. (2019) and Wong et al. (2007) investigated human visual properties of a 3D-based air traffic control (ATC) display. Moreover, Anne, Wang, and Ropp (2015) suggested that a computer-generated 3D model using AR would improve training and technical task performance in aviation, and Han, Shah, and Lee (2019) applied MR to a 3D ATC display.

First-Person vs. Third-Person Views' Effectiveness in Spatial Cognition

Human spatial cognition involves various frames of reference. Generally, while navigating to destinations, people refer to spatial information both from the first-person view and the third-person view. The first-person view (egocentric view) includes a pilot's point of view from the cockpit. Landmark knowledge (i.e., navigating with reference to a notable landmark in the area of interest) and route knowledge (i.e., navigating with procedural routes to a destination) are egocentric (Wickens, Hollands, Banbury, & Parasuraman, 2015). A third-person view (allocentric view) is the flying bird's viewpoint. From this view, ownship (one's own vehicle) is seen as only an object within the area of interest. The allocentric orientation refers to the elements and features of an area of interest independent of the actor's viewpoint (Ruggiero, Iachini, Ruotolo, & Senese, 2009). Survey knowledge (i.e., high-level navigational information, such as traffic conditions or shortcuts) is allocentric (Wickens et al., 2015). For spatial navigation, people depend more on the egocentric view (Fabroyir & Teng, 2018; Kallinen, Salminen, Ravaja, Kedzior, & Sääksjärvi, 2007; Filimon, 2015; Kosslyn, 1996; Millar, 1994). The allocentric view offers its own intrinsic advantages of projecting future situations for navigational information (Milner & Goodale, 2008).

Basically, the first-person view offers more advantages than the third-person view in spatial navigation such as pathfinding. Filimon (2015) suggested that all spatial representations tend to depend on the egocentric frame of reference. Wen, Ishikawa, and Sato (2013) discovered that people with a good sense of direction might utilize landmark and route knowledge to create their own egocentric survey knowledge, which then transforms into allocentric survey knowledge. People who had conducted navigation tasks in a virtual environment preferred egocentric techniques (Fabroyir & Teng, 2018). Zhong and Kozhevnikov (2016) found that people reproduced their own spatial perceptions while learning spatial routes by mainly using egocentric perspectives. Ruggiero et al. (2009) found that processing egocentric representations performed better than the allocentric approach with respect to speed and accuracy.

However, the combined egocentric and allocentric view offers considerable potentials for improved spatial perception (Burgess, 2006; Ruotolo, van Der Ham, Iachini, & Postma, 2011). Meilinger and Vosgerau (2010) found that the first-person and third-person views could interact with each other rather than comprising separate representations for complex spatial representations. Burgess (2006) asserted that using egocentric as well as allocentric representations would complement both approaches, resulting in a comprehensive spatial perception that depends on both views. Moreover, he suggested that allocentric representations play a role in supporting movements between the presentation and retrieval, as well as recalling and familiarization, of spatial objects' properties. According to Ruotolo et al. (2011), the combination of allocentric and egocentric frames of reference must be considered with respect to the two views' interaction with each other in judging coordinates, but both frames could be independent to each other in categorical and coordinate dimensions.

Current VR products have been developed so that VR devices can best use the first-person view. AR and MR, meanwhile, can be utilized to compose a third-person 3D view. VR can also combine with AR or MR to utilize the distinct advantages of each technology. An example of a combined first-person and third-person view is the advanced aircraft cockpit display of the Taxiway Navigation and Situation Awareness (T-NASA) system, which adopted both the first-person view in its head-up display (HUD) and the third-person view in its electronic moving map (EMM) on the cockpit display (Foyle, Andre, & Hooey, 2005). This combined system showed improved performance in aircraft ground taxiing operations (Foyle et al., 2005).

