Multi-agent system approach for improved real-time visual summaries of geographical data streams

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Abstract: Interdisciplinary efforts are needed to support visual exploration and analysis of spatio-temporal data streams from sensor networks, depending on the size and complexity of data that must be analysed before being displayed. For this, several emerging approaches have been proposed known as ‘Visual Summaries’ of datasets that will help users find what is most important and interesting to visualise in the mass of available information. In this paper, we present an approach for generating automatically the visual summaries in real time. For this, we have adopted chorem-based visual representations of territories issued from both geometric and semantic generalisation. Our approach relies on a multi-agent framework; an extraction knowledge agent is able to extract important spatiotemporal patterns of data streams coming from a sensor network as interesting regions, and a visualisation agent which displays those patterns as simplified maps. We validate this model with an example taken from the meteorology field.

Keywords: geovisualisation; sensors networks; important patterns; chorems; multi-agent systems; MAS; visual summaries; automatic generalisation.

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1 Introduction

There is an increasing need to effectively manage the enormous amount of data collected by 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 (David et al., 2004). A Sensor network collects data from the environment, such as temperature, humidity, sound or proximity to objects; the collected data are then transmitted to a control station. Applications running on the control station analyse the received data, perform appropriate computations and display the results to the user. Therefore, efficient techniques are necessary to explore abnormal environmental phenomena in sensor network that are continuously streamed to applications. Visualisation is a desirable solution to this problem by archiving and presenting data across a wide range of time scales and geographic areas (Bouattou et al., 2016). Visualisation of geographic data are essential to allow a human analyst to understand data in space, to extract relevant and important information, and to derive knowledge for efficient decision-making (Kraak, 2003). 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 and to provide intuitive filtering paths to explore and compare the spatiotemporal patterns (Thomas and Cook, 2006). In fact, when a large quantity of data are available, which is increasingly available thanks to new advances in communication technologies, the synthesis of information and ideas from this can lead to time consuming and costly activity. In addition, when it comes to real-time geographic data coming from sensors network, here the complexity increases further. As visual presentation and analysis of these data are currently a very promising research topic (Andrienko and Andrienko, 2013), the scope will be not to determine the cartographic layout once at all, but more specially to calculate it on-the-fly and in real time in order to schematise evolution and to understand the structures both in space and time.

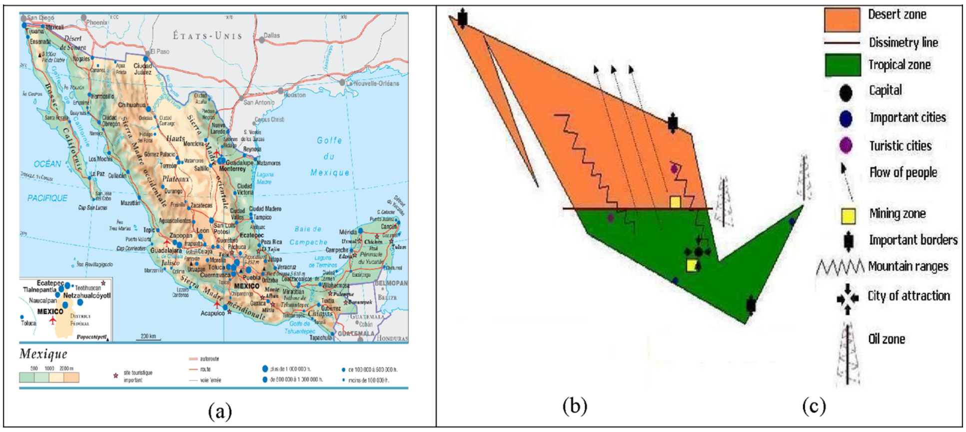
In parallel with this effervescence, recent results have demonstrated that chorems can be used to both catch a thematic global view of a territory and its phenomena and investigate complex spatial phenomena by accessing data characterising them (De Chiara et al., 2011; Del Fatto et al., 2008; Klippel et al., 2005). A chorem is a schematised spatial representation, which eliminates any detail unnecessary to the map comprehension (Brunet, 1986). Figure 1(b) shows an example derived from a traditional map of the Mexico country (see Figure 1(a)), where the following aspects are highlighted as specified by the legend (see Figure 1(c)):

- the geometric shape
- the most important cities
- the most important borders
- the important flow of people.

