

Augmented Reality Assistance in Forest Fire Fighting

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Abstract

Forest fire fighting is unfortunately a very important activity for many fire departments. A forest fire is always a very complex situation to manage, in which lots of ground teams and aircraft have to cooperate in order to control such an incident. Aircraft fleet has an important role: the identification, selection and notification of elements of interest. The current problem is the lack of a precise and effective technology to assist this task. In this work, we describe the definition and application of a low-cost augmented reality solution that allows an accurate selection of all the items an aircraft is able to visualize from its privileged position, and the integration of this information in a 3D terrain visualization system in real-time.

Categories and Subject Descriptors (according to ACM CCS): I.3.6 [Computer Graphics]: Interaction techniques

1. Introduction

Forest fire fighting is an important activity for many fire departments. In this kind of emergency situations, the centralization of all the information is critical. Dozens of ground units (vehicles, volunteers, heavy equipment, emergency crews, police etc.) and several aircraft are usually assigned to the affected area.

A 3D terrain visualization system in real-time is an important first step in order to control all the involved elements in a unique scene. Using the orthophoto and the DEM (Digital Elevation Model) of the affected area, and a fleet control system (GPS and a communication device like a radio transmitter), it is possible to visualize what it is happening in real-time (up-to-date position and status information of all the resources deployed in the area).

The problem comes when there are elements taking part in the incident which positions are unknown (like volunteers, police, ambulances, and other emergency crews of different divisions or without GPS devices). In this case, the role of some of the aircraft is essential.

In such a situation, an aircraft, thanks to its privileged position, is able to identify and find all the elements of interest, and not only ground units but important events like new surrounding fires, people who needs assistance etc. Currently, just static images and informal communication (radio) are

the only possibilities in order to transmit these elements of interest to the headquarters or fire-control centers and command posts. The consequences of such a situation are severe misunderstandings that provoke serious problems and important delays in the fire extinguishment.

In the present work, an Augmented Reality (AR) solution that solves this problem is presented. The basic idea is firstly, as it is common in AR applications, to supplement what the aircraft crew is able to see with virtual information (that helps in their understanding of the environment). Secondly, and even more important, to be able to transmit to the fire-control center an accurate (perfectly geo-referenced) position of any important element or event the aircraft identifies. Based on a video monitor AR scheme (see [Azu97]), an operator on the aircraft is able to identify and select an accurate position (in UTM coordinates) of any element. This information is immediately transmitted using GPRS, allowing in this way one of the most important objectives of this project: a formal and accurate selection and notification of elements of interest. This avoids informal (radio conversations) communication between aircraft and the fire-control center.

The solution has been developed with a low-cost platform: a PC computer with touch-screen, a calibrated standard video camera with a tracking device, a GPS and a GPRS

device. The system is being used by the fire department of the province of Alicante in Spain.

2. Related work

AR is becoming a real productivity tool in several fields (see [ABB*01]), providing very powerful and flexible solutions in human-computer interaction. AR is useful either for supplementing the real world vision with functional virtual information or for allowing the user a comfortable interaction and selection mechanism of environmental elements.

On the other hand, 3D terrain visualization techniques are currently able to provide real-time functionality on PC machines, even with huge terrain areas (geometry and texture) locally or through the use of streaming technology (see [LP02], [LH04] and [HDJ05]). A proof of that is the spread of several earth navigation systems that works with global geographic information through advanced streaming techniques (see [goo]). This evolution is forcing the migration of the traditional GIS (Geographic Information Systems) to a 3D framework (also called 3D GIS systems).

GIS solutions have been used for a long time as an assistance tool in forest fire fighting (see [GXS94] and [PPL*05] for two examples). Basically they are used as extensions of traditional fleet control systems, with additional and specific features for fire control and management. Another well-known solution is the GeoMAC system (see [geo]), a real-time application that provides geospatial information on the status, location and proximity of wild fires to life, property and infrastructure, using GPS data and infrared imagery from fixed wing and satellite platforms. Even 3D-based solutions have been previously described (see [FVF*02]) in which the 3D component helps in the interpretation of what is happening and in the decision making process.