Research Motivation and Objective

VR, AR, and MR have not been widely used in aircraft pilot training, but their effectiveness in higher-level training utilizing 3D spatial representation has become evident. For flight debriefing, flight instructors are usually interested in student pilots' behaviors in the cockpit during flight tasks, which involves the first-person view. In addition, as stated above, prior research has implied that the combined first-person and third-person views would benefit the perception of spatial representations. The current MR technologies can be used to develop effective 3D representations with the third-person view. Also, VR technologies provide effective first-person views. However, most research and development for recent nontraditional pilot training systems have focused on VR alone. The present study was motivated by the potential effectiveness of a flight training system prototype that provides both a first-person view using VR and a third-person view using MR. These two perspectives from two different technologies connect to implement each technology's effectiveness within a single system. The current study uses the design of a comprehensive pilot training system to evaluate whether a system with both first-person and third-person views result in better spatial situation awareness and, therefore, better flight training.

Development of a Connected VR and MR-Based Pilot Training System

For this study, the prototype of comprehensive pilot training system that utilizes both the first-person and third-person views was developed by connecting a VR flight simulator and an MR headset device. The VR flight simulator enables a pilot to conduct realistic simulated flights,

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and the flight performance data is automatically created as the pilot conducts flights in the simulator. The VR simulator adopted a HP Reverb VR headset, a motion platform, and a yoke, throttle, and rudder pedal set (Figure 1). The VR simulator's role was to generate the first-person view representation for a pilot; it shows the pilot a cockpit view of X-Plane 11 flight simulation program via the VR headset (Figure 1). The pilot flew a Cessna 172 airplane using the simulator.

Figure 1. VR simulator controllers, VR simulator seat, and motion platform: X-Plane VR cockpit view (from left to right).

This system adopted Microsoft HoloLens as its MR device. All flight performance data (e.g., aircraft altitude, airspeed, attitude, and location) were saved as a cumulative text file in the X-Plane program of the flight simulator, and this file was then transmitted to the HoloLens application via computer network. The text file became the sources of 3D situational graphics in the HoloLens. As the pilot in the VR simulator proceeded with a flight task, the HoloLens application regenerated a third-person, 3D view presentation in near-real-time. The HoloLens user was able to place the 3D hologram on an empty table or floor surface. The development of 3D terrains in the HoloLens application, and moving aircraft above these terrains, used Unity3D game engine and related toolkits. Figure 2 illustrates the combination of the VR simulator and the HoloLens MR application.

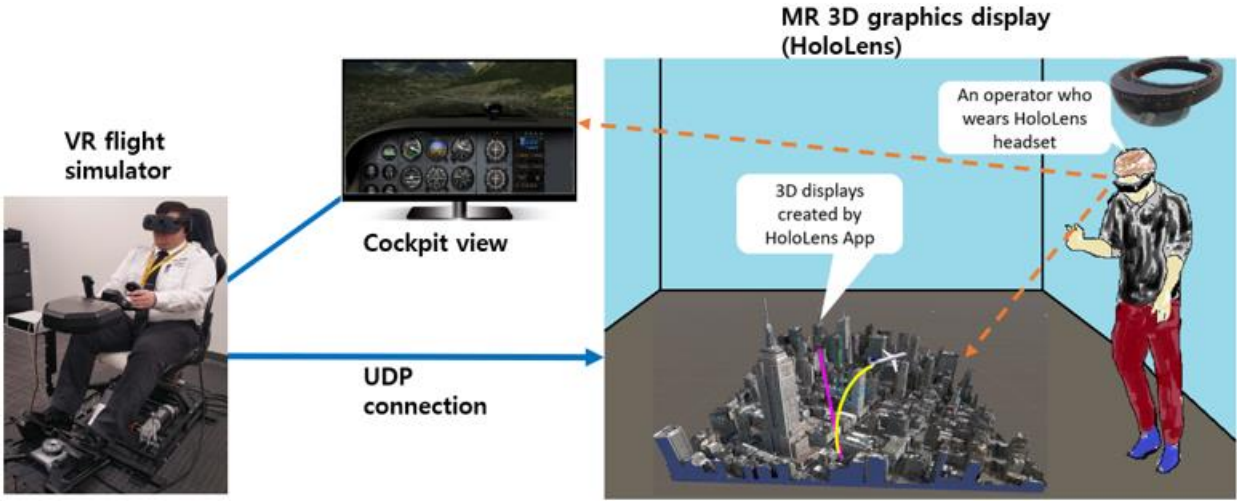

Figure 2. Structure of the connected VR–MR system for this study.

