MOBILE AUGMENTED REALITY FOR FLOOD EVENTS MANAGEMENT

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ABSTRACT

The frequency of flood events worldwide has increased significantly over the past decades, and with it so has the need to employ information technologies able to help mobile workforces, both technicians and volunteers, during surveys in the emergency phases. In view of this, a client-server framework for the development of a mobile application that uses Augmented Reality (AR) was implemented. This platform, which increases visual perception of the real world merging additional information with the natural scene in real time, allows mobile workforces to more easily reach the most critical areas subject to flooding and rapidly make a decision on the level of flood protection. The performance of the prototype was evaluated on the Bradano river, located in the south-eastern Basilicata region (Italy), both in a real case study and in a simulated one. The obtained results show how the application represents an innovative tool compared to the existing ones, being it able to show, timely and continuously up-to-date, augmented information on various vulnerability scenarios during the emergency phases, helping both technical and non-technical operators to quickly intervene, containing or preventing secondary disasters, thus reducing deaths and injuries, and limiting the resulting economic losses and social disruption.

Keywords: augmented reality, field surveys, flood event, GUI, mobile application, POI

1 INTRODUCTION

Floods are among the most devastating natural hazards in the world, claiming more lives and causing more property damage than any other natural phenomenon. The EMDAT database of the Centre for Research on the Epidemiology of Disasters (CRED) shows that flooding caused the majority of calamities between 1994 and 2013, accounting for 43% of all recorded events and affecting nearly 2.5 billion people (CRED [1]). In the next 15 years flood events in the world are expected to triple due to climate changes, growing of population and development of urban zones. According to the World Resources Institute (Luo *et al*. [2]), the number of people at risk within the flood-prone areas will rise from 21 million today to 54 million in 2030. Despite an increase in flood protection investments during the last two decades, the population tends to grow in socio-economically attractive flood-prone areas, and it is therefore likely that the vulnerability level of such areas will continue to increase in the future.

For these reasons, it is advisable to employ technologically advanced systems, which support emergency and mitigation actions.

Today, a number of applications are available to array and display data for technical experts, to explain programs of flood damage reduction to the decision makers, and to communicate real-time forecasts and warnings to the public. However, the majority of them are generally limited to tabular data, basic 2D plot visualisation, or standard 2D GIS tools designed for the desktop and not suitable for mobile use. Moreover, the existing tools are not interactive enough to be able to update the information easily, nor are they flexible enough to develop scenarios and provide visual and quantitative information regarding the real-time status during the forecasted event, often having restricted connectivity and limited

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interoperability. In a more flexible and interactive direction, a client-server framework for the development of a mobile application that uses AR has been implemented by the present research. It could help field workers to quickly move within the critical areas during an extreme event, in order to communicate the state of structures and infrastructures to the operating centre in real time and identify the mitigation measure. AR technology allows the user to see virtual elements generated by the computer overlaying onto the visual perception of physical reality through a camera (Hincapie *et al*. [3]). This virtual-real merge is achieved via the appropriate GUIs on portable devices (smartphones, tablets, etc.) handheld by the user.

Commercially, AR is mainly found in mobile applications and, in recent years, has attracted wider interest from businesses. The fields of application are potentially endless, including the display of information, navigation in real-world environments, advertising, art and games (Geroimenko [4]). In water resources management, the application of AR is still restricted, despite its recognised usefulness during field surveys (Centeno *et al*. [5], Lange & Haynes [6]). In fact, because the present platform is able to leverage the visualisation of geo-referenced sensors measurements and simulation data of hydraulic and vulnerability models (Mirauda & Ostoich [7], Amicarelli *et al*. [8], Albano *et al*. [9], Mirauda *et al*. [10], Greco & Mirauda [11, 12]) in a seamless integrated view of the real-world context, it could be useful if extended out of the field of emergency management into the environmental monitoring in general. In addition, this AR application implemented on mobile devices could support technicians in on-site inspections and in the fault management of gauge stations spread over the basin, as well as in the control and maintenance of works interacting with the flow (e.g., weirs, dams, gabions, piles of bridges, etc.). Finally, users could also benefit from cartographies and guidance materials layered onto the real world in order to understand the phenomenon better and to move around even in less-known areas.

2 APPLICATION ARCHITECTURE

In this work, through the use of AR, an application able to visualise geo-referenced sensors measurements and integrate simulation data of hydraulic and hydrological models on mobile devices was implemented. This application, developed in the Metaio framework, can run on mobile devices equipped with a webcam and sensors such as a gyroscope, a compass and a GPS. It is based on a client-server architecture where: (1) the client (i.e. a smartphone) interacts with a server application (Web Service) through messages; (2) once the request is accepted, the Web Service queries the database and sends the retrieved information to the client; (3) the client interprets the response and renders the information on the screen as virtual objects overlaying onto the real environment being viewed. This architecture is able to manage different information sets associated to some elements, called Points Of Interest (POIs), in the real surroundings. In particular, after capturing a scene on their mobile device, users receive added details for each POI which increase their information content. A POI represents a specific point, a marker detected through geographic coordinates (latitude, longitude, and altitude), corresponding to locations such as a road, a bridge, a church, or a specific address and can be displayed through a graphical symbol on a mobile device. In this paper, the POIs are hydrometric stations or structures/infrastructures within flood-prone areas. They are displayed through billboards overlaid onto a scene captured by the device camera. The billboards are icons that take different shapes and colours based on the POI, each associated with a label that shows different data such as the distance between the mobile device and the POI (Fig. 1).

