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

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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,

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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

3 **1. Introduction**

4 In the general context of nowadays-environmental crisis, a key challenge
5 is represented by the necessity of conciliate the needs of modern agriculture,
6 whose main goal is to feed billion of people, with that of preserve an adequate
7 environmental quality conditions. In this context, the quality of fresh run-
8 ning and underground water is a key issue (Stoate et al. (2009)). The modern
9 approach to water protection, in agricultural conditions and over wide ru-
10 ral territories is based, among others, on the use of linear buffer strips (BS)

11 along watercourses. These structures are commonly improved to reduce the
12 run-off, the accumulation of bank-top sediments and the leaking of pesticides
13 into fresh-waters. These vegetated strips benefit the overall quality of sur-
14 face waters reducing the potential impacts due to agricultural activities and
15 other sources of pollution (Roberts et al. (2012); Balestrini et al. (2011)). As
16 a matter of fact, buffer strips play a set of positive functions, such as: pol-
17 lutant adsorption, riverbank stabilization, micro climate improvement etc.
18 To achieve an effective protection, is known that the network of vegetated
19 strips must be designed with a stringent scheme and carefully installed and
20 maintained during time. The protective network needs to comply with two
21 capital conditions: the integrity of the spatial continuity of the protecting
22 belt and a constant man-work of maintenance of riverbanks. The monitor-
23 ing over a wide network of vegetated linear features, whose pattern stretches
24 across thousands of miles, is a hard task. Despite the potentialities of GIS
25 in managing geo-datasets and delivering relevant thematic maps are well
26 known, the use of specific applications is still broadly missing; indeed, ge-
27 ographical visualization of wide datasets directly in the field require costly
28 and specialized equipment. A significant improvement of the environmen-
29 tal monitoring and control can be achieved by adopting effective manage-
30 ment strategies to increase awareness of risks (Armenakis and Nirupama
31 (2013);Hochrainer-Stigler et al. (2013);Hsu et al. (2013)). The possibility
32 of taking sound strategies depends by the amount and by the quality of
33 the information available for all the people involved in the management and
34 control-chain. The visualization of geographic data is a suitable approach
35 to enhance communication during decision-making processes (Rhyne et al.

36 (2004);Jiang and Li (2005);Shahabi et al. (2010)). In particular, viewing
37 the physical real world “augmented” by computer-generated sensory inputs
38 represents a powerful tool to deliver supplementary information about the
39 surrounding environment and its objects, enriching the human perception.
40 This kind of visualization is known as augmented reality (AR), a technol-
41 ogy able to integrate multiple datasets with one view, enhancing the user
42 cognition of the surroundings (Lee et al. (2015)).

43 In this frame our purpose is to provide management authorities, land
44 managers and farmers with an intuitive and dynamic real-time visualization
45 tool. The proposed solution combines GIS-based models with the use of
46 relevant AR technology. From the technological point of view, the system
47 architecture is made of a cloud-based service for data sharing and of a mobile
48 application using a GPS-based AR engine for augmented data visualization
49 using smart phones or glasses. On the one hand, GIS allows for managing,
50 modelling and maintaining relevant amount of geo-data, delivering suitable
51 thematic layers. On the other hand, AR enriches the geo-layers with a real-
52 time visualization on-site. In this way we increase and improve geographic
53 information management, whose readability becomes more explicit thanks to
54 the connection between the real world and its modelled representation dis-
55 played by thematic maps. Such new form of enriched or, better, augmented
56 geo-information reduces the efforts in operating a mental transformation from
57 map to reality. In turn this enables users (i.e., managers and field-workers) to
58 interact in a more intuitive way with risk maps and management plans. All
59 that is of particular importance for field workers, because using GIS-based
60 AR services would help risk control surveyors by reducing the operational

61 time of surveying, as well as improving the access to relevant information
62 not always available during field campaigns. The overall idea is to prove as
63 AR could trigger smarter watershed control and riverbank maintenance with
64 less time-consuming during on-site inspections. The challenge is to use AR to
65 overcome technological limitations imposed by the use of mere GIS. Indeed,
66 merging these technologies has meant to set up a specific platform for data
67 exchange as well as an infrastructure to make data available in real time. We
68 have designed an experimental data visualization test to encourage land man-
69 agers and other potential users to perform more advanced monitoring and
70 management practices. More in depth, we have outlined a novel approach to
71 the way in which officers could perform the health-check of linear vegetated
72 BS protecting riverbanks. The GIS coverage, which usually makes the base
73 of reference for the auditing and for the on-site inspections, has been enriched
74 by AR driven information on the position of targeted features, environmen-
75 tal state, degree of pollution, etc. within the reporting area, at river basin
76 scale. The paper is partially following the schema of Lee et al. (2015) and
77 main novelties and differences are: on the particular proposed application;
78 on the use of a standard platform for AR, that is a popular framework for
79 location based AR application; on the proposal of a novel data layer proposed
80 as standard and common way of describing riverbank maintenance toward a
81 consistence standard data layer; on the applicability of the proposed archi-
82 tecture to smart phones and glasses; on the automation of the whole pipeline,
83 going from satellite images, to GIS-ready data, to cloud based services, until
84 AR user interactions; on the experimental test bed, based on real user ex-
85 periences and real data, that provides a powerful contamination experience

86 between computer scientists and geo-scientists. The aim of the whole system
87 is to ease the operational tasks during on-site inspections over large terri-
88 tories, with less time-consuming procedures. Faster and smarter operations
89 would lead towards an improved and more effective decision-making chain,
90 lowering the operational costs and making more effective the containment of
91 risks. The paper is organized in the following sections. Section 2 illustrates
92 a survey about environmental monitoring by mobile devices and AR, Section
93 3 describes the case study adopted for the tests, Section 4 is dedicated to
94 the explanation of the application workflow. Concluding remarks and future
95 developments are reported in Sections 5 and 6.

