A Tool for Visualization of Meteorological Data Studied for Integration in a Multi Risk Management System

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Abstract This paper presents a tool for visualization of meteorological data integrated in an application for management of a multi risk situation. As part of a much more complex and demanding visualization system, the tool was developed taking into account some constraints as the scarcity of screen space and processing power in the considered system. Due to these limitations the tool was developed as web application optimized for mobile devices and is capable to present time series data in a compact and effective visualization. The tool also can process the available data in order to detect exceptional events and to put them in the contest allowing a very fast visual analysis.

1 Introduction

The development of multimedia computer simulations, communications and scientific visualizations have deeply changed the techniques for risk and the emergency management. Simulation of emergency situations and advanced visualizations provide help to practitioners and decision makers in Emergency Management (E.M.), while multimedia communications, social networks and web applications are useful tools for emergency operators [1, 2].

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Mobile devices, through multimedia communication, are the perfect receivers for multimedia broadcast information, for example, in critical situations they can show evacuations routes to people in risk area [3]. Conversely, the mobile devices allow the operators to obtain more information from the ground about the emergency situations [4] and transform witness in diffuse information sources [5]. This huge information flow coming from multiple sources is organized, processed and visualized in an emergency control room, where the information from the field is integrated with the one obtained from time series processing.

The project SIGMA[1] is an Italian research project aimed to the development of a system that collects data from many sensor networks (rain, phreatic, seismic, volcanic) in order to monitor the environment and to provide useful data for prevention and management of multi-risk situation.

The system presented in this paper is targeted to the visualization of weather data and outliers of time series precipitation data [8]. The system is designed as part of the visualization system of the whole project, that comprises also many other parts related to seismic risk, volcano monitoring, and industrial risk, and was designed to be simple and easy to navigate. The system was built as a web application and the information is presented in a very compact form for an important reason: both the monitor space in the control room and the display occupation in a mobile device are a limited resource. Some systems have been proposed for the visualization of the emergency situation occurring in a given place. We describe here some examples of systems and applications of visualization in emergency situations employing techniques and solutions for specific critical situations.

In [6] a system for emergency management in flood emergency is presented. The work is related to a project involving the emergency management in Portuguese dam system. The system is provided with a three dimensional terrain visualization that represents the involved valleys. The specific particularity of the work is that the authors cast this application as a real time strategy game where a user can analyze the single involved entity clicking on the item and reading the corresponding information. The geographic information is managed with a Geographic Information System. A geographic data stack is used to manage terrain features such as roads, water streams and buildings. The proposed interface is bound to geographic data and provides information for the values of the rivers and the dams. The system does not provide an analysis of the previous values and local point by point information is presented. The action to be taken and the visualization of the relevant information is left to the user who directs his attention to the items assessed as the most relevant. The visualization on a map is very useful, while the evaluation relies on the user experience and his heuristics due to the lack of data analysis.

In [7] an approach for the management of emergencies in public transportation is described, using the Valencia metro as a study case. Their approach considers the emergency as a process and combines the information from different sources to describe the applied plans. The proposed approach presents different emergency resolution paths to the users who can choose the most adapt ones according to the

[1] http://www.sigma.pa.icar.cnr.it/.

collected information. Information is retrieved and managed according to its validity and the emergency status. Communication and collaboration are described as fundamental aspects of the visualization system. A key aspect for the authors is the system capability to generate valuable information and to spot what is important out the data collected by all the sensors. As in this case, our system is aimed at visualizing information that come from a net of heterogeneous sensors. We don't consider the emergency plans as we are focused on data collection rather than on the execution of an emergency plan. Notwithstanding we consider of great importance the capability, for the visualization system, to provide information coming from multiple sources and visualize important aspect of information highlighting the most relevant and significative information.

2 System Description

A prior analysis of the operating environment and the recent strong presence of mobile devices has greatly influenced the choice of architecture, shown in the Fig. 1, the adopted technologies and the development of user interfaces. We chose to develop a web application because of the following reasons. *Data and computing capacity*: as we manage heterogeneous data, coming from several remote sources, in our application we used a relational database as common storage, warehouse for both row and processed data (analysis, filtering, merging the data, etc.). Server side computing capacity is greater than the one of the mobile device and this allow for an easier and more accessible front-end to the user. *Availability and update propagation*: web applications are immediately available to users through a browser on a wide range of devices (smartphone, tablet, laptop, PC, etc.), without downloads and