The work presented in this paper is based on the approach presented in Bouattou et al. (2017) where the authors propose a new approach concerning the use of chorems for automated and dynamic geo-data processing applications. Becoming temporal chorems, they must integrate the temporal dimension as essential especially when dealing with complex datasets and unknown that often change over time. Several methods and concepts are proposed to automate the process of real-time chorematic mapping, but a framework for their combination in a fully automatic process is still missing. In addition, they still lack the autonomy and intelligence to decide for themselves what to do, when to do and how to do the proper treatment when generating maps. This autonomy can be obtained by using the multi-agent paradigm (Wooldridge and Jennings, 1994). A multi-agent system (MAS) consists of software entities also called agents; each agent is able to act autonomously in its environment to achieve its objectives (Wooldridge and Jennings, 1994). In this paper, a MAS architecture is proposed that deals with these problems for improving the automatic generation of visual summaries as web map in real-time by using technology agent and MAS architecture; this can be used for an intelligent approach for automatic generating chorematic maps of real-time data provided by sensors network for the purpose of surveillance of specific areas and rapid deployment for interest areas. Although isolated methods of visual synthesis have been studied before, we do not know of any system that intelligently combines these different techniques to form a synthesis framework whether semantic or cartographic generalisation, that is, their integration into an automated and comprehensive generalisation process. Remember that some works such as presented in the book (Ruas and Duchêne, 2007) deal only with cartographic generalisation based on multi-agent techniques, but never for semantic generalisations.

The rest of the document is structured as follows: after briefly introducing the related works necessary for the understanding our research, the proposed approach is detailed, followed by an implementation process. Along the paper, an example is used, based on meteorological data. Then, we conclude by suggesting some further perspectives.

Figure 1 (a) A traditional map; (b) a chorematic map of Mexico and (c) its legend (see online version for colours)



Source: Lopez (2010)

2 Related work

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

2.1 Cartography, geographic information system and geovisualisation

Cartography is an ancient discipline developed from the practice of making maps, combining science and complex computer techniques in an effort to portray the world accurately and to effectively convey information to the map reader (Kraak, 2003). Geographic information systems (GIS) were developed much more recently as software systems designed to perform a wide range of operations on geographic information. The two fields have converged by becoming some expanded digital technologies and GIS opens up new possibilities that offer to follow many constraints from manual map-making operations. Cartography is both an art and a science, whereas GIS evolved as a digital analysis approach concerning what is observable and measurable on the surface of the Earth. Many researchers found the traditional term cartography too limiting as a description of this new, much richer world, and begin to describe their field as geovisualisation (GVis) which is considered as a means of representing spatial information visually in a way that allows people to explore, synthesise, refine, analyses, and communicate conclusions and ideas. Geovisualisation is much more than cartography since it includes other methods to represent the geographic reality for decision-makers (Kraak, 2003).

2.2 Visual summaries of geographic data

An existing visualisation approach involves the direct representation of each record in a set of data to enable the analyst (Carvalho et al., 2008), to extract and lay out remarkable patterns and to interact with them. However, these techniques may not be effective when applied to very large and complex datasets, which are increasingly common. Users may also have difficulties in collecting, monitoring and understanding many visual elements that change simultaneously. But the speed in which graphics are displayed and in which responses to user interactions are solicited may become too slow for efficient understanding and cognition. To overcome these drawbacks, the main goal is not to return exactly some visualisation of geographic data with a high level of details, but rather to show the most relevant aspects of territories and phenomena. By putting the user's attention on important features such as patterns, trends, dependencies and outliers (Rinzivillo et al., 2008). Such spatial curiosity led directly to new ideas and other geovisualisation methods emerged known as 'visual summaries' (De Chiara et al., 2011; Del Fatto et al., 2008) of datasets that will help an analyst to find what is the more important out of the mass of available information, and to answer questions quickly and efficiently. Visual summaries of geographic data can be the results of both semantic and geometric generalisations.

2.2.1 Semantic generalisation

Semantic generalisation also called model generalisation is defined by Ruas (2002) as: "an information synthesis process of simplifying the information in a geographic database, to meet some needs (e.g., the analysis of a geographic phenomenon to a wider level of abstraction than the initial database)". This reduces the level of detail of the original data, while highlighting the important elements in view of this need (Duchêne, 2003). We can compare this process with that of a summary text which aims to reduce the number of words, retain the key ideas, not to make false direction and if possible to preserve the author's style. Obviously, the text must respect the rules of language both in the spelling of that grammar. To generalise the initial information, it must also reduce the amount of information, highlighting the most important information, stay true to the original information and, in the case of a map, follow the rules of semiotics that allow a good reading of the information.

2.2.2 Geometric generalisation

Geometric generalisation also called cartographic generalisation is a particular type of generalisation of geographic data designed to produce a map (no matter that it should be displayed on screen or printed on paper) (Jabeur, 2006; Lamy et al., 1999). Before the advent of digital data, cartographic generalisation was used to create a map at a given scale from another map to a larger scale. Today, cartographic generalisation can also be used to create a map from a geographic database too detailed in relation to the desired scale. Cartographic generalisation is a holistic process because of its subjective nature of and the absence of well-defined rules to guide decision-making (Jabeur, 2006).

