Interactive Maps of Chorems Explaining Urban Contexts to Align Smart Community's Actors

Pietro Battistoni, Michele Grimaldi, Marco Romano(✉), Monica Sebillo, and Giuliana Vitiello

University of Salerno, 84084 Fisciano, SA, Italy
{pbattistoni,migrimaldi,marromano,msebillo,gvitiello}@unisa.it

Abstract. The actualization of the three pillars of the Open Government paradigm, namely transparency, participation and collaboration, motivates the importance for a smart city administration to share decisions with citizens to receive real support and legitimize the decisions made. A way to engage citizens is to make available government data as open. This allows achieving a higher transparency in decision-making that also fosters citizens to support the strategic objectives of the city and improve the individual and collective quality of life. The goal of this paper is to show the effectiveness of chorems as a communication and support tool for understanding the dynamic realities of a territory. When used to visually synthesize urban contexts, maps of chorems can produce a territorial schematic representation, which eliminates details not useful to the map comprehension, and emphasizes relevant information to enable decision makers, experts and ordinary citizens to share knowledge about complex phenomena occurring in urban areas. A use case is built, which describes how the urban heat island phenomenon and the factors involved in its development are analyzed through a set of chorems and operators. This phenomenon is invisible but typically present in most of the modern cities. It is composed of different urban elements present on the urban territory and its understanding implies technical and scientific knowledge not common among citizens and administrators. By visually interacting with chorems, it is possible support data manipulation by expert users, and data interpretation by citizens, thus aligning the different actors of a smart community towards a shared sustainability goal.

Keywords: GeoVisualization · Smart communities · Urban heat islands · Chorems

1 Introduction

Nowadays, the topic of the smart cities is increasingly central in the dynamics of management, transformation and redesign of modern cities, and is strongly

Partially supported by MIUR PRIN 2017 grant number 2017JMHK4F_004, and MIUR 2019 grant number AIM1872991-2.

© Springer Nature Switzerland AG 2021
O. Gervasi et al. (Eds.): ICCSA 2021, LNCS 12953, pp. 549–564, 2021.
https://doi.org/10.1007/978-3-030-86976-2_37

related to the concept of smart communities. In [14] the authors synthetize a smart city as "*a city exploiting IT services to connect people to each other, to city services, infrastructures and organizations with the goal to create a common conscience or knowledge that can improve the community life of the same city*". Speaking of smart community, instead, it is defined as a "*community in which government, business, and residents understand the potential of information technology, and make a conscious decision to use that technology to transform life and work in their region in significant and positive ways*" [18]. Although in both those contexts, technology is imagined as the main objective [17], many researchers and local administrators prefer to put the citizen at the center, and consider technology a mere support for the community to share common visions and reach common goals. Such an approach is in line with the actualization of the three pillars of the Open Government (OG) paradigm, namely transparency, participation and collaboration [11], which motivate the importance for a smart city administration to share decisions with citizens to receive real support and legitimize the decisions made.

As explained in [10,17] a way to engage citizens is to make available government data as open. Open data allows the administration to achieve a higher transparency in decision-making and foster citizens to support the strategic objectives of the city by building a network for improving the individual and collective quality of life. However, data and information used to make administrative decisions and involve citizens can sometimes represent complex territorial phenomena and processes, which therefore require specific knowledge to be interpreted. Problems may arise, in particular, when data and information are related to phenomena that are implicitly complex by nature. This is the case of phenomena in which several and different by nature parameters concur, which can also have a different weight depending on the scale with which they are evaluated.

Failing this sharing goal means to generate a misalignment of purposes among the different community's actors, which represents a typical problem of any public or private goal-oriented organization. To deal with it, organizations generally use the so-called alignment diagrams [8]. These are visual artifacts designed to help organizations align their internal people towards shared goals with the aim to generate a unique value. However, such diagrams are not adequate when dealing with huge amounts of data underlying complex spatio-temporal phenomena, even if some of their principles could be taken into account to design a more suitable artifact, such as the ability to represent both an overview of a scenario that is self-explanatory, and multiple dimensions for a multilevel analysis.

The goal of this paper is to show the effectiveness of chorems as a communication and support tool for understanding the dynamic realities of a territory. When used to visually synthesize urban contexts, maps of chorems can produce a territorial schematic representation, which eliminates details not useful to the map comprehension, and emphasizes relevant information to enable decision makers, experts and ordinary citizens to share knowledge about complex phenomena occurring in urban areas. In particular, to show the efficacy of chorems, in this paper they are adopted to represent the complex phenomenon of urban heat island (UHI).

