ImmersiFLY: Next Generation of Immersive Pilot Training

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***Abstract*—** After a considerable amount of simulation-based training, pilots still often encounter anxiety and tension during their first flight. Much of this can be traced back to the lack of realism in virtual simulators. Such simulators are meant to allow the trainee to become acquainted with the aircraft's instrumentation and to get a sense of real flight. Unfortunately, existing simulators do not provide a fully immersive experience of an actual flight. In this paper, we propose a merged reality flight simulation system that is immersive and that bridges the gap between flight training through a virtual simulator and real-world flight. Through our system, pilots achieve more realistic flight training and are able to feel more comfortable and confident during their first flight.

***Keywords*—** Telepresence, Flight Simulator, Merged Reality, Pilot training, UAV

I. Introduction

Contemporary high-end simulators have highly realistic inputs which include dashboards and instrumentation that are equal to that onboard aircrafts. But, the level of immersion stops at the latter. When looking at a simulator’s screen(s), it is noticeable that the world in which a flight takes place is merely virtual. Looking at a static screen(s) which displays a virtual environment can never truly break the barrier that allows pilots to feel as if they are actually flying in the real world, whilst being stationed in ground flight simulator.

Stephen M. Casner et al. [1] insisted that the lack of realism in these systems can often lead to pilots being unprepared for actual emergency situations. These simulators often run on near-predetermined flight patterns. When a pilot encounters an emergency situation during simulated training, it may feel as if they are merely pushing a set of buttons to get a predetermined output. Given the latter, it is possible that the pilot may not feel the urgency of the situation because the virtual emergency is systematic and training sessions may be very similar each time. It has been noted that, when training in simulators where these emergency events come at abnormal or less predetermined times, the reaction times of pilots were often magnitudes longer. This is reflected in crash data showing that pilots who should be trained for these abnormal encounters will sometimes not take the appropriate counter actions.

But, overall, the training process to become a multi-engine commercial pilot is very extensive. One must spend 30 hours doing ground training followed by 10 hours in a simulator [2][6]. After completing these requirements, a pilot must achieve 1,500 hours of total flight time. With all of these hours necessary to achieve certification, the training costs can outweigh the possible financial return for these pilots-in-training [3].

In this paper, we propose a flight simulation system that is immersive, economic and aims to allow for more efficient ground-based flight training.

II. State of the art

In order to receive an Airline Transport Pilot (ATP) certification, pilots need at least six hours of training in a Level-C full motion simulator [3]. A full motion Level-C simulator must have three key functions; six degrees of freedom, lower latency than level A and B, and a horizontal view of at least 75 degrees [4].

With the six degrees of freedom, most commercially available Level-C simulators are capable of making the pilot feel immersed, but their display systems are still not adequate to enable a fully immersive flight simulation. To achieve the notion of immersion, such flight simulation systems would need to address the factors that allow for high-resolution realism and high quality user engagement. Overall, an immersive flight simulator would allow the trainee to feel present onboard an actual flight [10]. However, current commercially available systems just use multiple large screens that display the flight environment and graphical interfaces which are far from realistic. One way to improve the level of immersion of the outside environment could be to use a single screen that surrounds the pilot, instead of having multiple large screens. The pilot would then be able to look around with basic head movements and not be disturbed by breaks between screens.

Valentino et al. in [5] created a flight simulator using Unity, a smartphone, a Samsung Galaxy Gear VR headset, and a gamepad. Their simulator allowed the pilot to travel across an expansive terrain but lacked realism in the visualizations and physical gestures. The functionality of the simulator was built to run on a mobile device. But, by making the simulator mobile-friendly it made its functionality not equal to that of a normal aircraft. With a main focus on mobile-friendliness, the simulator did not allow for physical motion since the pilot would be required to sit in a normal chair.

