Smart maintenance of riverbanks using a standard data layer and augmented reality

Original
Smart maintenance of riverbanks using a standard data layer and augmented reality / Pierdicca, Roberto; Frontoni, Emanuele; Zingaretti, Primo; Mancini, Adriano; Malinverni, Eva Savina; Tassetti, Annanora; Marcheggiani, Ernesto; Galli, Andrea. - In: COMPUTERS & GEOSCIENCES. - ISSN 0098-3004. - STAMPA. - 95:(2016), pp. 67-74. [10.1016/j.cageo.2016.06.018]

Published
DOI:10.1016/j.cageo.2016.06.018

Smart maintenance of riverbanks using a standard data layer and augmented reality

Roberto Pierdicca[a,*], Emanuele Frontoni[a], Primo Zingaretti[a],
Adriano Mancini[a], Eva Savina Malinverni[b], Anna Nora Tassetti[b],
Ernesto Marcheggiani[c,d], Andrea Galli[c]

[a] *Università Politecnica delle Marche*
Dipartimento di Ingegneria dell'Informazione
[b] *Università Politecnica delle Marche*
Dipartimento di Ingegneria Civile, Edile e Architettura
[c] *Università Politecnica delle Marche*
Dipartimento di Scienze Agrarie, Alimentari ed Ambientali
[d] *Department of Earth and Environmental Research, KU Leuven*

Abstract

Linear buffer strips (BS) along watercourses are commonly adopted to reduce run-off, accumulation of bank-top sediments and the leaking of pesticides into fresh-waters, which strongly increase water pollution. However, the monitoring of their conditions is a hard task because they are scattered over wide rural areas. This work demonstrates the benefits of using a standard data layer and Augmented Reality (AR) in watershed control and outlines the guideline of a novel approach for the health-check of linear BS. We designed a mobile environmental monitoring system for smart maintenance of riverbanks by embedding the AR technology within a Geographical Information System (GIS). From the technological point of view, the system's architecture consists of a cloud-based service for data sharing, using a standard data layer,

---

[*] Corresponding author. Tel.: +39 3283248263.
Email address: `r.pierdicca@univpm.it` (Roberto Pierdicca)

and of a mobile device provided with a GPS based AR engine for augmented data visualization. The proposed solution aims to ease the overall inspection process by reducing the time required to run a survey. Indeed, ordinary operational survey conditions are usually performed basing the fieldwork on just classical digitized maps. Our application proposes to enrich inspections by superimposing information on the device screen with the same point of view of the camera, providing an intuitive visualization of buffer strip location. This way, the inspection officer can quickly and dynamically access relevant information overlaying geographic features, comments and other contents in real time. The solution has been tested in fieldwork to prove at what extent this cutting-edge technology contributes to an effective monitoring over large territorial settings. The aim is to encourage officers, land managers and practitioners toward more effective monitoring and management practices.

Keywords:
Buffer Strips, Augmented Reality, Environmental Monitoring,
Mobile Visualization, GIS

1. Introduction

In the general context of nowadays-environmental crisis, a key challenge is represented by the necessity of conciliate the needs of modern agriculture, whose main goal is to feed billion of people, with that of preserve an adequate environmental quality conditions. In this context, the quality of fresh running and underground water is a key issue (Stoate et al. (2009)). The modern approach to water protection, in agricultural conditions and over wide rural territories is based, among others, on the use of linear buffer strips (BS) along watercourses. These structures are commonly improved to reduce the run-off, the accumulation of bank-top sediments and the leaking of pesticides into fresh-waters. These vegetated strips benefit the overall quality of surface waters reducing the potential impacts due to agricultural activities and other sources of pollution (Roberts et al. (2012); Balestrini et al. (2011)). As a matter of fact, buffer strips play a set of positive functions, such as: pollutant adsorption, riverbank stabilization, micro climate improvement etc. To achieve an effective protection, is known that the network of vegetated strips must be designed with a stringent scheme and carefully installed and maintained during time. The protective network needs to comply with two capital conditions: the integrity of the spatial continuity of the protecting belt and a constant man-work of maintenance of riverbanks. The monitoring over a wide network of vegetated linear features, whose pattern stretches across thousands of miles, is a hard task. Despite the potentialities of GIS in managing geo-datasets and delivering relevant thematic maps are well known, the use of specific applications is still broadly missing; indeed, geographical visualization of wide datasets directly in the field require costly and specialized equipment. A significant improvement of the environmental monitoring and control can be achieved by adopting effective management strategies to increase awareness of risks (Armenakis and Nirupama (2013);Hochrainer-Stigler et al. (2013);Hsu et al. (2013)). The possibility of taking sound strategies depends by the amount and by the quality of the information available for all the people involved in the management and control-chain. The visualization of geographic data is a suitable approach to enhance communication during decision-making processes (Rhyne et al.

(2004);Jiang and Li (2005);Shahabi et al. (2010)). In particular, viewing the physical real world "augmented" by computer-generated sensory inputs represents a powerful tool to deliver supplementary information about the surrounding environment and its objects, enriching the human perception. This kind of visualization is known as augmented reality (AR), a technology able to integrate multiple datasets with one view, enhancing the user cognition of the surroundings (Lee et al. (2015)).

