GoAR: Augmented Reality drone navigation from multiple spatial sensors

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May 2019

Abstract

Drones and Augmented Reality (AR) have been gradually increasing their position in the future. Over the years scientific publications were testing and basing the central role of what augmented reality can bring to this branch. Throughout the project, we had different examples of how the combination of everything that had already been done can increment results in our final goal and key problem.

This project had as the main goal to present an implemented solution for the analysis of missions with drones, using augmented reality technology, and with this achieve better planning for future missions. With this prototype, we tried to aim to bigger cooperation between the participants, allowing the share of different analysis in a constant way. Thus, it was possible to generate a greater data dispersion in this 360-degree surrounding environment.

1. Introduction

Drones are more and more playing a fundamental role in the recent world driven by the technology advance. These UAVs has been used to capture different types of data in the most diverse application areas. Using a drone to operate a mission has fewer costs than if we had, for instance, a helicopter to execute the same mission. It is possible to enumerate more advantages like the dimensions, where we can now access locations not possible before, the fuel, flight time, security, easy to use and more. In a near future, drones will be responsible to assist in detection missions, in recognition and identification (DRI), in firefighting, in traffic monitoring, in event coverage, among multiple other applications. In this sense, this dissertation was carried out in collaboration with the TEKEVER business group, which, in turn, was the main driver of this augmented reality project.

1.1 Motivation

One of the major motivations was to help, using augmented reality (AR), the growth in mission analysis (mission replay) - Through the provision of other forms of interaction, as well as the increase of data and its organization driving to new meetings dynamics. It would be motivating as well, in the future to improve this technology to a point where it could be possible to interact with the objects that leads to a change in the course of events.

In today's mission replay application, TEKEVER finds a way to gauge the success or failure of a
mission that has already taken place. In this application, we can see in a single monitor different types of data such as a map of the terrain where the mission occurred and what decisions were taken. An area where is possible to selected data and visualize its evolution over time and another area with the different streams captured. Both of these areas have information captured by the airplane payloads (All components inside the drone).

It is through this program and in a meeting room that several collaborators meet and discuss the various points of the mission and, in the end, they can perceive which aspects they must maintain, need to be improved and/or difficulties encountered so that in a future mission can be corrected.

AR area is not only in a great rise in the current panorama but has still much to give. Being able to bring to our reality this form of innovation is undoubtedly one of the main motivations for the development of this project. The fact that other areas already do it and demonstrate promising results also becomes a motivating factor.

1.2 Problem Description

After a brief description of the current model in the motivation subtopic, we were able to identify some points to improve. Nowadays it is fairly easy to understand a video, but we can’t go further from what it is passed to us and realize in real time all the information that is made available to us and in a personalized way to our real needs. In short, that’s the problem.

Given the amount of information displayed on a single monitor and the need to switch between different views using the keyboard and mouse, we can quickly see several points as a distracting focus. Going into more detail, due to the high volume of information and its condensation into one monitor it is possible to see that our focus it will disperse frequently to other parameters than the essential, as well as the heap of views, overlaying each other almost making it impossible to observe the two views simultaneously (map and camera of the drone, for example), if necessary. It is still visible the effort that we have to provide to move near to our mouse or keyboard only to change between menus.

Following this reasoning, we observed that in a meeting scenario multiple collaborator try to discuss the critical points of the mission, but since only the application moderator controls the application, whether we like it or not, it manages the course of the presentation and so inevitably it is not possible to access all requests from all employees. In this way, it is impossible for all to make their contribution, for instance, evaluating important characteristics and presenting these same data in real time in a schematic and perceptible way or exploring a mission based on different parameters.