2.3 Chorems

In the last few years, much work has been done on the chorem concept and on its exploitation as an appealing visual notation for communicating geographic information, especially for communicating highly synthesised and aggregated concepts. The neologism 'chorem' composed of the Greek word 'χώρα' meaning space, territory, place and the suffix '-ημα' meaning 'em', such as in the word 'problem'. As defined by the French geographer Roger Brunet who invented chorems, "a chorem is a schematic representation of the territory" (Brunet, 1986). Or in other words, a chorem can be considered as a sort of synthetic vision or a caricature emphasising salient aspects. More precisely in this paper, a chorem is defined as both geometric and semantic generalisations of a geographic data streams coming from sensor network. The main advantage of chorems is to facilitate the comparison of spatial systems thanks to a simple representation of complex organisations.

In addition, in the IT community, chorems also are used both in terms of applications and semantics as they are extensively discussed in Del Fatto et al. (2008) where the authors provide a thorough study about the history of chorems usage, from Brunet's definition to recent applications (De Chiara et al., 2011). In Klippel et al. (2005), authors propose chorems that can help in presenting highly generalised route information to better model human navigation, they uses the term 'wayfinding chorems' (called chorems by the authors) as established by Klippel and is inspired by but does not work with Brunet's chorems.

In the more recent years, much work has been carried out about chorems as visual summaries of geographic databases providing a novel definition and classification of chorems, in order both to standardise the construction and use of chorems, and to provide a useful framework computer system. In Del Fatto et al. (2008), the authors enhance the role that a chorem map may play in geographic domains, by extending the semantics associated with it through a more expressive visual notation. In particular, by adopting the revisited Shneiderman's mantra, namely "Overview, zoom and filter, details on demand" (De Chiara et al., 2011; Shneiderman, 1996) they allow users to acquire information about a single phenomenon by accessing data characterising it from the underlying database.

2.4 Multi-agent system and cartography

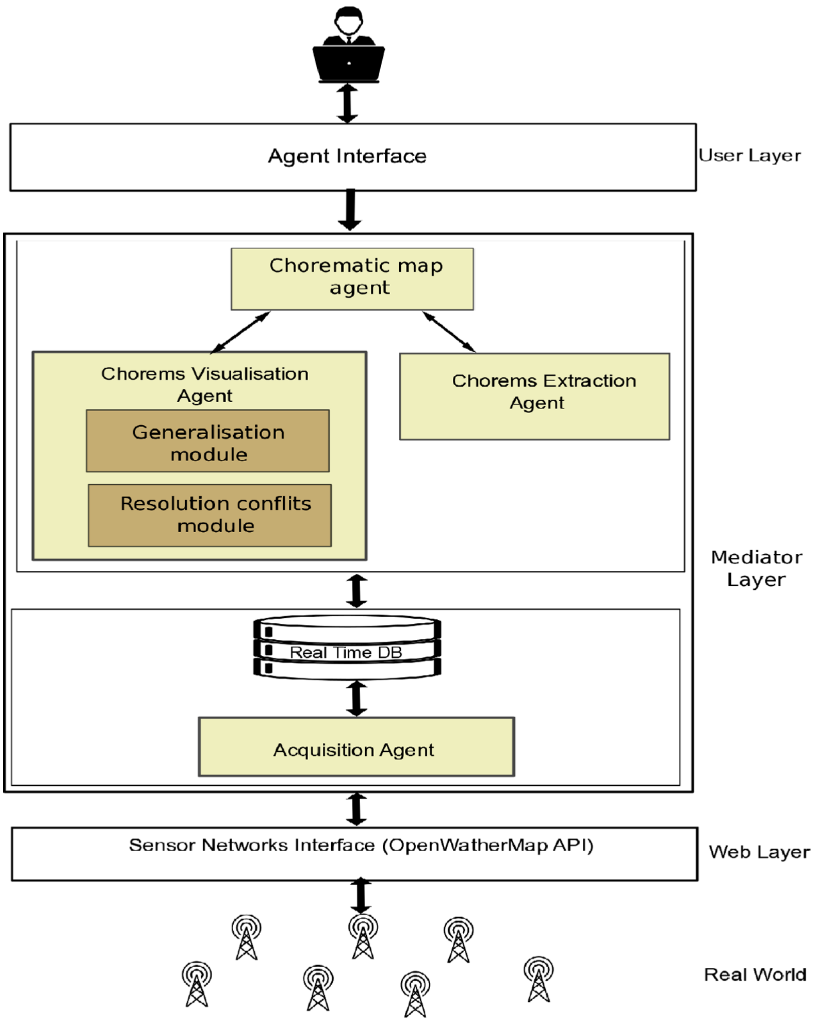
In cartography, a MAS may offer many advantages; several works based upon MAS have addressed specific topics of on-the-fly map generation. The main research work based on multi agent systems in automatic cartographic generation was the SIGERT project (Gbei, 2003). In addition, several research work based on MAS have addressed specific issues on of on-the-fly map generation, such as automated cartographic generalisation (Duchêne, 2003; Jabeur, 2006; Lamy et al., 1999). On the viewpoint of the map generation process, agents can be assigned to space objects. In this case, their interaction can model the entire automatic cartographic generalisation process in which objects are added, merged, eliminated or symbolised (Lamy et al., 1999). The cartographic generation is a very complex process as well as its automation, due to its holistic nature. A MAS may offer a proper support to face this complexity through its properties. In this paper, the real-time mapping is oriented to meteorological data. The automated mapping process will be implemented in a prototype application based on MAS architecture, as it can help decision-makers in their task to monitor developments and real situations of significant events, in real time and without any intervention.