The phenomenon of urban heat islands is invisible but typically present in most of the modern cities. It is composed of different elements present on the urban territory and its understanding implies technical and scientific knowledge not common among citizens and administrators, although it is a phenomenon affecting all of us daily. Then, in order to explain how factors involved in the occurrence of the phenomenon can be managed to reduce its impact, it is necessary to identify a visual paradigm that can be easily understood and used both by decision-makers, who have to interface with technical staff, and by citizens, who have to understand the reasons for the actions taken by the administration to mitigate the phenomenon.

Maps of chorems can represent a solution. They offer a synthetic global view that is suitable to guarantee such requirements.

The paper is organized as follows. Section 2 recalls the definition of *chorem* and briefly describes the set of operators defined to manage and analyze maps of chorems. In Sect. 3, the UHI phenomenon is described along with factors involved in its development. A model to determine criticality maps is recalled, which is used as a possible source for UHI chorems. Section 4 is addressed to show how chorems can be used to visually synthesize a urban context and some relevant phenomena and elements related to it. In particular, it depicts how the urban heat islands phenomenon can be investigated by manipulating a map of chorems. Two scenarios are depicted in Sect. 5 whose goal is to show how decision-makers and citizens can take advantages of maps of chorems in investigating urban contexts and understanding environmental phenomena affecting them. Concluding remarks and Future work are drawn in Sect. 6.

2 Chorems as Visual Synthesis of Spatio-Temporal Phenomena

The concept of *chorem* was first introduced in 1986 by the French geographer Brunet as a schematic territory representation, which eliminates details not useful to the map comprehension [3]. Since then, the concept has evolved over the years, although the proliferation of *ad hoc* solutions, due to the lack of a rigorous approach for chorem creation and composition, caused failing in conveying the information they were meant to [1,2,12].

Figure 1 shows a set of chorems, including industrial zones and big poles, which make up a thematic map referring to Spain. A definition and classification of chorems as visual syntheses of geographic database contents was first provided in [6], to homogenize chorem construction and usage and to provide a usable framework for computer systems. According to it, chorems can be grouped into three main categories, namely:

- Geographic chorems,
- Phenomenal chorems and
- Annotation chorems.

Geographic chorems represent geographic data with associated simple geometries, such as points, lines, polygons, and objects made up of their combinations, such as networks. Phenomenal chorems describe spatio-temporal phenomena involving one or more geographic chorems, and, when useful, they can be further classified in Flow, Tropism, and Spatial Diffusion. A Flow chorem represents objects movement between geographic chorems. A Tropism chorem represents an homogeneous attractive or repulsive space, around a geographic chorem. A Spatial Diffusion chorem represents a spatial progression or regression, from a geographic chorem along a given direction. Finally, an Annotation chorem represents map labels or remarks, useful to provide users with additional information about the map.

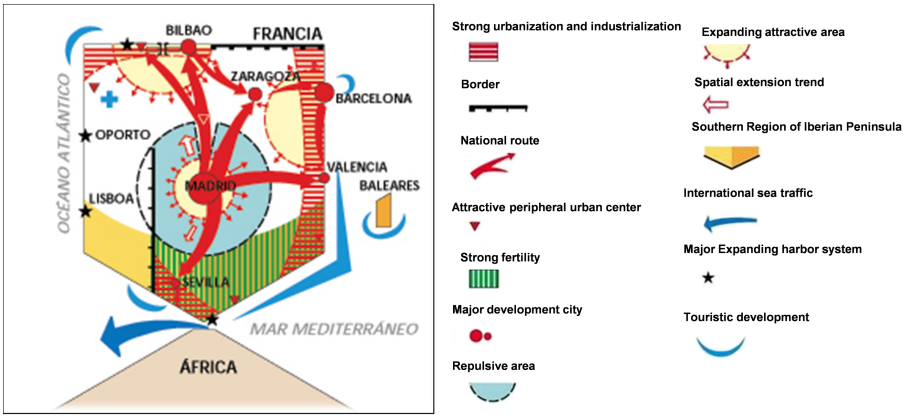

Fig. 1. A Map containing chorems about Spain (a) and its legend (b) [6]

Figure 2 depicts the underlying structure of a chorem, which was first described in [6]. It takes into account the complex nature of geographic data and phenomena by visually integrating the iconic and the property components. As for the former, the iconic representation assemblies a graphical component, corresponding to the visual representation, and a meaning, referring to the semantic component. In such a way, users can quickly perceive the meaning associated with data and use it properly. As for the property component of a chorem, it is divided into two parts, a type attribute specifying the category the chorem belongs to, namely geographic, phenomenal or annotation, and a source indicating where data could be retrieved (such as a table or a view name, a SQL query or a function). It is worth to notice that, in case of a phenomenal chorem, the type attribute also contains information about the geographic chorems which it is related to.