The 3D terrain graphics in the MR application provided elevation information for graphics components including hills and buildings. The aircraft's planned and actual flight paths were visualized in the application. Figure 3 shows the graphics elements. The planned path (the magenta line in Figure 3) was originally drawn from the departure airport to the destination airport as the most economic path for aircraft and visualizing the actual path (the blue line in Figure 3) progressed as the aircraft graphics moved forward. Users can see the augmented 3D virtual graphics that were reflected on the HoloLens's goggle component while watching the real objects at the same time.

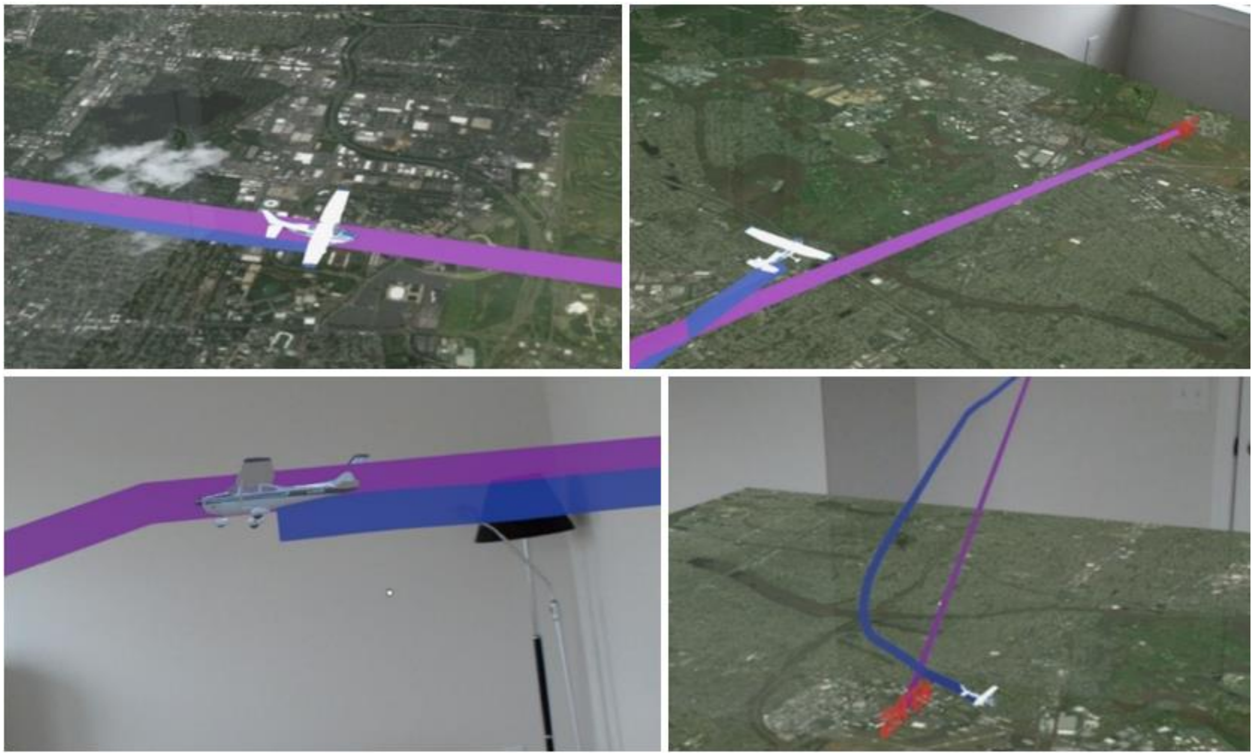

Figure 3. Different viewpoints of the aircraft in the MR application as the HoloLens user walks around.