96 **2. Environmental monitoring**

97 The environmental management includes the monitoring of specific ar-
98 eas to understand the changes and the evolutionary dynamics. The mobile
99 environmental monitoring represents a new promising field of application
100 for mobile devices. Such an advanced method of environmental monitoring
101 could represent a key approach to re-interpreting the concepts of monitoring
102 and maintenance. Certainly, on-site inspection is a base need for planners
103 and managers. Information collected during field surveys allow a deep un-
104 derstanding of reporting areas. Environmental officers and other land man-
105 agement authorities usually perform on-site inspections, during their daily
106 work, for monitoring changes, designing activities, searching for patterns or
107 for better understanding the specific existing conditions. Nevertheless, the
108 practice to manage the environmental processes by paper plans, which are
109 plotted as needed and manually annotated on a construction or maintenance

110 site, is still widespread (Schall et al. (2009)). This process leads to waste time
111 or, in the worst case, to incorrect interpretations of available data. Hence,
112 the environmental data analysis needs the introduction of technological tools
113 to make more effective and reliable the monitoring and maintenance phases.
114 These tools should considerably improve on-site inspections to assist author-
115 ities in the narrow implications with environmental changes; in this way, the
116 process of context understanding should be improved and the solution easier
117 to find. These considerations entail addressing the entire process of environ-
118 mental management toward the mobile approach (Yoo and Cheon (2006);
119 Chittaro (2006)). On-site work remains the only efficient link with the office
120 work, because it allows the gathering of own impressions and an aware data
121 processing. Nowadays, on-site work means mobile devices and activities al-
122 ways involve the use of different hardware devices, especially because they
123 are increasingly portable and less expensive. On-site activities do not replace
124 the office work but they have become mandatory for the entire workflow of
125 environment analysis. Farther, mobile devices are equipped with sensors that
126 help user in orientation and navigation and, above all, they put in contact
127 the devices, hence the user, with the real world. The introduction of the user
128 location, everywhere at every time, leads insiders and developers to think the
129 mobile approaches in a new manner, meaning that applications should always
130 put in contact the user with the real world. The challenge is to find the best
131 way to exploit the system potentiality since the most important thing for
132 risk managers is the visualization of data. Considering the needs of a geo-
133 scientist (e.g., availability of data, intuitive tools, reducing inspection time),
134 the challenge is to make GIS data suitable for mobile environment (e.g., vi-

135 sualization for monitoring), avoiding the waste of the fundamental metadata
136 intrinsic with the GIS objects and necessary for their geo localization and
137 visualization (Liarokapis et al. (2007)). Visualization is the most impor-
138 tant element of GIS. Indeed, as Deakin (2009) said, GIS is strictly related
139 to the visualization for its effectiveness. For this kind of applications, AR
140 could be considered the ultimate immersive system (Liarokapis et al. (2005));
141 even if in large urban areas the image recognition will become the norm by
142 opening the way for sub-meter GIS functionality Jang and Andrew (2010),
143 for landscape monitoring sensor based AR is the best solution Schmid and
144 Langerenken (2014). Thus all the sensors embedded inside devices should
145 cooperate simultaneously to visualize supplementary information as part of
146 the real world. Furthermore, once data are displayed, the user is be able to
147 interact with them, to update, upload, share or modify them in the mean-
148 while he's investigating a specific area. The cycle of work is explained in
149 fig. 1. To perform a monitoring task, in addition to object visualization, the
150 system must be able to guide the user toward the real position and, when
151 arrived, to recognize it in the real environment. Only under these conditions,
152 an accurate analysis and correct control activities will be possible.

153 *2.1. Real time data visualization using AR*

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

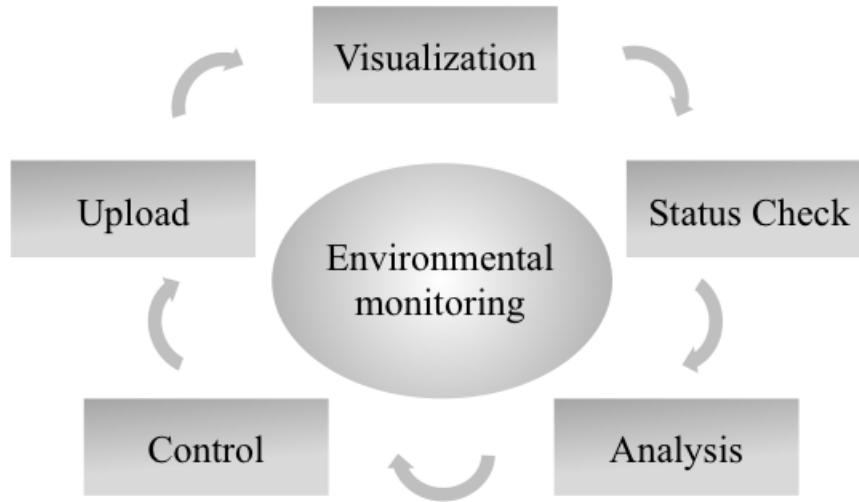


Figure 1: The cycle of environmental monitoring: the process starts with the AR visualization of GIS data and can be endlessly repeated since the app is directly linked with the server.