Based on this structure, a different classification can be provided that inherits the structural organization, typical of the well-established model used in GIS for managing spatial data, namely feature layer, layer and map.

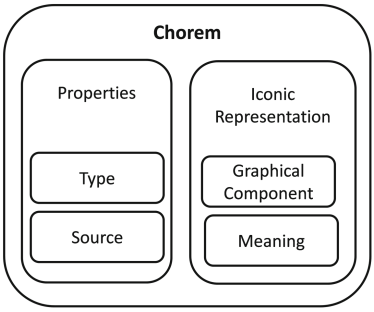

Fig. 2. The structure of chorems [6]

In particular, the concept of Chorem element, Chorem and Choromatic Map were introduced as follows:

- a Chorem element is a basic element representing either a single geographic object, such as a city and a road, or a single phenomenon, such as people migration and car mobility;
- a Chorem is a set of homogeneous chorem elements. For instance, the set of the most important Italian cities, or the set of the main flows between such cities.
- a Choromatic Map is a set of chorems, which schematize data of interest related to a specific place or region. A legend can be associated with a choromatic map, which explains the meaning of each chorem.

This classification emphasizes the relationships existing among a single instance of a chorem, the group to which it belongs, and the whole scenario where different chorems can be spatially arranged.

The potentiality of chorems was discussed by Laurini et al. in [5], where a list of the different roles that chorems may play is given. The authors state that chorems can be used to represent geographic knowledge, to visually summarize database contents and finally to underlie the creation of a novel entry system for geographic databases.

Following this line, in [4,6], the authors demonstrated how chorems can represent the starting point for further processing tasks aimed to derive spatial analysis data, and to support expert users in decision making. In particular, they introduced a set of operators, both geographic and semantic, to derive spatial knowledge, useful to help domain experts face and get rapid and exhaustive responses in critical situations.

Based on the Ben Shneiderman's mantra and on Keim's adaptation to the Visual Analytics domain [9,16], applying these operators allows users to navigate a choromatic map from an initial overview to a detail, as follows.

Geographic Zoom
This operation corresponds to the traditional map zooming (in/out) operator. When applied to a choromatic map, it acts exclusively on the visual aspect of the chorem, by changing the size of the visible details of the involved chorem elements, leaving them unchanged, also in terms of structure.

Semantic Zoom
Generally speaking, a semantic zoom (in/out) changes the type and meaning of information associated with chorems. When applied, it allows accessing to a different level of information, that is, it analyzes the chorem and its elements by (dis)aggregating and visualizing them in detail. In particular, when the operation is applied to geographical chorems, they are simply split up (resp., aggregated), by showing a new level of geographic data abstraction. The chorem structure is modified accordingly, by properly substituting the corresponding iconic representation component, both in terms of graphical component and meaning. When a semantic zoom is applied to a Phenomenal chorem, it is decomposed (resp., aggregated) along with the Geographic Chorems related to it. In this case, the chorem structure is differently modified. In fact, even if the output chorem still corresponds to the initial phenomenal chorem, its meaning changes, being referred to a different abstraction of the territory.

Geographic Filter
This operation allows the user to select Phenomenal Chorems elements by using the graphical component of one or more Geographic Chorems elements as spatial filter. In this case, the condition corresponds to the territory of interest where phenomenal chorems elements have to be analyzed. The output of the operation consists of one or more phenomenal chorems that satisfy the condition. The resulting chorems structure does not change in terms of properties and iconic representation, whereas the number of phenomenal chorem elements may vary in order to satisfy the condition.

Semantic Filter
This operation allows users to filter chorem elements that satisfy a particular condition, by directly operating on the semantics associated to them.

In order to show how the visual representation based on chorems can be useful to handle the information associated to the UHIs, the following Section briefly describes this environmental phenomenon and presents a model to process a set of parameters associated with it.

3 The Urban Heat Islands Phenomenon

The increase in temperature occurring in public urban areas with respect to surrounding outlying and rural areas determines a thermal anomaly known as Urban

Heat Island. This phenomenon can have significant differences between cities with a comparable population, and varies considerably according to weather conditions, season and time of day: it turns out to be a more significant phenomenon at night and in summer. Its most relevant effects are:

- an increase in energy consumption,
- high emissions of pollutants and so-called greenhouse gases,
- a worsening of the life and thermal comfort of the population, and
- an increase in storm phenomena in the urban area.

Together, these effects have a significant impact on the outdoor air quality, making UHI an important phenomenon to consider to improve urban life quality.

To reach this goal, it is necessary to take into account that urban areas are known to be richer in energy than rural areas, and this imbalance is even more fragile due to additional heat sources. The factors that influence a UHI are divided into three groups:

- factors related to the environmental context;
- factors related to the human component;
- factors related to the urban structure.

