Journal of Visual Languages and Computing 23 (2012) 63–77

Contents lists available at SciVerse ScienceDirect

Journal of Visual Languages and Computing

journal homepage: www.elsevier.com/locate/jvlc

From real to metaphoric maps: Cartography as a visual language for organizing and sharing knowledge ☆

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A R T I C L E I N F O

Available online 26 January 2012

Keywords:
Geographic web
Knowledge representation
Map
Metaphor
Navigation

A B S T R A C T

In this paper we discuss about geographic representations as a basis for describing, organizing, accessing and understanding heterogeneous shared information on the web. Maps are popular on the web, because of the reference to space, the most important domain of human experience, the proliferation of location aware devices and services and the availability of a set of tools that enable an heterogeneous population of users to explore and even modify these representations.

Metaphorical maps, representing concepts and relations of a specific knowledge domain with symbols taken from another well known and widely used domain, couple the benefits of cartographic representation with the power and intuitiveness of the metaphor, permitting the communication and sharing of such knowledge.

We introduce a classification of maps based on antinomies between real and imaginary worlds, and between direct and metaphoric knowledge; we argue that cartography can be used as a visual language for organizing and sharing knowledge related to different semantic domains, supporting our arguments with examples. Finally, we define a set of functions and related data structures able to support a user in browsing cartographic representations using state-of-art tools and systems available on the web.

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1. Introduction

The centrality of the World Wide Web as a host not only of shared communities but also of information systems and applications is a reality, and its relevance as a reference environment for distributed software development is growing. Named "Web 2.0" to distinguish its applications from those based on passive information delivery, it is at all effects "the" web as we use it today. One of the most prominent results of the switching from the old to the new paradigm is the participative role of users as information producers and not only as information consumers, with a continuum between the two roles; such a situation parallels and makes real the historical Ted Nelson's vision of hypertexts [1], centered on the lack of separation between writers and readers, reaching today a goal impossible on a large scale with the technology of 30 years ago.

The Web is only the most recent and evident scenario devoted to sharing heterogeneous information involving users interplaying different roles. Collaborative systems, cooperative design environments, e-government systems, to cite a few examples, share the same issues about the relationships between information producers and consumers, enforcing specific requirements such as security, privacy and reliability at a higher degree.

A fundamental issue users must face when acting as authors is how to organize the knowledge they want to bring to others, and how to describe it to other users, so that knowledge can be shared with them and they can be

☆ This paper has been recommended for acceptance by S. Levialdi.

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doi:10.1016/j.jvlc.2011.11.004

engaged in a cyclic process of knowledge production and enrichment. Among the problems posed, the differences in perception, understanding, interpretation and use of the same information by different users are of paramount importance, mainly in systems open to a wide audience with different backgrounds and skills.

A way to overcome interpretation errors is to rely on a formal language accurately defined. This is the road traced for the development of traditional information processing systems, based on formally defined algorithms and notations. Another way, more suitable to a large audience of non-specialist people – indeed at the basis of human communication for centuries – is to rely on an implicitly defined common ground of understanding, a common sense which could be assumed known and unambiguous for all users without the need of a formal support. For long times such a common ground has been found in the rhetoric figure of a *metaphor* [2–4].

In the domain of language studies a metaphor is, basically, an expression used "as a substitute for some other literal expression which would have expressed the same meaning" [2, p. 278–279]. Metaphors are justified by several needs, the most relevant being the lack of a synthetic literal expression to denote the desired meaning and, more often, a strong emotional connotation that a metaphoric expression holds with respect to the literal expression, resulting in a more vivid or immediate transmission of the meaning.

The concept of metaphor has been productively transposed from the human language domain to the domain of artificial languages used to interact with data and functions in computer based systems, culminating in the graphical user interface (GUI) metaphors developed since the 1980s. The base model comes from the Peirce semiotic [5], linking in a three-fold relation a concept (the *object*), a sign or symbol (the *representamen*) synthetically representing it, and an interpretation (the *intepretant*). A match between the *intepretant* and the *object* denotes a correct understanding of the *representamen*, i.e., the success of the metaphor.