160 Carmigniani et al. (2011)), which enhance the knowledge of the real world
 161 with information overlaid in real time. Even if virtual objects often help the
 162 user to simulate the reality (superimposing items that blend into a mixed re-
 163 ality), we consider the visualization of GIS data as particularly suitable not
 164 so much for enhancing the reality perception but for helping risk managers
 165 during on-site inspections. It allows the user to walk around and observe
 166 the environment, continuously getting a “correct view” on sensor data, since
 167 information overlapping gives the possibility to improve the knowledge of the
 168 real world. The AR technology strives to render computer-generated artifacts

169 correctly blended with the real world in real time. These artifacts appear
170 in the correct position relative to the point of view of the user. Further-
171 more, interactive visualization enables the communication and the exchange
172 of data (e.g., images, data, graphs) between an on-site observer and decision
173 makers. In fact, end users are expected to have a better view of the global
174 situation before, during and after an event by adopting image overlay tech-
175 niques depending on the user's location. In recent years many GIS-based
176 approach and AR services have been experienced for different usages and
177 manifold applications (Pundt and Brinkkter-Runde (2000)). Whereas AR
178 is widely spreading its usefulness for a variety of outdoor applications such
179 as Urban Excavation Operations (Talmaki et al. (2010)), Urban environment
180 exploration (Feiner et al. (1997)), GIS in architecture (Guo et al. (2008)),
181 Underground Infrastructure, Maintenance and Repair (Henderson and Feiner
182 (2009)), the usage of AR in environmental monitoring is quite novel (Schall
183 et al. (2009); Kruijff et al. (2010); Veas et al. (2013)). The case study of this
184 paper is particularly suitable for the visualization of information on mobile
185 devices; vegetated buffer strips are constantly evolving because of the sudden
186 growth of surrounding vegetation and because riverbanks are continuously
187 changing. Besides, since buffer strips are disseminated among wide areas,
188 on-site monitoring is a challenging activity. Given the above, the only way
189 to ensure their correct maintenance by the owner is on-site inspection using
190 tools that can identify the Point of Interest (POI) in the correct location in
191 the real world. If the main purpose is the one described above, other impor-
192 tant aspects are the availability of shared comments during the inspection
193 and the internal data storage in case of lack of Internet connection, both

194 described in this paper.

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

196 The case study chosen for the experimental test is located in central
197 Italy, into the Musone valley (Province of Ancona, Marche Region, Italy).
198 The area surrounding the Musone River is a typical rural complex with hilly
199 farmland setting, with some urban and small industrial settlements. The
200 operational background for the case study is the new Common Agriculture
201 Policy (CAP), with a focus on the standards named Good Agricultural and
202 Environmental Condition (CE Reg 73/2009, annex III), revised according to
203 Common Agriculture Policy in 2009, known as “Health Check” .(CE Reg.
204 72/2009, CE Reg. 73/2009, CE Reg. 74/2009, Directive 2009/61/CE). Our
205 attention is given to the GAEC standard number 5.2, which requires Euro-
206 pean member states to implement and protect vegetated Buffer Strips along
207 watercourses. The 5.2 standard aims to hamper, or at least to reduce the
208 run-off and the accumulation of sediments, organic matter and pesticides; in
209 other words, water pollution. The GAEC 5.2 has been introduced in Italy
210 in January 2011 and adopted by the Marche Region (Italy) in early 2012.
211 Vegetated buffers along river streams have therefore become a requirement
212 for farmers who want to step into the funding and payments of subsidies.
213 Despite Common Agriculture Policies (CAP) never meant to be a planning
214 tool, their impacts on the management of primary sector are widely known.
215 Far beyond the mere delivering of goods, today, the multi-functional role of
216 agriculture imprints changes on wide surfaces across the globe. The monitor-
217 ing of changes and the analysis of policies compel for the implementation of