The first two components are defined in [13] as uncontrollable, while the causes linked to the anthropic modification of the territory, defined as controllable variables, are urban geometry, properties of urban materials and urban green.

The urban geometry contributes to the UHI phenomenon through the so-called urban canyons, consisting of the high building walls that face each other along the streets. Here, the solar radiation is reflected several times from the road surface and the walls of the buildings, remaining trapped inside the canyon and causing a rise in temperatures. The materials used in urban areas modify the energy balance mainly through the albedo, which indicates the fraction of incident radiation that is reflected off a surface and varies considerably in relation to the color and type of surface. The materials present in the city are characterized by a much lower albedo than in the countryside. The presence of green areas, on the other hand, offers a mitigating contribution to the phenomenon. The crowns of the trees are able to shield the solar radiation and use a part of this for photosynthesis.

Based on the analysis of these factors, it is possible to identify specific mitigation actions, i.e. interventions that should:

- modify the morphology and adopt materials with lower thermal admittance, thus reducing the flow of heat stored in the urban structure;
- increase the albedo of the surfaces and modify the geometry of the buildings, thus reducing the net radiation;
- increase the permeability of surfaces and the presence of vegetation;
- reduce the vehicular traffic and improve energy efficiency, thus reducing the flow of anthropogenic heat.

As for the visual representation of the UHI phenomenon, its inner complexity implies that components to be visually analyzed must be selected depending on the scale by which the phenomenon is investigated. In [7] the authors studied more than 250 scientific articles on urban heat mapping indicators, and mapping techniques. They found that one hundred thirty-three articles did use a cartographic map to indicate UHIs. However, although it is popular to visually analyze the UHI phenomenon with mapping, it is still challenging to represent a single complex indicator derived by multi-variate data. In reason of this complexity, the chorem paradigm, with its geographic and sematic operators, appears to be a valuable mechanism for a more immediate understanding of the causes of the phenomenon at any scale.

In the following Section, the controllable variables are modelled in terms of chorems and are used to visually express the basic features of the critical zones identified by a model underlying the structure of the UHI chorem.

4 Chorematic Maps to Visually Synthesize and Analyze Urban Contexts

Starting from the basic elements previously mentioned, and representing them through proper chorems, it is possible to design and build chorematic maps to support decision makers in their monitoring activities conceived to improve citizens' life.

The goal of this Section is twofold. First, it is addressed to describe a set of chorems specifically conceived to visually synthesize a urban context and some relevant phenomena and elements related to it. Then, it is shown how geographic and semantic operators can be applied to the built chorematic maps in order to investigate the UHI phenomenon.

4.1 Chorems for the Urban Context

Figure 3 shows the list of chorems associated with the UHI phenomenon and each factor contributing to its development, namely Urban Area, Urban Greenery, Urban Geometry and Albedo. They are structured as described in Fig. 2 and, when applicable, a classification of their possible values is given in terms of ranges. The Urban Area geographic chorem represents the visual synthesis of a urbanized area to which several phenomena can be associated. As an example of instances, districts and quarters can be considered.

The Urban Greenery geographic chorem represents the visual synthesis of public landscaping and urban forestry created to let citizens benefit from environmental green spaces. Arboretum, parks and urban vegetable gardens are instances of Urban Greenery.

Associated with the Urban Area chorem, Urban Geometry and Albedo are Spatial Diffusion chorems. The Urban Geometry source is calculated as the average urban complexity, which takes into account some spatial indices, such as size,

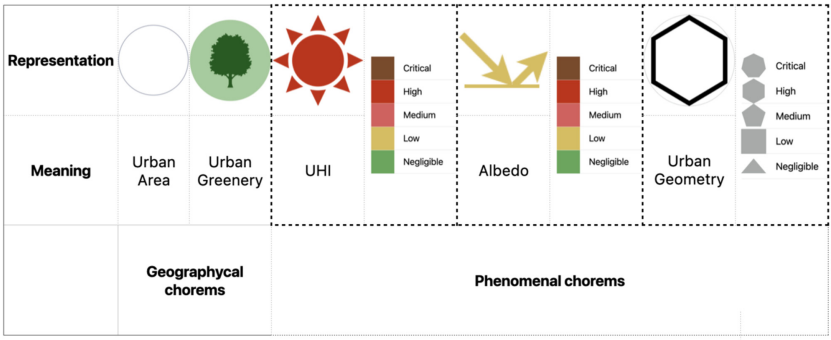

Fig. 3. Chorems for the UHI phenomenon (Source: Authors' elaboration)

shape, skyline and openess of the area of interest. It is represented by a polygon whose number of sides ranges from 3 (negligible geometry) to 7 (critical urban geometry), thus increasing with the criticality performed.

