Journal of Visual Language and Computing

journal homepage: www.ksiresearch.org/jvlc/

Computer-Assisted Visual Reasoning for Territorial Intelligence

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ARTICLE INFO

Article History:
Submitted 7.31.2022
Revised 8.27.2022
Accepted 9.5.2022

Keywords:
Geographic knowledge
Visual Reasoning,
Geovisualization,
Territorial Intelligence
Visual Analytics,
Datascapes.

ABSTRACT

In territorial intelligence, it is very interesting to provide computer-based tools to help reasoning especially in urban, regional and environmental planning. Traditionally, decision-makers use maps in their daily work, but they are limited in the expressive power to help reasoning, i.e., to assist them in deducing knowledge about salient problems and opportunities, and generating ideas and future projects. By means of visual analytics, and more specifically geovisualization, it seems possible. The scope of this paper is to rapidly analyze how painting has passed from representing objects as they are recognized to showing their relationships as a first step for reasoning. A similar study is made from conventional mapping to geovisualization, beyond traditional cartography, namely cartograms, chorems, datascapes, etc. as a way to base visual reasoning.

1. Introduction

For decision-makers in local authorities, it is important to capture and manage data, but overall information and knowledge in order to govern the territory under their jurisdiction. For that purpose, various software products have been created ranging for GIS systems, spatial analysis tools to recent systems based on deep learning and knowledge management, i.e., systems with some reasoning capabilities, for instance in urban and regional planning. In geographic applications knowledge has no meaning in itself but derives its value from its use in practice.

For a territory, knowledge corresponds to information potentially useful in order to make reasoning such as (Laurini et al. 2022):

- explaining and making understandable the dynamics of a territory as well as its interactions with other adjoining places in the same or neighboring countries.
- managing a territory by some local authorities, i.e., by means of some decision-support system, in the spirit of territorial intelligence;
- monitoring its daily development through feedbacks and adaptation;
- simulating the future, and design novel projects;
- orienting actions for the future.

In parallel, visual representation of territories has evolved from conventional cartography to geovisualization systems. According to MacEachren (2004) geovisualization (short for geographic visualization), also known as cartographic visualization, refers to a set of tools and techniques supporting the analysis of geospatial data through the use of interactive visualization. Like the related fields of scientific visualization and information visualization (Stuart et al., 1999), geovisualization emphasizes knowledge

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DOI reference number: 10.18293/JVLC2022-N2-021

construction over knowledge storage or information transmission. To do this, geovisualization communicates geospatial information in ways that, when combined with human understanding, allows for data exploration and decision-making processes (Jiang and Li, 2005; MacEachren, 2004).

What is visual reasoning? First, according to the Merriam-Webster dictionary, reasoning is defined as the use of reason, and especially the drawing of inferences or conclusions through the use of reason.

So, the research question addressed in this paper is to analyze how computer-based visualization can provide novel methods of reasoning about a territory. To help answer this question, we will study a few historical issues before the advent of computers, then examine what the possible solutions are existing now for visual reasoning.

2. Some Historical Landmarks

In this section, it seems interesting to study in what degree the visual representations were made in order to help reason. From a historical point of view, two directions will be detailed, namely painting and cartography.

2.1 Painting

The goal of this section is not to make a global history of painting but rather to examine a few ideas regarding the relationships between painting and the reality.

Fig. 1. Egyptians used to represent objects as they are recognized. Source https://www.britishmuseum.org/collection/object/Y_EA37983

Regarding prehistoric people, it seems that some paintings in cave have a sort of magic power to act on reality (Bégouen 1929). Later during the Egyptian period, the idea was to represent objects as they are recognized. For instance, in the famous Nebamon tumb, there is a painting (Figure 1) representing plants and animals in a garden: their flat representation allows anybody to recognize them without any problem. In the same idea, ask a child to represent a fish, s/he will not draw it from the top, from the bottom nor the face but rather from its side to easily recognize it.

Then, in painting, the dominant idea was rather to show some mythologic or religious paintings, sometimes far from reality. Later with the discovery of perspective, in 1435 Alberti wrote a treatise entitled *De Pictura* (On Painting) in which he outlined a process for creating an effective painting using one-point perspective (Sinisgalli, 2011). Now it was possible to represent objects as they are seen (see a painting in Figure 2 from Piero Perugino in 1481. The summum was reached by Leonardo da Vinci (1452-1519) in his *Trattato della pittura* (Treatise on Painting).

Fig. 2. Pietro Perugino's painting representing objects as they are seen. Source: https://www.analisidellopera.it/consegna-delle-chiavi-a-san-pietro-perugino/

Fig. 3. Pablo Picasso's Guernica. Painting emphasizing relationship between objects. Source: https://www.museoreinasofia.es/en/collection/artwork/guernica

Later during the early 20th-century art rebelled against the traditional understandings of painting. They focused on the relationship between the objects rather than on the traditional single-point perspective.