The fact that information is all agglomerated and concentrated in a single user is highlighted as one of the main focuses of the problem since in a discussion of ideas people cannot all interact in the same way in the conversation. Therefore, does not exist an environment so emerging, which in the end, results in a user very susceptible to other inputs from abroad.
1.3 Objectives

With the use of AR, it is possible to move from a monitor to a much larger viewing area, for example obtain a 180 or 360-degree view, depending on the necessities. Since, as we now have a larger area with which we can work, many of the problems described above were quickly resolved. Thus, it is possible to abstract the different views of the mission replay in multiple viewing areas, arranged around the room, such as the map, video player and some graphics.

Through interaction with simple drag and drop gestures, we can manipulate the order or even which video we want to watch at the moment, whether or not it is in the preview pane. There also exists a mapping of a table, which function as an alternative to gestural interaction, since some types of more specific and detailed interactions may eventually require the use of the table because it is simpler to handle and requires less effort in terms of positioning the superior members. The table is where you will find the selection panel of data captured by the drone's sensors, where other graphics will be created, among other features that are considered necessary.

With this work, we aim to prove that with the expertise of the latest augmented reality technologies will bring much less room for errors and failures and is advantageous at many levels like portability, setup time, tasks speed, terrain realism as well as airplane behavior, the collaboration between stakeholders, reduce mission costs and stimulation to the use of new technologies.

With this system, we intend to validate if we can achieve a better future planning of the missions, through a systematic analysis of them.

1.4 Document Structure

First, in section 2, we will identify some projects with similar purposes. These are divided into three categories: Drone Control and Missions Visualization, AR Applications for command and control and finally Others. In this section, we intend to explore the most diverse problems and realize how augmented reality can help in solving them. In section 3, we will explain our approach to these problems and how other augmented reality projects have influenced our solution. In section 4, we discuss how the tests will be performed and what the evaluation parameters are. Finally, in section 5 we present our final result and how it can help and/or be carried out in the future.

2 Related Work

Below we start describing information obtained in works and articles, which we considered relevant for the development of this project.

To organize the information, we decided to divide works and articles into three main subsections. The first one concerns the control of drones and visualization of missions. The second is about command and control AR applications. In the last group, we've included some global AR projects grouped by different areas.

2.1 Drone Control and Missions Visualization

In 2017, the 'Ground Replay Station' system was developed by SAAB [1]. This software allows, through a two-dimensional interface, the review of missions performed by aerial platforms through the visualization of multiple video streams.
Similar tools to 'Ground Replay Station' were developed by other entities, namely: the company Simulyze that presents the 'Mission Insight' [2], which in addition to the capabilities for planning and processing of data, also has a post-mission phase, with review capability.

With the advancement of time, a more complex system is presented by the company General Dynamics. They developed the TAC-MAAS tool [3], which includes several distinct capabilities of interest for Intelligence Surveillance and Reconnaissance operations, especially the post-mission 'Ground-based video replay' analysis and replication service. The TAC-MAAS is an advanced processing, exploration and dissemination of motion images (PED) software, which provides significant productivity and intelligence benefits for Intelligence Surveillance and Recognition (ISR) operations. The TAC-MAAS allows, for example, the graphics provision of multiple data collected and processed during and / or after the mission, georeferencing them and making them available on a terrain map, as well as generating mission reports, which facilitates a review of the most relevant parts by the users, in a fast and efficient way.

2.2 AR Application for command and control

In 2015, immersive viewers and the way they build spatial knowledge in multi-UAV operations will once again become a topic. This article, titled "Immersive displays for building spatial knowledge in multi-UAV operations" [4], presents an experience in which the operator needs to understand not only the 3D spatial relationships between UAVs but also how the UAV behaves in relation to obstacles.

In 2018 a Command and Control (C2) display system using the Microsoft HoloLens and the Intelligent Multi-UxV Planner with Adaptive Collaborative Control Technologies (IMPACT) has been developed as a demonstration of a new advanced user interface and that’s the theme of “Command and Control Collaboration Sand Table (C2-CST)” [5] article.

With this system it is possible for human-to-human-to-machine collaboration for situational awareness, decision making, and C2 planning and execution of simulated multiunmanned heterogeneous autonomous vehicles. The advanced user interface allows multiple operators to collaborate across a shared holographic sand table and control multiple vehicles.