3 Proposed approach

As previously told, this work is based on the approach inspired by the concept of chorem proposed in Bouattou et al. (2017). We combine multi-agent architecture and generalisation process for improving the delivery time of chorematic map and resolving spatial conflicts to increase the quality of result map. This approach aims exclusively to improve the map both semantic and geometric generalisation process by using MAS paradigm.

There is a strong link between the choice of agents and the purposes for what they are designed, given that we intend to generate and transfer maps based on the importance of their content to users. The working mechanism presented in Figure 2 which describes a general proposed system and it indicates different components used in the system and how they are related to each other, meaning both to generate a map on-the-fly and to resolve spatial conflicts could be presented in three core steps where each agent is responsible for a specific task.

Figure 2 The architecture of the multi-agent system (see online version for colours)



We must realise, in real time, the following main tasks: acquisition stream data from sensor networks, chorems extraction (semantic generalisation) and chorems visualisation (geometric generalisation). Each task can be assigned to an agent or group of agents. The interior structures and procedures of categories of agents will be proposed in the following section.

3.1 Acquisition agent

The real-time data used in the project come from the *OpenWeatherMap* API[1]; these data are collected with different types of sensors in the region of *Algeria* (18.97°N, 37.09°N Latitude and –8.66°E, 11.98°E Longitude).

In our prototype, each of the existing meteorological stations contributes from the *OpenWeatherMap* API to an XML file on current weather conditions; this file is updated every time a station sends a new set of observations. There is currently no direct method to retrieve these data 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 Algeria, which can then be analysed, this task is accomplished by using a MAS, the agent is listening to the sensors to recover data streams from several stations iteratively each 15 minutes, and the observations are then stored in a PostgreSQL/PostGIS[2] database. The reason we choose PostgreSQL is because it is open source and popular and supported by a wide variety of systems.

3.2 Chorematic map agent

It is the supervisory agent that aims to guide the process of automatic generation of visual summaries in the form of a chorematic map. The role of the supervisor is limited to the synchronisation of the execution of the different agents; extraction agent and visualisation agent and synchronise the activation of these agents sequentially. During the process of data generalisation, conflicts may appear and cannot be resolved by the viewer, for example, when it does not find a solution due to lack of space in map. In this situation, the visualisation agent sends a request to the supervisor to resolve these conflicts. The supervisor intervenes to propose a solution.

3.3 Chorems extraction agent

This agent acts as an intelligent information assistant; it replaces human intervention, which allows filtering the real-time data streams, similar to the role of meteorological experts in emergency operations centres. The objective of this agent is therefore to describe the data by calculating descriptive statistics (e.g., average, variance) using a sliding window model (Babcock et al., 2002), which tend towards a normal distribution when the number of measurements becomes important. In order to avoid expensive calculations in real time, we propose a method to calculate on the fly, takes into account the contribution of what goes in and out without having to recalculate these parameters at each iteration (Bouattou et al., 2017).

We assume a time series S coming from sensors C over a period p, between k and $k + p - 1, k \in T$.

Suppose a new value x_{k+p} arrives at a moment $p + k$ from sensor u_i, $i = 1, \ldots, C$, the moving average μ_{k+1} at time $p+k$ depending to μ_k at time $p + k - 1$:

$$\mu_{k+1} = \mu_k + \frac{1}{p}\left(x_{p+k} - x_k\right) \tag{1}$$

and the moving variance σ_{k+1}^2 depending of μ_{k+1}, μ_k, and the new arrival values x_{p+k}:

$$\sigma_{k+1}^2 = \frac{1}{p-1}\left(\left(x_{p+k} - \mu_{k+1}\right)^2 - \left(x_k - \mu_{k+1}\right)^2\right) + \sigma_k^2 + \frac{p}{p-1}\left(\mu_k - \mu_{k+1}\right)^2 \tag{2}$$