218 suitable tools enabling sound planning systems and supporting the decision-
219 making. This urge has become paramount in Europe. Within this frame, a
220 previous research delivered a suitable geo-database and tested a multi-scale
221 GIS approach to determine the optimal type and location of buffer strips, at
222 both parcel and catchment level, and to investigate their adaptability to the
223 Marche Region conditions. The work by the Division of Earth and Environ-
224 mental Sciences at KU Leuven in Belgium Tsakiris et al. (2013)) delivered a
225 GIS model to support land managers in deciding the best alternative Buffer
226 Strip typology, starting from given spatial conditions. Floodplain maps,
227 land use maps, erosion maps, DEMs, etc. were used to accommodate the
228 best allocation of buffer strip typology. The model has a parametric itera-
229 tive decisional tree structure, made of two sequential sub-models: the first
230 one sets the pre-conditions that define and split the problems into differ-
231 ent layers; the second sub-model classifies lands (usually parcels) assigning
232 specific buffer strip categories according to outcomes of the above iterative
233 sequence. The adaptation of the model to the Italian conditions was possible
234 thanks to the contribution of an Italian team Piselli et al. (2013). In par-
235 ticular, land use maps were updated thanks to a hybrid Land Cover Land
236 Use (LCLU) classification by high spatial resolution multispectral imagery
237 and LiDAR data Malinverni et al. (2011). As shown in fig. 2, a set of fea-
238 tures buffered along watercourses are generated In this context, our purpose
239 is to take advantage of a new solution assigning buffer zone to specific areas,
240 adjacent watercourses, and turning this information in an AR environment.
241 This solution enables to visualize buffer strips as geo- layers in the physical
242 world thanks to AR.

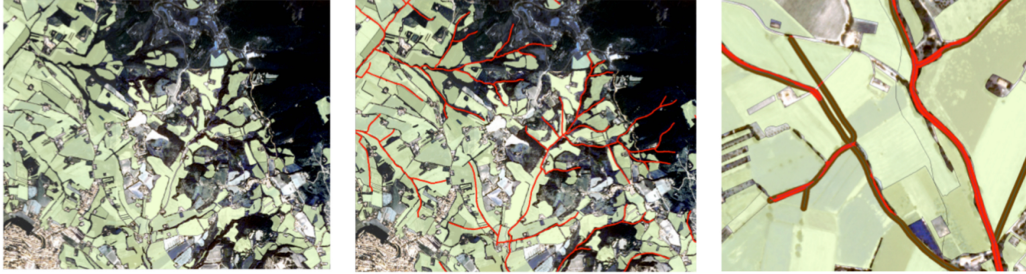


Figure 2: Case study area viewed on WorldView 2. Left: assignment of each piece of land along the water courses to a specific buffer strip typology. Center: buffer strips built by buffering parcels according to a given distance from the river streams (red). Right: detailed view of intersections between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

243 4. Methodology

244 The visualization of buffer strips directly on-site is fundamental; as a
245 matter of fact, farmers who want to step-up into the Common Agriculture
246 Policy funding scheme and claim for the payments of subsidies, must com-
247 pel with a set of conditions (Good Agricultural Environmental Conditions),
248 among which the maintenance of vegetated strips (BS) along watercourses is
249 compulsory. Local authority has to ensure that the network of BS is kept and
250 maintained over the time by the farmer. The faster way to monitoring the
251 operational state of the network is to identify the linear pattern and verify
252 its maintenance status. In the following section a mobile AR application for
253 GIS data visualization is described. In the following section a mobile AR
254 application for GIS data visualization is described. Our tool provides the
255 necessary information to properly inspect the area of investigation and to vi-
256 sualize in real time the buffer strips. Buffer strips are contextualized within
257 the real environment once the camera is on and placed in the correct location

258 where they are fitted in the GIS cartography. The purpose is to provide a
259 geo-visualization method for real time and on-site data visualization, partic-
260 ularly suitable for this case study, but that could be used for many other
261 GIS data. Details of the development phases, libraries and functionality of
262 the application are presented in the following section.

263 *4.1. From GIS to AR environment*

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

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

272 The first part of the workflow consists in translating the polyline shape
273 file (“shp”) of the BS and all related files (“sbn”, “sbx”, “shx”, “dbf”) to
274 “kmz” or “dxf” exchange CAD formats. For the AR experience in-situ, the
275 visualization of a 3D model is preferable, so we extruded the “shp” polygon
276 importing it into a three-dimensional modelling program (e.g., Sketch-up);
277 once the model is imported, the user can apply every required changes (e.g.,
278 material, color, extrusion, and so on). Next step is to edit this model by
279 Laya3D model converter, a powerful tool which enable this transformation

280 (Layar (2009)); the most suitable format for this kind of operations is the
281 “.obj”, because of its capability to maintain the original file object and the
282 possibility of being edited. In this phase, it is also possible to geo-reference
283 the model on a common Open-Street Map environment. The final output
284 is an l3d file, which can be defined as a geo-layer ready for being uploaded
285 to a web-server. From web-side implementation, it is necessary a Relational
286 Database Management System (RDBMS) and a classical web-server that
287 hosts php pages. For this test we adopted the open source MySQL server.
288 In the database we built a table that contains data regarding the Point of
289 Interest (POI), geometrical transformation, description and link to external
290 resources. A web service is needed to fetch the POI information (in JSON
291 format) and get it back to the AR platform. More in deep, we stored the
292 POIs within the database table linked to the application created specifically
293 to contain them; in particular, about each POI, is essential to store latitude
294 and longitude (to correctly register geo-location), title, description and other
295 information of interest for the user. To retrieve these points at user’s request
296 it also necessary that the application generate a php script that returns the
297 POIs. The parameters to correct locate the model above the screen are:
298 latitude, longitude and a radius of influence. Within the circle of specified
299 radius, the application seeks for relevant POIs, starting from user’s location.
300 At this point the last step to complete the workflow is to perform a series
301 of asynchronous calls to activate the php script, which is possible from any
302 operative system, passing the user’s location coordinates as parameters. Fig.
303 3 is an explanatory scheme of how the architecture works. From now then
304 the mobile app can interact with the stored contents.