Results showed that human interface improvements in the presentation, understanding, and collaboration for C2 systems can achieve better situational awareness, decision making and effective interaction.

2.3 Others

In this subsection, we will now talk about other projects that were very useful for the development of this prototype. In here we explore all the AR capabilities and see some examples of what it is possible to do. This way, we achieved a better adaptation to this kind of technology as well as some ideas for some developments.
After analyzing some other areas, presented in the main document, Microsoft itself offered a set of projects that helps developers to get accustomed to the technology and where a lot of capabilities are shown. Projects like Galaxy Explorer [6], Periodic Table of the Elements [7], Flying the lunar module [8] and Fragments [9].

2.4 Analysis

After analyzing the articles and works presented above, we find different types of visualizations, interactions, and applications. It is possible to verify different types of prototypes, some that relate to UAVs and others distributed in the different areas of knowledge. Studies have been done on different types of technology, including 2D, 3D, VR and AR and where different themes are discussed such as simulators for planning, missions’ reviews and Real-time applications for mission’s execution. In all, the results were very conclusive, because it was verified that through the separation and automation of concepts, it is possible to reduce the operator’s work, improve the planning of missions and also improve the mitigation of failures. We have also looked at the work that has been done in RA, in other areas, where unmanned vehicles are not protagonists, but other capabilities and ideas can be acquired.

It is noteworthy that several studies mention collaboration between the mission actors as the object of study and as a great improvement. It has therefore been taken into account as a focal point for implementation since it is intended to provide a great deal of freedom for users to be able to analyze the data they want and then be able to share any relevant information.

3 GoAR

In this chapter, we will talk about the execution of the GoAR prototype. It has been designed in AR and projected to bridge some of the current 2D application flaws, but also provide another more dynamic and optimized form of mission analysis with a strong collaborative component.

For the construction of this AR new capability being added to the actual MR, we used HoloLens glasses technology to reproduce an augmented reality environment. Not only because it was the device available by the company, but also due to the optical see-through system. These glasses have the technology for voice recognition, audio and countless sensors with different capacities, such as spatial mapping, gesture detection, among others.

Through some glasses functions, it is possible to create common endpoints that will serve as a communication portal for all collaborators. In this way, it is possible to take into account one or more points of observation common to all. The room will be mapped and will function as a 180º or 360º viewer, where the tables will be another way of interacting with the surrounding environment. The tables will have some commands, such as the selection of metadata supplied by the UAVS payloads, the manipulation of videos, among others.

To validate whether this AR component is feasible to be used or to perceive its strongest points has been defined a set of parameters that we consider fundamental to evaluate the success of mission review meetings.

Taking into account the 2D version and the RA, we chose as time factors the portability, the setup time of the Setup and the execution time of the tasks. Time factors were considered fundamental.
because they often influence the dynamics of work.

As factors for the minimization of errors and failures, I emphasize, among others, the realism of the terrain and the airplane and the arrangement of the different views. By reducing this critical factor, we can not only improve software and hardware but also achieve better planning of future missions. With regard to the cost reduction factor, the goal is always the same, to increase the quality and reduce the number of resources to achieve it.

Collaboration among users is highlighted as one of the most important factors, as it calls for the participation of all stakeholders in a mission review, in which everyone analyzes and makes their own contribution.

We also consider the stimulus for the use of new technologies as one of the factors.

3.1 Architecture

The architecture below shows the actual Mission Replay capabilities. Actually, there is an implemented 2D application that is used to review missions. Now one more feature will be added to that application, the Augmented Reality technology.

In a first analysis, we adopted an MVC approach. Where after a scan, a module is created to control the whole scene, what objects to create, what actions to do next, summarizing monitor the full pace of the application. Then two important module, Video & Metadata Streams and Metadata Selection, are placed in the world. The first one that supplied the current state, our data model, with information extracted from the drone’s components like described below and the second one that mapped the data of the current model in a view for the user to select what that he wished to observe.