On the basis of this consideration, we can define an importance function $\beta = f(x_{p+k}, \mu_{k+1}, \sigma_{k+1})$ as follows:

$$\beta = \left|\frac{x_{p+k} - \mu_{k+1}}{\sigma_{t+1}}\right| \tag{3}$$

Our approach is based on the generation and transfer of the map according to the importance of data for the gradual users we consider as a β weight of importance. To achieve this, the spatial data are classified into several levels based on its importance to the context of use of the map to generate. According to β, we can define the following set of rules to decide what the salient phenomena are:

1 if $0 \le \beta \le 1$, x_{p+k} is of a trivial importance

2 if $1 \le \beta \le 2$, x_{p+k} is of moderately importance

3 if $2 \le \beta \le 3$, x_{p+k} is of remarkable importance

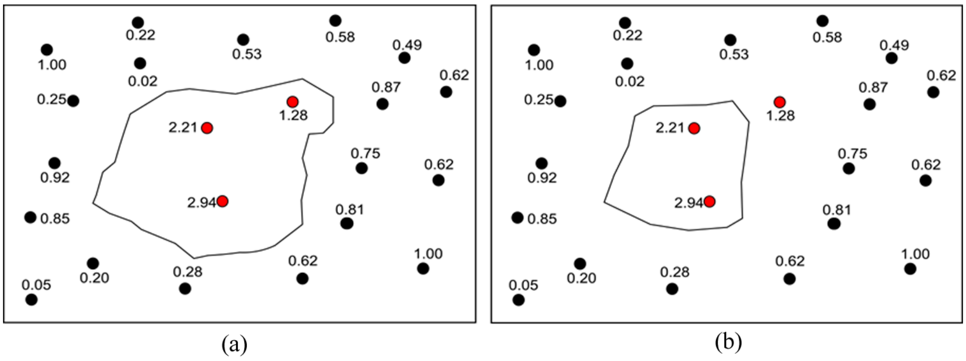
4 if $3 \le \beta \le 4$, x_{p+k} is of exceptional importance

5 if $\beta \le 5$, x_{p+k} is of historical importance and very rare.

Figure 3 shows an example that illustrates the effect of β on an important region per degree, where the sensors are marked by their values of β. Figure 3(a) shows an important region that has been determined using $\beta > 1$. In Figure 3(b), $\beta > 2$ and, consequently, a sensor is excluded from the important region, even if it has a value $\beta > 1$. In addition, using the inverse distance weighted (IDW) method (Lu and Wong, 2008) with parameter β allows additional filtering on detected aberrant sensors. The value of β specifies the minimum value required to make an outlier sensor large enough to be included in a large region or not.

Hence from the extraction agent, we obtained the important patterns as spatial region characterised by the initial position and its data. This will identify critical elements and values for the detection of important regions that are used to generate summaries of values to help users understand and guide the synthesis process, its regions detected as a polygon geographic object. Polygonal subdivisions, i.e. the representation of data in the vector model, are a common data type in GIS applications, in thematic maps, in topographic maps and in digital landscape models. Their cartographic generalisation is termed polygon generalisation. These spatial objects are then stored in a spatial database in geometric format which presents itself as a mapping visualisation process input. This dataset was enriched by multiple representations of spatial objects.

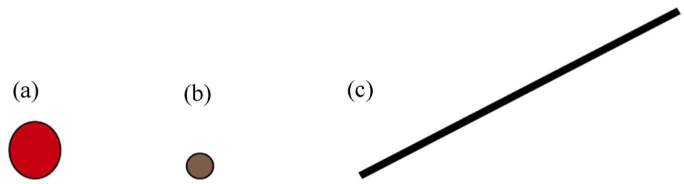
Figure 3 Example of an important region based on the value of β: (a) important region with $\beta > 1$ and (b) important region with $\beta > 2$ (see online version for colours)



3.4 Chorems visualisation agent

According to Del Fatto et al. (2008), chorems can be classified into three main categories namely; geographic chorems; phenomenal chorems and annotation chorems. For geographic chorems, we choose some chorems proposed by *Brunet* as the point representing the important cities, the polygon to represent administrative boundaries, and thematic areas, lines to represent the geographic barriers (see Figure 4).

Figure 4 Some geographic chorems: (a) a capital city; (b) important cities and (c) barrier (see online version for colours)



In addition for geographic phenomena, we propose our own chorems based on *J. Bertin's* graphic semiology (Bertin, 1983); that can be viewed by symbols, such as icons. Finally, annotation chorems represent the names of important cities and legend.

The visualisation agent consists of two main modules: generalisation module and spatial conflict resolution module.

