Automatic Generation of an Interactive, Real time, Web-based Maps from Sensor-based Geographic Databases

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Abstract — In recent years, we have seen a growing number of location-based sensors used to measure increasingly diverse phenomena. Therefore, we consider the increasing need to efficiently manage the huge amount of data collected from located wireless sensor networks (WSN). In some phenomena, it is fundamental to generate maps in real time. Data can be grouped into web-cartography for diverse purposes; so finally, we develop a web-based mapping on demand. In this paper, in addition to cartographic functionalities mentioned above, we are facing another challenge. Indeed, we encounter the problem of avoiding on-the-fly overlays of multiple visual layers in order to get a result that is easy to interpret due to visual interference between graphic elements. The present paper describes an approach to the cartographic visualization of geo-data regularly acquired by WSN and exhibits a prototype portal based on an open source platform for integrated visualization as visual realtime summaries. An application in meteorology is proposed.

Keywords-component; real-time database; sensors, real-time cartography; interactive visualization; geovisualization, semiology.

I. INTRODUCTION

In the last decade, a new concept has emerged known as "Digital Earth" for which one is seeking ways to ensure access to information resources and to deliver geo-referenced knowledge to everyone. To reach this goal, many problems need to be addressed. One of the key issues is the development of novel methods coupling big data arriving in real time from sensor networks and the appropriate visualization in a way that allows users of its rapid and correct understanding. As visual presentation and analysis of these data are currently a very promising research topic; the scope will be not to determine the mapping once at all, but more especially to calculate it in real time in order to visualize evolution and to understand information in space and time by means of visual summaries.

In addition, much of the research effort in geovisualization research has made to improve dynamic, interactive maps, especially for broadcast on the Internet [1]. The number of applications has grown exponentially with the advent of application programming interfaces (APIs), such as Google Maps API[1], OpenLayers API[2], OpenStreetMap[3]. Further research actions in exploratory geovisualization have resulted in significant efforts to understand the use and improve the usability of interactive applications for the Web-based maps [2, 3]. However, many current systems only allow static layout for relatively large data sets display. In the current web cartography, tools will require unique solutions for navigation, querying, viewing and interpretation of millions data in space and time.

Moreover when it comes to real time geographic data coming from the sensor network, here the complexity of geovisualization increases further. In addition, existing cartographic design principles must be adapted to cope with the production of on-the-fly maps associated with large volumes of data.

In this paper, our challenge is multiple:

- Because of the problems caused by data entry and processing time data streams coming from sensors networks, we are motivated to introduce a dynamic system that will collect and input data automatically into a GIS system, to process and to visualize these data on a real time web-cartography.
- Graphic semiology for real-time environments: The integration of real-time data in interactive cartographic visualization has gained little attention in research to date, many maps (especially digital versions) are of poor cartographic quality containing huge amounts of data (e.g. synoptic maps), despite existing guidelines. Accordingly, these maps are difficult to understand and interpret what hinders the flow of information and communication of important phenomena available, so, how can we improve the presentation and cartographic visualization communication?
- In some kind of maps, usually called atlases, only one variable is mapped separately and often two of them are presented together. But sometimes there is an attempt to

[1] https://developers.google.com/maps/
[2] http://openlayers.org/
[3] https://www.openstreetmap.org/

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show three or four variables with a result that is difficult to interpret due to the interference between visual graphics, so the question is: how in a single map computed in real-time, to visualize multiple variables in a very readable and understandable way?

In this paper, we will deal with these questions and introduce a new approach method of visualization of sensor data. The rest of the paper is organized as follows. Section 2 presents related works. Section 3 presents the methodology of our system. Section 4 we present our preliminary result and discussion. We conclude our paper in section 5 and suggest some further perspectives. Along the paper, an example is used, based on meteorological data.

II. STATE OF THE ART

In this section, we briefly discuss related works required to understand our research.

A. Sensor network

Sensor network consists of an autonomous node set, battery-powered, randomly distributed in a geographic area that defines the territory of interest for the captured phenomena; each of these nodes has the capability to collect and route data either to other sensors or to some gateways [4] (see Figure 1).