In this frame our purpose is to provide management authorities, land managers and farmers with an intuitive and dynamic real-time visualization tool. The proposed solution combines GIS-based models with the use of relevant AR technology. From the technological point of view, the system architecture is made of a cloud-based service for data sharing and of a mobile application using a GPS-based AR engine for augmented data visualization using smart phones or glasses. On the one hand, GIS allows for managing, modelling and maintaining relevant amount of geo-data, delivering suitable thematic layers. On the other hand, AR enriches the geo-layers with a real-time visualization on-site. In this way we increase and improve geographic information management, whose readability becomes more explicit thanks to the connection between the real world and its modelled representation displayed by thematic maps. Such new form of enriched or, better, augmented geo-information reduces the efforts in operating a mental transformation from map to reality. In turn this enables users (i.e., managers and field-workers) to interact in a more intuitive way with risk maps and management plans. All that is of particular importance for field workers, because using GIS-based AR services would help risk control surveyors by reducing the operational time of surveying, as well as improving the access to relevant information not always available during field campaigns. The overall idea is to prove as AR could trigger smarter watershed control and riverbank maintenance with less time-consuming during on-site inspections. The challenge is to use AR to overcome technological limitations imposed by the use of mere GIS. Indeed, merging these technologies has meant to set up a specific platform for data exchange as well as an infrastructure to make data available in real time. We have designed an experimental data visualization test to encourage land managers and other potential users to perform more advanced monitoring and management practices. More in depth, we have outlined a novel approach to the way in which officers could perform the health-check of linear vegetated BS protecting riverbanks. The GIS coverage, which usually makes the base of reference for the auditing and for the on-site inspections, has been enriched by AR driven information on the position of targeted features, environmental state, degree of pollution, etc. within the reporting area, at river basin scale. The paper is partially following the schema of Lee et al. (2015) and main novelties and differences are: on the particular proposed application; on the use of a standard platform for AR, that is a popular framework for location based AR application; on the proposal of a novel data layer proposed as standard and common way of describing riverbank maintenance toward a consistence standard data layer; on the applicability of the proposed architecture to smart phones and glasses; on the automation of the whole pipeline, going from satellite images, to GIS-ready data, to cloud based services, until AR user interactions; on the experimental test bed, based on real user experiences and real data, that provides a powerful contamination experience between computer scientists and geo-scientists. The aim of the whole system is to ease the operational tasks during on-site inspections over large territories, with less time-consuming procedures. Faster and smarter operations would lead towards an improved and more effective decision-making chain, lowering the operational costs and making more effective the containment of risks. The paper is organized in the following sections. Section 2 illustrates a survey about environmental monitoring by mobile devices and AR, Section 3 describes the case study adopted for the tests, Section 4 is dedicated to the explanation of the application workflow. Concluding remarks and future developments are reported in Sections 5 and 6.

2. Environmental monitoring

The environmental management includes the monitoring of specific areas to understand the changes and the evolutionary dynamics. The mobile environmental monitoring represents a new promising field of application for mobile devices. Such an advanced method of environmental monitoring could represent a key approach to re-interpreting the concepts of monitoring and maintenance. Certainly, on-site inspection is a base need for planners and managers. Information collected during field surveys allow a deep understanding of reporting areas. Environmental officers and other land management authorities usually perform on-site inspections, during their daily work, for monitoring changes, designing activities, searching for patterns or for better understanding the specific existing conditions. Nevertheless, the practice to manage the environmental processes by paper plans, which are plotted as needed and manually annotated on a construction or maintenance site, is still widespread (Schall et al. (2009)). This process leads to waste time or, in the worst case, to incorrect interpretations of available data. Hence, the environmental data analysis needs the introduction of technological tools to make more effective and reliable the monitoring and maintenance phases. These tools should considerably improve on-site inspections to assist authorities in the narrow implications with environmental changes; in this way, the process of context understanding should be improved and the solution easier to find. These considerations entail addressing the entire process of environmental management toward the mobile approach (Yoo and Cheon (2006); Chittaro (2006)). On-site work remains the only efficient link with the office work, because it allows the gathering of own impressions and an aware data processing. Nowadays, on-site work means mobile devices and activities always involve the use of different hardware devices, especially because they are increasingly portable and less expensive. On-site activities do not replace the office work but they have become mandatory for the entire workflow of environment analysis. Farther, mobile devices are equipped with sensors that help user in orientation and navigation and, above all, they put in contact the devices, hence the user, with the real world. The introduction of the user location, everywhere at every time, leads insiders and developers to think the mobile approaches in a new manner, meaning that applications should always put in contact the user with the real world. The challenge is to find the best way to exploit the system potentiality since the most important thing for risk managers is the visualization of data. Considering the needs of a geoscientist (e.g., availability of data, intuitive tools, reducing inspection time), the challenge is to make GIS data suitable for mobile environment (e.g., visualization for monitoring), avoiding the waste of the fundamental metadata intrinsic with the GIS objects and necessary for their geo localization and visualization (Liarokapis et al. (2007)). Visualization is the most important element of GIS. Indeed, as Deakin (2009) said, GIS is strictly related to the visualization for its effectiveness. For this kind of applications, AR could be considered the ultimate immersive system (Liarokapis et al. (2005)); even if in large urban areas the image recognition will become the norm by opening the way for sub-meter GIS functionality Jang and Andrew (2010), for landscape monitoring sensor based AR is the best solution Schmid and Langerenken (2014). Thus all the sensors embedded inside devices should cooperate simultaneously to visualize supplementary information as part of the real world. Furthermore, once data are displayed, the user is be able to interact with them, to update, upload, share or modify them in the meanwhile he's investigating a specific area. The cycle of work is explained in fig. 1. To perform a monitoring task, in addition to object visualization, the system must be able to guide the user toward the real position and, when arrived, to recognize it in the real environment. Only under these conditions, an accurate analysis and correct control activities will be possible.