To conclude this section about painting, a sort of evolution schema can be outlined ranging from the visual representation of objects as they are recognized, as they are seen and finally the relationship between them which will be considered as a first step for reasoning.

2.2 *Cartography of Small Territories*

This is not the goal of this section to write a history of cartography and not to detail the ways of representing the whole earth, rather to give a few salient characteristics for maps made for reasoning about a territory.

The majority of maps are made to describe a territory, for instance in physical, economic and political geographies. Of course, even if they are limited to the description, they can assist any human to make reasoning, but their initial purpose was to explain.

Apparently, the first map was a slab discovered in Saint-Bélec, Brittany from the Bronze Age as presented in Figure 4. It shows a region, presumably in 3D.

Several centuries after, there was the well-known Peutinger map. This is the only Roman world map known to have survived antiquity showing the Roman road network. Preserved in a single, medieval copy now housed in the Austrian National Library in Vienna, the map stretches from Britain in the west to India in the east, covering a series of 11 parchment rectangles. The idea behind this map is not to show the shape and locations of cities and rivers, but overall to help find an itinerary from one city to another city. For instance, the Adriatic Sea is very narrow (at the top of Figure 5), whereas Carthage is depicted just below Rome! Knowing where you are and where you want to go, by reading this map, you can get the list of cities to cross. Of course, at this period, there were not signposts to give directions, but the solution was to ask to a person living in this city.

Fig. 4. Saint-Bélec Slab showing a map of the Bronze Age. Presenting things as they are located Source: https://allthatsinteresting.com/saint-belec-slab.

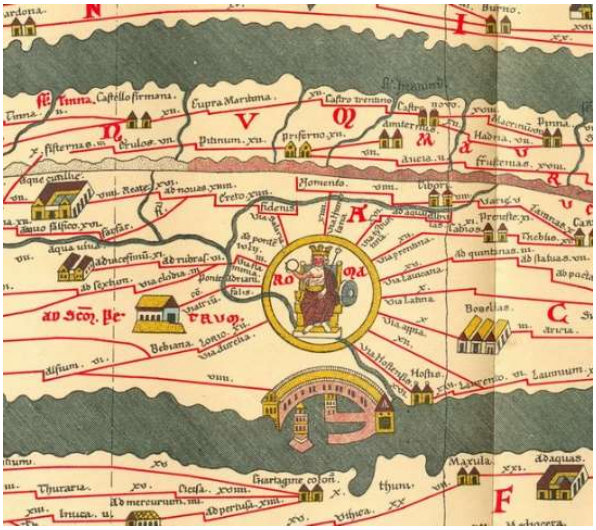

Fig. 5. An excerpt of the so-called Peutinger map centered in Rome, showing the Roman road network. Can be seen as a way of reasoning for finding itineraries. Source: https://www.onb.ac.at/

3. From Visual Data Mining to Geovisualization

In this section, we intend to clarify the differences between several notions such as visual data mining, visual analytics, visual reasoning and geovisualization

3.1 *Visual Data Mining*

According to Simoff (2020), visual data mining is the process of interaction and analytical reasoning with one or more visual representations of abstract data. At the difference with conventional data mining in which knowledge chunks are automatically collected often as patterns or associative rules, in visual data mining, the human interaction is the key: by observing particularities or regularities, someone can identify interesting issues, maybe leading to novel knowledge chunks.

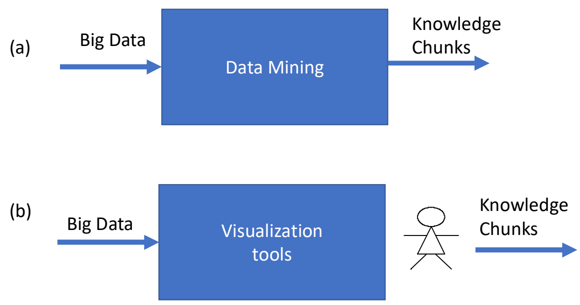

Fig. 6. Two ways of capturing knowledge. (a) via data mining. (b) via visualization tools (visual data mining).

In Figure 6, one can see the main difference between conventional data mining (a) in which knowledge chunks are identified by a computer whereas in visual data mining (b), knowledge chunks are identified by a human.

3.2 Visual Analytics

Wong and Thomas (2004) gave the following definition: visual analytics is an outgrowth of the fields of information visualization and scientific visualization that focuses on analytical reasoning facilitated by interactive visual interfaces. In Figure 7, Keim et al. (2010) depict a visual analytics workflow as a methodology to produce knowledge through visualization.