As for the Albedo chorem, its iconic representation is similar to a *tick* made up of two arrows, whose colour shows the capability of the associated area to absorb/reflect the solar light.

Finally, UHI is a Spatial Diffusion chorem associated with the Urban Area chorem. The UHI source corresponds to the calculation performed on the factors as defined in Sect. 3. Its iconic representation is a *sun* whose colour intensity indicates the level of criticality.

In addition to the above chorems, the urban context is also characterized by a set of phenomena whose presence and intensity can affect one or more factors underlying the UHI phenomenon, such as the average temperature of the area, pollution, wind, traffic and the quality of the urban greenery. Then, to derive a complete scenario of the urban context, it is necessary to associate a chorem representation with each of them. This approach allows decision makers both to obtain a global overview of an area of interest, and analyse every single object and phenomenon featuring it.

Figure 4 collects chorems modelled to this aim, namely Pollution, Winds, Traffic, Temperature and Urban Greenery Quality. They are Spatial Diffusion chorems associated with the Urban Area chorem. In particular, Pollution, Winds and Traffic represent elements that can affect the temperature, and their sources are the sensors located in the area of interest, along with sensors for temperature. The iconic representation of Temperature is given also by a numeric annotation, showing that the arrow moves in clockwise (resp., counterclockwise) when the average temperature measured in the area is higher (resp., lower) than the city average temperature.

Finally, the Urban Greenery Quality indicates the quality of the vegetation in the depicted area, which can depend on the seasons and the care of the plants. The high quality of the urban greenery alleviates the impact of the heat island. Its source is a database frequently updated with a quality index ranging from 1

to 10 and estimated with data from satellite images or field inspections. Its iconic representation is made up by two concentric circles containing a tree. The outer circle represents the extension of the green, the inner one the quality, whose size is directly proportional to the quality index.

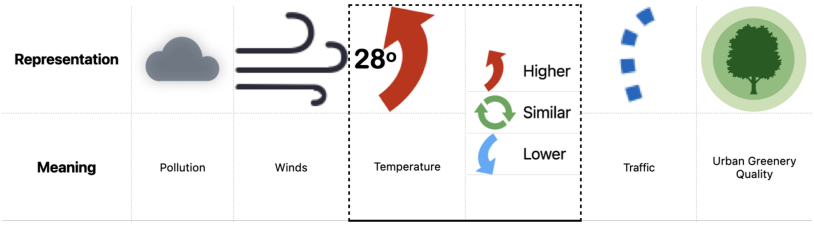

Fig. 4. Chorems affecting the UHI phenomenon (Source: Authors' elaboration)

4.2 Analysing the UHI Phenomenon

A chorematic map is able to emphasize important aspects of a territory, which are useful for a better comprehension of the visualized phenomena. It offers a synthetic global overview that can be further investigated to analyze specific spatio-temporal information built upon large sets of source data, otherwise difficult to manage. In particular, by zooming and filtering tasks in terms of geographic and semantic operators, users may gradually reduce the search space and select a subset of data in agreement with the visual information-seeking paradigm based on the Shneiderman's mantra and Keim's interpretations. Then, users can select and query a chorem element in order to obtain descriptive information related to it.

As the map scale (ranging from 2 km to 500 m), the north indicator, and the map source (Google 2021) are not meaningful to the current purpose, in the following, all figures have been clipped from the map viewer to obtain a better visualization for readers.

Figure 5 (on the left) shows a chorematic map containing seven UHI chorems, different for intensity.

A geographic zoom-in derives the scenario depicted on the right. By applying a semantic zoom-in to the red UHI chorem, it is disaggregated according to the parameters described in Sect. 3, while the given scale still holds, as shown in Fig. 6. In particular, it shows the involved chorems, namely Urban Area, Albedo, Urban Geometry and Urban Greenery, where the area represents the extension of the UHI phenomenon, the color of the Albedo chorem indicates the medium level of the albedo in that area, the level of average urban geometry is high, being represented by an hexagon, and the presence of urban greenery is indicated by two chorems, differently sized to represent their different impact on the heat island. Finally, the average temperature of the area is reported and the red

arrow indicates the increment of the temperature with respect to the average temperature of the city.