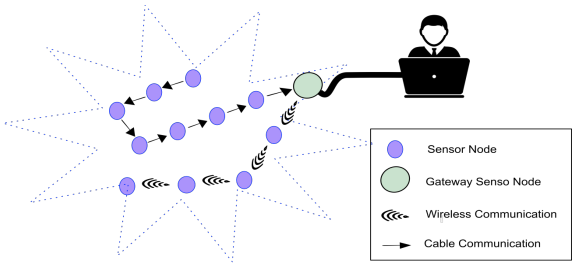


Figure 1. Sensor networks architecture.

Data streams coming from sensor networks are defined as "sequences of ordered data (usually by arrival time), continuous and real-time" [5]. They are different from conventional data, characterized by the spatial dimension of data which determine the sensor position, and the time dimension of the data which determines the moment of shared sensors measurement. Both are carriers of information and play a crucial role in the information synthesis. However, the real-time data streams are not easy to retrieve and to process. Few software products and applications dealing with such data due to their continuous nature and volume and all in real-time, manage such data in a workable set of constraints and challenges.

B. Cartography, GIS, geovisualization

Cartography is an ancient discipline developed from the practice of making maps, combining science, and complex techniques in an effort to portray the world accurately and effectively convey information to the map-reader [1]. As a GIS (acronym of Geographic Information Science), was developed much more recently as software systems designed to perform a wide range of operations on geographic information. GIS is supported by progress from various disciplines such as geography, surveying, engineering, space science, computer science, cartography, statistics, and so on. Cartography is both an art and a science. Many researchers found the traditional term cartography too limited as a description of this new, much richer world, and begin to describe their field as geovisualization. Geovisualization (GVis) [1] is considered as a means of representing spatial information visually in a way that allows people to explore, synthesize, refine, analyses, and communicate conclusions and ideas. Geovisualization is much more than cartography since it includes other methods to represent the geographic reality for decision-makers.

C. Related Works in real-time Web-cartography

Integrating web cartography has been studied since 1997 [6]. Several techniques have been added to maps, making them more interactive, dynamic, multimedia and improving the access to information (accessibility, timeliness, authenticity). These techniques fully exploiting its potential must be addressed for the need in terms of more complete communication and effective and improved cartographic analysis. The design of the web cartography maps is constituted by a set of sophisticated visualization functions which allow users to interact with maps through a GUI (Graphical User Interface) for example by increasing the level of details by zooming, remove less important elements by filtering, GUI must be laid out clearly and functions must be easily identifiable and manageable to ensure an uncontained use and intuitive system [7].

Another starting point is in the information visualization topic, several authors [8, 9] adopted the Visual Information-Seeking mantra stated by Ben Shneiderman [10], namely "Overview, Zoom and Filter, Details on Demand" as a starting point to create a good visualization; it is a well-known visualization paradigm which encompasses several visual design guidelines and provides a general framework for designing information visualization applications:

- Overview: gain an overview of the entire collection;
- Zoom: zoom in on items of interest;
- Filter: filter out uninteresting items;
- Details-on-demand: select an item or group and get details when needed.

Interactive functionality and web-based technology for an expert tool in the field of natural phenomenon management has been identified in recent research, in [3] authors have developed a web-based application for real-time visualization of hydrological data. This application provides tools to control interactively, trace, and compare available information. Another research project focuses on the methodology and scientific issues involved in real-time cartographic in operational hydrology field [11]. This project aims at automating mapping steps applied to real-time data measurement from sensors. To serve as a proof of concept and demonstration purposes, an information system to map in real time hydrological data was established. It consists of a space

base in real time and a user interface based on Web mapping. This kind of application allows real time control of all operations and also allows synchronization with time and especially in the field of early warning, for a discussion of the strategy to introduce real time in the cartographer the reader can refer to [12].

D. *Semilogy and cartography*

Cartography is the result of a structured model, organized; the final quality resulted from the inclusion of simple rules of graphic semiology and map design. They follow the graphic semiology developed by Bertin [14]. Web cartography is associated with technical restrictions and specific semiotic requirements. Signs, graphic variables, color, context, density are all aspects to be considered in the cartography.