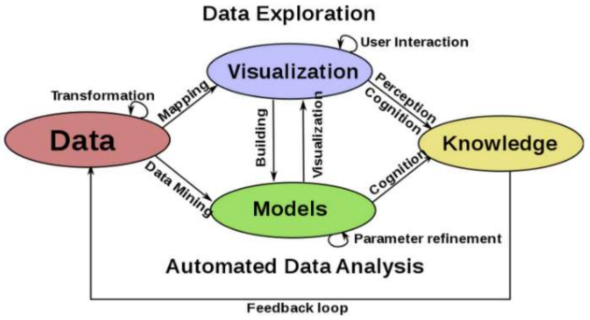

Fig. 7. Visual analytics workflow. From Keim et al. (2010).

According to Thomas-Cook (2005) here are a few recommendations in research about visual analytics:

• build upon theoretical foundations of reasoning, sense-making, cognition, and perception to create visually enabled tools to support collaborative analytic reasoning about complex and dynamic problems;

• create a science of visual representations based on cognitive and perceptual principles that can be deployed through engineered, reusable components. Visual representation principles must address all types of data, address scale and information complexity, enable knowledge discovery through information synthesis, and facilitate analytical reasoning;

• develop a new science of interactions that supports the analytical reasoning process. This interaction science must provide a taxonomy of interaction techniques ranging from the low-level interactions to more complex interaction techniques and must address the challenge to scale across different types of display environments and tasks;

• create methods to synthesize information of different types and from different sources into a unified data representation so that analysts, first responders, and border personnel may focus on the meaning of the data.

3.3 Visual Reasoning

Emily Daw (2022) defines visual reasoning as the process of analyzing visual information and being able to solve problems based upon it. In other words, visual reasoning produces knowledge. But what are the characteristics of this knowledge? For humans, overall knowledge is verbal but multimedia knowledge is also important: think about music, images, videos, gastronomy, domains for which sometimes it is difficult to transmit knowledge with words.

A good example of visual reasoning is a crime board (Figure 8) which can be seen in practical all police series and detective shows: in this board are pinned suspects' photos, crime maps, relationships between them, pieces of evidence, etc. As soon as new information is discovered, this is put onto the board. By looking at it, detectives formulate assumptions. Often the solution comes from a missing relation.

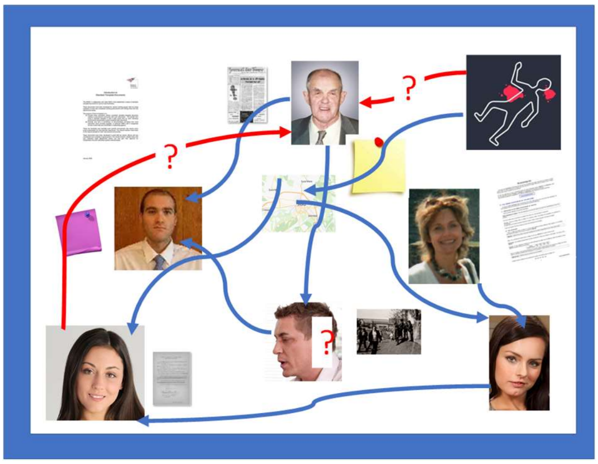

Fig. 8. Example of a detective crime board. By visual reasoning, the solution of the crime is found.

In this paper, we only try to examine how knowledge can derive from figures, drawings, schemata and especially from information mapping, i.e., coming from visual analytics, and geovisualization.

3.4 Definition of Geovisualization

According to MacEachren and Kraak (1997), Geovisualization, short term for "Geographic Visualization" can be defined as a set of tools and techniques to support geospatial data analysis through the use of interactive visualization. Like the related fields of scientific visualization and information visualization, geovisualization emphasizes information transmission. Geovisualization communicates geospatial information in ways that, combined with human understanding, allows data exploration and decision-making processes. Beyond cartography whose goal is representing territory with fidelity (usually physical or topographical), geovisualization tries to highlight the more important issues.

To summarize, geovisualization is an interesting and useful field of research for different reasons:
• it can reduce the time to search information, and support decision-making;
• it can enhance the recognition of patterns, relations, trends and critical points etc.;
• it can give a global vision of a situation, a phenomenon, etc.;
• it enables the use of human visual memory and the capability of perceptual processing of data;
• it permits a better interaction between user and the information system;
• and it can possibly lead to the discovery of new bunches of knowledge.

4. Geovisualization For Reasoning

According to Lacoste (1976), in his provocative book, explained that geography was a form of strategic and political knowledge, central to the military strategy and the exercise of political power. In other words, geography help reason for war. But the role of geography is more than that since it permits reasoning in other domains such as urban, regional and environmental planning. For instance, reasoning is useful for the following issues (Laurini, 2020):
• Where to put a new airport, a new hospital, a new stadium, a new recreational park, etc.?
• Is this new construction project compliant with planning rules?
• What is the best mode or the best way to get from *A* to *B*?
• How to organize a plan for green spaces in a city?
• How to reorganize common transportation?
• How to fight pollution?
• What could be the cost of a projected development?