The main purpose of the present work is to take the most of these technologies and to integrate an AR solution in order to guarantee the additional management and control of non-GPS tracked elements in the fire.

3. The global project

In Figure 7 a general diagram of the global project is presented. The main purpose is to have in just one 3D scene all available information about the fire.

A specifically developed 3D terrain engine for the project, with GIS functionalities, is installed in the fire-control system. There, all the resources deployed can be visualized over the 3D scene (current status and also the possibility to analyze any previous period), as it can be seen in Figure 1.

Most of the fire fighters' vehicles and crews transmit, with a GPS and a trunked radio transmitter, their beacons to the fire-control center. A copy of the current status is also sent to the command posts which have also a 3D terrain visualization engine.

Part of the aircraft fleet has a very important role: identification, selection and notification of all the non-GPS controlled elements and events of interest, for what an AR application has been developed as is going to be described next.

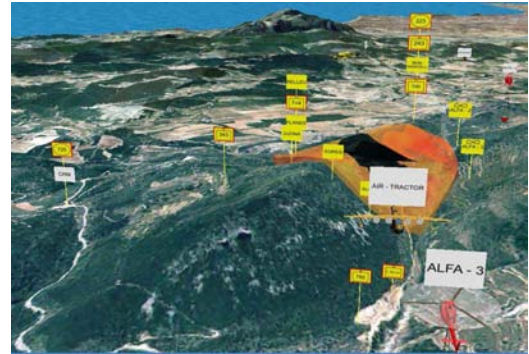


Figure 1: *The application installed at the fire-control centre visualizing all the resources deployed in a forest fire. Some of them correspond to beacons sent by the AR solution.*

4. AR identification and selection from the aircraft

In the development of the forest fire control system, the elements without GPS and communication devices and any kind of events that happen over the affected area are the main problem, and their perfect geo-referencing is a challenge. Our solution for the aircraft based on AR becomes an important advance over the traditional 'see and notify' informal method.

From the very beginning of the project, the main objectives were:

- To provide to the aircraft crew virtual information of interest as a supplement to the camera images (standard AR functionality).
- To guarantee a highly accurate geo-referencing process in the selection of important items. The correctness of the beacons received is critical.
- To be able to provide a low-cost solution, taking the most of the current hardware and devices installed on the aircraft.
- To design a practical and easy-to-use software solution. The operator of the system (normally the second aboard) suffers from continuous motion and limited room (factors that jeopardize the quality of the operator selections).

In order to accomplish these requirements, a video monitor AR scheme was developed. The different elements of this system can be seen in Figure 8.

4.1. Previous infrastructure

A common infrastructure on aircraft used for forest fire management is composed by a video system able to transmit

static images and video to the fire-control center. The objective of our work was to be able to complement this configuration with low-cost elements in order to allow an AR functionality.

Initially, it was even possible to use an already installed magnetometer and inclinometer, with which it was possible to get the camera yaw and pitch. The second aboard, using a joystick, is able to turn the camera up-down and left-right. The magnetometer was connected via RS-232 at 9600bps with a 100Hz rate to one of the serial ports. The inclinometer was connected to another serial port using a RS-485 to RS-232 converter. Due to the RS-485 half-duplex nature, the speed was much inferior (a 15ms delay in sending information request, 300ms in the request processing and 15ms in the inclinometer switching to reception mode), having finally a 2Hz rate. The inclinometer error was less than 0.15 degrees. The GPS was connected to another RS-232 serial port at 9600bps, with a 1Hz rate and an error of 8 meters in 90% of the time.

With this configuration, it was possible to send, using GPRS, a static image, the position of the aircraft and the yaw and pitch of the camera (a Canon GL1) when the image was captured. This originally installed system provided a limited functionality, not being able to avoid the use of radio conversations for the notification of elements of interest and their positions.