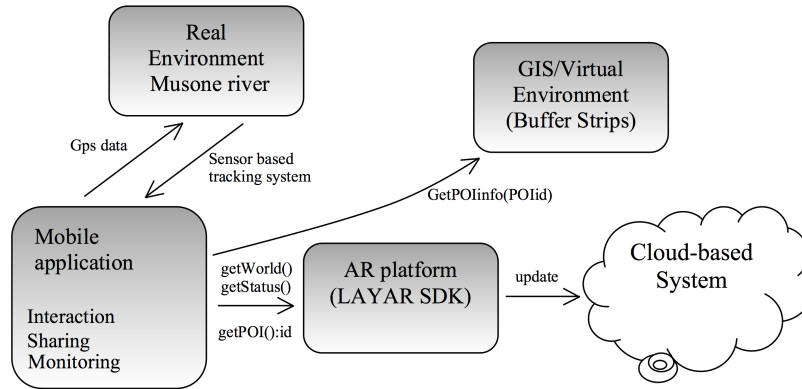


Figure 3: System architecture diagram and test-bed.

305 *4.2. Standard Data Layer and Mobile Application*

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

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

- 312 • Identification data: are used for textual and id identification of the main-
 313 tenance POIs, use a short name (NAME), a id number and a long name
 314 (TRADITIONALNAME)
- 315 • Description data (DESCRIPTION): are used to describe the maintenance
 316 POIs and uses geolocation, identified by an international standard address,
 317 the maintenance area (TECHDATA), the identification of this area as a risky
 318 one and every detail about the risk type, the status of the risk, etc.

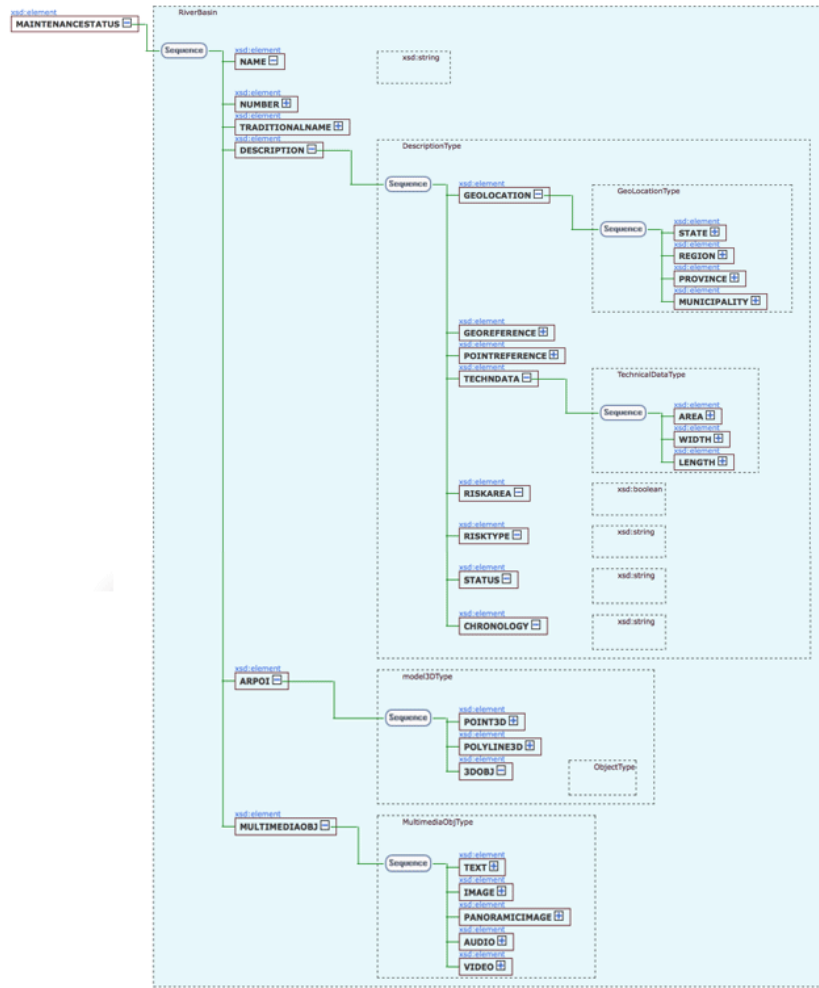


Figure 4: Standard data layer architecture of the main system, with the data structure of every components.

- 319 • AR data (ARPOI): are used to show in AR all the spatial information
- 320 superimposed to the real scene, using the LayAR standard description for
- 321 points, poli-lines and shapes.
- 322 • Multimedia data: are used to add multimedia information to the AR data

323 layer to add or gather, using also on user interactions (e.g. like tag) and
324 user generated contents, text, images, panoramic images, audio and video
325 contents. All this data are part of the proposed standard and detailed de-
326 scription can be found on the project web page.