Since we only assessed 2D maps, Jacques Bertin's definition of the characteristics of point [13], line and area symbolization served as a basis. These six visual variables: color hue, color value, shape, size, orientation, and texture have been actively discussed and extended by several authors. However, we only included variables that were present in at least one of the assessed cartography. Bertin's six visual variables were consequently extended with color saturation added by MacEachren [14] and transparency added by Wilkinson [15]. These variables were analyzed in order to assess which variables are used for natural hazard visualizations and what values they are assigned. Figure 2 gives an overview of the visual variables.

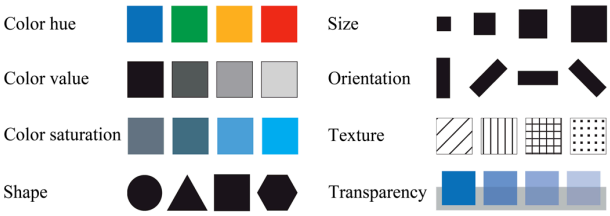


Figure 2. Overview on the visual variables [21]

Pang [16] addresses the issue of the uncertainty associated with data on natural hazards in detail and presents potential methods to visualize the uncertainty of natural hazards such as the application of blurriness, transparency or shake, using the tint color, saturation, or value, a grid overlay which is modified according to the uncertainty values, the drawing of the contour lines, the variation of the thickness, brightness or connectivity symbolization, the use of glyphs, histograms or plots.

Color is a visual variable widely used in large-scale cartography. Different color shades allow different thematic distinguished. Generally colors ranging from blue are often used for water depths of illustration, but also to show a decrease amount. The red colors, are often used to show a risk, a hazard, but also an increase of the amount. While green is often used for forestry, tan for deserts. Color choice should be made by carefully because it is an important variable to create visual attention [19]. A bad choice of color can confuse user map [20].

More than 90% of cartographers used color hue for the symbolization area in maps, the colors are preferred in the realization of a large-scale map [21]. Although the texture is a visual variable that would be well suited to solve the map overlay multivariate problems, only some of the maps contain the variable analyzed visual texture. If more than one layer of thematic data is displayed, the textures can superimpose and lead to the omission of important information thanks to the effect of laciness [18]. In addition, if the texture is carefully chosen and applied, it may seem chaotic and disturbing the overall balance of the map.

III. METHODOLOGY : AN GIS BASED WSN DATA VISUALIZATION SYSTEM

In this section, we discuss how challenges described above are solved in the proposed methodology. Specifically we first briefly describe the details about the manner we build GIS visualization systems with WSN geo-data. We then present the perceptual basis for our design map and describe its implementation in a public weather display in comprehensive adopted the Visual Information-Seeking mantra stated by Ben Shneiderman [10]. Then because our prototype WSN is deployed to monitoring we chose to superpose multiple layers of visualisation to inform the developments made by Plaisant, Wilkinson, and Bertin [14, 15, 16]. We finish with a discussion of the implications of those results.

A. *Used data and test area*

Real-time data set processed in the project comes from OpenWeatherMap API[4]. This API provides access to weather sensor stations that are directly connected to the Internet and enables us to collect high frequency updates from potentially hundreds of thousand sensors deployed over a larger area. We used altogether 160 stations distributed in the region of France. With such a data format, we can potentially use a variety of meteorological data to describe different weather phenomena, their distribution organization in space. The temporal resolution is chosen as fifteen minutes. Active sensors acquire data stream for each climate, density variable, perhaps a few values such as: temperature, humidity, pressure, speed and direction of wind, the presence of clouds and precipitation.

B. *Real-time workflow and functions*

Figure 3 gives an overview workflow which shows the various components used in the system and how they are connected to each other. To view the sensor data collected from our WSN deployed, we need three steps:

- Geo-data collection,
- Geo-data preprocessing and storage,

[4] http://openweathermap.org

- Geo-data display in web-cartography (semiology...)

1) Geo-data collection*: URL to database*

Each of the stations contributes from the *OpenWeatherMap API* to an *XML* file on current meteorological conditions; this file is updated every time the station sends a new set of observations. There is currently no direct method to retrieve these conditions concerning several weather stations; they are individually accessible via an *URL* that contains the *ID* of the station of interest. To create a complete set of meteorological observations for France, which can then be analyzed, a small Java program was developed to collect data streams from several stations iteratively each fifteen minutes, and the observations are then stored in a PostgreSQL/PostGIS [5] database.