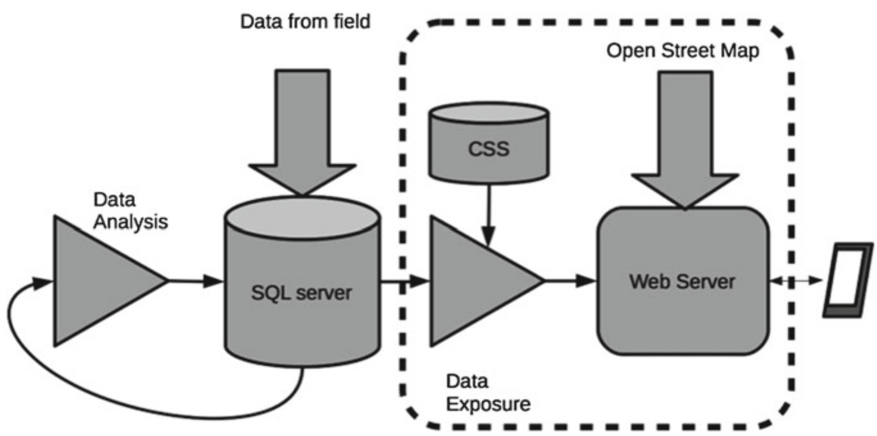

Fig. 1 Block diagram of web application system architecture

installations and can update their content in real time. *User-experience*: the progress and evolution of web standards and the strong improvement of interfaces and connectivity to mobile devices, have reduced the distance between web and mobile applications feature-wise. Our application needs to convey a wealth of information in very limited time and space. We have considered a set of principles to be adopted to create an effective interface to show relevant information and create an interface able to vehiculate these contents in a critical environment and situations. These principles are: *Clarity*: the interface should be as easy as possible. We strove to encapsulate all the relevant information in the visual medium. Some visualizations embed statistical information, such as the size of the circles representing the number of exceptional events for each station. *Modularity:* a user can switch from a visualization tool to another maintaining the attention focus on the relevant information. Multiple information can be obtained clicking on the menus obtained clicking on the stations. *Information Density:* we concentrated all the useful informations in few screenshots allowing a rich visualization in a glance. For example, we used the visualization of some averaged values (daily precipitation in Fig. 4) as a background for the visualization of the location of exceptional events, in order to put these points in a context. *Consistency:* the interface maintains the same underlying structure in all the visualization layers. The dots representing the stations can be clicked to open further menus that show multiple graphs. The outliers can be analysed in detail clicking on the outlier symbol and opening a detailed map. Every visualization can be accessed with a touch on a mobile device and all informations can be reached with few clicks. The proposed visualization system has a modular structure, organized in levels of visualization, that can be composed using many stacked layers. On the device screen (a laptop or a mobile phone) each level overlaps the previous ones and the final visualization is composed by all the information coming from multiple layers. Furthermore, a reduced number of visualization levels is also important for mobile devices. Figure 2 shows the logical structure of the visualizations implemented in the system. The first visualization level is depicted on the left of Fig. 2 and it is composed by overlapping layers over a geographical map. The two layers at the bottom of the structure show the positions of the weather stations or the positions of the sensor for water ponds level. Another kind of information is the average values of some measurements distributed on the whole region; for example the monthly or yearly average precipitation values or averaged temperatures. Operators in the control room can add to this first level any other information layer such as a georeferenced image. In Fig. 3 these layers are at the top on the first level and they are selected using a scroll menu.

The sensor layer allows the user to access to a set of visualizations related to time series data for temperature, precipitation or water pond level. Selecting one sensory station, the user can access the graphical representation of the time series. These more complex visualizations are obtained from the time series processing in order to offer a deep analysis of the measurements in a specific area by processing the time series data of each single station, in some cases the obtained values are compared with the surrounding measurements. In the following sections the two levels and the visualizations are described in details.