The pilot who flew in the VR flight simulator only saw the cockpit view. The HoloLens users could see the aircraft graphics and the terrains in the 3D MR application. The users could walk around the generated 3D holograms to see all 360 horizontal and vertical degrees of the features, maintaining their consciousness of a real space. The aircraft within the MR application moved as an animation effect, and the HoloLens user could see the accurate 3D situations and evaluate the pilot's performance from the third-person's perspective. This MR application prototype included two modes: a real-time monitoring mode (Figure 4) and a replay mode (Figure 5). The replay mode included a progress bar that the HoloLens users could manipulate for flight debriefing. Users could examine the situation happened in a specific timeframe manipulating the progress bar.

Figure 4. The MR application's real-time monitoring mode.

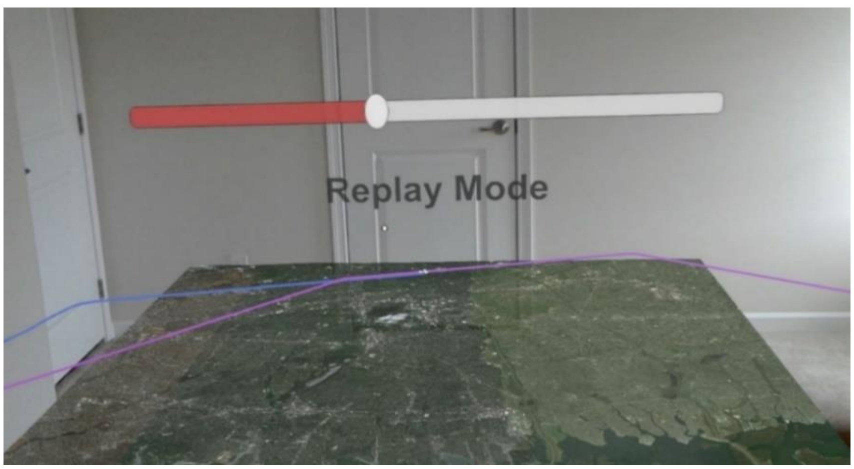

Figure 5. The MR application's replay mode.

While the pilot flew in the VR simulator, the instructor (the HoloLens user) could see the pilot's flight from the bird's-eye view (allocentric view) using HoloLens 3D graphics and saw the cockpit view of X-Plane on a separate monitor display (Figure 6). Also, the fundamental flight performance data—such as mission time, airspeed, wind speed, wind direction, and flight distance—are augmented as textual information on the side space within the MR application so that the HoloLens user can view them (Figure 6).

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Figure 6. Augmented flight information visible in the space, cockpit view on a separate monitor, and VR simulator visible while wearing a HoloLens headset (from left to right).

Evaluation of the Developed Prototype

Flight instructors who had conducted debriefing for student pilots' flight operations as part of their job were asked to try the MR-based real-time monitoring and debriefing system and then interviewed about their perceptions of the prototype. Interview sessions were conducted by a small number of participants for their responses of design review questions rather than dealing with a dataset to find meaningful statistical tendencies. Participants were provided with a HoloLens headset embedding the beta version of the MR application.

Evaluation Procedures

The experimenter instructed participants in how to use the application. Then, participants were asked to test the application by themselves while a student pilot conducted a flight operation in the VR flight simulator beside the space upon which the hologram was visible through the HoloLens. Participants saw the regenerated 3D flight situations that the pilot originally experienced in the VR simulator. In the simulator, the pilot departed from John F. Kennedy Airport (KJFK) and landed at Republic Airport (KFRG), flying along the most economic path. Participants saw the aircraft graphics and terrains in 3D from the third-person view. After completing the flight operation, the participants then tested the MR application's replay mode, manipulating the progress bar in order to replay the flight operation from the beginning. After the participants tested all the application's functions, the experimenter issued them a questionnaire comprising four questions regarding their perceptions of the MR application with respect to its potential effectiveness in training. Table 1 shows the questionnaire applied in this test.

Table 1

Questionnaire Set

Question No.	Question
Q1	How do you think about the real time monitoring function both from the first-person view (the cockpit view) using the separate monitor and the third-person view using the HoloLens headset?
Q2	How do you think about the function of replay mode for flight debriefing?
Q3	How do you see the 3D graphics to evaluate the pilot's flight performance compared with the 2D-based applications or the 3D applications on the 2D screen?
Q4	Do you have any suggestion of function or design to add in this system for a good flight monitoring and debriefing system?