The video of the mission that we are analysing had to be synchronized with the provided metadata so that we could explore the different parameters exhaustively and in detail. This point above was one of the challenges explored, being able to associate the data with the exact moments and integrate them as if they were part of the video itself. This implementation was performed using the FFmpeg framework. After synchronization and data extraction from the KLV stream, they will be stored in a data model, called Current State. Thus, any data that is needed will be readily available. From the moment that data exists in the data model, other modules can now consume the model.

All modules have different forms of interaction with each other. Mostly throughout events, but two more forms were utilized like http requests and voice recognition with a speech dictionary. Below each component is described in more detail.

3.2 UI

In terms of the user interface, it is important to note that the prototype offers many ways for the user to communicate with the application. The user interface has many forms of interaction,
being the gaze, gestures, and voice. With them, you can click the UI buttons that control the video player, for example, the play/pause, forward, rewind, speed control buttons and choose which metadata we want to analyze over time. With voice input, you can enable an overlay view, the HUD. The HUD also has different components, and all of them can be turned on or off by voice input.

The surrounding environment will consist of several panels. One more to the left responsible for the visualization of graphics, a central one for the reproduction of the video of the mission (with an anchor point, making it visible to every participant in the room) and still one more to the right that will be the panel of interaction between the collaborators. Also, to be highlighted is the inclusion in the middle of the field of view, below the central panel, the placement of a 3D map of the world with the respective elevations and also a drone model. Both will be in accordance with the data embedded in the video. Different additional information can be entered, such as mission waypoints, or other relevant factors. We would also like to point out a view mapped in a table for users to interact with the graphics views.

Some of the software will be based on the *Holotoolkit* Framework, which provides tools for user interaction with the application (both voice and gesture), spatial mapping components, user collaboration, and more.

3.3 Discussion

After this brief explanation of the architecture, it is possible to verify that this prototype presents the most different views and modules for good mission analysis, always taking into account the collaborative component between users. In this sense, using all that has been explained previously, it is possible to observe how the whole application works. Firstly, a user is asked to be responsible for mapping the room. Then anchor points are created for all users in the room, namely Video Player and Share View. Once the common points have been created the remaining components are created by the scene controller, which are unique for each user, among them navigation map, graphics with metadata and metadata selection. After all this process it is then time to begin to analyze the mission, being this one customizable according to the preference of each one. Once a failure or something significant is detected, users can share what are seeing with all the staff present at the meeting.

Next, we intend to demonstrate the results of the AR prototype and compare them with what is currently in Mission Replay 2D.

4 Evaluation

For this project, the evaluation consisted of only one final phase of testing.
In this phase, a prototype of the product was already presented with all the implemented requirements. Thus, with the enrolment of 8 users, a conference room and HoloLens goggles, they undertook a review of a mission using AR technology. Data sharing, mission visualization, interaction with the data visualization model, both by gestures and voice, dynamic visualization of the mission through the map presented below the panel and correct synchronization of all data with the different modules were tested. During the tests, the same users who tested in AR performed the same tasks in the mission replay 2D model. After this evaluation, it was time to evaluate the results of the tests performed, and thus, to know in which points it is necessary to improve and where are the gains of this aspect in RA of MR.

4.1 Methodology

The main objective of the evaluation was to see if users were prepared to transition to the AR version in cooperative meetings or individual analyzes.

The users, in a TEKEVER meeting room with some specific equipment, had a set of steps to follow where each one needed to complete tasks individually detailed in the next section. It was asked for them to perform these in sequence, and the Test Coordinator provided an order of execution.

