Computers & Geosciences 95 (2016) 67–74

Contents lists available at ScienceDirect

Computers & Geosciences

journal homepage: www.elsevier.com/locate/cageo

Research paper

Smart maintenance of riverbanks using a standard data layer and Augmented Reality

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ARTICLE INFO

Article history:
Received 28 June 2015
Received in revised form
24 June 2016
Accepted 25 June 2016
Available online 6 July 2016

Keywords:
Buffer strips
Augmented Reality
Environmental monitoring
Mobile visualization
GIS

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 difficult 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, 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.

1. Introduction

In the general context of nowadays-environmental crisis, the key challenge for modern agriculture is twofold: on one hand, there is the necessity to feed many billions of people. On the other hand, the preservation of good quality conditions is compulsory. Accordingly, the quality of fresh running and underground water is a key issue (Stoate et al., 2009). In the agricultural landscape and over wide rural territories, the modern approach of water protection is based, among others, on the use of linear buffer strips (BS) along watercourses. These conservation buffers are small bands of land in permanent vegetation, designed 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 effective protection, it is well known that the network of vegetated strips must be designed with a carefully installed and well-maintained stringent scheme. The protective network needs to comply with two main conditions: the integrity of the spatial continuity of the protecting belt and constant man-hours 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 requires costly and specialized equipment. A significant improvement of the environmental monitoring and

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http://dx.doi.org/10.1016/j.cageo.2016.06.018

control can be achieved by adopting effective management strategies to increase the awareness of risks (Armenakis and Nirupama, 2013; Hochrainer-Stigler et al., 2013; Hsu et al., 2013). The possibility of taking sound strategies depends on the amount and on 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). AR could trigger smarter watershed control and riverbank maintenance with less time-consuming during on-site inspections; furthermore, it can be used to cope with the technological limitations that cannot be overcome by using GIS as a stand alone platform. By merging these technologies into a single platform, data become available in real time.

In this light, our purpose is to provide management authorities, land managers and insiders with an intuitive and dynamic real-time visualization tool. The proposed solution combines an existing Geographical Information System (GIS) with the use of relevant Augmented Reality technology. 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 builds 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. 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 one hand, GIS allows for managing, modeling 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 modeled representation displayed by thematic maps. Such new forms of enriched or, better, augmented geo-information reduce the efforts in operating a mental transformation from map to reality (Schall et al., 2009). 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 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 applications; on the proposal of a novel data layer 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 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. Afterwards, in Section 5 we comment on experimental results illustrating the reliability and affordability of the proposed application. Concluding remarks and future developments are reported in Sections 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 has proved to represent a promising field of application for mobile devices (Kruijff et al., 2010). 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 allows 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). Therefore, the environmental data analysis process needs the introduction of technological tools to make more effective and reliable monitoring and maintenance phases (Hugues et al., 2013). 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 self-impressions and an aware method of 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 an environmental analysis. Furthermore, mobile devices are equipped with sensors that help user in orientation and navigation and, above all, they network the devices, and hence the user, with the real world. The introduction of the user location, everywhere at every time, leads insiders and developers to rethink the mobile approaches in a new manner, meaning that applications would tend to 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), exploiting the metadata intrinsic with the GIS objects and necessary for their geo-localization and visualization. GIS and visualization systems are both approaches to discovering and understanding patterns and issues found in geospatial data (Hugues et al., 2013). Indeed, according to Deakin (2009), GIS is strictly related to the visualization for its effectiveness.

For this kind of application, AR could be considered the ultimate immersive system (Liarokapis et al., 2005); even if in large