Participants

Six flight instructors who taught student pilots at Kent State University Aeronautics program were interviewed. Instructors' flight hours stood at 300, 730, 780, 2,700, 5,500, and 7,300, respectively. Participants were not compensated for their involvement in this study. Institutional Review Board (IRB) approval was granted, and its guidelines were followed throughout this research.

Evaluation Results

The questionnaire responses were interpreted qualitatively. The participants' responses comprised a mixture of positive and negative perceptions about the MR application. Perceptions differed between the group of instructors with more than 1,000 flight hours and the group of instructors with fewer than 1,000 flight hours. Comparatively, the instructors with more than 1,000 flight hours expressed more negative opinions on the use of the 3D MR application. Their responses to Question 1 included, "While monitoring the MR application, the instructor can miss observation of student's important control input in the cockpit." For Question 2, responses included, "There is not a lot of value for debriefing what is seen from the overhead perspective." These respondents mainly valued the cockpit view for monitoring students' performance and debriefing. For Question 3, responses included, "The 3D graphics on the 2D screen is better. Some features in the MR application were not recognizable." Comparatively, the instructors with fewer than 1,000 flight hours expressed more positive responses, such as, "It is useful to see how the deviation from the desired course happens from the 3D view while uncovering the student's bad habits in the cockpit" for Question 1. For Question 2, this group's responses included, "If I can point out the specific moment of student's error, I will be able to have a better discussion on how to correct future errors." For Question 3, this group's responses included, "The 3D application is more helpful to show students how the maneuvers they have performed actually look from outside the cockpit."

The design recommendations instructors provided in response to Question 4 included additional augmented graphics components, such as 3D bad-weather clouds and severe crosswinds by means of arrow lines, alphanumeric information for altitude and heading above the 3D aircraft graphics, and more other aircraft graphics. Adding a frame to the cockpit view displayed on the side wall in the MR application space—instead of users watching the separate monitor—was another effective design recommendation. The design recommendations also included visualizing eye-tracking trajectories to the VR cockpit view in order to evaluate students' visual attention.

Discussions

This study introduced an initial version of an innovative connected VR–MR system for pilot training that provides both the first-person and third-person views. Six flight instructors interacted with the developed 3D graphics to assess the third-person view situations, wearing a HoloLens headset in accordance with the experimenters' guidance. The empirical test outcomes did not show the system that provides both a first-person view-based VR simulation and a third-person view-based MR 3D application for monitoring and debriefing ongoing or finished flight tasks to be obviously effective and was not found to be more effective than either conventional first-person view-based VR simulations or VR simulations with a 2D debriefing map. However, the participating instructors, with fewer than 1,000 flight hours, suggested that the flexibility of providing both the first-person and third-person view options offered significant potential for better use in flight debriefing to point out pilots' weaknesses. This result indicates that these instructors understood the third-person views' benefit in flight debriefing. This study's prototype with both the first-person and third-person views was designed to enable users to selectively search for more useful perspectives about a situation—rather than focusing on the first-person view only. The instructors with fewer than 1,000 flight hours may have been more open to new technologies that could change their operational environment. Stating that the current debriefing scheme using only the first-person cockpit view is effective enough, the instructors with more than 1,000 flight hours nonetheless provided many valuable design recommendations. Figure 7 shows the added cockpit view, cloning the X-Plane's cockpit view to the HoloLens application, implementing the recommendation from the instructor with 2,700 flight hours. The cockpit view frame implemented inside the MR application involves a slight computer memory problem, with failing to process the high-resolution video file for the real-time monitoring mode. However, this function enables instructors to pay more attention to debriefing situations during the replay mode than while they watch the display monitor outside the MR application separately.