4.1 Generalities about Geovisualization

Anyhow, perhaps one of the first geovisualization display was made by Minard regarding the march of Napoleon against Russia as depicted in Figure 9 in which the size of the line is proportional to the number of soldiers, yellow when going and black when returning. Due to bad temperatures, he lost more or less 2/3 of his army when marching; during the battle few soldiers died, and in the way back very few soldiers returned home.

Among geovisualization methods, let us rapidly present cartograms, chorems, datascapes and 3D representations. The first two can be seen as 2D representations as extensions of thematic cartography whereas datascapes be considered as 2½ D visualization tool.

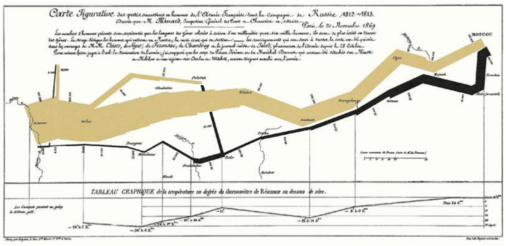

Fig. 9. March of Napoleon against Russia by Minard. Source: https://www.edwardtufte.com/tufte/minard. It is considered as a first geovisual representation.

4.2 Cartograms

According to Grover (2014), cartograms are a kind of maps which take some measurable variable: total population, age of inhabitants, electoral votes, GDP, etc., and then manipulate a place's area to be sized accordingly. The produced cartogram can really look quite different from the maps of cities, states, countries, and the whole world. It all depends on how a cartographer needs or wants to display the information. An example is given Figure 10 showing GDP wealth in 2018; look at Russia, China and Africa for distortions.

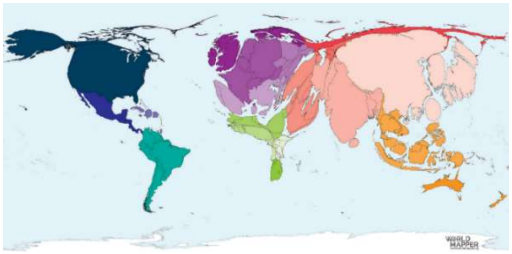

Fig. 10. Example of a cartogram emphasizing Gross Domestic Product wealth in 2018. Source https://worldmapper.org/maps/gdp-2018/

There are various forms of cartograms (Field 2017):
• non-contiguous cartogram: adjacencies are compromised as areas shrink or grow; individual area shapes are preserved but they become detached from the overall map;
• contiguous cartogram: adjacencies are maintained but shape is distorted to accommodate the mapped variable
• graphical cartogram: maintains neither shape, topology or location; instead using non-overlapping geometric shapes (e.g., circles or squares) to represent the mapped variable (see example Figure 11);
• gridded cartogram: uses repeating shapes of the same or different size to create a tessellated representation of the mapped variable;
• topology: non-metric spatial relationships that are preserved under continuous transformation e.g. adjacency.

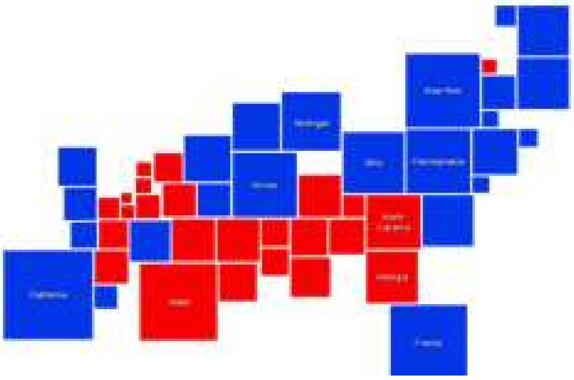

Fig. 11. Example of a cartogram presenting the U.S. Presidential election results as a cartogram based on squares. Source: https://gistbok.ucgis.org/bok-topics/cartograms.

Cartograms, by adapting shapes in accordance a very well-defined variable, permit reasoning which were not possible with traditional.

4.3 Chorems

Chorems were created in 1980 by Pr. Roger Brunet, a French geographer as a schematic representation of a territory. This word comes from the Greek χώρα which means space, territory. It is not a raw simplification of the reality, but rather aims at representing the whole complexity with simple geometric shapes. Even if it looks a simplification, the chorem tries to represent the structure and the evolution of a territory with a rigorous manner. The basis of a chorem is in general a geometric shape in which some other shapes symbolize the past and current mechanisms. Brunet has proposed a table of 28 elementary chorems, each of them representing an elementary spatial configuration, and so allowing them to represent various spatial phenomena at different scales.

According to Brunet, chorems are a tool among other to model the reality, but it is a very precious tool not only as a visual system, but also as a spatial analysis too. Considering Mexico, Figure 12 presents both a traditional (physical) map and a chorematic map in which the salient issues are considered (Lopez et al. 2009).