The methodology of conducting the tests assumes the following steps, Distribution of the Testing Guide and its reading by users, users fill in an Initial Questionnaire to register the user profile and its demographic characteristics, a brief presentation of the project to users, including their objectives and operation, demonstration by the Test Coordinator of prototype functionalities, free trial of the prototype by the user, execution by the user of the three tasks indicated by the Test Coordinator in AR, execution by the user of the three tasks indicated by the Test Coordinator in AR by the second time, execution by the user of the three tasks indicated by the Test Coordinator in the MR 2D application, completion, by the user, of a Final Questionnaire to record their experience and opinion about the test performed.

4.2 Results Analysis

In order to test the performance of the application, eight users were asked to respond to a set of questionnaires and perform predefined tasks, explained at the testing guide.

The tasks were performed in a predefined order, being that initially an initial questionnaire was carried out, going through the execution of the tasks and finally a final questionnaire in which each one of the users gives his opinion on the experience.

The first step had as a purpose to create the user profile, then took place a quantitative analysis, followed by a qualitative analysis. For more details about the results it’s possible to fall back on the main document.
4.3 Discussion

After the formal completion of the tests, it was possible to obtain feedback from several users, who in general were all very pleased with the experience provided. In this way and after an analysis of the results, I believe I can say that the tests were carried out successfully.

Next, the results obtained in the previous section will be analyzed. Starting from the relationship of the user's experience with the tasks times obtained in the first test it was found that all those who already showed experience in the use of augmented reality with glasses, had immediately more satisfactory results than those users who were starting in this technology. Now making the bridge for the second test, and after the users have two adaptation phases, one during the first contact with the application and other in the first test, a substantial reduction of the tasks times was observed by almost all. The exception belongs to those who already have high levels of experience. This shows that it is a fast-paced application.

In order to obtain some comparison times between mission replay applications, the same users were asked to try to perform the same tasks proposed in AR, now in an already well-integrated application for mission analysis, the 2D Mission Replay. Overall comparing the results of the first AR test with the MR 2D test, the last generally shows some gains compared to GoAR. However, when compared to the second AR test the results were very similar. Note that the users found plenty of difficulties in completing the MR 2D tests. This happens because this application does not have some features that the AR application presents.

A common point to all users was the almost unanimity in answers, regarding the proper functioning of the application in all views presented by the AR application and also that the prototype presents very good tools for collaboration.

5 Conclusion

The development of the present study allowed an analysis of how the creation of software using augmented reality technologies can increase improvements in the quality of aeronautical mission analysis. This involved a literature search that could substantiate this claim either through written documentation about applications related to drone control and visualization of missions or from AR applications. In general, after the analysis of the selected articles, it was verified that through the separation and automation of concepts, it is possible to reduce the operator's work, as well as to improve the planning of missions reducing the place to failures.

It was decided to present chronologically subsequent articles within the subtopics, in order to analyze the evolution of augmented reality technology and how it contributed in each time period to the most different areas, with special attention to the area of focus of the project, aeronautics.

The goal of this work was to bring the best of augmented reality and what each of the articles has to offer, and apply it to Mission Replay, based on a broader visualization format with resources to various forms of interaction and arrangement.
of simultaneous images, giving freedom of choice to the operator, and following a model that aims at a greater abstraction of the visualizations. With all of this combine it was possible to bring to life a prototype for mission review with a view to better future planning.

As a future work there is still much work to be done. Not only in terms of UI but also features. Currently, in terms of UI, telemetry and other data are mapped to a table, accessible with a gaze and gestures, but in the near future, the table will be provided with some sensors, allowing users to click on the table just like any other 2D interface we are accustomed. This will be an improvement, as it will allow users to rest their upper limbs, used in most other interactions. One more upgrade to the interface will be in the navigation map where we’ll be able to check the mission waypoints as well as the view from the different cameras inside the airplane.

With these upgrades and some more in terms of software to control the airplane in a near future maybe we’ll be able not only to replay mission but also watch in real time and even control the drone.

References


5. Bryan L. Croft; Crisrael Lucero; David Neurnberger; Fred Greene; Allen Qiu; Roni Higgins and Eric Gustafson,“Command and Control Collaboration Sand Table”; 2018