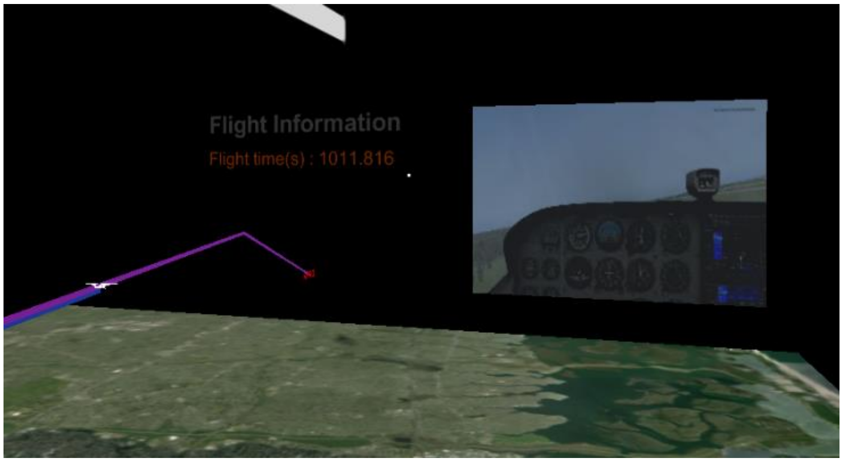

Figure 7. Added cockpit view in the HoloLens application, implementing a participant's recommendation.

A possible reason for the limited positive feedback is the prototype's insufficiency in terms of functional fidelity. Time synchronization between the VR simulation and the MR real-time monitoring mode was not accurately implemented, and the visualization of 3D graphics within the MR application was delayed by two to three seconds after the pilot did something in the VR simulator, maybe due to the HoloLens's hardware limitation. Moreover, graphically placing the aircraft on the ground before take-off was difficult in the 3D MR application, as was implementing an accurate elevation of the aircraft with respect to the ground terrain. The instructors with more than 1,000 flight hours had negative perceptions about the prototype due to the functionalities' incompleteness, inaccuracies, and their own preferences for conventional debriefing and training schemes that have been used. Since these instructors might have spent many years only monitoring pilots' behavior within the cockpit during simulator training sessions, they may not have felt the need for a third-person view in flight debriefing. The fidelity of the prototype's third-person view functionalities in the 3D environment should be high enough to attract expert pilots' interest.

Google Earth provides a web-based 3D flight trajectory application for flight debriefing. It visualizes 3D graphics on a 2D screen with a considerable amount of effective flight performance data in a well-organized website composition. Thus, the MR application in this study requires further functional upgrades to show that its holographic 3D features' effectiveness can surpass the Google Earth functions for situation awareness. The MR application's suggested advantage over the Google Earth functions is its easier orientation recognition because users do not need to rotate the 3D graphics' orientation.

Future Utilities of a Connected VR–MR-Based System

This study's prototype connected VR–MR system can be utilized in areas other than general aviation (GA) pilot training systems. First, it can apply to a military fighter pilot training system in order to monitor and debrief air-to-air and air-to-ground missions in the battlefield. The military application would be able to identify all the potential mission factors in order to improve strategies using 3D graphics of the battlefield and aircraft. Second, urban air mobility (UAM) can apply this system to overcome the limitation of conventional 2D traffic management displays monitoring 3D space in order to develop optimized flight paths in urban airspaces. Third, this system can apply to multiple unmanned aerial vehicles' (UAVs') conflict resolution or to UAVs' visualization of various mission factors using an effective 3D spatial representation (e.g., search and rescue mission in various regions).

The design recommendations acquired in this study provided insights for high-level design elements of future 3D applications. MR technology is flexible, and it can add more design elements to the holographic environment. For example, it can add more helpful flight related information proximal to aircraft graphics itself, rather than augmenting in the side space of MR application. The development of a multiple-MR-user version of the system will also be available

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for a collaborative debriefing system as the MR technology progresses. Kiyokawa (2007) showed that an AR system can be designed for a collaborative system for human communication. The visualization of sophisticated factors of safety and pilot situation awareness is another option. Aragon and Hearst (2005) tested an airflow hazard visualization for pilot safety in conventional flight simulations, and this visualization could be implemented in this study's MR application.