Fig. 5. A geographic zoom-in (Source: Authors' elaboration)

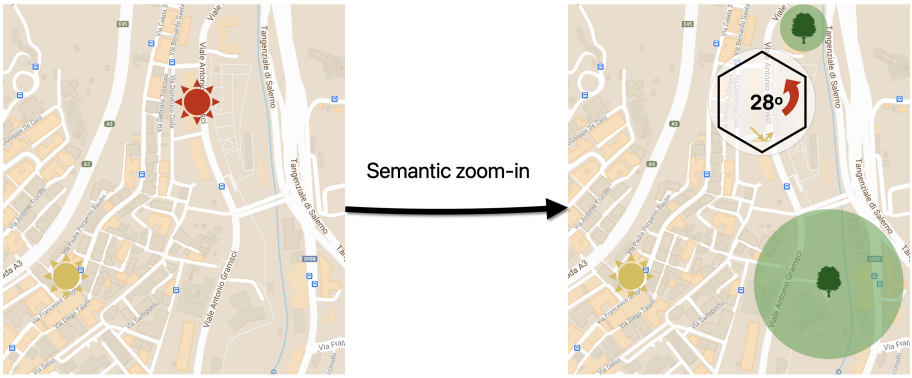

Fig. 6. A semantic zoom-in (Source: Authors' elaboration)

Figure 7 shows a semantic filter applied to derive UHIs whose criticality is higher than "Low".

Figure 8 displays a choromatic map where instances of each type of chorems previously introduced occur for the UHI chorem under investigation. Here, data about lines of traffic, air pollution, temperature, the presence of winds, and the quality of the urban greenery is acquired through the proper sensors distributed on the territory.

Finally, Fig. 9 shows a choromatic map resulting from a semantic zoom-in applied to two UHIs. This map allows users to investigate the phenomenon

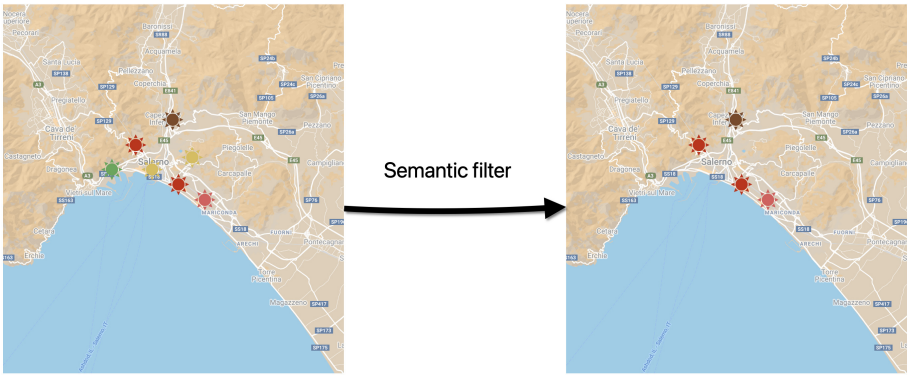

Fig. 7. A semantic filter (Source: Authors' elaboration)

occurring in two different areas by comparing the corresponding factors in the form of chorems.

5 A Chorem-Based Approach to Get Citizens Involved in Decision Making

The goal of this Section is to show how decision-makers and citizens can take advantages of chorematic maps in investigating urban contexts and understanding environmental phenomena impacting on them. Two scenarios are described in which decision-makers are supported in designing plans and communicating them to citizens through a simple visual language based on the expressive power of chorems.

5.1 Identify a Portion of Territory on Which to Rethink the Urban Greenery

Today, political decision-makers design and plan installation and renovation of urban green parks and tree-lined avenues often considering them as street furniture or leisure areas instead of strategic urban elements. Various criteria come into play in these design activities, such as the cost of work, the possible complications for mobility and the possibility of recovering degraded spaces, while others, equally relevant for their impact, are not sufficiently considered, such as the urban heat islands. This discrepancy is mainly due to the reduced availability of simple methods and tools that can be used to study complex phenomena, as well as the lack of knowledge to understand factors influencing them.

A chorem-based approach can represent a solution to bridge te gap. Decision-makers, who aim to explore city areas, can adopt chorematic maps and analyze specific contexts to identify complex phenomena, such as UHIs in the urban area, without any effort. In fact, the criticism of each UHI is represented by its

own color and decision-makers can apply a semantic filter to identify those areas whose criticality overcomes a given threshold. Then, the areas affected by these UHIs can be taken into main consideration with respect to the others for the reorganization of the urban greenery. Moreover, a semantic zoom-in on a selected UHI, allows decision-makers to know the extension of the critical area and the presence of the greenery nearby, whose level of quality can be observed, in turn. Hence, the adopted chorematic map simplifies and highlights the comprehension of the UHI phenomenon and facilitates its use as an additional criterion to identify the portion of territory where intervening.