3.4.1 Generalisation module

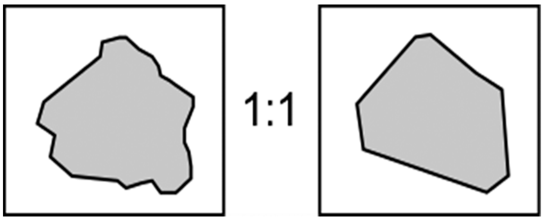
The progress of the automatic process of generalisation is carried out in several stages which are ordered as follows:

- the definition of the area of the environment that will be generalised (basemap)
- simplification
- smoothing
- symbolisation.

(1) Basemap: Definition of the area of the environment that will be generalised, a general strategy for the automated construction of chorem-based maps is first to create the territorial outline of the region of interest; for that highly generalised territorial outline, i.e. our basemap is made once by using the point removal techniques thanks to the Douglas–Peucker algorithms (Douglas and Peucker, 1973) then we define the major cities (which can be retrieved by means SQL Selects).

(2) Simplification: This eliminates unnecessary details of a spatial object, by selecting a subset of the coordinates that compose it, and retaining its original shape; the simplification reduces the number of points used to represent a line or polygon boundary (Figure 5).

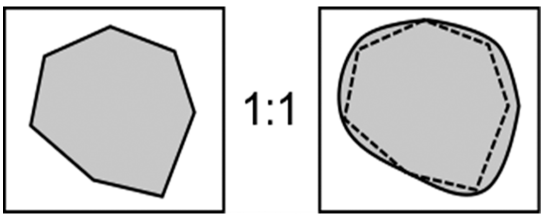
Figure 5 Simplification operation



The algorithms that filter the vertices of the lines correspond to this class of operators. Simplification is an operation of generalisation of identity relation (1 : 1).

(3) Smoothing: The smoothing is an operation of generalisation of identity relation (1 : 1). It is a generalisation operation that corrects small imperfections by shifting the coordinates of the spatial object involved improving its appearance. Smoothing can insert additional details to protect against sudden changes in the directivity of form, or modify the original coordinates as in the case of weak or strong filtering. In the present work, the smoothing of the polygons was done with Bezier-tube algorithm (Shao and Zhou, 1996) (Figure 6).

Figure 6 Smoothing polygons with Bezier-tube



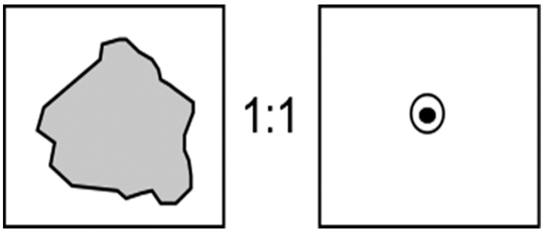
(4) Symbolisation: The symbolisation is often linked to a collapse of the form, which amounts to saying that the original polygonal form is transformed either into a point. The collapsed polygons will be displayed by a symbol which could help the user to better understand the geographical space. Additional geometry for a point symbol, expressing the extent required for the symbol, may be important for moving. In the present work, the different symbols of a given spatial object are stored in SVG[3] files. During processing, agents manipulate rectangular shells instead of manipulating symbols. These shells have prefixed sizes that are identified according to the display scale. By analogy with symbol

placement, our heuristic consists in placing symbols at the barycentre of the object as long as this symbol does not completely cover the object (Figure 7).

The use of symbols with space objects allows us to give visual information that underlines the types or semantics of these objects.

Visual variables are widely used in large-scale cartography. Different colour shades allow distinguishing different topics. Generally, colours ranging from blue are often used for water depths for illustration but also to show a decrease amount, about the red colours, are often used to show a risk, a hazard but also an increase of amount, while green is often used for forest and brown for deserts.

Figure 7 Symbolisation operations



3.4.2 Elimination of spatial conflict module

In order to answer our first research question, we need to be able to automatically generate the required maps. An underlying problem of this difficult task is to resolve spatial conflicts that may occur between spatial objects as well as between symbols and objects. These conflicts can reduce the readability of maps that users can be confused.

To realise our application, we chose to treat certain conflicts because it is difficult to identify all the conflicts that may appear between the geographical objects at a given moment. By way of example: superposition and intersection. To do this, we propose a refinement process to avoid overlapping symbols to increase the quality of the visual information on the resulting map in real time. To solve spatial conflicts, different generalisation operators are applied. To this end, we have implemented some measures that we have considered primordial to guide a process of generalisation. The violation of a constraint generates conflicts that require a specific detection method; before this requirement we have chosen to use simple methods to implement:

(1) Superposition: The method used to detect overlay is the intersection calculation. There are mainly two types of overlays, the superposition of two or more symbols and superposition of the polygon with the polyline. To encode the first type, we used the algorithm for calculating the intersection between two symbols and for the second type we applied the superposition algorithm of a polyline and a polygon. In the first case, considering two rectangles carrying the spatial object, it is sufficient to find whether the two given rectangles overlap or not.

