On-Site Monitoring of Environmental Processes using Mobile Augmented Reality (HYDROSYS)

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Abstract. HYDROSYS is a project targeted at improving monitoring and understanding of environmental processes and their management. The project introduces innovative concepts of on-site monitoring and event-driven campaigns using mobile interactive visualization systems.

Keywords: Mobile applications, environmental monitoring, augmented reality.

1 Introduction

HYDROSYS aims at analyzing environmental processes where they truly happen, namely in the field. As such, it advances current practice of informal observations in the field and specific analyses done in the office. Environmental monitoring can be defined as the process of observing continuously and measuring regularly environmental parameters of a specific area in order to identify environmental changes and aid the decision making process related to the site. In this context, on-site environmental monitoring comprises all activities that are done in the field such as identifying key variables of the problem, taking measures, data and images communication, understanding the site as a whole, and validation of a technical solution in order to optimize the management of natural areas. At all times, it is important to understand that on-site monitoring is not replacing nor can it be replaced by remote monitoring: it is a complementary task. The system is expected to aid in better understanding physical processes while they happen, by being able to combine mentally the results of measurements and the actual site being viewed. Furthermore, and highly interconnected, the system allows for better communication between various parties while discussing solutions to mitigate environmental degradation.

The HYDROSYS interactive system deploys a large sensor network system setup at sites in Switzerland and Finland that feeds mobile units with live data while users monitor processes in the field. Additionally, new data acquisition methods are applied, such as a blimp (zeppelin) that captures optical and thermal data to refine terrain models and provide for detailed textures and thermal image maps. The novelty of the system is in the deployment of so-called augmented reality (AR) techniques on mobile units (Feiner et al 1997). Whereas some solutions exist for outdoor AR in the field of construction work (Schall et al 2007), the usage of AR in environmental monitoring is novel. AR merges real world views captured by video cameras with synthetic data. It allows the user to walk around and observe the environment, continuously getting a “correct view” on the sensor data. The task of augmented reality is to render computer generated artifacts correctly registered with the real world in real time. Coupled to the interactive visualization, HYDROSYS enables communication and exchange of data (e.g. images, data, graphs) from an on-site observer to decision makers who are generally at workplace and vice versa. In fact, end users are expected to have a better view of the global situation before, during and after an event with the image transmission and overlay techniques. It will save time and money doing onsite and online analysis and users will have a better visualization of the field when they are in office. In this publication, we will describe the technical framework, the interactive visualization methods, and a short application example.

2 Interactive visualization system for sensor data

Data is gathered from sensors, and possibly by a blimp to generate a dense information space from a small area. The blimp is equipped with an optical and thermal camera: it can capture image footage that is used in cohesion with computer vision methods to generate refined digital terrain models, and thermal imaging that can be verified with spot measurements. The data is fed over cell phone networks or WiFi into the Global Sensor Network system (GSN, http://sourceforge.net/apps/trac/gsn/) where it is processed and stored.

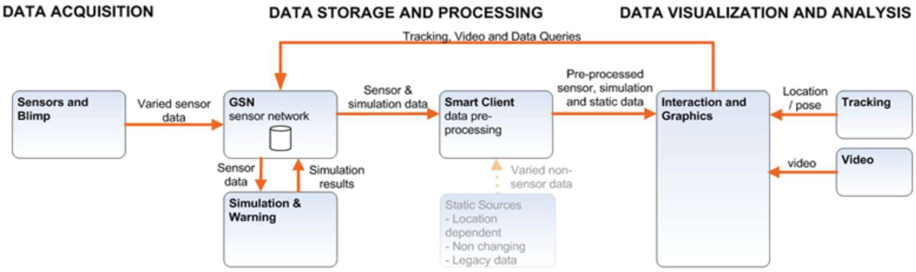

Fig. 1. High-level system architecture

The simulation and warning system acts as a node to the GSN system, processing the sensor data using both simple and complex models. Users can trigger simulations in the office using a web interface to see the results later on in the field once complex simulations are used. Data is accessed through the SmartClient to the handheld platforms, which are both the in this article briefly described augmented reality system, and cell phones. Potentially, WiFi bridges are used to relay networks at remote locations. The SmartClient also deals with static data such as terrain models and other legacy data. The handheld platforms form the front-end to the sensor data, visualizing the various sensor data types and simulation results that are pre-processed off-site. Hereby, the user will be able to access various cameras that are located on-site, to get a better overview from multiple perspectives to aid in understanding the problem at hand. Experiments have been performed with various user interface techniques to understand the premises of such a "multi-camera framework", on a cognitive and technical level, showing positive results (Veas et al 2010).