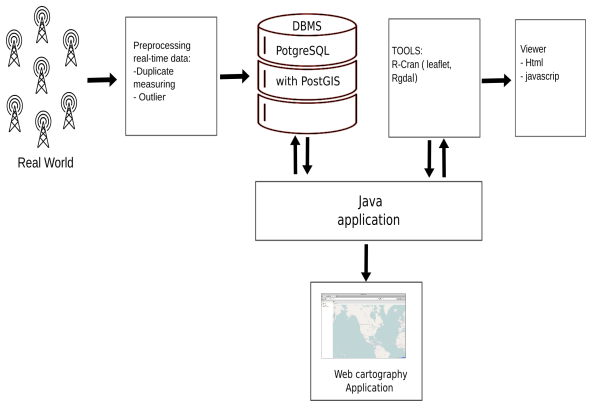


Figure 3. System architecture and used technologies for the workflow.

PostGIS extension can provide support to the database for storing multiple geographic coordinates. The reason we chose PostgreSQL is because it is open source, popular and supported by a wide variety of systems (See Figure 4). A JDOM[6] API is dealing the browse of the returned XML[7] document and retrieves the data to immediately decipher the response returned by the service (OpenWeatherMap API).

2) Geo-data preprocessing and storage

Before the insertion into the database will occur, data are checked and cleaned (e.g., duplicate measuring time, type of data such as text or number, outliers). If the data fail to meet these conditions, either no data or pre-set values are stored. So we had to consider a degree of confidence for data in real time when used for filtering and comparison with the historical data.

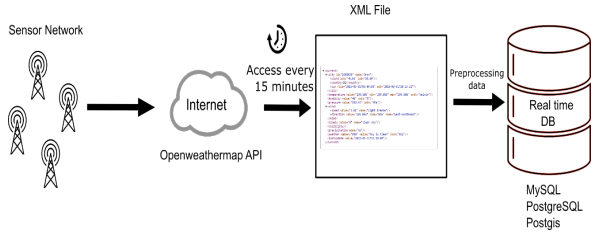
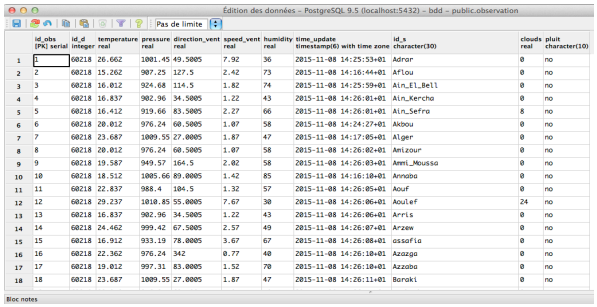


Figure 4. Real time acquisition geo-data process

We use R-project to create a web-cartography and geographic information using Leaflet[8] and Rgdal[9] package. The first reason or choosing R is that its open source software and freely available. And the second was that possible to generate directly a web-map from R.

3) Geo-data display in web-cartography

After the work steps between the extraction and the backup of the database, the data is automatically converted into graphic formats so that they can be presented in the cartographic interface based on the Web. In this section, we present the details of how we present the geographical data. These include how to display the map, the different layer data in web-cartography application, semiology, the visual value.