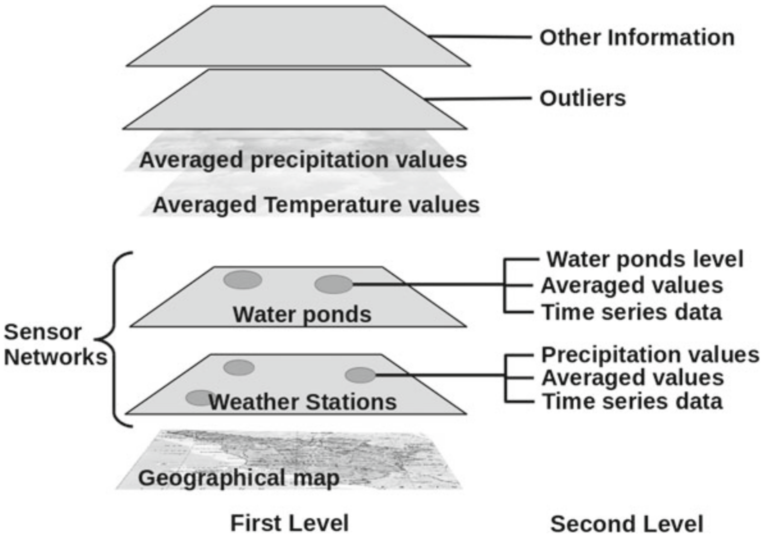

Fig. 2 The two visualization level obtained from the proposed system

Fig. 3 On the *left* and *center* part of the image there is the homepage of the mobile version, that provides the first level visualization; on the *right* part there is the second level visualization, with the set of visualizations related to time series data, available for each station

2.1 First Visualization Level

This level shows information obtained processing meteorological data for the whole region. For example it shows the averaged precipitation values that allow the user to spot the areas with heavy rainfalls. Other visualizations are extracted through

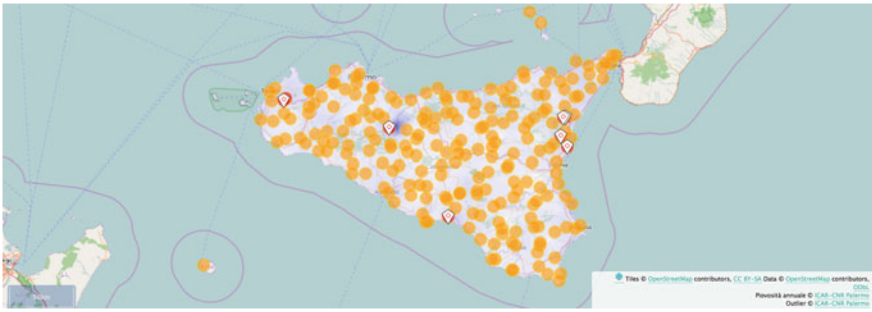

Fig. 4 The "Osservatorio delle Acque" and "SIAS" Station position. *Red circles* indicates the stations that registrated at least one exceptional precipitation event. The outlier are also visualized using the "diamond" placeholder. The rainfall density is represented by the intensity of the *blue color* (colour figure online)

complex processes, for example the one related to the outlier values and their frequency. In detail we find: a base layer displaying a geographical map, from OpenStreetMap or MapQuest, an informational layer to display measurement stations of rainfall data and temperature of *SIAS - Sicilian Agrometeorological Information Service*,[2] an informational layer displaying measurement stations of rainfall data and temperature of *Osservatorio delle Acque*,[3] an informational layer showing data relating to the levels of annual rainfall, an informational layer for displaying stations whose rainfall values outlie those of nearby stations.

Stations Position and Frequency of Exceptional Events. The visualization of the geographical position of the stations is the simplest information obtained from the selection menu of the system, and it is also the less informative visualization. We combined this information with a much more interesting visualization by using placeholders of different colors, in particular different levels of red, as reported in Fig. 4. These colors highlight those stations that registered at least one exceptional precipitation event. Each dot is scaledon the number of these events. These exceptional events are important because they are very often connected to flood events, so the visualization conveys the user attention towards the places where the precipitations can represent a serious risk for the people.

Outlier Calculation and Averaged Precipitation Density Values Visualization. Informally, an outlier is a point in a complex system where the behaviour of a given phenomenon is inconsistent with other points in its neighbourhood. Assuming that the presence of an outlier could help the detection of critical situations, we previously proposed an algorithm to spot the outlier from time series data [8] in complex geographical scenarios. As sensor networks can be modelled using graphs, the connections among the nodes can be used to convey the influence that each node has on its neighbours, provided that it can be expressed using a distance function.

[2] http://www.sias.regione.sicilia.it/.

[3] http://www.osservatorioacque.it/.

In the proposed algorithm the distance function used is Mutual Information, and is computed for each couple of nodes after a uniform discretization of the relevant time series values that allows the construction of probability densities, according to the frequentist interpretation of probability. Outliers are marked on the geographical map, as shown in Fig. 4. In this figure the outliers overlap to the averaged precipitation density values already calculated using the whole time series for the region, the density is represented by the intensity of the blue color.

2.2 Second Visualization Level

The visualizations on this level deal with the time series of the measurements for a single station.