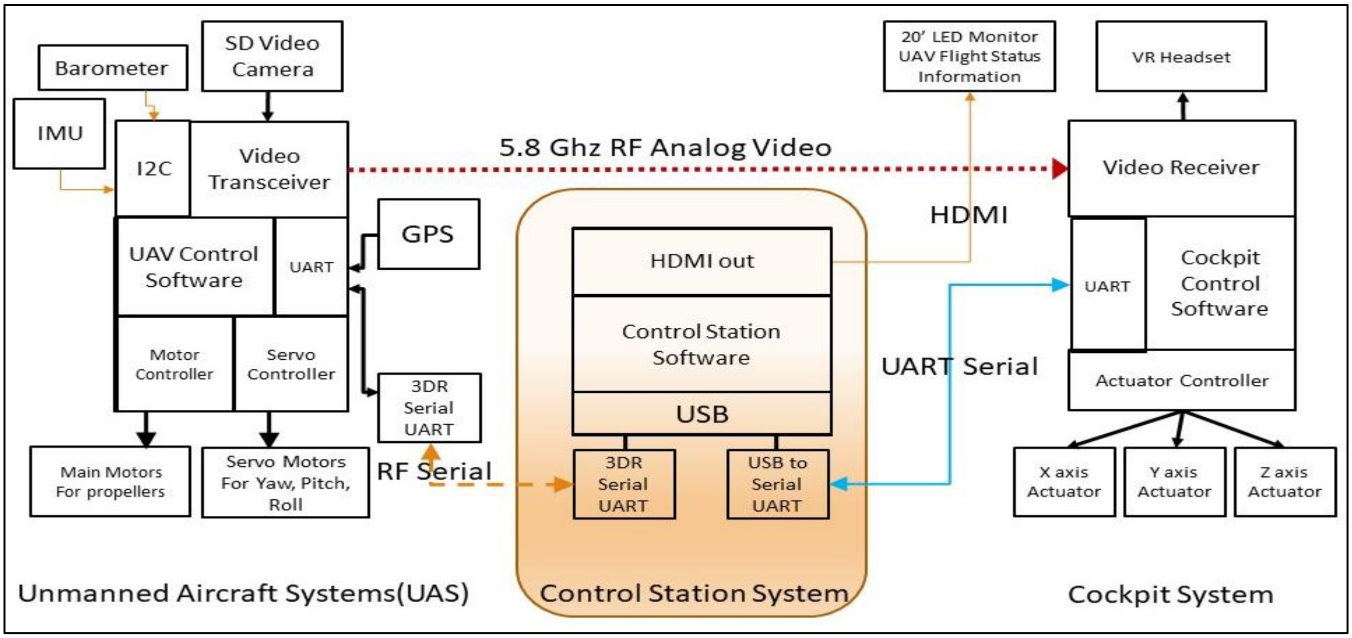

Fig. 1 ImmersiFLY System Architecture

The same can be said about the mobility of using single-monitor flight simulators which are not as immersive either. Another limiting factor was that the pilot was in a fixed view, and the headset did not register any head movements from the pilot.

Other approaches such as that of Yavrucuk's et al. [9] helicopter simulator, make use of hardware components to improve the level of immersion. The pilot is provided with a set of joysticks and pedals to control the helicopter. Furthermore, the pilot's hands are visible in the virtual world through the use of Data Gloves, which are displayed onto two LCD screens in a Cybermind SVGA Head-Mount-Display (HMD). In Gu et al. [8], another form of low cost flight simulator is discussed. This simulator uses some elements of merged reality, i.e. a headset allowing them to see their hand movements virtually, but the system is still massively reliant on a flight dynamics engine, JSBSim, to test their product. Considering existing simulators and previous research, the visual environment of any simulator could be greatly improved through the use of an actual aircraft and a camera that captures the area around the aircraft. Furthermore, to address the issue regarding the pilot being in a fixed position, there could be a mount for the camera that registers the pilot's head movements and replicates the motions accordingly. Our solution provides such features, allowing for a more advanced setup that surpasses the virtual world entirely. Without having to virtually simulate the movements of an aircraft or anomalies, such as turbulence, pilots will be better prepared to fly without ever leaving the ground.

III. Proposed Architecture

To address the issues with current pilot simulators, we developed an UAS-based pilot training system, called ImmersiFLY. ImmersiFLY is a merged reality simulator that enables pilots to feel as if they were flying an actual aircraft by giving them first-person-point-of-view (FPV) of the cockpit and the surrounding environment of an unmanned aircraft. Thus, it allows the pilot to explore the environment via head motions. The ability of modern day VR headsets to accurately track head motions at low latency, allows for a greater immersion into the cockpit. As the unmanned aircraft flies in the real world, pilots experience the real aerodynamics of piloting an aircraft in person. When changing conditions arise in the unmanned aircraft's environment such as wind direction, the pilot is able to notice the changes visually and physically through the head-mounted display and through the mechanical motions of the ground simulator, respectively.

The system architecture of ImmersiFLY is depicted in Fig. 1. It has three main subsystems; the unmanned aircraft system (UAS), the control station, and the cockpit simulator system (CSS). In order for the system to run efficiently all three of the subsystems need to communicate with each other. The UAS streams a video feed of it's cockpit into the control station. This video stream is transmitted over a 5GHz radio frequency signal. The stream is then displayed on the headset device which is part of the CSS.