In the domain of interactive systems the choice of a suitable metaphor to represent a given class of problems is a crucial issue [6,7]: the well known example of the desktop metaphor for operating systems GUIs, while universally adopted, shows indeed pros and cons of metaphoric assumptions when the everyday experience with images and gestures are transposed to a different perceptual plane [8]. For example, only in recent versions a major operating system has differentiated the basket icon (symbol of file deletion and removable media ejection) that turns into the standard VCR eject symbol when a removable media is selected. It is still argument of discussion if moving a document icon on an application icon is a correct metaphor, since in real life we use to apply tools to objects, and not the opposite.

Among the metaphors developed to represent information spaces and the interaction with them, map based representations have become popular in recent years: the map is indeed a fundamental type of representation, used since the early years of the human civilization. The information visualization domain has developed models and tools to make information more evident and complete using geographic spaces [11,12]. The proliferation of location aware devices and services has given to context, mainly to spatial context, a primary role in accessing and understanding information. At the same time, cartography has evolved, finding more accurate ways to measure and represent the territory, putting into evidence different aspects of a land and different facts related to a wide fan of human and social activities.

Maps occur not only when the primary information managed is related to a land, but also as a background tissue to make evident the relations between different chunks of information, the places where it occurs or to which it refers, and the locations visited or simply imagined by the user during information access. The reasons for such a popularity are several and diverse.

First, humans grow and live in a common real space. We all experience during our whole life how representing space and reasoning about it is essential to live (and sometimes to survive) [13]. In our daily life we move and act in a real space, defined by dimensions, sizes and directions; we experience the difficulties of climbing a mountain or the fatigue of covering a long distance by foot. Quoting Kuhn, "space is fundamental to perception and cognition because it provides a common ground for our senses as well as for our actions … space is not just any domain of experience, but the most important one, and as such uniquely qualified as a metaphor source" [14].

Second, the territory in which we live is usually described by maps, and using a map is a common experience, which evolved during the history together with the knowledge about Earth, the means used to measure it, and the need to share such knowledge and measures with other people for social activities and relationships. Such experience, even if shared according to a set of common assumptions, is however mediated, because it depends on the culture, technical skill and ability of both the author of the map and the user [15–17].

Third, a growing cause of interest for maps comes from the technology evolution which has made new tools available in desktop and mobile environments; together with the emergence of the geographic web [18] they offer to users new possibilities of interaction and knowledge creation and stimulate the rise of new user capabilities. Web services such as Google Maps [31], Yahoo Maps [32] and Microsoft Bing Maps (once called Live Search) [33] enable people to add personal content to a map making it a container of a large set of sharable information.

In this work we aim at coupling the benefits of the map based representation with the power and the intuitiveness of the metaphor, with the final goal of defining a language for organizing and sharing knowledge.

The remainder of this paper is organized as follows: in Section 2 we introduce a classification of maps according to their ability to represent real, imaginary and metaphoric territories, linking known geographic concepts and relations to concepts and relations of some new, different knowledge domain. Section 3 discusses an example of a metaphoric map interpretation where the elements of the metaphor are accurately chosen and consistently used. Section 4 discusses the web mapping tools and how they are currently used for the representation of the different map types. Sections 5 and 6 discuss how the interactive widgets available in most web mapping applications may be used as elements of a language for cartography based knowledge management, to create complex map-based knowledge networks. Finally, Section 7 draws the conclusions.

2. Between reality, abstraction and metaphor

The road leading to the standards of modern geographic representation is long and has been populated with disagreements and false interpretations. The history of cartography shows how the progress in science and discoveries has produced maps that are not only more complete and accurate in the Earth representation, but also more apt to address specific goals, due to consolidated user agreements on symbols and conventions. The temporal and cultural distance between the map preparation and its interpretation makes evident how understanding a map is more difficult than understanding a territory because maps are abstractions.