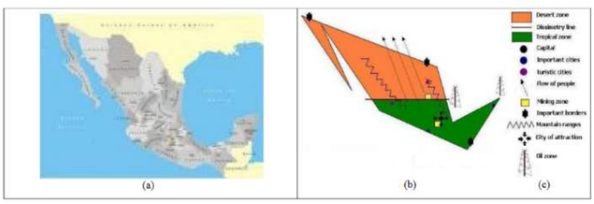

Fig. 12. Fig. 12 Example of chorem; (a) A traditional map, (b) a chorematic map of Mexico and (c) its legend. (Lopez et al. 2009).

In Bouattou et al. (2017) an experimentation of chorem generation in real time is presented with an application in meteorology in Algeria. See Figure 13.

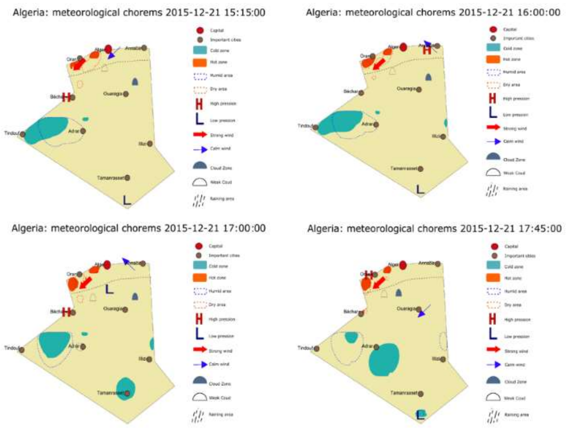

Fig. 13. Example of animated chorem showing weather evolution at different dates in Algeria (Bouattou et al. (2017).

To conclude this rapid presentation about chorems, let us say that they can be seen as a sort of generalization, both geometrically and semantically. Those salient issues can be extracted by data mining and then visualized; thanks to the chorematic presentation, new knowledge bundles can be discovered.

4.4 3D Representations and Datascapes

An innovative data driven graphic approach to model environmental, territorial and urban systems is the representation of natural and anthropic systems and phenomena as "datascapes", literally "data landscapes".

Fig. 14. Datascape in urban area (by N. Amoroso), data elaboration with the software DataAppeal; presence of CO2 in Grenoble, France. Source: https://archinect.com

This approach integrates the methods that describes the elements of the "physical and real" landscape systems, that can traditionally be represented by means of the 2D GIS cartography. And with the datascape representation, it is possible to describe the "visible and invisible" phenomena that spatially represent them using the third dimension, in a "virtual landscape of data" (datascape) in 3D.

Nadia Amoroso, an expert in Data Visualization, defines datascapes as "densityscape maps" and "a visual representation of all the quantifiable forces that influence a system" (Amoroso, 2010) and also as "digital landscape", literally "digital landscapes". See Figures 14, 15 and 16.

The datascape representation is particularly suitable to model different kinds of territorial systems: from simple structural systems that only describe the physical structure of a system, to more complex systems such as urban systems and ecological networks. So, many non-structural, and not visible aspects are added, such as invisible phenomena that are related to the visible structure of the system, and also relations among different kinds of phenomena. In fact, in the datascape approach, it is possible to describe all the different elements and phenomena that are present simultaneously and in the same place that can be quantitatively described, and that require a large amount of data

Fig. 15. Fig. 15. Datascape in urban area (by N. Amoroso), data elaboration with the software DataAppeal; Traffic accidents and pedestrian traffic in Toronto. Source: https://archinect.com

This consideration is even clearer when considering the evolution of the concept of environmental and urban systems towards more complex approaches, which, in particular, take into consideration not only the monitoring of natural and territorial phenomena, but also of anthropic phenomena and with them also of new functional and management managerial and new aspects.

This is because we move from a "structural" approach, in which the identification of the areas and the connections between them has a single specific purpose, i.e., for the ecological networks, the protection of biodiversity, to a "multi-purpose" approach that combines different objectives.

Fig. 16. Datascape in urban area (by N. Amoroso), data elaboration with the software DataAppeal; Population density in NY. Source: https://archinect.com

In the example of the representation of ecological networks, there is a combination of objectives to reach and to describe: the aim of the biodiversity protection is combined with the aim of implementing eco-systemic services for the population living in the territory; therefore, new elements are taken into consideration and are integrated into the system description: this fact increases the degree of complexity of the system-network and of the phenomena associated with it. Furthermore the "datascape modeling", as we said, is suitable to represent variables of non-visible urban and extra-urban phenomena (temperature trend, pollution and pollen dispersion etc.), and this potential can also greatly increase the complexity of the representation.

4.4.1 Differences between cartograms, chorems and datascapes

The main difference between cartograms, chorems and datascapes is that cartograms and chorems deform the real cartographic representation, instead the datascape representation displays simultaneously the real cartographic representation and the virtual representation of the variables that we need to represent (Donolo-Laurini 2015).