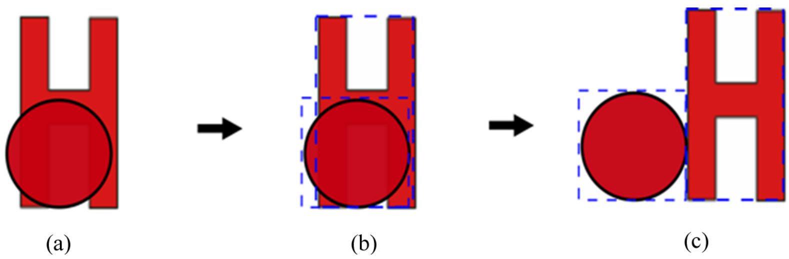
(2) Displacement: The move operation is used to resolve cartographic conflicts (overlapping) between two or more objects; it can also be applied to several distinct objects (point, symbol). Thus, in this step, the distance between all spatial objects

Dist (*V*1, *V*2) in the map is calculated in the form of a distance matrix, and then for each pair of objects that overlap, the symbol is moved. An example is show in Figure 8.

3.5 Agent interface

An interface agent has also been added between the user and the module of the generalisation of the cards whose objective is to manage the communication between them. It allows the user to transmit his requests. The transmitted request contains important information for searching for data, such as area identification, map type and detail level (see Figure 2).

Figure 8 Example of overlaps elimination: (a) a possible initial configuration; (b) with minimum bounding rectangles and (c) after displacement (see online version for colours)



4 Results and discussion

A web map is the main part of the end-user application. The final map result is depicted in Figure 9 and the zoom part in Figure 10, meet the basic principles of readability and comprehension in terms of colour and symbol elements. So, the raw output of our visualisation method contains symbols referring to the *Algeria* country with a generalised geometric shape, in which some aspects are highlighted, such as the most important cities; various meteorological phenomena are represented by polygons enriched by symbols by synthesising and compiling especially hot and/or cold phenomena. However, in the whole country, certain phenomena are not important, so are not displayed. Hence chorem-based map highlights the relationships between data values associated with a region.

To facilitate the understanding of the map and adapt its content to users' expectations, we propose to emphasise the objects which are important to the user by using multiple representations: graphic, semantic, and geometric representations (Figure 11).

With our framework, we want to make available an application that automates much of the cartographic design process using multi-agent-system. We also wish to make available a centralised tool by increasing the temporal aspects of thematic data so that the temporal dynamics can be clearly visualised and examined. In terms of weather event management, information can be entered quickly as the peaks and/ or holes of the event, namely, the time available to take against measures to make other decisions.

Figure 9 Chorematic maps showing interesting regions (see online version for colours)

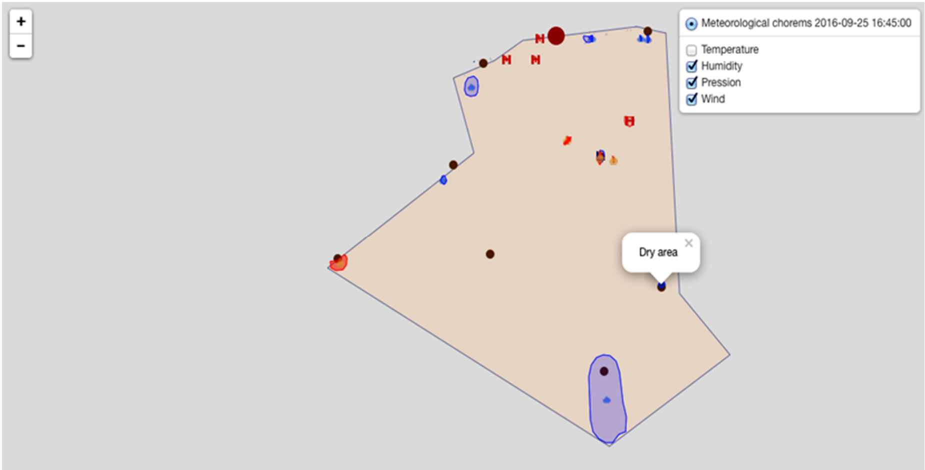


Figure 10 Increase of map legibility as a result of a zoom in operation (see online version for colours)

