Preliminary Results of an Augmented Reality Tool for Supporting Remote Site Exploration

Francesca Vergara, Andrea Dan Ryals, Antonio Arenella, Lorenzo Pollini
Dipartimento di Ingegneria dell'Informazione
University of Pisa
Pisa, Italy
corresponding author: lorenzo.pollini@unipi.it

***Abstract*—This brief paper describes an augmented reality tool as proof of concept of a system for increasing situational awareness during remote site exploration: the system allows the operator see an avatar of its vehicle through the obstacles, as if they were transparent, and adds nearby obstacles as seen by a Lidar sensor as 3D features to facilitate the perception of depth, a key point in making the whole concept usable. The paper presents briefly the idea, highlights the need and importance of a calibration procedure, and shows preliminary results achieved in a controlled laboratory environment using a Meta Oculus Quest 2 and an indoor motion tracking system.**

I. Introduction

Situational awareness in remote piloting of a drone refers to the ability to understand the operational environment and potential hazards while flying from a remote location and is often tackled using cameras in the so called first-person-view piloting mode.

The key idea developed in this paper is to use augmented reality technology to improve the ability of remote pilots to maintain situational awareness and operate remote vehicles more safely and effectively: When the vehicle and its surroundings are in sight of the pilot, the pilot uses this information to control it by looking at it from his/her perspective, but when obstacles obstruct the view of the vehicle, augmented reality techniques can be employed to help the remote operator visualize the vehicle and its surroundings as he/she might see through obstacles.

Literature presents several attempts to tackle this problem, using various approaches [1], [2], [3], [4]. All these examples share a common issue: the need to perform a calibration between the reference system of the headset and a real world reference system: a fundamental step that cannot be considered a solved problem. Often registration between reference frames is performed manually with methods that are not suitable for a real outdoor large scale application.

One objective of this research is to define a calibration procedure that, although demonstrated in a laboratory setup, has the possibility of being replicated on a much larger scale and in outdoor scenarios.

Although cameras are one of the most commonly used sensors in UAV applications, and they play a critical role in situational awareness , another broadly used technology to sense and detect obstacles and potentially hazardous elements is LIDAR (Light Detection and Ranging) [5], [6], a technology that uses laser light to measure distances from surrounding objects. This information can be critical for a remote pilot to make informed decisions about the drone's flight path and to avoid potential hazards.

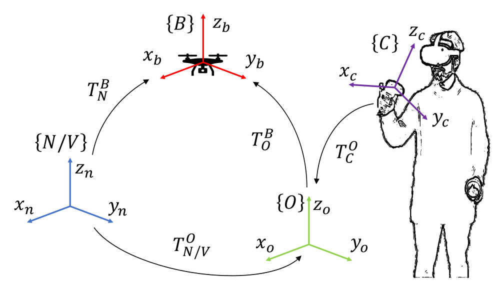

Fig. 1. Reference Frames

The second goal of this research is to present such information to the pilot in an innovative and intuitive way: lidar echos that all together describe the "borders" of the nearby obstacles will be displayed as 3D features in an augmented reality display, together with a 3D avatar of the vehicle, so that the pilot could easily tell where the vehicle is with respect to obstacles, even when behind them.

Since the images created in an augmented reality display are drawn with respect to reference system that is usually defined at device power on and can be arbitrarily different from the navigation system of the vehicle, a registration or calibration procedure is needed to achieve the desired goal.

II. Reference Frames Registration

The calibration procedure developed consists in measuring the motion of a known object in both reference frames along a certain trajectory and then to compute the relative roto-translation matrix (T_N^O in Figure 1). As reference object we used one of the Oculus Quest 2 Controllers, the augmented reality headset used in this research, placed on top of a mold that keeps it aligned with a known reference system on a calibration plate. The plate is moved arbitrarily and positions and orientations of plate and controller are recorded with respect their reference frames, then the calibration procedure is run. During the experiments, a Vicon motion capture system was used, while for future outdoor tests the actual vehicle navigation system will be used.

Fig. 2. Simulated Inspection Task - snapshots with and without showing the Lidar echos.

Calibration accuracy is key in obtaining a good situational awareness and safety of flight and it is well known to degrade when going away, as in the case of remote piloting, from the area where the calibration was performed. Thus, a three-steps procedure was developed:

1) Find a suitable initial guess for T_N^O by solving a least square problem using only the acquired position data (this is usually the standard and enough for most cases);
2) Refine the estimate of the rotation part only in T_N^O by weighting also attitude measurements;
3) Refine the estimate of the translation part only of T_N^O by minimizing again the re-projection error.

This approach proved in laboratory tests to produce the estimate with the lowest errors in areas afar from the calibration area. This is a fundamental feature of this approach since it should allow to maintain a better avatar-real vehicle superposition even when going away from the calibration area.

III. Experimental Results

Experiments were performed using a dummy vehicle, equipped with the entire set of sensors and computing power of a real multi-copter fit for indoor inspection.

In order to make obstacles, as seen from the Lidar sensor, visible as Augmented Reality features, each Lidar echo, namely a 3D point in the dummy vehicle reference frames representing where the laser ray has hit an obstacle, was transformed into a large blue dot in the Quest display, and positioned at the height of the dummy vehicle avatar (compensating for roll and pitch of the vehicle). Close-by blue dots form segments that actually represent the boundaries of the room and of all obstacles therein.

A physical wall was build in the room using foam panels and a flight was simulated. Figure 2 shows a series of snapshots taken from a video of the experiments with the vehicle going from in front of the wall (right hand side) to behind the wall (left hand side).

The upper part of Figure 2 shows how the scene would appear when showing the vehicle avatar only. It can be clearly seen that the vehicle is visible, thanks to its avatar, also when behind the wall, but, at the same time, it is also evident that telling, by looking at the avatar only, if the vehicle is in front or behind the wall is very difficult.

The lower part of Figure 2 shows instead how the scene would appear when showing the vehicle avatar and all the Lidar echos.In this case, the room borders that are currently in view of the Lidar become easy to tell and it is much easier to tell also when the vehicle is in front or behind the wall since the borders of the ”room” where the vehicle is entering become visible when going past the edge of the wall itself.

It becomes also possible to tell where the vehicle is with respect to the room it is in, with a clear advantage for keeping distance from walls or avoiding obstacles otherwise completely hidden. On our opinion, looking at the snapshots on the lower row and comparing them with the corresponding ones on the upper row makes the potential of this approach for situational awareness improvement evident.

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