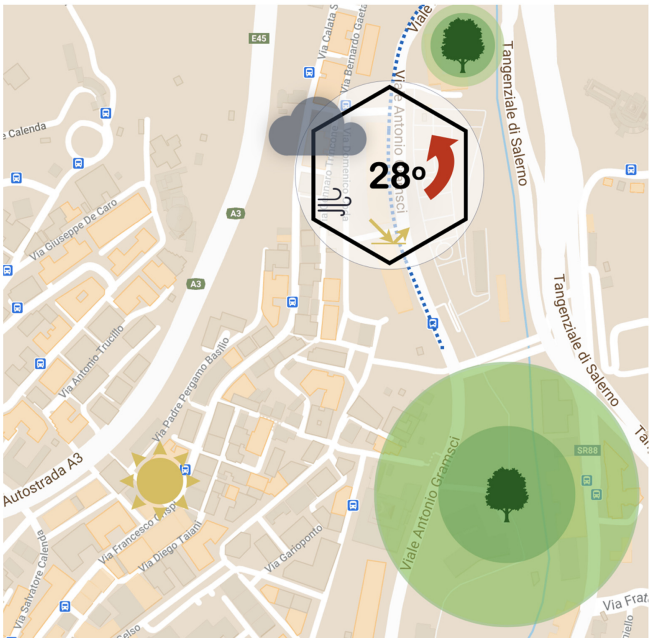

Fig. 8. Chorems in a urban context (Source: Authors' elaboration)

Finally, the adoption of chorematic maps as communication tool can be useful for sharing the planned urban works, and in particular the urban green redesign plans, with citizens. A map, in fact, can support citizens' understanding of the project by showing them how the proposed interventions are useful for addressing the UHI phenomenon that occur in urban areas, thus improving the well-being of the entire community and avoiding the general regret due to the lack of understanding of the reasons why the planned interventions involve one area of the city rather than another.

5.2 Designing Targeted Interventions for the Prevention of Heatwaves to Protect the Health of the Elderly and Children

During the summer, the elderly and children can be severely prone to heat waves, which can cause serious health risks. The municipal administration arranges for the deployment of ambulances and mobile medical points in various areas to quickly bring help. They can also set up points for the administration of water bottles and arrange sun covers in the avenues. Finally, they may want to communicate to the population to stay at home and avoid some particularly affected areas. Making such a plan involves a great waste of time and resources.

Based on choremic maps, the city administration can easily identify the areas of the city most prone to the UHI phenomenon by selecting the most serious ones through a semantic filter. Moreover, areas at risk with sensitive sites can be detected by applying geographic and semantic zooms, such as schools, nursing homes, parks and squares. This approach allows the municipal administration to allocate its resources in the best way.

As for citizens, in order to let them know the resources distribution, it is possible to set up public totems in strategic areas, such as bus and subway stops, where running a choromatic map showing the main UHIs and the corresponding temperature increment. This can help citizens understand the gravity of the phenomenon and plan their routes and activities for the rest of the day avoiding the riskiest areas.

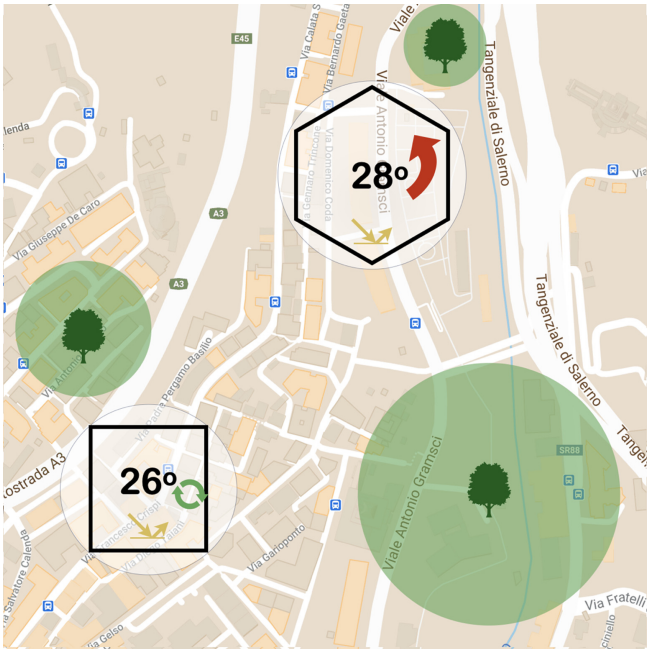

Fig. 9. Comparing UHIs (Source: Authors' elaboration)

6 Conclusions and Future Work

Generally speaking, by performing map overview and querying tasks, it is possible to obtain a global view of a scenario featuring a domain of interest. However, visual and interactive methods may be not adequate when dealing with large amounts of data because of the high risk of getting lost inside the original data collection. In this case, it is reasonable to apply first some analysis computations and then provide an overview of the resulting relevant contents and details on demand.

Chorematic maps for urban contexts follow this paradigm. Namely, they visually summarize relevant objects and phenomena of an area of interest and, when manipulated by geographic and semantic operators, they provide users with information useful to better understand what characterizes a scenario.