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

330 • Augmented reality tool:

331 this functionality allows the user to activate the augmented reality browser
332 and to search for all the POIs close to him/her. Compass displayed on the
333 screen visualize the nearest POI; in this way the user can easily reach the
334 area where the strip is located. To implement this feature we took advantage
335 from the set of embedded sensors of mobile devices e.g. compass, gyroscope,
336 accelerometer and GPS receiver. A good examination about AR tracking
337 systems can be found in Zhou et al. (2008). For adjusting the search area ,
338 the user can set a search radius from the device. This is particularly helpful
339 during the campaign to retrieve information of a limited set of POI nearby
340 the user. As default, the radius value is 500 m. Moreover, the application
341 allows obtaining more information by displaying in a popup window the
342 title, description, footnote and the image associated with the POI selected,
343 as well as the BS typology. All these features have been implemented by
344 using libraries provided by API LayarSDK: a static library that implements
345 augmented reality and geo-localization functions. Fig. 5 shows an example
346 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.

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

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

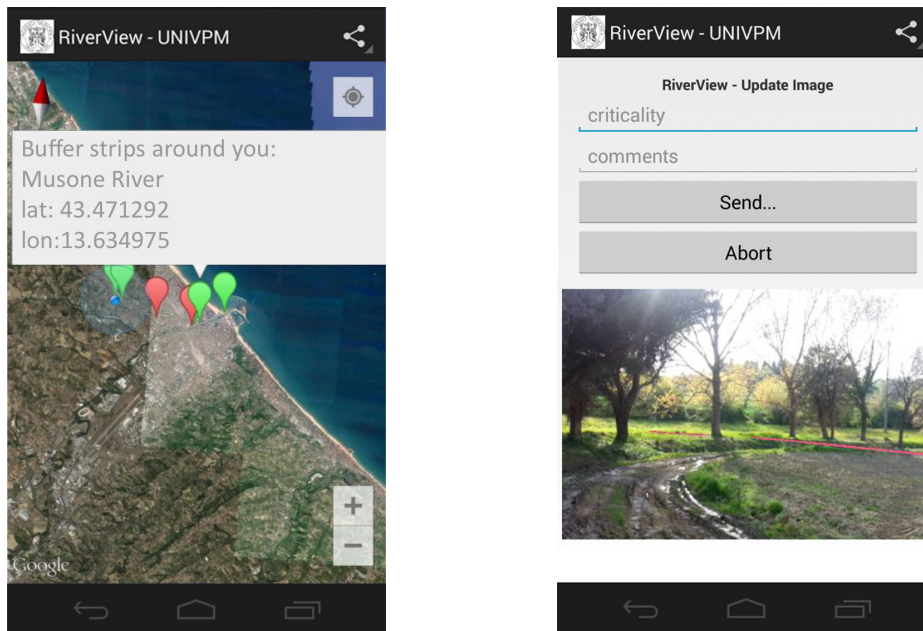


Figure 6: Left: POI visualization on the map. Center: Real time visualization of buffer strip (in red) with the possibility to share information or comments.

367 • Data Management:

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

379 5. Results and validation

380 We have designed different test cases under different conditions. The
381 tests were made in real scenarios, at a latitude of $43^{\circ}33'36''N$ and longitude
382 of $13^{\circ}30'05''E$ with different daytime, mainly focusing on the usability and
383 positioning accuracy. Considering that during the testing phase we did not
384 observed false positives and that all the recorded points of interest reported
385 to have a good accuracy, the suitability for GIS/desktop purposes resulted
386 to be more than satisfactory. For the evaluation of the usability we have
387 tested the system with subjects involved in the environmental management
388 such as: planners, land-managers, officers and practitioners of different age.
389 To make up the panel of expert for the tests , we also gathered information
390 about their habits and technological skills. From the gathered information,

391 we realized that people involved with the planning and management of the
392 environment are not skilled in the use of technology and they still prefer to
393 perform their activity from the office. Nevertheless, the users appreciated
394 the system. Almost all users didn't know AR but appreciated this technol-
395 ogy. The majority of the sample (70%) retains that similar applications are
396 necessary resources to improve monitoring activities. They have generally
397 found that the application is simple to use, although with respect to the
398 general idea, they suggest strengthening the relationship between desktop
399 and mobile sides. For testing the accuracy of the tracking system, we tried
400 different 3D models of the buffer strips, in different locations and times. The
401 devices used in our test were an iPad 2 and a Samsung S3. The system is also
402 compatible with LayAR for Google Glasses. With the overlapping of several
403 screen shots, we checked that the positioning of the virtual contents were
404 stable and visualized in the same position for both devices. With the GNSS
405 service available, accuracy was between 5 m up to 10 m, depending on veg-
406 etation canopy coverage. By the way, the accuracy of the superimposing of
407 digital contents is strictly depending from the current accuracy of consumer
408 grade GPS receiver. The current state of sensor-based and marker-less AR
409 technology is mainly limited by positioning issue; moreover, the spreading
410 of cutting edge technology for geospatial applications will depend from the
411 growing in the customer market of more accurate positioning systems. De-
412 spite the system architecture is complex, we have designed a simple user
413 interface (UI) to ease user's approach. In this way it is possible to cope with
414 all potential difficulties that users could face during the work on field, such
415 as bad weather conditions or impervious accessible areas. The more intuitive

416 is the UI the faster the inspection will be. Let us underline that our purpose
417 is to create a monitoring tool that is at the same time a maintenance tool. In
418 fact, the proposed solution, besides allowing monitor and supervise report-
419 ing area (in our specific case, the buffer strips at catchment basin scale), also
420 allows to share observations and surveyed data in real time, by uploading
421 and linking this information in a GIS environment. In particular, the cycle
422 shown in section 3 can be re-iterated endlessly: the health-check status of
423 buffer strips can be monitored and verified at any time and the environment
424 constantly maintained.