2.1. Real time data visualization using AR

Augmented Reality is a cutting-edge technology which combines the reality with computer-generated data, enhancing the perception of the real world through layers of digital information. AR merges real world views captured by video cameras with synthetic data: in our application, extra-layers arise form GIS. AR is the enrichment of the sensory understanding through a series of digital or computer-generated contents (Behzadan and Kamat (2007);

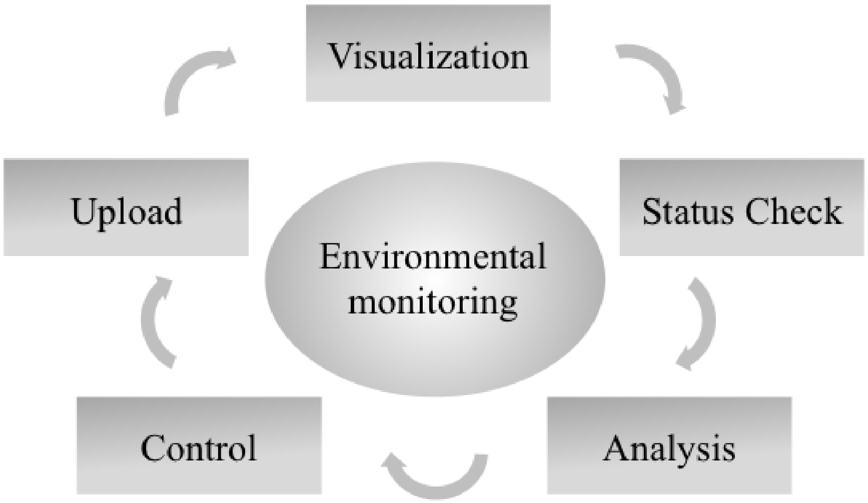

Figure 1: The cycle of environmental monitoring: the process starts with the AR visualization of GIS data and can be endlessly repeated since the app is directly linked with the server.

Carmigniani et al. (2011)), which enhance the knowledge of the real world with information overlaid in real time. Even if virtual objects often help the user to simulate the reality (superimposing items that blend into a mixed reality), we consider the visualization of GIS data as particularly suitable not so much for enhancing the reality perception but for helping risk managers during on-site inspections. It allows the user to walk around and observe the environment, continuously getting a "correct view" on sensor data, since information overlapping gives the possibility to improve the knowledge of the real world. The AR technology strives to render computer-generated artifacts correctly blended with the real world in real time. These artifacts appear in the correct position relative to the point of view of the user. Furthermore, interactive visualization enables the communication and the exchange of data (e.g., images, data, graphs) between an on-site observer and decision makers. In fact, end users are expected to have a better view of the global situation before, during and after an event by adopting image overlay techniques depending on the user's location. In recent years many GIS-based approach and AR services have been experienced for different usages and manifold applications (Pundt and Brinkktter-Runde (2000)). Whereas AR is widely spreading its usefulness for a variety of outdoor applications such as Urban Excavation Operations (Talmaki et al. (2010)), Urban environment exploration (Feiner et al. (1997)), GIS in architecture (Guo et al. (2008)), Underground Infrastructure, Maintenance and Repair (Henderson and Feiner (2009)), the usage of AR in environmental monitoring is quite novel (Schall et al. (2009); Kruijff et al. (2010); Veas et al. (2013)). The case study of this paper is particularly suitable for the visualization of information on mobile devices; vegetated buffer strips are constantly evolving because of the sudden growth of surrounding vegetation and because riverbanks are continuously changing. Besides, since buffer strips are disseminated among wide areas, on-site monitoring is a challenging activity. Given the above, the only way to ensure their correct maintenance by the owner is on-site inspection using tools that can identify the Point of Interest (POI) in the correct location in the real world. If the main purpose is the one described above, other important aspects are the availability of shared comments during the inspection and the internal data storage in case of lack of Internet connection, both described in this paper.

3. Case study settings: GIS context for AR geo-layers creation

The case study chosen for the experimental test is located in central Italy, into the Musone valley (Province of Ancona, Marche Region, Italy). The area surrounding the Musone River is a typical rural complex with hilly farmland setting, with some urban and small industrial settlements. The operational background for the case study is the new Common Agriculture Policy (CAP), with a focus on the standards named Good Agricultural and Environmental Condition (CE Reg 73/2009, annex III), revised according to Common Agriculture Policy in 2009, known as "Health Check" .(CE Reg. 72/2009, CE Reg. 73/2009, CE Reg. 74/2009, Directive 2009/61/CE). Our attention is given to the GAEC standard number 5.2, which requires European member states to implement and protect vegetated Buffer Strips along watercourses. The 5.2 standard aims to hamper, or at least to reduce the run-off and the accumulation of sediments, organic matter and pesticides; in other words, water pollution. The GAEC 5.2 has been introduced in Italy in January 2011 and adopted by the Marche Region (Italy) in early 2012. Vegetated buffers along river streams have therefore become a requirement for farmers who want to step into the funding and payments of subsidies. Despite Common Agriculture Policies (CAP) never meant to be a planning tool, their impacts on the management of primary sector are widely known. Far beyond the mere delivering of goods, today, the multi-functional role of agriculture imprints changes on wide surfaces across the globe. The monitoring of changes and the analysis of polices compel for the implementation of suitable tools enabling sound planning systems and supporting the decision-making. This urge has become paramount in Europe. Within this frame, a previous research delivered a suitable geo-database and tested a multi-scale GIS approach to determine the optimal type and location of buffer strips, at both parcel and catchment level, and to investigate their adaptability to the Marche Region conditions. The work by the Division of Earth and Environmental Sciences at KU Leuven in Belgium Tsakiris et al. (2013)) delivered a GIS model to support land managers in deciding the best alternative Buffer Strip typology, starting from given spatial conditions. Floodplain maps, land use maps, erosion maps, DEMs, etc. were used to accommodate the best allocation of buffer strip typology. The model has a parametric iterative decisional tree structure, made of two sequential sub-models: the first one sets the pre-conditions that define and split the problems into different layers; the second sub-model classifies lands (usually parcels) assigning specific buffer strip categories according to outcomes of the above iterative sequence. The adaptation of the model to the Italian conditions was possible thanks to the contribution of an Italian team Piselli et al. (2013). In particular, land use maps were updated thanks to a hybrid Land Cover Land Use (LCLU) classification by high spatial resolution multispectral imagery and LiDAR data Malinverni et al. (2011). As shown in fig. 2, a set of features buffered along watercourses are generated In this context, our purpose is to take advantage of a new solution assigning buffer zone to specific areas, adjacent watercourses, and turning this information in an AR environment. This solution enables to visualize buffer strips as geo- layers in the physical world thanks to AR.