4.2. Camera settings and tracking

With the equipment described in the previous section as the starting point, a new inclinometer was introduced in order to get the camera roll (see Figure 2). The angles were sent to a preliminary version of the AR application as well as a required offset in order to correct the misalignment between camera and the different measurement devices.

This first solution worked perfectly in ground tests and quite reasonably on helicopters, but a new problem arose when it was tested on airplanes. An important misalignment was produced in the horizon line when the airplane turned left or right (producing a centrifugal force). In such a condition, the inclinometers, which work by gravity, generated a significant error in their measures.

In order to solve this problem, the introduction of a new gyro-stabilized tracking device was required. A specific model, 3DM-GX1, was selected for this mission, specifically designed for air navigation. This device offers a 100Hz rate (processed data) and 350Hz rate (unprocessed data). Since this device provides the three required angles, it substituted also the previous installed devices. Working on a RS-232 port at 38400bps, it has a precision of ± 0.1 degrees in static conditions and ± 2 degrees in dynamic conditions. One of the possible returned data from this device is the orientation matrix which it is directly used for the AR solution.



Figure 2: *The first approach to the camera tracking, with two inclinometers and a magnetometer, was successful in ground tests and over helicopters, but insufficient for airplanes.*

With this device, the overall rate of the camera tracking and positioning is still 1Hz due the GPS device.

In the camera calibration, a practical consideration was taken: to use only two possible zooms, i.e., the two extremes (15 and 45 degrees). This simplification was common in the previous procedure.

The angular aperture was calculated manually. Focusing the camera in order to have a particular signal (a point) in one extreme, the final angle was obtained by turning the camera (only in the proper direction) until the signal was in the opposite extreme.

The final adjustment between the virtual and real world is very accurate, being the GPS rate, 1Hz, the one which influences the most in the overall system. Some captures of the system running can be seen in Figure 3.

4.3. Selection of items of interest

In the development of the solution, besides the classic problems related with AR techniques (optical distortions, mechanical misalignments, tracking errors, incorrect viewing parameters, etc.) it was necessary to consider the special conditions in which the system operators carry out their work: continuous motion and lack of room.

Furthermore, it is critical to guarantee the maximum accuracy in the selection of points of interest, and this is particularly complex when the selection is undertaken over large terrain areas, generally in perspective, where errors can be easily magnified.

In such a condition, the traditional selection process which is directly done over the real image can jeopardize

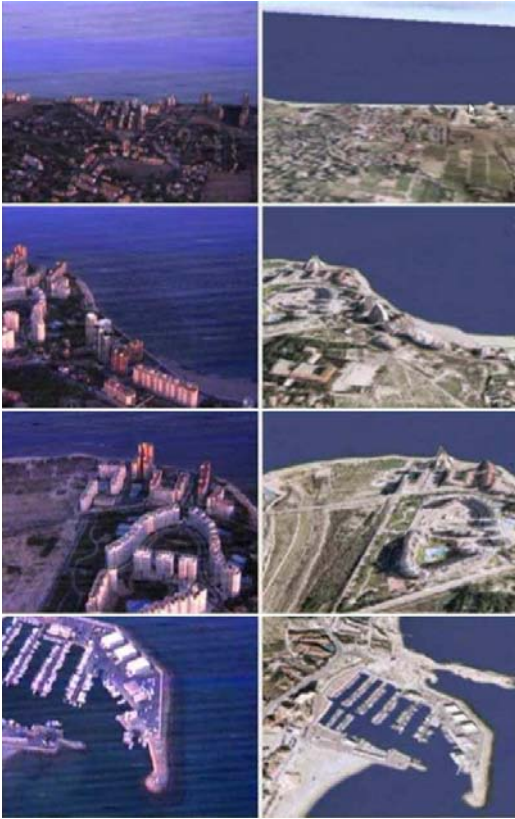


Figure 3: Some examples of pairs of virtual and real images obtained by the AR solution (left real, right virtual). A high degree of alignment has been achieved. The last row is the worst, which was taken when the airplane was turning left where, although a gyro-stabilized tracker was used, the error in the angle measurements are greater (+2 degrees).

the accuracy of the selection. This is the reason that justifies a dual vision, virtual and real, over a split screen application.