Fig. 1 shows on the left side a famous Babylonian world map of 600 BC, incised on a clay tablet residing at the British Museum in London. The map is made of simple geometric elements recalling a simplified view of the represented world; for example, the regions are shown as triangles, the way they would look when approached by water [34]. On the right the archeologists' interpretation is shown. While the drawing is basically the same – it uses the same schematic signs to represent land elements – in the archeologists' interpretation the map is annotated with explicit references to natural elements and locations, thus linking the map to the real territory it represents. Such references, ambiguous in the original representation because of the map abstraction, have been recovered through a rigorous interpretation process confirmed by archeological findings [19].

Another example of map abstraction can be seen in the drawings of a group of Yanomami natives, displayed in Fig. 2. The Yanomami are a large indigenous population living in the Amazonia rainforest, largely untouched by the western civilization until recent times. The drawings, made in the context of a project undertaken by the anthropologist Antonio Pérez in 1979, were presented at the 2009 edition of the *Biennale Art Exhibition* in Venice [20,35]. The anthropologist asked the natives, that had no previous acquaintance with the outside civilization, to create drawings representing their territory (Fig. 2). The drawings are indeed highly abstracted maps, and seem to represent combinations of different geographical entities such as territory partitions, connecting paths and landmarks (Fig. 2a–d). In some cases maps feature signs representing animals and other entities characterizing the land they depict (Fig. 2e and f), thus establishing a direct link with the territory use. The cultural distance from the Yanomami prevents a precise and complete decoding of their meaning by the average western observer.

An interesting example of a highly symbolic representation of a territory is the *chorem*, a highly schematic geographic representation proposed by the French geographer Roger Brunet in 1980. The schematization acts by consistently reducing the geographic details of a map, to leave only a less distracting general view of a land; a few symbols representing the most important geographic entities and the human activities observed, drawn according to a predefined vocabulary of shapes and geometric entities and properly placed in the map create a graphical representation of specific relevant issues about the represented land [9,10].

2.1. A map classification space

The cartography in the current age spans over a wide spread of map types: physical, political, geologic, thematic, etc., each representing a subset of the properties of a territory. Thematic maps are indeed open-ended, since they associate data related to a large number of categories to geographic locations, sometimes adapting the graphical

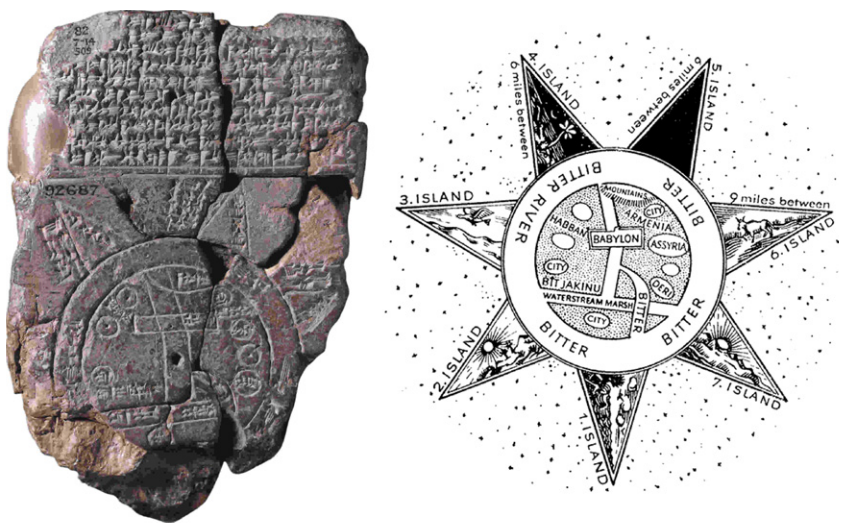

Fig. 1. A Babylonian world map (600 BC) and the archeologist's interpretation.