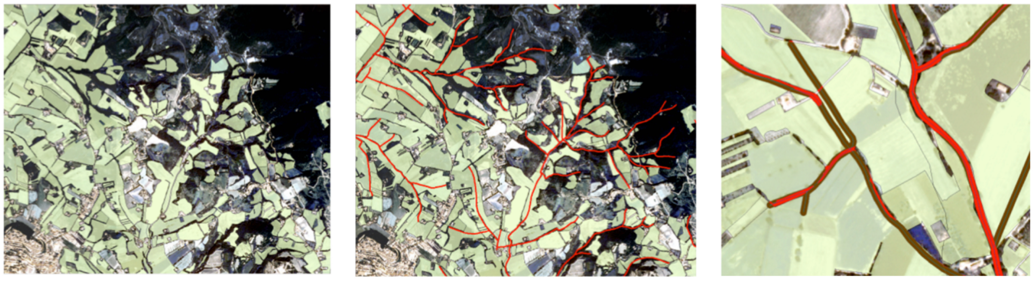

Figure 2: Case study area viewed on WorldView 2. Left: assignment of each piece of land along the water courses to a specific buffer strip typology. Center: buffer strips built by buffering parcels according to a given distance from the river streams (red). Right: detailed view of intersections between classified parcels and buffer strips.

4. Methodology

The visualization of buffer strips directly on-site is fundamental; as a matter of fact, farmers who want to step-up into the Common Agriculture Policy funding scheme and claim for the payments of subsidies, must compel with a set of conditions (Good Agricultural Environmental Conditions), among which the maintenance of vegetated strips (BS) along watercourses is compulsory. Local authority has to ensure that the network of BS is kept and maintained over the time by the farmer. The faster way to monitoring the operational state of the network is to identify the linear pattern and verify its maintenance status. In the following section a mobile AR application for GIS data visualization is described. In the following section a mobile AR application for GIS data visualization is described. Our tool provides the necessary information to properly inspect the area of investigation and to visualize in real time the buffer strips. Buffer strips are contextualized within the real environment once the camera is on and placed in the correct location where they are fitted in the GIS cartography. The purpose is to provide a geo-visualization method for real time and on-site data visualization, particularly suitable for this case study, but that could be used for many other GIS data. Details of the development phases, libraries and functionality of the application are presented in the following section.

4.1. From GIS to AR environment

To move from GIS model to AR Geo-layer we designed a workflow based sequential several items. Starting from the decisional model described in Section 3, we need:

- availability of geo-referenced data from the GIS;
- contents to be overlaid once the user is on-site;
- a tracking system;
- link to sending data to the cloud
- interaction with the superimposed contents.

The first part of the workflow consists in translating the polyline shape file ("shp") of the BS and all related files ("sbn", "sbx", "shx", "dbf") to "kmz" or "dxf" exchange CAD formats. For the AR experience in-situ, the visualization of a 3D model is preferable, so we extruded the "shp" polygon importing it into a three-dimensional modelling program (e.g., Sketch-up); once the model is imported, the user can apply every required changes (e.g., material, color, extrusion, and so on). Next step is to edit this model by Layar3D model converter, a powerful tool which enable this transformation

(Layar (2009)); the most suitable format for this kind of operations is the ".obj", because of its capability to maintain the original file object and the possibility of being edited. In this phase, it is also possible to geo-reference the model on a common Open-Street Map environment. The final output is an l3d file, which can be defined as a geo-layer ready for being uploaded to a web-server. From web-side implementation, it is necessary a Relational Database Management System (RDBMS) and a classical web-server that hosts php pages. For this test we adopted the open source MySQL server. In the database we built a table that contains data regarding the Point of Interest (POI), geometrical transformation, description and link to external resources. A web service is needed to fetch the POI information (in JSON format) and get it back to the AR platform. More in deep, we stored the POIs within the database table linked to the application created specifically to contain them; in particular, about each POI, is essential to store latitude and longitude (to correctly register geo-location), title, description and other information of interest for the user. To retrieve these points at user's request it also necessary that the application generate a php script that returns the POIs. The parameters to correct locate the model above the screen are: latitude, longitude and a radius of influence. Within the circle of specified radius, the application seeks for relevant POIs, starting from user's location. At this point the last step to complete the workflow is to perform a series of asynchronous calls to activate the php script, which is possible from any operative system, passing the user's location coordinates as parameters. Fig. 3 is an explanatory scheme of how the architecture works. From now then the mobile app can interact with the stored contents.