4.4.2 Datascape Modeling

As previously said, the cartographic representations of territorial data can be very complex, since they present different levels of information at the same time and in a multi-dimensional space; one of the main advantages of datascape modeling is given by the potential of representation, for both temporal and spatial dimensions, of the numerous geo-spatial elements and associated phenomena that are present simultaneously in a territory; in particular, it should be noted that:

a) Datascape potential of representation for the “spatial dimension”: in a territorial system, in addition to the physical elements visible in the three dimensions of the "physical" space (x, y, z), (e.g. lakes, woods, deserts, etc.), there are simultaneously both visible phenomena (and graphically easily representable (such as the presence of a population of wild animals) and non-visible phenomena more difficult to be represented (such as the presence of atmospheric or aquatic pollutants, or the variation of the average temperature, etc.). Those elements can be visualized and represented using the three dimensions of a “metaphorical or virtual graphic space” (x_1, y_1, z_1) which can be superimposed on the physical space (x, y, z), since it can be translated along the z axis.

b) Datascape potential of representation for the “temporal dimension”: in a territorial system, different phenomena occur simultaneously, and the "metaphorical space" (x_1, y_1, z_1) helps visualize different phenomena in the same moment, or one phenomena in different moments, because the "metaphorical space" is replicable for each time considered ($x_1, y_1, z_1 \ldots\ldots\ldots x_n, y_n, z_n$) and is superimposable n-times on the physical space (x, y, z), and also because it is a space in which the quantities that vary over time can be represented dynamically in real time.

In other words, we want to highlight that the use of the three-dimensional digital data models allows to view urban and extra-urban systems with a greater visualization and analysis potential than the two-dimensional "flat" models; this is not only due to the insertion of the third dimension (z) to integrate the traditional graphic representation of the GIS in 2D (x, y), which would lead to a representation of the territory in 3D, (x, y, z), that is already used in the digital terrain models (Digital Terrain Model, DTM, Digital Surface Model DSM, Digital Elevation Model DEM), but because a real new "metaphorical space" is added in 3D (x_1, y_1, z_1). This additional graphic representation constitutes a kind of "augmented reality" and in fact produces an alternative and integrative morphology (or more morphologies) with respect to the real morphology of the selected territory, and therefore is also called "meta-morphology".

4.4.3 Advantages of the Datascape modeling

The advantage of having an additional virtual space for displaying data and indicators brings with it other positive aspects:

a) Since the variable z of the "metaphorical space in 3D (x, y, z)" can assume both positive and negative values, it is also possible to use the representation space underlying the surface identified by the plan ($z = 0$), consequently it increases the space that can be used to graphically represent more phenomena in a single "view" of digital cartography; As an example, Figure 17 shows the representation in the urban context of the continuous variable "crime density" / "population density".

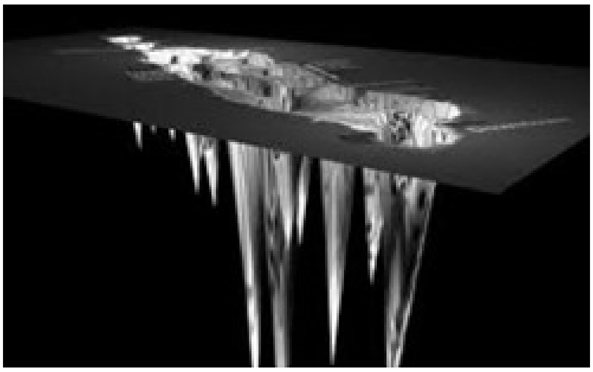

Fig. 17. Criminality datascape (Crimescape) of London, elaboration by N. Amoroso. University of Toronto Magazine, 2013.

b) As already known for the representations of ecological networks in 2D with GIS tools, an advantage of the graphic representation of datascape in 3D is the possibility to customize and optimize the use of graphic variables (color, shape, size, etc.), also called “visual variables”, and their combinations. In fact, as the global number of the variables available increases (considering that the variables of the new "metaphorical space" (x_1, y_1, z_1), and the time variable t, are added to the spatial variables (x, y, z) of the territory under examination), also increases the number of visual variables that can be associated to the total spatial variables (x, y, z, x_1, y_1, z_1, and t) and therefore also increases the number of possible combinations between the visual variables and the possible ways of representing the same phenomenon. Visual variables have been defined as "a way to modify graphic signs" (Pumain et al., 1989). In particular, datascape modeling presents an additional visual variable compared to the traditional 2D GIS representation which is possible exactly the third additional dimension: "the perspective". The main visual variables whose most effective use was analyzed to highlight qualitative or quantitative differences between the graphic objects represented by Bertin (1967). It should be noted that other researchers have subsequently discussed and expanded the systematization of Bertin's visual variables, and their optimal use based on the properties of the data to be represented.