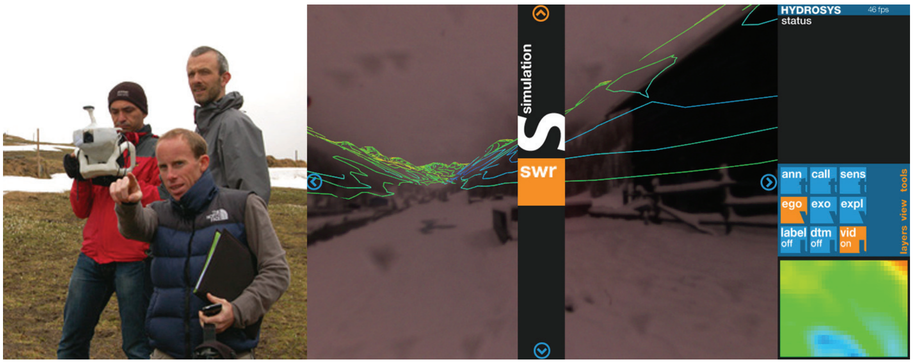

Fig. 2. Outdoor users, intermediate stage of user interfaces, isophotes rendering.

The handheld augmented reality system leverages advanced visualization techniques to render and overlay views of the data depending on the user's location. Hardware-wise, the platform consists of a robust outdoor computer (UMPC), a camera, an orientation and a GPS sensor and a special encasing. Meanwhile, a more advanced and smaller handheld platform has been designed (compare Figure 2, left and Figure 3). The sensors mounted in the encasing are important to define the "pose" of the user to correctly render the digital content over the video image, hence, the perspective of the user: the required accuracy can, by far, not be met by other platforms such as cell phones that are also used for simple Augmented Reality applications. An inferior pose is likely to result in some interpretation problems due to mismatching of video and graphics. Nonetheless, the sensor data is correctly matched to the underlying model (the DTM), meaning that it is always possible to view the 3D model with the sensor data visualizations. In general, users make use of "real-world verification" to compare the data on the screen to the real world. Still, a cell phone application would have difficulties to show the computationally demanding information, since even the latest platforms have limited processing and graphics performance. At this point, it is important to mention that HYDROSYS actually includes cell phones as a second visualization platform: cell phones are being used to run a graphically less demanding application which shows a 3D model of the environment, and associated sensor data. This platform is predominantly used in several application scenarios that take place in Finland, and fall outside the scope of this article.

Returning to the issue of localization, at current more refined tracking methods are under development that solves some of the problems related to registration of digital content over video imagery, as can also be seen in Figure 2 (isophotes offset from actual environment). The current state of development affords 1.5m accuracy and better orientation drifting and offset handling, among others by using ultra wideband localization mounted on a vehicle setup.

At the handheld, the user can make use of several advanced interface modules to perform a multitude of actions in the field. First, the user can select sensor data from the various sensors available in the field. This data is, in general, rendered as "registered labels" that show the sensor data in numeric format, connected to the actual location the data is retrieved from (the sensor or sensor station). Users can also transfer to exploration mode: in this mode, the video imaging is replaced by a full-screen representation showing the list of sensor types connected to a specific sensor station with their latest readings. Potentially, users can analyze sensor readings over time using plots that are shown in the same mode: these plots can be generated at the GSN server at predefined intervals and transferred to the handheld upon request. An additional view mode of interpreting the sensor data as well as the simulation data described hereafter is to switch to map-mode, which provides a top-view of the site. Simulations are started by using a simple web front-end that can directly access the data stored at the sensor network, and the physical models that are used for simulation. After the simulation results have been produced a semi-automated, user supervised is required to transform the simulation results in a form appropriate to run at the handheld software platform.