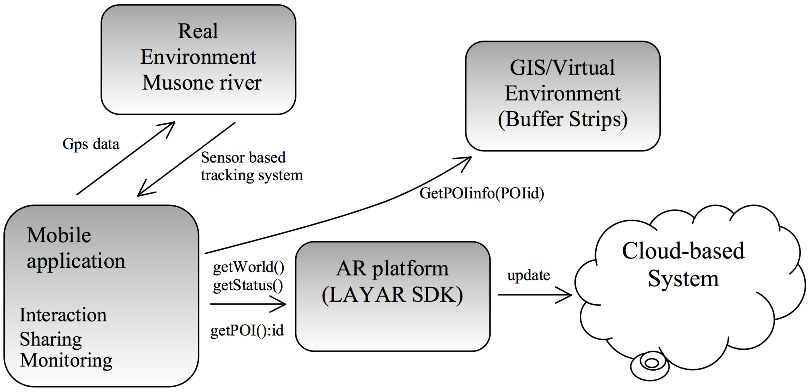

Figure 3: System architecture diagram and test-bed.

4.2. Standard Data Layer and Mobile Application

The major purposes of the developed application are: to interact with the buffer strips, to update comments, to send reports and to give users the possibility of localizing POI. The data structure of the whole architecture is summarized in fig. 4.

The data layer describes the following components of the XSD element named MAINTENANCESTATUS:

- Identification data: are used for textual and id identification of the maintenance POIs, use a short name (NAME), a id number and a long name (TRADITIONALNAME)

- Description data (DESCRIPTION): are used to describe the maintenance POIs and uses geolocation, identified by an international standard address, the maintenance area (TECHDATA), the identification of this area as a risky one and every detail about the risk type, the status of the risk, etc.

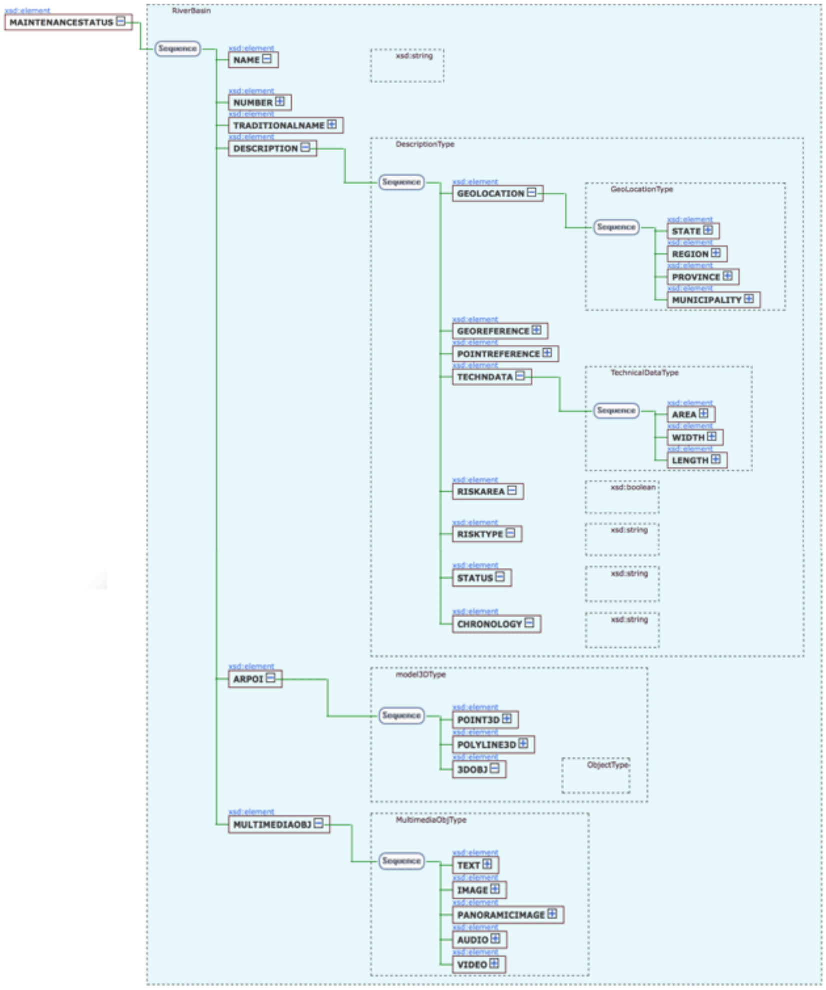

Figure 4: Standard data layer architecture of the main system, with the data structure of every components.

- AR data (ARPOI): are used to show in AR all the spatial information superimposed to the real scene, using the LayAR standard description for points, poli-lines and shapes.

- Multimedia data: are used to add multimedia information to the AR data layer to add or gather, using also on user interactions (e.g. like tag) and user generated contents, text, images, panoramic images, audio and video contents. All this data are part of the proposed standard and detailed description con be found on the project web page.

Other features of the mobile application are an easy to use and user-friendly interface, and the possibility to operate without network connection. The main functionality are listed below.