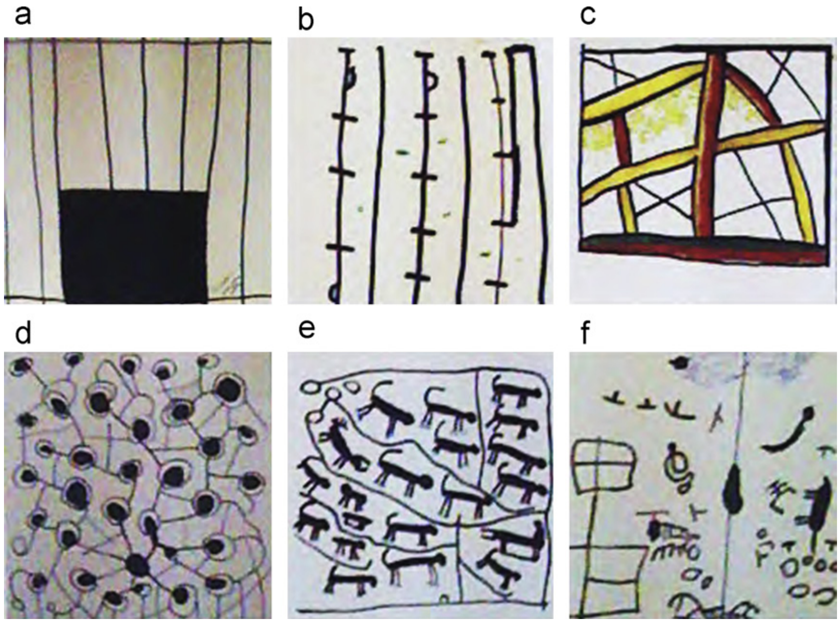

Fig. 2. Maps of the territory drawn by Yanomami natives (photos by the authors).

representation of the territory to better convey the meaning of the data [11]. As the data become suitable of an interpretation beyond the bare numbers – e.g., have a political impact or are used with the manifest goal to make evident social or political phenomena subject to debates and different opinions – thematic maps turn into *allegoric* maps, a good example being the satirical representations of political events very popular during the first half of the past Century; several blog sites have interesting collections of such maps, for example [36,37]. The distance between an allegoric representation of facts related to a real land and the use of fictitious maps to represent allegories in another knowledge domain is short: *metaphoric* maps use cartography to represent both real and fictitious lands which subsume the properties, entities and relationships of some knowledge domain unrelated with the real geography.

The strength of maps to support metaphors relies on the old technique of mentally associating information to be remembered to spatial and geographical entities [21]. In analogy, a corpus of knowledge can be organized as a virtual geographical space, stored in an information system instead of the user mind.

The human collaboration in exploring a knowledge space uses metaphorically the same tools and practices used in the exploring the real world: trips, marked on the map and annotated with narrations and references to landmarks, propose an ordered access to different "territories" of the knowledge according to the "destination" desired, i.e., the cognitive goal expected.

A symbolic, thematic annotation of a real land, and a metaphorical representation of knowledge mapped through the symbols of geography are thus two representations laying at two opposite end-points of the interval marking different degrees of adherence to a reality of a representation: direct vs. metaphoric.

Another classification concerns the truth of the geographic representation itself. Geolocated web applications map obviously the real world.[1] Imaginary worlds, since the mythological inventions of the ancient past, through literary fiction until recent social experiments like *Second Life*, can as well be represented with the same geographical properties of a real world as long as their components belong to the realm of the human experience.

Combining the direct vs. imaginary classification of a territory with the real vs. metaphoric interpretation of geographic entities leads to a scenario divided in four quadrants hosting a variety of map types, each defining a different type of knowledge and the way it is represented (Fig. 3). The label *direct* on the horizontal axis marks the cases where the map components denote the properties of real objects having a specific location on the territory. The label *metaphoric* denotes the case where the map components are mapped to objects and concepts that are not located on a land, but may benefit from a representation based on similarity with land features. The vertical axis is related to the type of reference world making the map basis; *real* and *imaginary* worlds can be used as territories on which the map is drawn. In each quadrant a sample map of the knowledge subsumed is displayed.