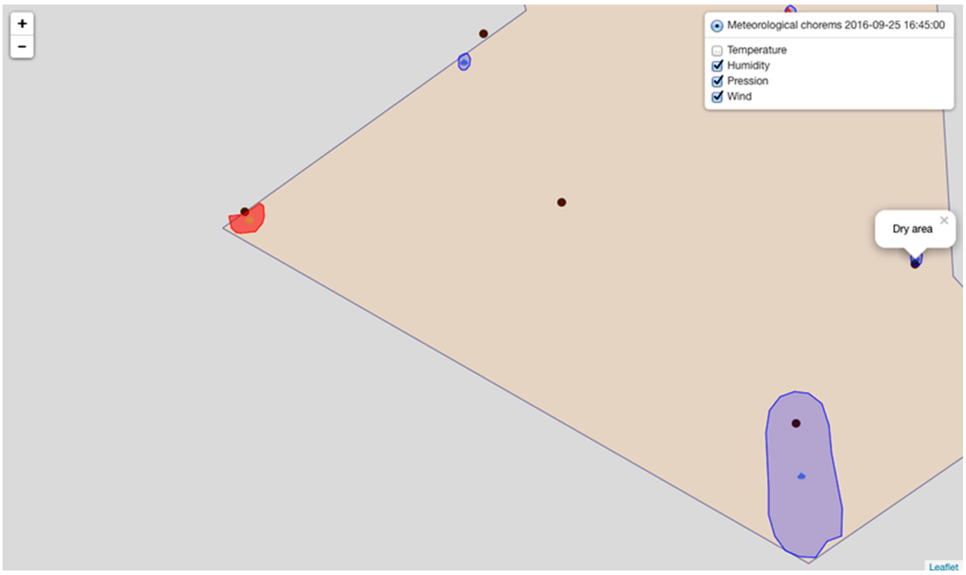


Figure 11 Example of use of multiple representations: (a) geometric, (b) geometric-graphic and (c) geometric-graphic-semantic (see online version for colours)

(a) (b) (c)

This visualisation is necessary to ensure that decision-makers:

- Are able to enter and explore the overall picture of the situation in real-time quickly.
- Can track the short-term evolution of the state system.
- It is a way to clearly and quickly identify and discuss peaks and holes areas on both spatial and temporal dimension.
- Could learn of past events by comparing real-time data.

5 Comparison with existing cartography approaches

It is true that applications such as Google Earth[4], YahooMaps[5] all provide maps to users in a short time. However, they do not apply any transformation to spatial objects on the fly. They retrieve and display only pre-processed data that is previously stored in special databases. The application of real-time transformations to spatial objects allows us to generate maps, and in particular to improve the semantic personalisation of their content. In some contexts (such as military intervention and emergency management), users may need ready-to-use maps, especially when they have neither the time nor knowledge needed to interact with the map. Therefore, we need an approach of on-the-fly generation of the visual summaries by adopting the chorematic modelling of point of view a semantic and cartographic generalisation. The main objective is not to return exactly a cartographic visualisation with a high level of detail but rather to show the most relevant aspects of the phenomena by putting the user's attention on important characteristics such as patterns, trends, dependencies, and aberrant regions. Our approach has overcome this drawback by extraction and presenting temporal important information coming from sensor networks.

6 Conclusion and future works

In this paper, we have presented our approach to generate mapping solutions. This solution represents adequately complex information from geographic database in real time using multi agent system architecture. MAS provides various advantages to real-time map generalisation and quality of data such as, the autonomy and flexibility which improve the personalisation of maps at the time of their creations, finding the best solution and resolve all the appearance spatial conflicts. The proposed approach differs from other techniques for calculating the change in the perspective of an acceptable solution within a relatively short time and solves the most important spatial constraints. Because our primary interest was not to represent the entire available information, but rather a general overview in a visual summary, a novel solution was proposed based on the concept of chorem-based map and its ability to synthesise scenes that contain geographic objects and real-time spatiotemporal phenomena by associating them with schematised visual notations. Remember that chorems are not only a schematised representation of a territory (Brunet, 1986), but overall for us they can be defined as both a geometric and semantic generalisations from a geographic database or visual summaries.

Our work opens many research directions:

1 Especially with regard to the use of big data analysis tools (Hadoop, Spark, Kafka, SparkR and Hadoop-GIS).

2 We also seek to integrate in our approach some information about obstacles in a given sensor network, this means that the map contains not only the thematic information in the form of simple objects such as polygons and polylines, but there are also buildings, roads, rivers or lakes that are complex objects. Such barriers could mitigate the effects of certain phenomena and therefore we want the region detection technique to integrate this information into the process of generating an important region.

3 Another aspect will concern the maximum number of chorems to be selected (presently 7–10). So the question will be: “what is the maximum number of chorems to be visualised together while keeping a high degree of understanding and readability, taking the size of the territory and the scale of maps into account?”.

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Notes

[1]http://openweathermap.org

[2]http://www.postgresql.org/

[3]Scalable vector graphics.

[4]https://www.google.com/earth/

[5]https://search.yahoo.com/search/?p=maps