- Augmented reality tool:

this functionality allows the user to activate the augmented reality browser and to search for all the POIs close to him/her. Compass displayed on the screen visualize the nearest POI; in this way the user can easily reach the area where the strip is located. To implement this feature we took advantage from the set of embedded sensors of mobile devices e.g. compass, gyroscope, accelerometer and GPS receiver. A good examination about AR tracking systems can be found in Zhou et al. (2008). For adjusting the search area , the user can set a search radius from the device. This is particularly helpful during the campaign to retrieve information of a limited set of POI nearby the user. As default, the radius value is 500 m. Moreover, the application allows obtaining more information by displaying in a popup window the title, description, footnote and the image associated with the POI selected, as well as the BS typology. All these features have been implemented by using libraries provided by API LayarSDK: a static library that implements augmented reality and geo-localization functions. Fig. 5 shows an example of AR applied to river basin on the study area.

Figure 5: Screenshot in landscape mode, taken during on-site inspection. On the upper side, the radar guides the user among the countryside towards the POIs. The red line is the buffer strip automatically appears when the frame the area. The lower side shows the strip typology, the metadata arising from the GIS database.

- The use of the map:

the map function is a key tool to have a quick overview of all the relevant POIs of a specific are, keeping trace about previous comments associated to it. The map module was designed to expedite the inspection; in fact, helps to immediately identify the BS distribution and assists in understanding the nearby environment. Thanks to the map visualization, the user can suddenly reach the complete set of information such as typology, length, coordinates and all data stored into the database regarding BS (see fig. 6). This functions were implemented using the Google Maps V3 API.

- Management of Points of Interest:

each time a specific buffer strip is selected by clicking on it, users can choose between two alternative actions: to “add a comment” or to “enrich” the scene with AR contents. The first one allows to report relevant information about the specific POI by simply posting a comment, or to mark any potential issue affecting a specific strip feature. Being stored into the remote server, these comments are suddenly available in GIS-ready mode. The second option allows users to enrich the scene by enhancing information with all comments regarding a specific POI. This function helps surveyor in taking critical choice during the trip and also to easily retrieve all the information once he is back at office. (see fig. 6).

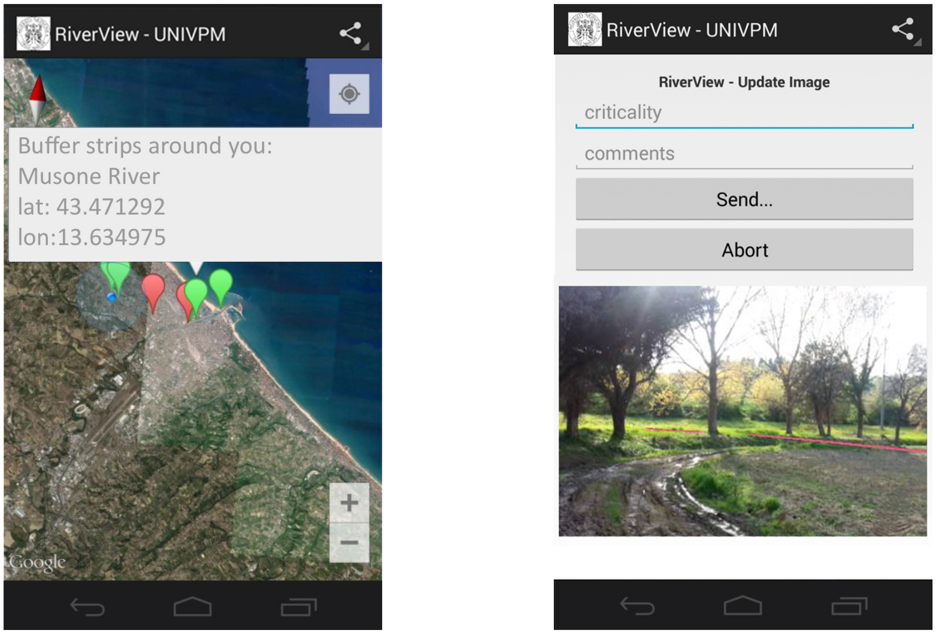
Buffer strips around you:
Musone River
lat: 43.471292
lon:13.634975

Figure 6: Left: POI visualization on the map. Center: Real time visualization of buffer strip (in red) with the possibility to share information or comments.

- Data Management:

this functionality copes with the need of updating POI comments also in case of lack of network connection; data are locally stored into a mobile device (i.e., tablet or smartphone). A structure containing the local database and a POI table is created in order to to: add, read and update POI locally. A suitable class is created to manage the POI data structure within the local database. The Database class is used each time a user needs to store a comment or a related file (i.e. a picture) in offline mode. To upload local data into the remote database a specific class is instantiated every time an item of the application's main menu is selected: it checks if the local database is empty, checks the network connection and, in case of affirmative result, uploads the local data to the remote database.