The operator is invited to undertake the selection directly over a frozen virtual scene, ensuring a highly effective georeferencing of the elements of interest by an accurate calculation of the intersections against terrain geometry (see Figure 4). Thanks to the GIS functionality of the system, the operator is even able to trace the fire edge through a polygon generation (see Figure 5).

4.4. 3D terrain visualization engine

The 3D terrain visualization solution used in the AR application and fire-control center is a specific implementation of the ROAM2 algorithm (see [HDJ05]). Specifically designed for working with huge (even planetary) orthophotos and MDEs, this multiresolution algorithm divides their structures using diamonds as the basic primitive. Starting

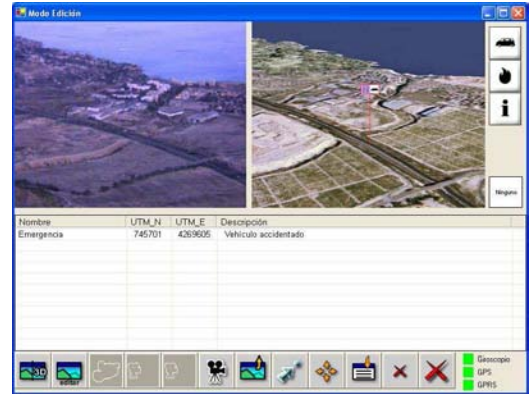


Figure 4: Process in which the operator is able to select elements of interest. The application offers a split screen, one half for the real image from the camera and the other half its virtual correspondence. The operator is invited to select an icon which represents the event or element of interest and to indicate its accurate position over the virtual scene (which the user can froze at any time). A working place in motion, the errors produce by the devices and the necessity of a high accuracy, justify this approach.

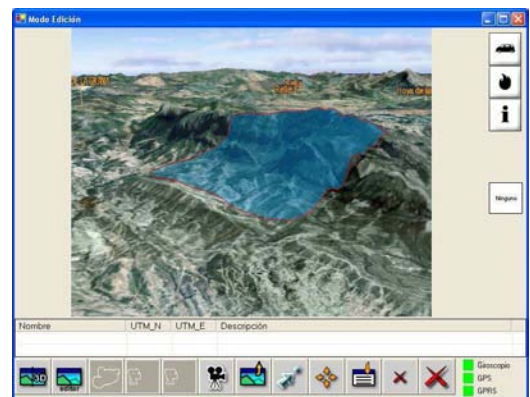


Figure 5: One of the additional functionalities the system offers to the aircraft operator is the selection of the fire edge. This is particularly interesting since its privilege position is decisive in determining this area. This information, a polygon, can be traced just by clicking over a frozen virtual image.

with one diamond, an error function and a split/merge dual queue structure, this algorithm provides a very efficient technique for general terrain visualization purposes. Catching and streaming capabilities were also added.

Finally, some GIS features were integrated in the engine in order to allow, among others, these two possibilities:

- Additional raster images with alpha blending controlled

by the user (raster layers supporting geographical information).

- Vector information: labels, polylines, polygons, etc. all geo-referenced and even with the possibility of adapting their traces to the MDE heights.

In the Figure 6, a screenshot with the most important elements can be seen.

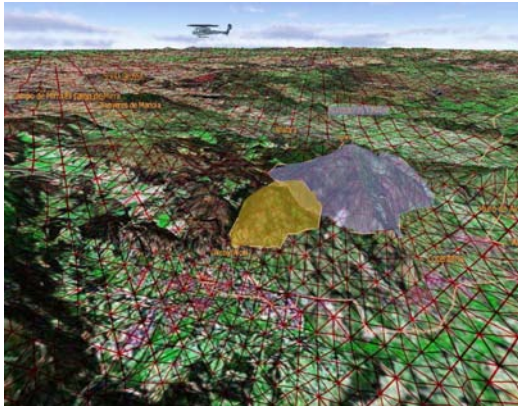


Figure 6: The 3D terrain engine developed for the project. It takes the most of a specific implementation of the ROAM2 algorithm, and supports several GIS functionalities.