Conclusions

This study shows that a prototype connecting VR and MR can provide both the first-person and third-person views-flight situation monitoring and debriefing for the purpose of pilot training. Although the study's short interviews with six flight instructors indicated some limitations in considering this system as an effective pilot training scheme compared with conventional systems, the participated instructors with fewer flight hours expressed perceptions of the prototype's potential effectiveness using the third-person view. The proposed prototype should be evaluated again with higher fidelity after further development.

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References

Anne, A., Wang, Y., & Ropp, T. D. (2015). Using augmented reality and computer-generated three-dimensional models to improve training and technical tasks in aviation. *18th International Symposium on Aviation Psychology*, Dayton, OH (pp. 452-457).

Aragon, C. R., & Hearst, M. A. (2005, April). Improving aviation safety with information visualization: A flight simulation study. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, Portland, OR (pp. 441-450). https://doi.org/10.1145/1054972.1055033

Burgess, N. (2006). Spatial memory: How egocentric and allocentric combine. *Trends in Cognitive Sciences*, *10*(12), 551-557. https://doi.org/10.1016/j.tics.2006.10.005

Dixon, S., Fitzhugh, E., & Aleva, D. (2009, May). Human factors guidelines for applications of 3D perspectives: A literature review. In *Display Technologies and Applications for Defense, Security, and Avionics III* (Vol. 7327, p. 73270K). *International Society for Optics and Photonics,* San Diego, CA. https://doi.org/10.1117/12.820853

Eschen, H., Kötter, T., Rodeck, R., Harnisch, M., & Schüppstuhl, T. (2018). Augmented and virtual reality for inspection and maintenance processes in the aviation industry. *Procedia Manufacturing*, *19*, 156-163. https://doi.org/10.1016/j.promfg.2018.01.022

Fabroyir, H., & Teng, W.-C. (2018). Navigation in virtual environments using head-mounted displays: Allocentric vs. egocentric behaviors. *Computers in Human Behavior*, *80*, 331-343. https://doi.org/10.1016/j.chb.2017.11.033

Farrell, W. A. (2018). Learning becomes doing: Applying augmented and virtual reality to improve performance. *Performance Improvement*, *57*(4), 19-28. https://doi.org/10.1002/pfi.21775

Filimon, F. (2015). Are all spatial reference frames egocentric? Reinterpreting evidence for allocentric, object-centered, or world-centered reference frames. *Frontiers in Human Neuroscience*, *9*, 648. https://doi.org/10.3389/fnhum.2015.00648

Foyle, D. C., Andre, A. D., & Hooey, B. L. (2005, July). Situation awareness in an augmented reality cockpit: Design, viewpoints and cognitive glue. *Proceedings of the 11th International Conference on Human Computer Interaction*, Las Vegas, NV, Vol. 1, pp. 3-9.

Han, K., Shah, S. H. H., & Lee, J. W. (2019). Holographic mixed reality system for air traffic control and management. *Applied Sciences*, *9*(16), 3370. https://doi.org/10.3390/app9163370

Jo, G. S., Oh, K. J., Ha, I., Lee, K. S., Hong, M. D., Neumann, U., & You, S. (2014, June). A unified framework for augmented reality and knowledge-based systems in maintaining aircraft. In *Twenty-Sixth IAAI Conference*, Quebec City, Quebec, Canada.

Kallinen, K., Salminen, M., Ravaja, N., Kedzior, R., & Sääksjärvi, M. (2007). Presence and emotion in computer game players during 1st person vs. 3rd person playing view: Evidence from self-report, eye-tracking, and facial muscle activity data. *Proceedings of the PRESENCE*, Barcelona, Spain, 187-190.