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

425 **6. Future works and conclusions**

426 In a further development of our research we aim to integrate the technol-
427 ogy of Augmented Reality in a video/image stream from a remote manned/
428 unmanned robotic platform equipped with a wide range of sensors. The idea
429 will be experienced within the “River View” project granted by the Ministry
430 for Economic Development to support research programs; the project deals

431 with the study, design and prototyping of a system for mapping and classi-
432 fication of risk cases at river and lake basins by using autonomous robotic
433 systems and sensory advanced platforms. We are building unmanned robotic
434 vehicles, both aerial (UAV) and surface (USV), to perform fast environmen-
435 tal surveys on targeted regions of interest with particular focus on small river
436 basins and lakes (fig. 7). These platforms are particularly suitable to all that
437 sites where human access is uneasy or forbidden due to specific restrictions
438 for nature protection. We are currently working to make the overlaying of
439 GIS data and AR contents fully operative in real time. This will make the
440 video stream enriched with additional information related to the survey (e.g.
441 weak lake bank, dangerous area and so on). It does not represent a simple
442 overlay of telemetry data, rather an actual interaction of the reality, as per-
443 ceived by the user, with a set of complex contents, such as 2D/3D objects,
444 linked with the user's point of view. The whole system can be performed in
445 a constant stream of information about the area under investigation, in GIS
446 and geo-DB environment. Users could benefit of the Augmented Reality for
447 a more reliable control on the survey. Although in many countries the world-
448 as-a-user interface paradigm is wide spreading for commercial use, currently
449 no monitoring applications for Head Mounted Devices (HMD) have been re-
450 alized yet. Therefore we also expect, for the near future, to test this kind
451 of applications also for wearable devices. Finally, potential scenario to fur-
452 ther exploring the potential of AR solution, in combination with geographic
453 representations, is the quality control of automatic land use classification. A
454 previous research (Malinverni et al. (2014)) has delivered an interesting tool
455 for automatic Land Cover/Land Use classification; the idea is to use AR as a

456 tool to validate the performances of classification. We presented an approach
457 to prove the potentials offered by Augmented Reality (AR). By combining
458 GIS-based environmental modelling with the use of relevant AR technologies
459 we outlined a novel approach to the health-check of linear vegetated strips
460 protecting river banks, overcoming several limitations of a classical approach
461 to mobile environmental monitoring. The methodology offers a set of im-
462 provements. Above all, it gives users a quick access to relevant information,
463 thanks to the dynamic superimposing of geographic features, comments and
464 other contents. Furthermore, the user-friendly interface makes the system
465 suitable for different users. The system allows for real-time interactions of
466 GIS data and AR contents; in particular, thanks to the cloud based DB
467 for GIS data, modification of data is possible in the real-time. We expect
468 that in the next few years AR will become a widespread technology and a
469 best practice application for environmental protection, monitoring and land
470 management. The overall idea inspiring our work is that AR could trigger
471 a “smarter” environmental control with less time-consuming for on-site in-
472 spections. We expect that in the near future AR technology will become a
473 widespread application for environmental monitoring, land management and
474 environmental protection, using smart phones and glasses.

475 **References**

- 476 Armenakis, C., Nirupama, N., 2013. Prioritization of disaster risk in a com-
477 munity using gis. *Natural Hazards* 66 (1), 15–29.
- 478 Balestrini, R., Arese, C., Delconte, C., Lotti, A., Salerno, F., 2011. Nitrogen
479 removal in subsurface water by narrow buffer strips in the intensive farming

- 480 landscape of the po river watershed, italy. *Ecological Engineering* 37 (2),
481 148–157.
- 482 Behzadan, A. H., Kamat, V. R., 2007. Georeferenced registration of construc-
483 tion graphics in mobile outdoor augmented reality. *Journal of Computing*
484 *in Civil Engineering* 21 (4), 247–258.
- 485 Carmigniani, J., Furht, B., Anisetti, M., Ceravolo, P., Damiani, E., Ivkovic,
486 M., 2011. Augmented reality technologies, systems and applications. *Mul-*
487 *timedia Tools and Applications* 51 (1), 341–377.
- 488 Chittaro, L., 2006. Visualizing information on mobile devices. *Computer*
489 39 (3), 40–45.
- 490 Deakin, A., 2009. Evolution of geographic information systems and visual-
491 ization systems. *Environmental monitoring. EOLSS*.
- 492 Feiner, S., MacIntyre, B., Hllerer, T., Webster, A., 1997. A touring machine:
493 Prototyping 3d mobile augmented reality systems for exploring the urban
494 environment. *Personal and Ubiquitous Computing* 1 (4), 208–217.
- 495 Guo, Y., Du, Q., Luo, Y., Zhang, W., Xu, L., 2008. Application of augmented
496 reality gis in architecture. *ISPRS* 8.
- 497 Henderson, S., Feiner, S., 2009. Evaluating the benefits of augmented reality
498 for task localization in maintenance of an armored personnel carrier turret.
499 pp. 135–144.
- 500 Hochrainer-Stigler, S., Pflug, G., Luger, N., 2013. Flood risk in a changing

501 climate: A multilevel approach for risk management. *Integrated Catastro-*
502 *phe Risk Modeling*, 263–279.