Fig. 3. Latest version of handheld platform.

Users can select simulation results that are produced by the various simulation engines available in the system. The pre-processed data is shown as registered overlay over the terrain model (and thus the video image), similar to interpolated maps. As a result, the user can compare various sensor readings and simulation results at one glance. In addition, users can access further information that is useful in the field. This information encompasses height information, and network coverage. The latter is very much useful when installing sensors in rough terrain, where an initially selected location may not turn out to be ideal once inspected on-site.

The information being visualized is separated in 1D/2D and 3D data. The user interface allows smooth transition between the various information sources: during the end-user workshops performed at the start and middle of the project, a clear tendency can be seen towards the usage of 3D visualizations, still, many users want to access the 1D and 2D sources too. Moreover, some users are skeptical about 3D information visualization. We hope that by mixing the various information sources in a direct and easy way, more users will actively make use of 3D visualizations.

One potential issue of interpreting the visuals in outdoor situations are both the size of the screen being watched, and perceptual interferences such as bright sunlight and reflections. Whereas the outdoor computer being used has been optimized for such conditions, viewing conditions are still limited. The consortium is producing methods that perceptually optimize visuals to cover for this issue, as for example the usage of isophotes as shown in Figure 2. Additionally, there are several other modules that are currently being finalized, which allow for other tasks to be performed. The collaboration module affords making annotations for noting down problems and ideas, and users may make use of voice calls to communicate over longer distances once dispersed over the site. The camera module focuses at providing access to different cameras located at the site, observing the site from different locations to get a better overview. These modules actively make use of a WiFi bridge system that has been developed as part of the project. The WiFi bridge allows high-speed network access at remote sites, and can be quickly set up: once a high-bandwidth network connection is available within the vicinity of the site being monitored, network can be relayed successfully over several kilometers.

Furthermore, a simulation module is under development that focuses at segmenting simulation results for better analysis, and combines to a sensor placement module that is used for taking manual measurements with a sensor connected directly to the handheld unit. The sensed data can be read and analyzed directly using the unit.

3 Application example

In mountainous regions wet-snow avalanches are important natural hazards occurring especially in late winter and springtime. They are characterized by high frequency and a high degree of potential damage to infrastructure. So far the processes which cause the formation and triggering of these avalanches are poorly investigated. The Dorfberg (Davos, Switzerland), a new field site for wet-snow avalanche research has been equipped with several sensors including a complete meteorological station. With steep slopes and a southwards aspect the Dorfberg, is a proper place for this purpose and frequent small wet snow avalanches and some big events have been monitored in the area in the last years.

When being on site the HYDROSYS interactive visualization system can be used to access data from the sensors (e.g. air temperature, snow surface temperature, radiation) in almost real-time. As a first step, the blimp can be used to monitor the site, capturing detailed optical and thermal data of the surface. These data can be queried and displayed with the handheld. The sensor data can be plotted on the handheld and are used as input for a simulation system running Alpine3D (Lehning et al. 2006), a physical based model which has been developed to describe alpine surface processes. As output Alpine3D produces area wide simulations for different parameters (e.g. snow surface temperature, snow water content) which are important for understanding the formation of the wet-snow avalanches. If deviations between model result and real observation are observed, a simpler one-dimensional model can be run with real-time data. This might help to understand the processes which caused the observed deviations. All together the HYDROSYS system enables the researcher to get an impression of the current conditions while being on the field site. This could help to understand the obtained manual field observations and the processes which affect these conditions.

Fig. 4. Wet-snow avalanche at Dorfberg, Davos, Switzerland.

4 Conclusion and outlook

The HYDROSYS project is in the final stage, with a first range of successful monitoring actions performed. Whereas the system development and integration is not finished yet, at current, there is no system known that is as advanced as the presented system and can operate in the rough and remote locations as is reflected in the project test sites. Still, there are some improvements needed, such as the further refinement of the localization, and the integration of all sub-systems in a single prototype.

After finalization, the developed research system prototype will likely yield a strong basis for further development and usage by a wider public. Most results will be made available as Open Source. Information on how to obtain the software will be made available at the HYDROSYS website (www.hydrosysonline.eu).

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