Station Daily Mean Precipitation Values: "Tiles" visualization. This visualization shows, in a compact form, the daily mean precipitation value for a time span of several years. The overall visualization resembles a tile mosaic and reports a whole year on each horizontal strip and the weeks over the columns of the visualization. The color of each tile is related to the average precipitation value, referred to the global mean of the precipitation value for the station. Figure 5 shows an example of this visualization. On the left there is the visualization format for the mobile devices. This can be enlarged and a single day average value can be obtained hovering on the single "tile". This visualization was used since it is more readable than overlapped graphs. It allows the user to compare many years in a glance, and to spot patterns

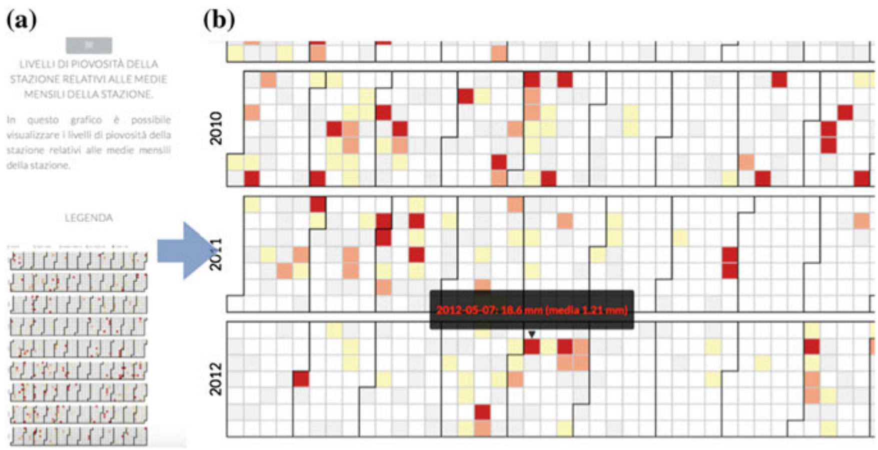

Fig. 5 Visualization of Daily Mean Precipitation Values. On the *left* **a** there is the visualization on a mobile device, on the *right* **b** the enlargement and the value of a selected point, inside the block rectangle. The visualization of the daily precipitation levels for a single station is the same as (**b**). In order to demonstrate the performance of the visualization tool, in this image we used the data acquired in Tuscany region that has a larger dataset than the Sicily region

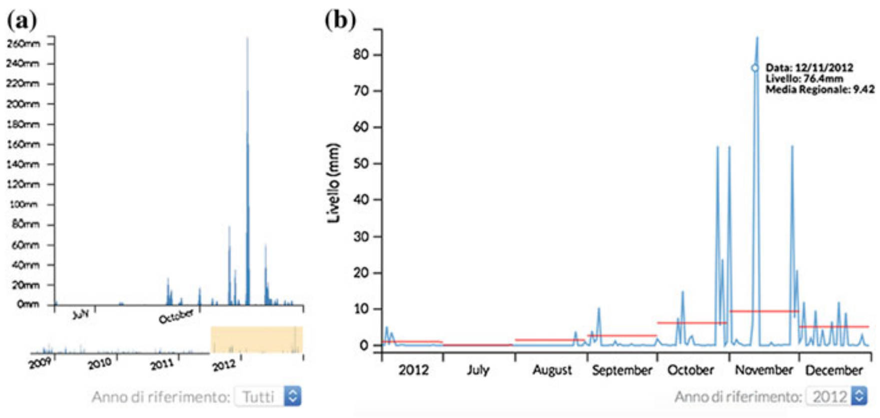

Fig. 6 **a** The whole time series of the averaged precipitation level for one station and zoom window. The listbox allows the user to select the year of interest, in this case all the measurements available are visualized. In order to demonstrate the performance of the visualization tool, in this image we used the data acquired in Tuscany region that has a larger dataset than the Sicily region. **b** The visualization of the daily precipitation mean against the monthly precipitation mean of the whole region

of events, if present. The graph visualization is also available and will be presented in the next section. The compact look of this visualization is effective on mobile devices and allows the user to have a global view on the time series data; it is also possible to zoom using the pinch-in gesture. The tiles are colored according the seven standardized levels by the Civil Protection[4]: C1: <1 mm, C2: 1 – 10 mm, C3: 10.1 – 20 mm, C4: 20.1 – 30 mm, C5: 30.1 – 40 mm, C6: 40.1 – 50 mm, C7: >50 mm. This visualization is the same as B part of Fig. 5. In order to demonstrate the performance of the *visualization tool*,[5] we used the data acquired in Tuscany region that has a larger dataset than the Sicily region.

Station Daily Mean Precipitation Values: time-line visualization. Each time series is also plotted using histograms. In this case the screen is split in two horizontal areas, as part A of Fig. 6 shows: on the bottom the whole time series is shown, so the user can spot the exceptional precipitation events. The use of a magnification tool over time axis allows a detailed inspection of the rainfall level values for the selected time slot.