5. Results and validation

We have designed different test cases under different conditions. The tests were made in real scenarios, at a latitude of $43°33'36''$N and longitude of $13°30'05''$E with different daytime, mainly focusing on the usability and positioning accuracy. Considering that during the testing phase we did not observed false positives and that all the recorded points of interest reported to have a good accuracy, the suitability for GIS/desktop purposes resulted to be more than satisfactory. For the evaluation of the usability we have tested the system with subjects involved in the environmental management such as: planners, land-managers, officers and practitioners of different age. To make up the panel of expert for the tests , we also gathered information about their habits and technological skills. From the gathered information, we realized that people involved with the planning and management of the environment are not skilled in the use of technology and they still prefer to perform their activity from the office. Nevertheless, the users appreciated the system. Almost all users didn't know AR but appreciated this technology. The majority of the sample (70%) retains that similar applications are necessary resources to improve monitoring activities. They have generally found that the application is simple to use, although with respect to the general idea, they suggest strengthening the relationship between desktop and mobile sides. For testing the accuracy of the tracking system, we tried different 3D models of the buffer strips, in different locations and times. The devices used in our test were an iPad 2 and a Samsung S3. The system is also compatible with LayAR for Google Glasses. With the overlapping of several screen shots, we checked that the positioning of the virtual contents were stable and visualized in the same position for both devices. With the GNSS service available, accuracy was between 5 m up to 10 m, depending on vegetation canopy coverage. By the way, the accuracy of the superimposing of digital contents is strictly depending from the current accuracy of consumer grade GPS receiver. The current state of sensor-based and marker-less AR technology is mainly limited by positioning issue; moreover, the spreading of cutting edge technology for geospatial applications will depend from the growing in the customer market of more accurate positioning systems. Despite the system architecture is complex, we have designed a simple user interface (UI) to ease user's approach. In this way it is possible to cope with all potential difficulties that users could face during the work on field, such as bad weather conditions or impervious accessible areas. The more intuitive is the UI the faster the inspection will be. Let us underline that our purpose is to create a monitoring tool that is at the same time a maintenance tool. In fact, the proposed solution, besides allowing monitor and supervise reporting area (in our specific case, the buffer strips at catchment basin scale), also allows to share observations and surveyed data in real time, by uploading and linking this information in a GIS environment. In particular, the cycle shown in section 3 can be re-iterated endlessly: the health-check status of buffer strips can be monitored and verified at any time and the environment constantly maintained.

Figure 7: Use case for AR applications Left: USV Survey Platform. Right. USV during the river basin survey.

6. Future works and conclusions

In a further development of our research we aim to integrate the technology of Augmented Reality in a video/image stream from a remote manned/ unmanned robotic platform equipped with a wide range of sensors. The idea will be experienced within the "River View" project granted by the Ministry for Economic Development to support research programs; the project deals with the study, design and prototyping of a system for mapping and classification of risk cases at river and lake basins by using autonomous robotic systems and sensory advanced platforms. We are building unmanned robotic vehicles, both aerial (UAV) and surface (USV), to perform fast environmental surveys on targeted regions of interest with particular focus on small river basins and lakes (fig. 7). These platforms are particularly suitable to all that sites where human access is unease or forbidden due to specific restrictions for nature protection. We are currently working to make the overlaying of GIS data and AR contents fully operative in real time. This will make the video stream enriched with additional information related to the survey (e.g. weak lake bank, dangerous area and so on). It does not represent a simple overlay of telemetry data, rather an actual interaction of the reality, as perceived by the user, with a set of complex contents, such as 2D/3D objects, linked with the user's point of view. The whole system can be performed in a constant stream of information about the area under investigation, in GIS and geo-DB environment. Users could benefit of the Augmented Reality for a more reliable control on the survey. Although in many countries the world-as-a-user interface paradigm is wide spreading for commercial use, currently no monitoring applications for Head Mounted Devices (HMD) have been realized yet. Therefore we also expect, for the near future, to test this kind of applications also for wearable devices. Finally, potential scenario to further exploring the potential of AR solution, in combination with geographic representations, is the quality control of automatic land use classification. A previous research (Malinverni et al. (2014)) has delivered an interesting tool for automatic Land Cover/Land Use classification; the idea is to use AR as a tool to validate the performances of classification. We presented an approach to prove the potentials offered by Augmented Reality (AR). By combining GIS-based environmental modelling with the use of relevant AR technologies we outlined a novel approach to the health-check of linear vegetated strips protecting river banks, overcoming several limitations of a classical approach to mobile environmental monitoring. The methodology offers a set of improvements. Above all, it gives users a quick access to relevant information, thanks to the dynamic superimposing of geographic features, comments and other contents. Furthermore, the user-friendly interface makes the system suitable for different users. The system allows for real-time interactions of GIS data and AR contents; in particular, thanks to the cloud based DB for GIS data, modification of data is possible in the real-time. We expect that in the next few years AR will become a widespread technology and a best practice application for environmental protection, monitoring and land management. The overall idea inspiring our work is that AR could trigger a "smarter" environmental control with less time-consuming for on-site inspections. We expect that in the near future AR technology will become a widespread application for environmental monitoring, land management and environmental protection, using smart phones and glasses.

References

Armenakis, C., Nirupama, N., 2013. Prioritization of disaster risk in a community using gis. Natural Hazards 66 (1), 15–29.

Balestrini, R., Arese, C., Delconte, C., Lotti, A., Salerno, F., 2011. Nitrogen removal in subsurface water by narrow buffer strips in the intensive farming landscape of the po river watershed, italy. Ecological Engineering 37 (2), 148–157.

Behzadan, A. H., Kamat, V. R., 2007. Georeferenced registration of construction graphics in mobile outdoor augmented reality. Journal of Computing in Civil Engineering 21 (4), 247–258.

Carmigniani, J., Furht, B., Anisetti, M., Ceravolo, P., Damiani, E., Ivkovic, M., 2011. Augmented reality technologies, systems and applications. Multimedia Tools and Applications 51 (1), 341–377.

Chittaro, L., 2006. Visualizing information on mobile devices. Computer 39 (3), 40–45.

Deakin, A., 2009. Evolution of geographic information systems and visualization systems. Environmental monitoring. EOLSS.

Feiner, S., MacIntyre, B., Hllerer, T., Webster, A., 1997. A touring machine: Prototyping 3d mobile augmented reality systems for exploring the urban environment. Personal and Ubiquitous Computing 1 (4), 208–217.