	id_obs [PK] serial	id_d integer	temperature real	pressure real	direction_vent real	speed_vent real	humidity real	time_update timestamp(6) with time zone	id_s character(30)	clouds real	pluit character(10)
1	1	60218	26.662	1001.45	49.5005	7.92	36	2015-11-08 14:25:53+01	Adrar	0	no
2	2	60218	15.262	907.25	127.5	2.42	73	2015-11-08 14:16:44+01	Aflou	0	no
3	3	60218	16.012	924.68	114.5	1.82	74	2015-11-08 14:25:59+01	Ain_El_Bell	0	no
4	4	60218	16.837	902.96	34.5005	1.22	43	2015-11-08 14:26:01+01	Ain_Kercha	0	no
5	5	60218	16.412	919.66	83.5005	2.27	66	2015-11-08 14:26:01+01	Ain_Sefra	8	no
6	6	60218	20.012	976.24	60.5005	1.07	58	2015-11-08 14:24:27+01	Akbou	0	no
7	7	60218	23.687	1009.55	27.0005	1.87	47	2015-11-08 14:17:05+01	Alger	0	no
8	8	60218	20.012	976.24	60.5005	1.07	58	2015-11-08 14:26:02+01	Amizour	0	no
9	9	60218	19.587	949.57	164.5	2.02	58	2015-11-08 14:26:03+01	Ammi_Moussa	0	no
10	10	60218	18.512	1005.66	89.0005	1.42	85	2015-11-08 14:16:10+01	Annaba	0	no
11	11	60218	22.837	988.4	104.5	1.32	57	2015-11-08 14:26:05+01	Aouf	0	no
12	12	60218	29.237	1010.85	55.0005	7.67	30	2015-11-08 14:26:06+01	Aoulef	24	no
13	13	60218	16.837	902.96	34.5005	1.22	43	2015-11-08 14:26:06+01	Arris	0	no
14	14	60218	24.462	999.42	67.5005	2.57	49	2015-11-08 14:26:07+01	Arzew	0	no
15	15	60218	16.912	933.19	78.0005	3.67	67	2015-11-08 14:26:08+01	assafia	0	no
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17	17	60218	19.012	997.31	83.0005	1.52	70	2015-11-08 14:26:10+01	Azzaba	0	no
18	18	60218	23.687	1009.55	27.0005	1.87	47	2015-11-08 14:26:11+01	Barakl	0	no

Figure 5. Overview of the archive data collection

In this paper, we have used four different layers to complete the map application. There are several basic components that are implicated in the development of web-cartography: basemap; thematic layers; additional information; interactivity; legend.

a) Basemap

There are eight types of predefined maps currently supported by ESRI. They are streets, satellite, hybrid, topography, grey, oceans, national-geographic, and OpenStreetMap (OSM).

[5] http://www.postgresql.org/
[6] http://www.jdom.org/
[7] Extensible Markup Language

[8] JavaScript library for interactive maps
[9] Geospatial Data Abstraction Library

```
library(leaflet)
map <- leaflet()
map <- addTiles(leaflet())
map <- fitBounds(map = map,
                 lng1 = -4.445833,
                 lat1 = 40.50306,
                 lng2 = 9.484722,
                 lat2 =  50.56417)
# Map Size
map$width <- 1000
map$height <-700
map<- addDrawToolbar(m)
map
```

Figure 6. Extract R-code basmap example

In our application we have used OSM as a basemap. OSM is used because it is an open and freely available database of geographic data. Moreover, it provides more desirable locations and easier traceable views than other available maps. An example in R is given in Figure 6.

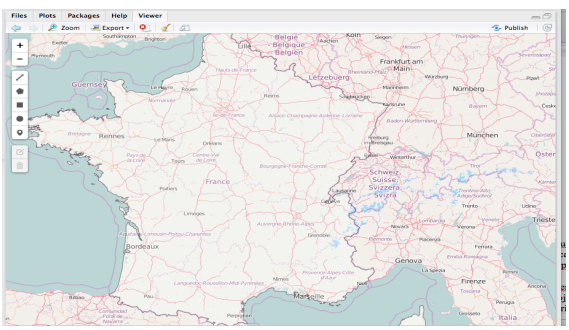

Figure 7. France Basemap with OpenStreetMap(OSM).

Here is the map built a basemap map inside the given HTML container. The scope of the map is the size of the container. The manufacturer Map includes a basemap name as the first parameter. Therefore, we use the fitBounds center setting, this ensures that, when a user opens the application, it is automatically centered on a desired location, so that the user does not need to know where is located, we define the map size by size map settings, default map has a contextual option that displays a minimum value related to the clicked point. As the default context menu cannot serve our purpose, we used to popup to display additional information.

b) Thematic layers

Visualization is important when working with data from sensors. According to Plaisant [17] the biggest problem when designing visualizations is mounting and the combination of visualization to the user's wishes. Try to view the data; different views of the same data set should be available. Recall our second objective; in real time, it is important particularly in the meteorological field when decisions must be taken in short terms, within hours or minutes. Such situations leave no time for the reader, it loses a lot of time between several maps to see several phenomena, but if in a single maps several phenomena without presented bunk and interactively or it can compare and interact with the map that will be more interesting to the reader for taking immediate decision. According to [21], it is impossible for humans to examine the information and understand the content and then discover and combine it in a short time under the pressure of time in disaster management.