c) A third positive aspect, is that the datascapes can be processed online with specific software products that use the interactive 3D map base of Google-Earth on the Web, which can be rotated and zoomed; with it, you can therefore rotate and zoom all the datascape representations superimposed on it: so the datascapes not only are dynamic, but also interactive and they allow you to explore the map from different perspectives, in order to extract out relationships between phenomena, trends, hidden criticalities, etc.

d) Another advantage is given by the fact that the datascape modeling not only allows to manage a large amount of data, but also different data configuration; in fact, through appropriate dashboards, they make possible the management and the modification in real time of both single datascape and multiple datascapes combined and correlated with each other: although a configuration of natural and anthropic phenomena can be temporally stabilized, at times, it is sufficient for a single phenomenon to undergo a modification, to modify whole series of phenomena; so it will not be sufficient to analyze a single reality, but a set of different possible realities. Even the digital environments of datascapes are multiple, fluid and are able to represent and monitor different configurations of phenomena; as an example, different datascapes can be used to represent ecological networks belonging to different animal populations.

e) It is possible to elaborate datascapes not only of the phenomena detected at a given moment, but also of possible future scenarios, which can also be compared with each other. One could also compare datascapes of phenomena belonging to different categories, for example by representing all datascapes deriving from anthropic phenomena under the z = 0 plan and all datascapes of natural phenomena above the z = 0 plan.

f) By working on datascapes on a large area scale, as the complexity of the ecological network increases with the increasing size of the concerned territorial area, with the datascape modeling, it is possible to work at different scales, which can also be compared.

g) With the datascape modelling it is possible to customize and optimize of the graphic symbology of the single datascape and therefore the management of the visual variables.

h) With the datascape modelling, the identification of hierarchies between datascapes is possible, which can be highlighted.

4.4.4 Critical aspects of the Datascape modeling

In this paragraph, are described some critical aspects to be considered in the representation of territorial systems/networks using the datascape approach.

a) The first aspect to be considered is the tendency to abuse the graphic technological potential and to represent too many territorial and visual variables at the same time in a single "view/display", decreasing the readability of the maps for both expert and non-expert users. There are studies in the psycho-cognitive literature (Sedig and Parsons, 2013) that aim to evaluate how many territorial and visual variables are able to simultaneously process human visual and cognitive capacity. In particular, it emerged that some combinations of territorial variables and visual variables are more effective than others for representing certain quantities or phenomena.

b) A second aspect to note is that, as previously mentioned, several information layers necessary to describe the environmental and anthropic phenomena of a territory. This will be produced not only one, but more datascapes, and therefore the development of the "datascape approach" would be necessary, and will concern the modification, analysis, comparison and display of multiple datascapes at the same time; although this is generally possible through a dashboard, which is used to manage the different datascapes, it remains a critical aspect, because it requires the use by experts at least in the design phase. A dashboard, however, can be made available online, and can allow even non-expert users to interact on the Web, and make changes and views in real time shared between multiple users. Figure 18 shows an example of the interface of the DataAppeal software Dashboard implemented by Nadia Amoroso.

Fig. 18. Example of datascape representation on the Web with the Dashboard for customization (to make graphic and analytical changes, including interactive online and in real time).

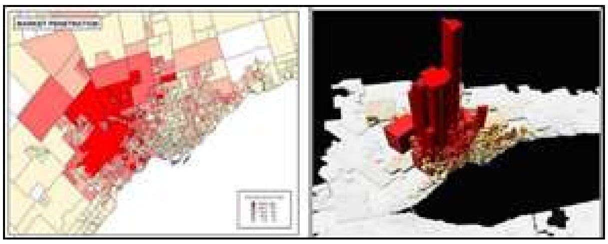

Fig. 19. Representation of the variable “diffusion of a product on the market” with two different approaches.

c) A third critical aspect concerns the poor readability of any graphic symbols / labels: also, in the case of datascapes, as for GIS maps in 2D, the use of graphic symbols superimposed on the cartography, adds information to the representation, but in the case of datascapes the perspective view in 3D could in some cases prevent them from being easily read.

4.4.5 Other Examples of 3D Representations

Figure 19 shows a comparison between the representation of the variable "diffusion of a product on the market": on the left the "traditional" GIS approach in 2D, on the right the "datascape" approach in 3D.

Below are shown other examples of 3D representations, created with opensource software; in Figure 20, is depicted an example of the temperature (or air pollution, etc.) in a canyon.

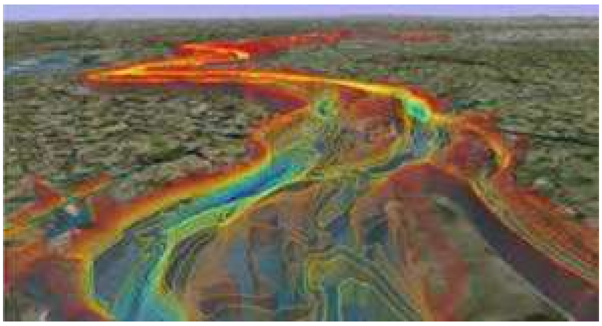

Fig. 20. Example of 3D representations of temperature / air pollutants in a canyon.