Kiyokawa, K. (2007). Human communication in collaborative augmented reality systems. In *Emerging technologies of augmented reality: Interfaces and design* (pp. 236-260). IGI Global. https://doi.org/10.4018/9781599040660.ch012

Kosslyn, S. M. (1996). *Image and brain: The resolution of the imagery debate*. Cambridge, MA: MIT Press. https://doi.org/10.7551/mitpress/3653.001.0001

Liu, Y., Trapsilawati, F., Lan, Z., Sourina, O., Johan, H., Li, F., . . . Mueller-Wittig, W. (2019, July). Human factors evaluation of ATC operational procedures in relation to use of 3D display. In *International Conference on Applied Human Factors and Ergonomics*, Springer, Cham, Washington, DC, USA, (pp. 715-726). https://doi.org/10.1007/978-3-030-20503-4_64

Losey, S. (2018, October 2). The Air Force is revolutionizing the way airmen learn to be aviators. Retrieved May 5, 2020 from https://www.airforcetimes.com/news/your-air-force/2018/09/30/the-air-force-is-revolutionizing-the-way-airmen-learn-to-be-aviators/

Macchiarella, N. D., Liu, D., Gangadharan, S. N., Vincenzi, D. A., & Majoros, A. E. (2005, September). Augmented reality as a training medium for aviation/aerospace application. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, SAGE Publications, Los Angeles, CA, Vol. 49, No. 25, pp. 2174-2178. https://doi.org/10.1177/154193120504902512

Macchiarella, N. D., & Vincenzi, D. A. (2004, October). Augmented reality in a learning paradigm for flight aerospace maintenance training. In *The 23rd Digital Avionics Systems Conference (IEEE Cat. No. 04CH37576)*, Salt Lake City, UT, Vol. 1, pp. 5-D. https://doi.org/10.1109/DASC.2004.1391342

Meilinger, T., & Vosgerau, G. (2010, August). Putting egocentric and allocentric into perspective. In *International Conference on Spatial Cognition*, Springer, Berlin, Heidelberg, 207-221. https://doi.org/10.1007/978-3-642-14749-4_19

Millar, S. (1994). *Understanding and representing space: Theory and evidence from studies with blind and sighted children*. Raleigh, NC: Clarendon Press/Oxford University Press. https://doi.org/10.1093/acprof:oso/9780198521426.001.0001

Milner, A. D., & Goodale, M. A. (2008). Two visual systems re-viewed. *Neuropsychologia*, *46*(3), 774-785. https://doi.org/10.1016/j.neuropsychologia.2007.10.005

Regenbrecht, H., Baratoff, G., & Wilke, W. (2005). Augmented reality projects in the automotive and aerospace industries. *IEEE Computer Graphics and Applications*, *25*(6), 48-56. doi:10.1109/MCG.2005.124

Ruggiero, G., Iachini, T., Ruotolo, F., & Senese, V. P. (2009). Spatial memory: The role of egocentric and allocentric frames of reference. *Spatial Memory: Visuospatial Processes*, 1-25.

Ruotolo, F., van Der Ham, I. J., Iachini, T., & Postma, A. (2011). The relationship between allocentric and egocentric frames of reference and categorical and coordinate spatial information processing. *Quarterly Journal of Experimental Psychology*, *64*(6), 1138-1156. https://doi.org/10.1080/17470218.2010.539700

Wang, Y., Anne, A., & Ropp, T. (2016). Applying the technology acceptance model to understand aviation students' perceptions toward augmented reality maintenance training instruction. *International Journal of Aviation, Aeronautics, and Aerospace*, *3*(4), 3. https://doi.org/10.15394/ijaaa.2016.1144

Wen, W., Ishikawa, T., & Sato, T. (2013). Individual differences in the encoding processes of egocentric and allocentric survey knowledge. *Cognitive Science*, *37*(1), 176-192. https://doi.org/10.1111/cogs.12005

Wickens, C. D., Hollands, J. G., Banbury, S., & Parasuraman, R. (2015). *Engineering psychology and human performance*. Psychology Press. https://doi.org/10.4324/9781315665177

Wong, B. L., Rozzi, S., Boccalatte, A., Gaukrodger, S., Amaldi, P., Fields, B., . . . Martin, P. (2007). 3D-in-2D Displays for ATC.

Zhong, J. Y., & Kozhevnikov, M. (2016). Relating allocentric and egocentric survey-based representations to the self-reported use of a navigation strategy of egocentric spatial updating. *Journal of Environmental Psychology*, *46*, 154-175. https://doi.org/10.1016/j.jenvp.2016.04.007

DOI: https://doi.org/10.15394/jaaer.2021.1851