Overlaying many of the different thematic layers is still a challenge in cartography: it is the central component of the application. To construct these layers, the database connection operations have been used to make the database available to R. When properly selected, it makes it more comfortable for a user to work with data and data can be understood more quickly and easily. The weather maps generally show the information using the contour intervals resulting from an interpolation method. Our mapping solution is to use visuals three channels; a color channel, a texture channel, and a symbol channel, to separate the perceptual variables and make them independently readable. Remember that the second objective of this paper is to provide visualization more easily and a method of combination that clarifies understanding, but not to obscure it. To this end, three different visualizations are used.

We chose to map the atmospheric pressure interval of color codes because it is so pervasive in modern weather visualizations whereas the wind speed is usually represented by proportional symbols. We added the digital text to provide additional wind information for the wind direction which is given by symbol orientation. Finally, we have chosen to represent temperature with texture with the use of contours, because it was the only channel and we found later that it provided a great opportunity to mix the use of texture with the use of contours, which are commonly used to represent the pressure in the weather maps and make abrupt changes in pressure visually prominent.

c) Generalization

Modern IT environments allow assessments of high spatial resolution cartography, which results in huge amounts of data. These raw data must be pre-processed before it can be viewed to avoid chaotic and overloaded maps. For these generalization techniques to be applied, it includes interpretation, selection and omission of facts available. To keep the balanced mapping of available information can be neglected or given a lower level of importance. An example is the smoothing of raster data so that the edges are rounded and can be integrated in the maps without being visually striking (see Figure 8).

Another important task is filtering the raw data before they are presented to the map-readers. The greatest responsibility takes over this task; an easier map can be read and interpreted by users

a) Interactivity

Zoom, filter, panoramic and layer visibility management are all functionalities that provide interactivity with

cartography. A more sophisticated mapping portal offers additional features such as tooltips or windows with information on attribute values, measure distances, search functions, uncertainty values and printing options.

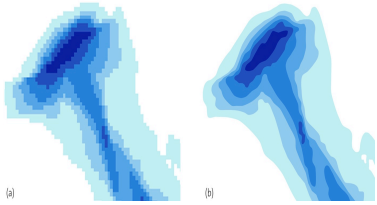

Figure 8. Raw raster data (a) can be visually striking and should be smoothed in order to obtain a natural appearance (b) [21].

b) Legend

The legend is a key that contains information on the thematic areas present; it supports the orientation of the map-reader. If the legend is not clearly visible or if ignored, by the map-readers, they cannot decrypt the contents of the map can lead to misinterpretation.

IV. PRELIMINARY RESULTS AND DISCUSSION

The outcome of implementing these methods is illustrated through a graphical user interface (Figure 9), it displays a simple form of the map contains meteorological data in real time that are automatically modified, processed, and displayed in an interactive web cartography and meets the basic principles of readability and comprehension, map illustrates how geographic data can be viewed by vector maps where various geometric and pictorial map symbols are presented. The expected temperatures are displayed as an interpolated surface filled with a visual value textured where the variation of the thickness proportional to the temperature value associated with the caption displayed in the auxiliary window (second legend right).

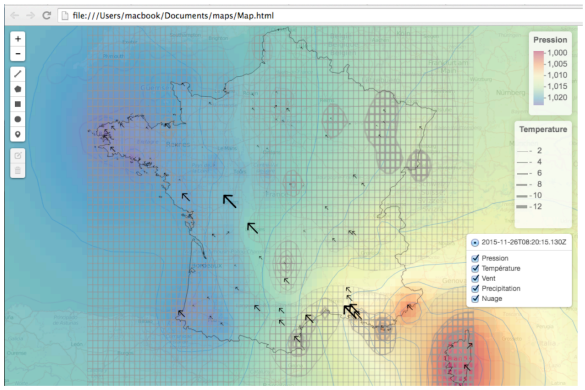

Figure 9. Web cartography created in real time

During writing of this paper, since we were unable to find previous examples using visualization isolines filled proportional texture, it was an opportunity to integrate and test in our prototype. As pressure is represented by isolines filled by the color level as depicted in legend right up. The wind speed is usually represented by proportional symbols; we added the digital text to provide additional wind information for the wind direction is given by the symbol orientation (an example is shown in Figure 10).