Monthly Mean Precipitation Values for Whole Region. The same visualization methods are available for the precipitation data of the whole region. The daily precipitation mean can be plotted over the averaged monthly precipitation of the whole region, in order to highlight the anomalies. The averaged daily mean precipitation level for the whole region is shown as a set of horizontal segments in part B of Fig. 6. This visualization provides additional information since precipitations are compared with whole region average, not only with the surrounding stations.

[4]http://www.protezionecivile.gov.it/.

[5]http://www.sigma.pa.icar.cnr.it/toscana/.

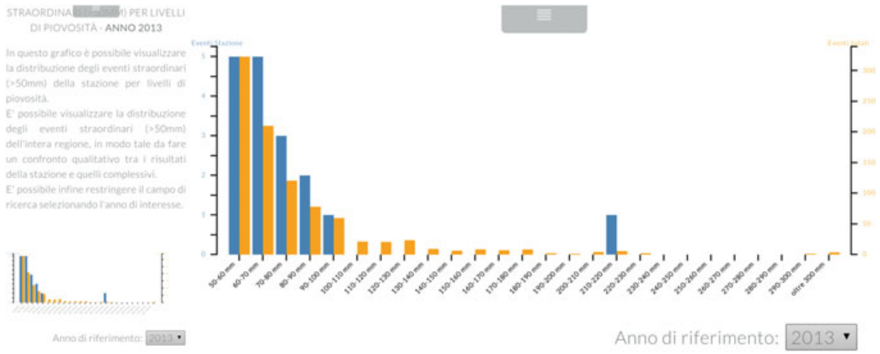

Fig. 7 Chart of the extraordinary events, *left* viewing on mobile, *right* on the PC/tablet

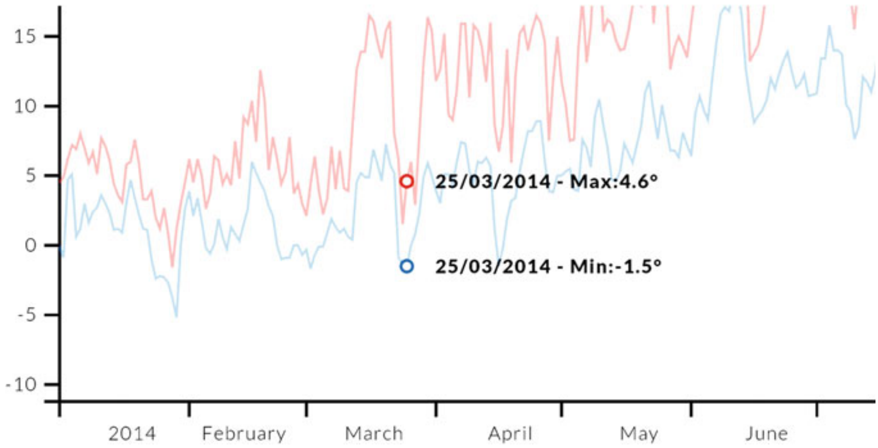

Fig. 8 Detail of the temperature value at a specific date

Extraordinary Events Distribution. A further view, shown in Fig. 7, allows the user to see a chart showing the distribution of the number of extraordinary events of the monitoring station (precipitation level greater than 50 mm) grouped by rainfall intervals. The chart, with a left scale of reference for the single station and a right scale for all stations in the region, shows the number of detected extraordinary events grouped by range of rainfall. Clicking on each bar the user can read the number of extraordinary events recorded in the individual station (blue bars) and in the whole region (orange bars). This graph displays the bands of greater concentration of the extraordinary events and allows a qualitative comparison of the overall behaviour across the region.

Temperature Trend. The temperature trend graph displays the variation of the maximum and minimum temperatures recorded by a station during the year. The application performs a real-time analysis of the time series temperature data of the selected station and plot it in a graph. The original appearance of the graph is maintained even on mobile devices, so you can have a global view on the time series just like on a personal computer. You can pinch to zoom and click to view the values of minimum and maximum temperatures recorded in a single day, thereby maintaining full data readability, as shown in Fig. 8.

3 Conclusions

The proposed system is part of a larger visualization tool developed in the context of the *SIGMA* multi-risk monitoring project. The system is aimed to visualization of precipitation and temperature time series data in order to support decision making during emergency situations.

The visualization was designed for mobile devices and it allows an easy integration with other visualization components that share the screen space. The system was developed as web application and made available for mobile devices on the field both for monitoring normal trends and for collecting information during emergency situations.

In the future we plan to test the system on the field in order to collect the user feedbacks.

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