Guo, Y., Du, Q., Luo, Y., Zhang, W., Xu, L., 2008. Application of augmented reality gis in architecture. ISPRS 8.

Henderson, S., Feiner, S., 2009. Evaluating the benefits of augmented reality for task localization in maintenance of an armored personnel carrier turret. pp. 135–144.

Hochrainer-Stigler, S., Pflug, G., Lugeri, N., 2013. Flood risk in a changing climate: A multilevel approach for risk management. Integrated Catastrophe Risk Modeling, 263–279.

Hsu, W.-K., Chiang, W.-L., Chen, C.-W., 2013. Earthquake risk assessment and optimal risk management strategies for hi-tech fabs in taiwan. Natural Hazards 65 (3), 2063–2076, cited By 5.

Jang, S., Andrew, H., 2010. Gis and augmented reality in 2015. Association of Geographic Information (AGI) Foresight Study.

Jiang, B., Li, Z., 2005. Geovisualization: Design, enhanced visual tools and applications. Cartographic Journal 42 (1), 3–4.

Kruijff, E., Mendez, E., Veas, E., Gruenewald, T., Simoni, S., Luyet, V., Salminen, O., Nurminen, A., Lehtinen, V., 2010. Hydrosys: Onsite monitoring and management of environmental processes using handheld devices. Geohydroinformatics: Integrating GIS and Water Engineering, 37–51.

Layar, 2009. Layar augmented reality.
URL `https://www.layar.com`

Lee, S., Suh, J., Park, H.-D., 2015. Boreholear: A mobile tablet application for effective borehole database visualization using an augmented reality technology. Computers and Geosciences 76, 41–49.

Liarokapis, F., Brujic-Okretic, V., Papakonstantinou, S., 2007. Exploring urban environments using virtual and augmented reality. GRAPP 2006 (3), 1–13.

Liarokapis, F., Greatbatch, I., Mountain, D., Gunesh, A., Brujic-Okretic, V., Raper, J., 2005. Mobile augmented reality techniques for geovisualisation. Vol. 2005. pp. 745–751.

Malinverni, E., Frontoni, E., Mancini, A., Tassetti, A., Pierdicca, R., Zingaretti., P., 2014. Integrating elevation data and multispectral high-resolution images for an improved hybrid land use/land cover mapping. In: SouthEastern European Journalof Earth Observation and Geomatics.

Malinverni, E., Tassetti, A., Mancini, A., Zingaretti, P., Frontoni, E., Bernardini, A., 2011. Hybrid object-based approach for land use/land cover mapping using high spatial resolution imagery. International Journal of Geographical Information Science 25 (6), 1025–1043.

Piselli, V., Marcheggiani, E., Gulinck, H., Galli, A., 2013. Buffer strips in the marche region. Rural Landscapes: Towards a Better Integration of Rural Development Policies, Urban and Landscape Planning.

Pundt, H., Brinkktter-Runde, K., 2000. Visualization of spatial data for field based gis. Computers and Geosciences 26 (1), 51–56.

Rhyne, T., MacEachren, A., Gahegan, M., Pike, W., Brewer, I., Cai, G., Lengerich, E., Hardisty, F., 2004. Geovisualization for knowledge construction and decision support. IEEE Computer Graphics and Applications 24 (1), 13–17.

Roberts, W. M., Stutter, M. I., Haygarth, P. M., 2012. Phosphorus retention and remobilisation in riparian vegetated buffer strips. In: EGU General Assembly Conference Abstracts. Vol. 14. p. 11348.

Schall, G., Mendez, E., Kruijff, E., Veas, E., Junghanns, S., Reitinger, B., Schmalstieg, D., 2009. Handheld augmented reality for underground infrastructure visualization. Personal and Ubiquitous Computing 13 (4), 281–291.

Schmid, F., Langerenken, D., 2014. Augmented reality and gis: On the possibilities and limits of markerless ar.

Shahabi, C., Banaei-Kashani, F., Khoshgozaran, A., Nocera, L., Xing, S., 2010. Geodec: A framework to visualize and query geospatial data for decision-making. Multimedia 17 (3), 14–23.

Stoate, C., Bldi, A., Beja, P., Boatman, N., Herzon, I., van Doorn, A., de Snoo, G., Rakosy, L., Ramwell, C., 2009. Ecological impacts of early 21st century agricultural change in europe - a review. Journal of Environmental Management 91 (1), 22–46.

Talmaki, S., Dong, S., Kamat, V., 2010. Geospatial databases and augmented reality visualization for improving safety in urban excavation operations. pp. 91–101.

Tsakiris, G., Nalbantis, I., Vangelis, H., Verbeiren, B., Huysmans, M., Tychon, B., Jacquemin, I., Canters, F., Vanderhaegen, S., Engelen, G., Poelmans, L., De Becker, P., Batelaan, O. g., 2013. A system-based paradigm of drought analysis for operational management. Water Resources Management 27 (15), 5281–5297.

Veas, E., Grasset, R., Ferencik, I., Grnewald, T., Schmalstieg, D., 2013. Mobile augmented reality for environmental monitoring. Personal and Ubiquitous Computing 17 (7), 1515–1531.

Yoo, H., Cheon, S., 2006. Visualization by information type on mobile device. Vol. 60. pp. 143–146.

Zhou, F., Dun, H.-L., Billinghurst, M., 2008. Trends in augmented reality tracking, interaction and display: A review of ten years of ismar. pp. 193–202.