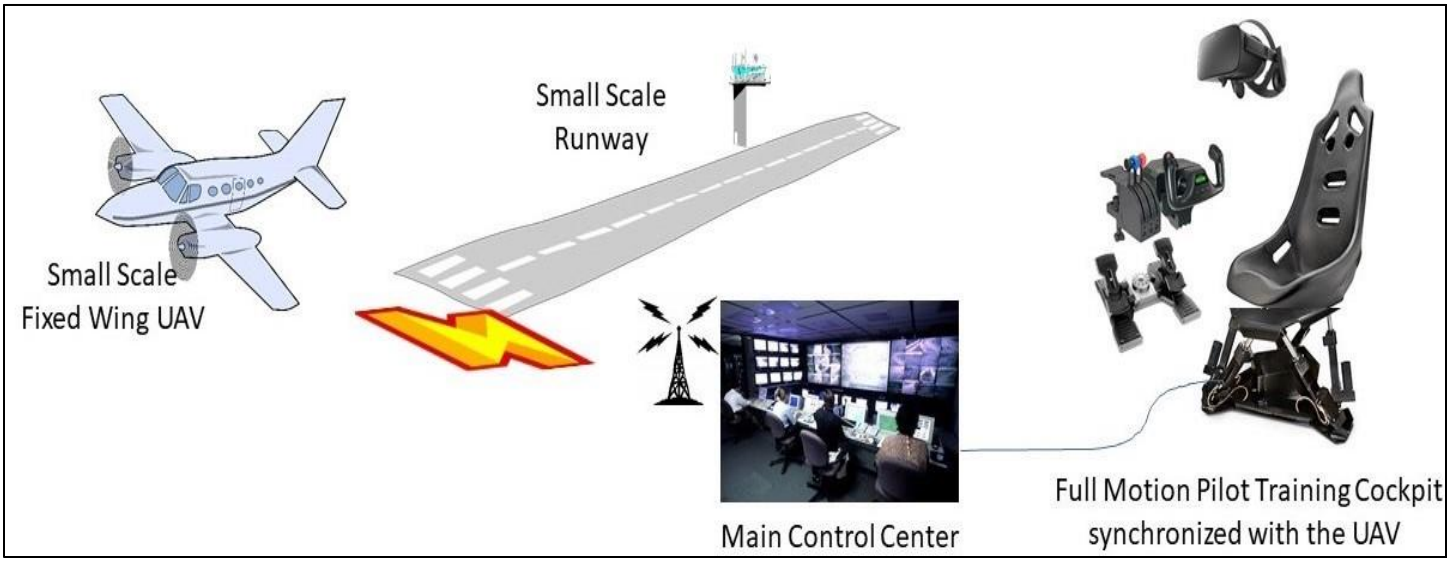

Fig. 2 Operational illustration of ImmersiFLY

In parallel, the UAS also sends data regarding the flight dynamics (roll, pitch, yaw) to the control station to be displayed on the monitor. The control station then sends this data to the CSS where the actuation of the motion chair takes place to replicate the dynamics of the UAS. In essence, such system would employ the features of a merged reality system. Our system is one that "merge[s] real and virtual worlds into the same new environment. In the new world physical and virtual objects exist simultaneously and interact in real time"[7].

The movement of the chair and view of an aircraft's dashboard and internal systems fixes the user's reality to be that of piloting an actual aerial vehicle while still confined to the motion chair.

IV. Preliminary work

Our current system is able to synchronize the CSS' motion chair to the motions of an unmanned aircraft. Internally, within the UAS, a pan-and-tilt hardware module holds a camera that streams video through to a socket connection. The socket connection is accessed through a smartphone application which also captures the pilot's head orientation and transmits it back to the UAS to be replicated as pan and tilt motions of the camera. The video stream is formatted and viewed through the smartphone application attached to a VR headset accessory.

ImmersiFLY merges simulated flight with real-life flight. This includes a motion chair, headset and an UAS that the pilot can control. The headset gives pilots a live view of what they would see if they were actually in the cockpit of the aircraft (UAS). The headset also collects the pilot's head motion through the use of an inertial measurement unit and sends the data to the pan-and-tilt camera module on the UAS. The camera module then mirrors how the pilot's head is moving. The UAS transmits back flight information and orientation measurements to the CSS motion chair to replicate via actuation, as illustrated in Fig. 2. The chair and headset allow the user to see and feel how they would if they were actually flying while controlling the UAS remotely.