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

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

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

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

514 Layar, 2009. Layar augmented reality.
515 URL <https://www.layar.com>

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

519 Liarokapis, F., Brujic-Okretic, V., Papakonstantinou, S., 2007. Exploring
520 urban environments using virtual and augmented reality. *GRAPP* 2006 (3),
521 1–13.

- 522 Liarokapis, F., Greatbatch, I., Mountain, D., Gunesh, A., Brujic-Okretic, V.,
523 Raper, J., 2005. Mobile augmented reality techniques for geovisualisation.
524 Vol. 2005. pp. 745–751.
- 525 Malinverni, E., Frontoni, E., Mancini, A., Tasseti, A., Pierdicca, R.,
526 Zingaretti, P., 2014. Integrating elevation data and multispectral high-
527 resolution images for an improved hybrid land use/land cover mapping.
528 In: SouthEastern European Journal of Earth Observation and Geomatics.
- 529 Malinverni, E., Tasseti, A., Mancini, A., Zingaretti, P., Frontoni, E., Bernar-
530 dini, A., 2011. Hybrid object-based approach for land use/land cover map-
531 ping using high spatial resolution imagery. *International Journal of Geo-*
532 *graphical Information Science* 25 (6), 1025–1043.
- 533 Piselli, V., Marcheggiani, E., Gulinck, H., Galli, A., 2013. Buffer strips in the
534 marche region. *Rural Landscapes: Towards a Better Integration of Rural*
535 *Development Policies, Urban and Landscape Planning*.
- 536 Pundt, H., Brinkttter-Runde, K., 2000. Visualization of spatial data for field
537 based gis. *Computers and Geosciences* 26 (1), 51–56.
- 538 Rhyne, T., MacEachren, A., Gahegan, M., Pike, W., Brewer, I., Cai, G.,
539 Lengerich, E., Hardisty, F., 2004. Geovisualization for knowledge construc-
540 tion and decision support. *IEEE Computer Graphics and Applications*
541 24 (1), 13–17.
- 542 Roberts, W. M., Stutter, M. I., Haygarth, P. M., 2012. Phosphorus retention
543 and remobilisation in riparian vegetated buffer strips. In: *EGU General*
544 *Assembly Conference Abstracts*. Vol. 14. p. 11348.

- 545 Schall, G., Mendez, E., Kruijff, E., Veas, E., Junghanns, S., Reitinger, B.,
546 Schmalstieg, D., 2009. Handheld augmented reality for underground infras-
547 tructure visualization. *Personal and Ubiquitous Computing* 13 (4), 281–
548 291.
- 549 Schmid, F., Langerenken, D., 2014. Augmented reality and gis: On the pos-
550 sibilities and limits of markerless ar.
- 551 Shahabi, C., Banaei-Kashani, F., Khoshgozaran, A., Nocera, L., Xing, S.,
552 2010. Geodec: A framework to visualize and query geospatial data for
553 decision-making. *Multimedia* 17 (3), 14–23.
- 554 Stoaate, C., Bldi, A., Beja, P., Boatman, N., Herzon, I., van Doorn, A.,
555 de Snoo, G., Rakosy, L., Ramwell, C., 2009. Ecological impacts of early 21st
556 century agricultural change in europe - a review. *Journal of Environmental*
557 *Management* 91 (1), 22–46.
- 558 Talmaki, S., Dong, S., Kamat, V., 2010. Geospatial databases and augmented
559 reality visualization for improving safety in urban excavation operations.
560 pp. 91–101.
- 561 Tsakiris, G., Nalbantis, I., Vangelis, H., Verbeiren, B., Huysmans, M., Ty-
562 chon, B., Jacquemin, I., Canters, F., Vanderhaegen, S., Engelen, G., Poel-
563 mans, L., De Becker, P., Batelaan, O. g., 2013. A system-based paradigm
564 of drought analysis for operational management. *Water Resources Man-*
565 *agement* 27 (15), 5281–5297.
- 566 Veas, E., Grasset, R., Ferencik, I., Grnewald, T., Schmalstieg, D., 2013. Mo-

- 567 bile augmented reality for environmental monitoring. *Personal and Ubiquitous Computing* 17 (7), 1515–1531.
- 568
- 569 Yoo, H., Cheon, S., 2006. Visualization by information type on mobile device.
- 570 Vol. 60. pp. 143–146.
- 571 Zhou, F., Dun, H.-L., Billinghamurst, M., 2008. Trends in augmented reality
- 572 tracking, interaction and display: A review of ten years of ismar. pp. 193–
- 573 202.