5. Conclusions

In the present paper, an AR application for assisting the forest fire control has been presented. This new solution is centered in solving one of the major problems in such an incident: the geo-referencing of all the uncontrolled elements (non-GPS actors and events of interest) that are visible from the privileged position of the aircraft.

After solving different problems with the devices used, a low-cost configuration has been achieved, in which a highly accurate selection is always possible by the system operator. This is possible by letting the operator select the elements over a frozen image of the virtual 3D scene, always seen with the real one in a split screen. Thanks to this approach, the difficult environment in which the operator is located when using the application does not affect the quality of the information sent to the fire-control center.

The development of a 3D terrain engine with GIS functionalities allows additional features like the fire edge definition by the operator. This information is also sent in real-time to the fire-control system, allowing them to use it in the analysis of the fire spreading.

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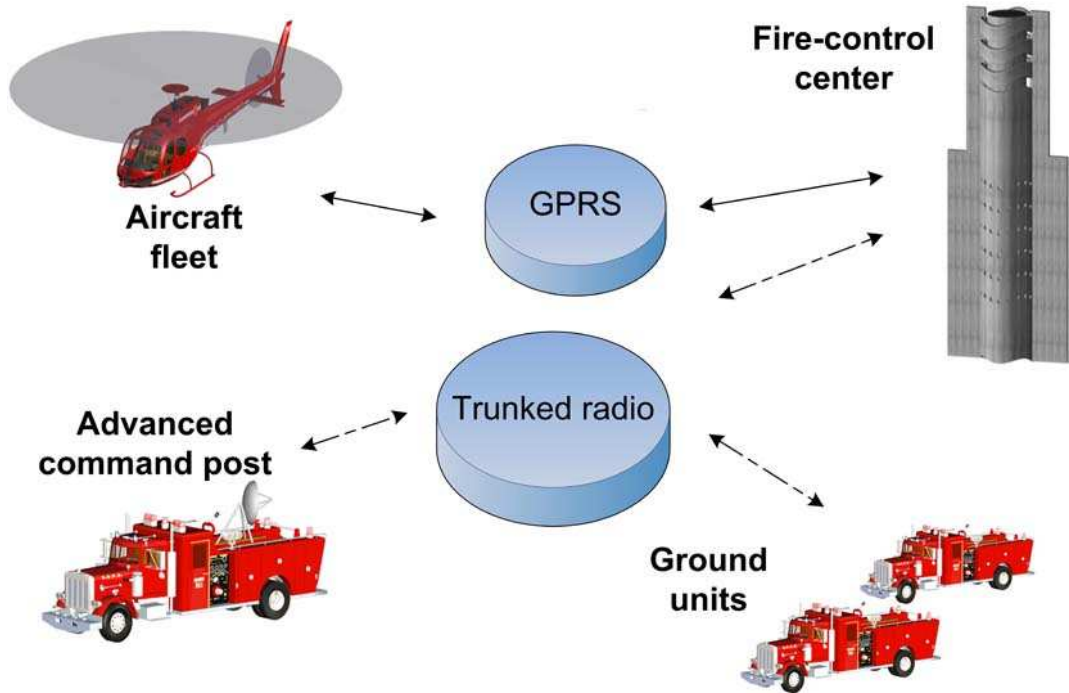


Figure 7: The global project for the fire department of the province of Alicante in Spain. In this paper, the AR solution for the aircraft is presented.



Figure 8: The main hardware components of the AR solution. A GPS and a video camera, controlled by a joystick, are already existent elements and very common on aircraft used for forest fire fighting. A tracking device and a PC with touch-screen are the only new additions to the system.