In this paper, the focus is on the UHI phenomenon and chorems have been adopted to represent both it and factors determining it. The model used to process those factors and calculate the extension of the critical zone is a "work in progress" from a physics point of view. Nevertheless, every its possible improvement can be revisited in terms of chorems thanks to the level of abstraction of their structure, which expresses each component in a way abstract enough to be independent of specific implementations. This feature also paves the way for the use of chorems to build "what if?" scenarios where the interaction is addressed to simulate the presence/absence of phenomena and the modification of parameters to evaluate possible outcomes.

As for a prototype specifically conceived to manage chorems and chorematic maps, the SAFE (SAfety for Families in Emergency) system described in [15] is under revision to embed a section where different typologies of users can interact, apply operators and pose queries on chorems and chorematic maps. SAFE is a spatial decision support system, developed to provide users with data (the user as a consumer) and acquire information from them (the user as a producer), thus increasing knowledge about a territory. Besides monitoring activities, SAFE was designed to improve certified procedures. Then, it is especially suitable to handle emergency procedures, both planned and extraordinary, and involve citizens in the identification of risks on a territory and in the planning of needs.

References

1. Arreghini, L.: La modélisation graphique dans la réalisation des atlas pour le développement. Les atlas pour le développement en coopération, pp. 1–10 (1995)
2. Batardy, C.: Le berry antique-de la carte au modèle-chorème. Revue archéologique du Centre de la France **43**, 253–258 (2005)
3. Brunet, R.: La carte-modèle et les chorèmes. Mappemonde (1986)
4. De Chiara, D., Del Fatto, V., Laurini, R., Sebillo, M., Vitiello, G.: A chorem-based approach for visually analyzing spatial data. J. Vis. Lang. Comput. **22**(3), 173–193 (2011)

5. Del Fatto, V., et al.: Potentialities of chorems as visual summaries of geographic databases contents. In: Qiu, G., Leung, C., Xue, X., Laurini, R. (eds.) VISUAL 2007. LNCS, vol. 4781, pp. 537–548. Springer, Heidelberg (2007). https://doi.org/10.1007/978-3-540-76414-4_52
6. Del Fatto, V., Laurini, R., Lopez, K., Sebillo, M., Vitiello, G.: A chorem-based approach for visually synthesizing complex phenomena. Inf. Vis. **7**(3–4), 253–264 (2008)
7. de Groot-Reichwein, M.A.M., van Lammeren, R.J.A., Goosen, H., Koekoek, A., Bregt, A.K., Vellinga, P.: Urban heat indicator map for climate adaptation planning. Mitig. Adapt. Strat. Glob. Change **23**(2), 169–185 (2015). https://doi.org/10.1007/s11027-015-9669-5
8. Kalbach, J.: Mapping Experiences. O'Reilly Media, Sebastopol (2020)
9. Keim, D.A., Mansmann, F., Schneidewind, J., Ziegler, H.: Challenges in visual data analysis. In: Tenth International Conference on Information Visualisation (IV 2006), pp. 9–16. IEEE (2006)
10. Morozov, E., Bria, F.: Rethinking the Smart City. Democratizing Urban Technology. Rosa Luxemburg Stiftung. City Series, no. 5 (2018)
11. Obama, B.: Transparency and open government: memorandum for the heads of executive departments and agencies (2009). Accessed 6 Sept 2016
12. Patrick, C.: Modélisation graphique et chorèmes: la gestion des parcours collectifs à massaroca (brésil du nordeste). Mappemonde **62** (2001)
13. Rizwan, A.M., Dennis, L.Y., Liu, C.: A review on the generation, determination and mitigation of urban heat island. J. Environ. Sci. **20**(1), 120–128 (2008)
14. Romano, M., Díaz, P., Aedo, I.: Emergency management and smart cities: civic engagement through gamification. In: Díaz, P., Bellamine Ben Saoud, N., Dugdale, J., Hanachi, C. (eds.) ISCRAM-med 2016. LNBIP, vol. 265, pp. 3–14. Springer, Cham (2016). https://doi.org/10.1007/978-3-319-47093-1_1
15. Sebillo, M., Vitiello, G., Grimaldi, M., De Piano, A.: A citizen-centric approach for the improvement of territorial services management. ISPRS Int. J. Geo-Inf. **9**(4) (2020)
16. Shneiderman, B.: The eyes have it: a task by data type taxonomy for information visualizations. In: Proceedings 1996 IEEE Symposium on Visual Languages, pp. 336–343 (1996). https://doi.org/10.1109/VL.1996.545307
17. Vives, A.: Smart City Barcelona: the Catalan quest to improve future urban living. Int. J. Iberian Stud. **33**(1), 103–104 (2018)
18. Wilson, P.: Smart communities guidebook. Governor of California, CA, USA (1997)