In Figure 21, are shown on the left an example of representation of green areas in an urban area, on the right: hen ta representation of flows (of information, passengers, etc.); from a datascape perspective, in this example, all the possible spatial and visual variables can be explored and exploited.

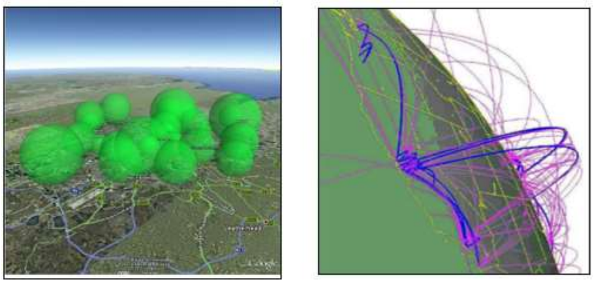

Fig. 21. Examples of datascape representations: on the left, green areas in an urban area and on the right, flow of information / passengers; (Internet source).

5. Towards Visual Reasoning

For territorial intelligence, those geovisualizations can assist visual reasoning in several directions:
• Detection of outliers: by observing a place where data are strange, a quality control action must be launched; otherwise the reasons why those data values are outside the range of other data must be identified;
• Detection of new critical points in geovisualizations, either social or environmental;
• Detection of new patterns, for instance polarization around a CBD (central business district) or along a traffic route;
• Detection of spatial correlations by comparing two datascape of the same place;
• Detection of hidden salient features;
• Confirmation of already-known information or knowledge.

The first step is to identify the main stages for visual reasoning; although it is too early to formalize them, let us list the main key aspects:
• When one is facing an unknown phenomenon exhibited by geovisualization, some questions arise such as its characterization, its magnitude and its origin.
• Then, another set of questions emerges such as how either to fight it (if the trend is negative) or to enhance it (if the trend is judged positive), leading to some action plans.

For instance, detecting a pick of air pollution, its location combined with location of plants can suggest the origin. However, for water pollution, this is more complicated, and the reasoning will differ whether this pollution is along a river or within sewerages. Regarding crimescapes, some comparisons with sociological data can suggest further actions: of course, those actions will differ when the problem is analyzed by the police or by a potential house purchaser.

More, another aspect concerns located data coming from sensors: generally, they can be examined through conventional techniques of spatial data mining, but through datascapes could be challenging; indeed, one can rapidly detect outliers, discover patterns or regularities.

Now, we are facing a kind of paradox. In one part, remember the Mark Monmonnier's book (1991) explaining that one can lie with maps deliberately or unconsciously: indeed, some persons want to mislead people with correct maps. And in the other part, some controlled map distortions can lead to, and bring the truth. In fact, Nadia Amoroso (2010) wrote: "the data should be truthful, but they have to be vivid and exiting. The data can be dramatized in an unrealistic way, which nevertheless is true" …. "This is meant to shock the audience to the risks of continuing to consume for example high levels of energy or water". In the crimescape maps, for instance, "sharp and deep pit-like points are represented that resemble an eerie landscape, in order to draw attention to the districts with high crime".

The original concept of the term datascape redefines information as "possible space" and "possible dramatized scenarios" that can lead to reasoning and in particular influence planning processes.

6. Conclusion

The scope of this paper was to examine how computer-assisted visual reasoning can help territorial intelligence. Starting from the evolution of painting and cartography, we have tried to show how geovisualization can highlight reasoning. Of course, other geovisualization methods may exist, but the general mechanisms are given Figure 22: sensors about a city send data to a geovisualization tool; the results are examined by an expert who can capture some knowledge chunks; those chunks added to already-known chunks are sent to a reasoning tool which infers suggestions; those solutions are studied by local decision-makers to launch actions plans.

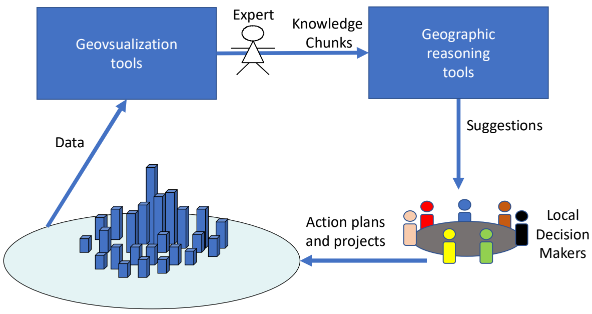

Fig. 22. Structure of visual reasoning for territorial intelligence.

Anyhow, this statement raises three kinds of questions:
1 – Are they existing other methods of visualization more adapted to derive visual knowledge which can be useful to reason?
2 – What are the main characteristics of visual knowledge chunks and bundles issued from geovisualization?
3 – How to formalize them in order to be used efficiently in inference engines?

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