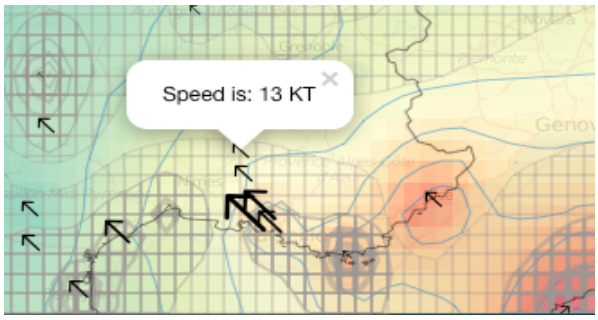

Figure 10. Popup window showing wind speed information

In our current implementation, the user has the ability to customize data. However, the user can interact with the map and change the view by interacting with the interactive menu (right down), followed by the date of the last updates as shown in Figure 10. In addition, spatial navigation controls such as zoom in/out, panoramic visual and re-centering are available, so users must be able to zoom in/out, and even a map of the edition menu (left of the interface).

Moreover, when users click on any location on the map, he opens a window on the map corresponding to the particular sensor or estimated values of adjacent sensor for more information. This is illustrated in Figure 11. At present, the service is not fully complete; however, it follows all the major concepts and supports mapping data arrives in real time from the sensor distributed over a territory.

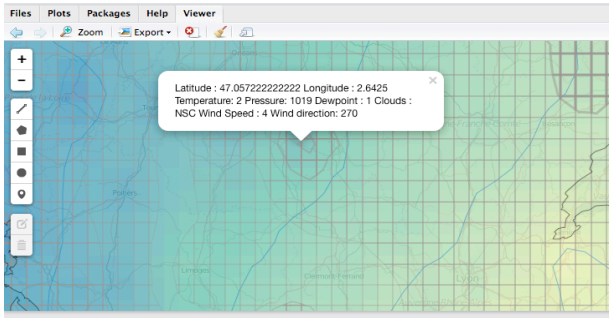

Figure 11. Popup window showing additional information

For exploration and visualization of measured sensor data, an interactive web map was developed; application complies with the basic design principles outlined above. Namely the multiple views and tasks and principle were followed as (overview, zoom and filter, and details on request) principles were followed. In this paper, our objective was twofold; firstly, we intend to have deeper processes parts of the

automated process of digital cartographic modeling and its implications for web-based interactive cartography.

On the other hand, we expect progress in the area of the temporal and real time GIS mapping, which is today a challenge that concerned many researchers. With our prototype, we would like to provide an application that can significantly reduce the work offline by automating much of the cartographic design process.

IV. CONCLUSION AND OUTLOOK

Sensor data are typically in the form of digital values; therefore, the understanding of processes or analysis is not trivial. Visualizations can be an interesting solution which is a complex process; take the digital data, analyze, use methods of extraction and aggregation, and then give the user a graphical interface represents a challenge. The ultimate goal is to provide automated way, real-time visualizations from the raw data of distributed measurement while respecting rules and modern cartographic standards.

In this paper, we present our first initial research efforts to store and manage and visualize big sensor data in a WSNs prototype based on GIS. By focusing on the cartographic visualization and friendly interaction to facilitate understanding the information, we present a web cartography application that provides responses to data requests effectively. We prove by our workflow, as the sensor data processing to achieve the visualization is possible on the fly. This allows users to visually relate the phenomenon represented by superimposing layer, it is the second objective of the research presented here; develop and implement strategies to symbolize appropriately aggregated data to support the visual interference. Our works are still in progress and research can be extended to include the following future work:

- First, we intend to add more functionalities as time navigation; we also plan to add alerts for certain types of data that automatically notify an interested user group.
- In order to establish rules of best practice in this area by facing this objective, a psycho-cognitive test can be presented as a questionnaire to validate the choice of the visual vocabulary order to interpret the results of the application of a simple and correct way.
- The visualization presented in real time requires a fully automated processing and no error due to non-possibility of verification data map before displaying. The main difficulty coming from the complexity of the workflow is the quality of data that is unknown. This problem was solved by a simple checking of the validity of real-time values on-the-fly before viewing, but we think that we still need more thorough research in our future work to solve this problem.

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