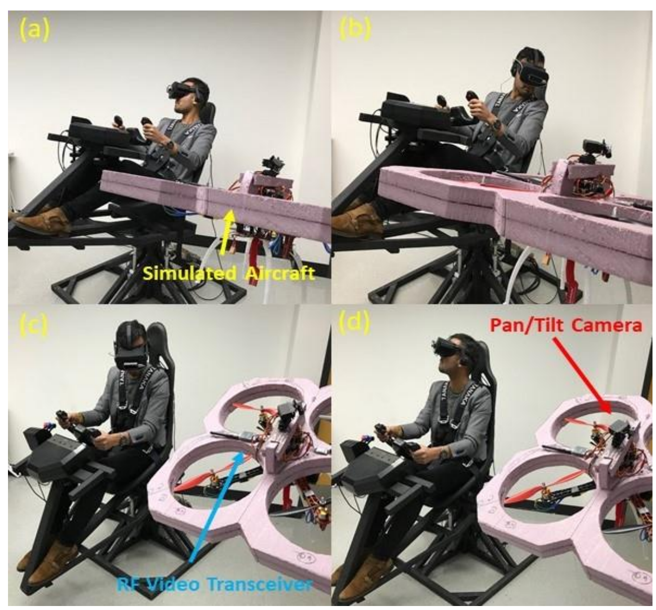

Fig. 3. Synchronization test between the Cockpit Simulator System and an Unmanned Aerial Systems

Figure 3 depicts a synchronization test between the Cockpit Simulator System and an Unmanned Aerial System. In this figure, we use a quadrotor that is equipped with a pan and tilt camera module to show how a pilot's head motions actuate the UAS' camera module. However, our final prototype is a fixed-wing aircraft that is internally equipped with a camera module, thus allowing the pilot to see the cockpit of the aircraft and the outside of the aircraft through the windows. Section (a) and (b) of Figure 3 show how an upwards pitch of the UAS drives the Cockpit Simulator System upwards and how in parallel the pilot's right and left head motion is replicated, respectively, by the radio-frequency camera module. Section (c) and (d) of Figure 3 show how a downward pitch of the UAS drive the Cockpit Simulator System downward and how in parallel the pilot's left-down head motion and right-up motion are replicated by the radio-frequency camera module.

V. Discussion and Future Work

ImmersiFLY is the first merged reality, closed-loop, flight-training simulator that can generate artifacts merged from a real and virtual flight for a highly immersive flight experience. Visual and auditory stimuli are captured by cameras and microphones, and send to the pilot's eyes and ears. Thus, it allows the pilot to see and hear as if flying an actual aircraft. Closing the loop of a real flight experience, the pilot can experience the aircraft's flight dynamics through the motion chair's replication of the aircraft's motions: six degrees-of-freedom, the three rotations pitch, roll and yaw; plus the three translational movements heave (up and down), sway (sideways) and surge (longitudinal).

Being a subset of the term virtual reality, the use of merged reality to improve on the flight experience brings health and safety concerns related to simulator sickness. Simulator sickness is known to arise when the brain requires extra effort to integrate visual artifacts with unexpected sensory input. It also known to take place when there inconsistencies in the pilot's expectations. For example, the pilot may rapidly bank the aircraft (roll motion) and expect to feel the flight dynamics of such rapid motion, but instead be provided with a slow or latent motion from the simulation chair. The latter could be due to various factors related to communication latency, or hardware and software issues. Therefore, emphasis on such issues is fully considered as part of our research and a mechanism that allows for a graceful degradation in the flight experience is currently being developed, prior to release of a commercially available product.

Furthermore, our current ongoing research focuses on developing an affordable integrated VR headset that uses cameras to superimpose the pilot's hands into the video stream received from the UAS. This could enhance the level of immersiveness by allowing the pilot to further receive visual stimuli of being present inside the aircraft. Further research is also taking place to explore the implications of touch feedback in our flight simulator. These two areas of research could be seen as a step towards a flight simulator that allows for telepresence - affording a pilot's cognitive and perceptual systems the feeling of presence.

The second development phase of ImmersiFLY, aims (1) to enhance immersion with various sensing and stimuli, (2) to optimize the hardware/software and (3) to minimize simulator sickness.

VI. Conclusions

In this paper, we proposed a novel UAS-based pilot training system, ImmersiFLY that merges together simulated flight and real-world flight in order to make training more realistic.

The usability analysis from the preliminary work indicated that affording a higher level of immersiveness provided through the actual flight of UAS, more responsibility and caution can be placed on pilots. Thus, it forces pilots to be more careful and conscious in how they maneuver the aircraft even during the use of our simulator. Eventually, it enables pilots to feel more comfortable during their first flight due to this merged experience of flight dynamics and the visuals of real-world flight during simulation-based training. In addition, it would also decrease the cost for pilot training by allowing for a more realistic ground training experience that could lead to more efficient flight training experience.

In the near future, we expect that our system will be introduced to many aviation schools as a standard flight-training program.

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