Figure 1: Some POIs of the presented application shown as billboards.

Furthermore, the platform, together with the POIs, provides images, graphs, videos, notes, tables, and more associated information, as well as POIs on 2D or 3D maps, which allow the user to move easily, to integrate the existing information seamlessly, to import new POIs into the database, and to export data and metadata out to other programs and software.

3 DISCUSSION OF THE RESULTS

A preliminary validation of the prototype performance was carried out on a sample basin represented by the Basento, one of the main rivers in the Basilicata region (Italy), both in a real case study and in a simulated one. The Basento originates in the north-west, flowing to the south-east of Basilicata and into the Ionian sea. It is 149-km long and its catchment is about 1,537 km^2. It is characterised by a seasonal variation of the flows: high levels in winter and low levels in summer. The platform application followed the collection phase of static data (e.g., location of the river gauge stations or the position of the structures/infrastructures at flood risk) and dynamic data (e.g., the water levels of the instrumented river sections or the alert thresholds) acquired both by the regional Civil Protection and through a series of field surveys.

3.1 Testing on a real case

The test includes visiting the Basento basin and locating interesting points where, for instance, gauge stations, buildings, or bridges can be found. Since it is necessary for this application to keep contact with the real environment as well as recognise and reach these points rapidly, it displays the location on the mobile device using virtual elements that enhance the position of the point. As reported in Figure 2, the AR application shows, for example, the gauge stations represented graphically by coloured drops. The colour of the drop can be either yellow, orange, or red if the values of the water depth acquired by the gauge station have reached the ordinary, moderate, or high criticality threshold, respectively. The drop can be oriented according to the user's position and the visualisation perspective through the mobile device screen. Its size increases progressively with the approaching to the POI, showing the

Figure 2: Some gauge stations of the Basento river represented graphically by coloured drops. Labels identify the user-station distance and the hydrometric level in real time.

user-station distance in real time. During the test, all these functions allowed the users not only to clearly visualise the gauge station position, relative distance and direction, but also to know the level of criticality of the gauge station itself. In addition, simply by clicking on the icon of the specific gauge station, the platform is also able to provide the hydrometric level updated on the billboard label and show the trend of the flow depth recorded during the day (Fig. 3a). Thanks to this function, the workforces managed to more easily monitor the river and the flood plains during the surveys. Even the interactiveness was increased by the application association of more information to the station, such as photos, images, videos, animations, and notes carrying indications of the previous field activities (Fig. 3b).

Figure 3: (a) The application shows the trend of the daily flow depths acquired by the gauge station. (b) Example of an image associated to one gauge station in AR mode.

3.2 Testing on a simulated case

The application was also tested simulating a real emergency situation, such as flood event in field, in order to verify the functionality and reliability of the developed program.

For this reason, a sample geographical space, which includes the river and the flood plain, was used to observe different vulnerability scenarios, built on the results of hydraulic models based on the measurements of gauge stations located along the basin. In particular, according to the model output, the platform shows different coloured symbols representing the structures and infrastructures within the flood-prone area (Fig. 4). In the presented survey, for instance, the yellow, orange, and red symbols showed that the POI was located in an area not at flood risk, at moderate or at high flood risk, respectively.

During these preliminary tests, it was noted that the use of such application was relatively easy when the communication between the interface and the models or other applications was available and fast, showing how the modelled situation affected the surrounding environment. The system was perceived as very simple to use, being designed to support total immersion applications when the performance of the mobile device is high. In addition, the workforces found that the integrated visualisation and comparison of different sources of information (libraries of photos, images, animations, videos, etc.) was a major advantage for decision making.

The success of the experiments was sometimes limited because of the hardware being used. Some issues occurred, which were related to the screen visibility under really bright conditions and to the battery life. Such inconvenience was avoided using mobile devices with a superior display resolution, a screen light/dark contrast control and an anti-reflective surface, together with the use of extra and long-lasting batteries.

Figure 4: 2D map visualisation of a sample flood-prone area within the Basento basin. The billboards of the structures and infrastructures display different colours according to the level of criticality simulated by hydraulic models.

CONCLUSIONS

The mobile application here developed, using AR technology, represents an innovative tool able to access a wide range of measurement sensors, deploy various visualisations, consult different data in real time, and integrate simulation results developed specifically to create a shared awareness in the field teams. The user's awareness is enhanced with perception of correspondence between the data and the surroundings in a way that allows the exploration of the relations between them, eliciting understanding and insight through continuous feedback.

For a preliminary validation, a real case study and a simulated one were organised. The results helped to define the benefits of outdoor visualisation, as well as its constraints in some conditions. Thanks to overlaid virtual objects onto real ones, the users are more aware of the potential danger around them in emergency situations, which allows speeding up both the decision-making processes and the crisis responses.

Both in the simulated emergency scenario and in normal environmental conditions, the platform is able to incorporate a variety of models and libraries (of photos, videos, texts, etc.) that drive the field activities, helping to increase knowledge of the phenomenon evolution.

The designed platform has its limitations and is not meant to replace traditional data analysis, but rather to be complementary, supplying localised views on the situation in real time. Further tests on different basins are advisable in order to improve the performance of the application and introduce new functionalities.

With the increasing hardware technology advancement, such platforms could perspectively grow in the environmental monitoring sector and possibly trigger a larger range of opportunities to improve the existing toolset and explore new potential uses.

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