The *road map* in the lower left quadrant is the classical example of direct representation of a real territory, whose goal is to assist travelers by showing them a symbolic scaled representation of what they are seeing (or will see) when moving in the real environment.

In the upper left quadrant the map of *Second Life* [39], the artificial world where people may meet in a virtual

[1] Albeit in some cases physically inaccessible, like the Mars surface mapped by Google Mars [38].

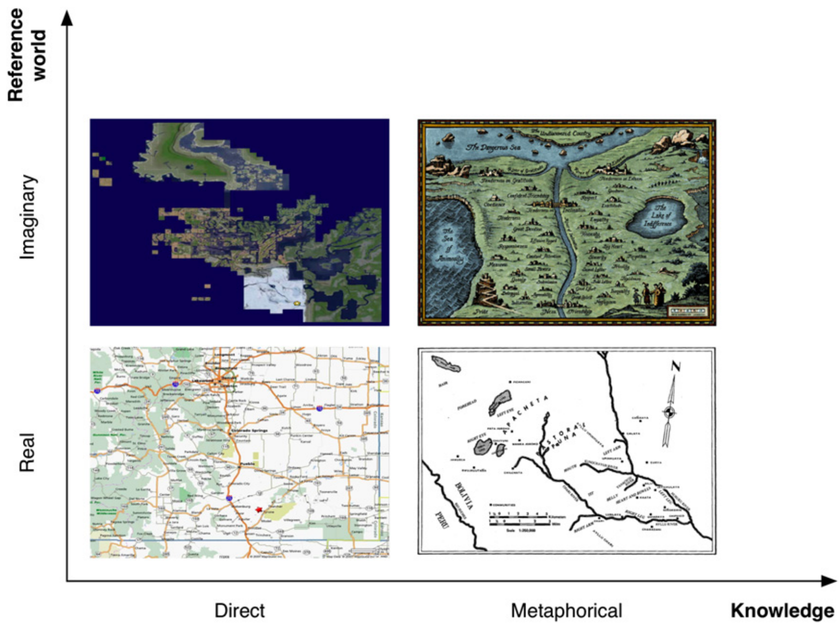

Fig. 3. The map classification space.

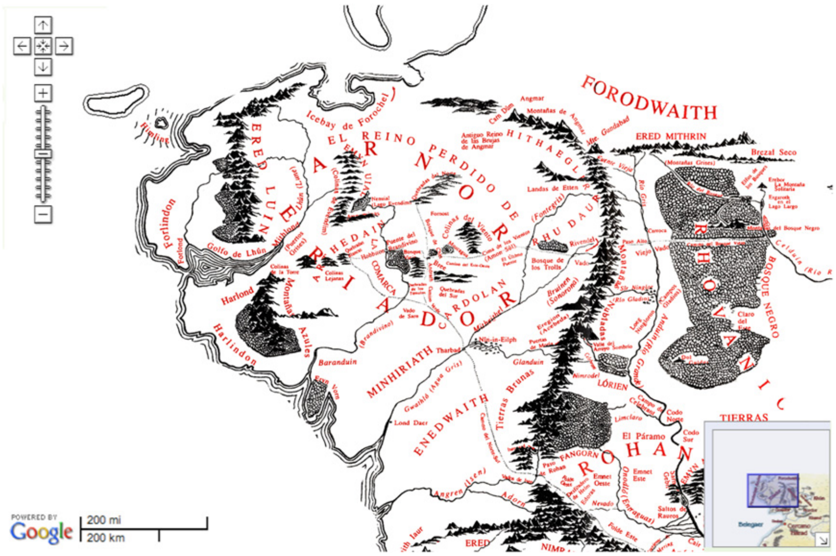

Fig. 4. The Middle Earth on Google Maps (from [40]).

land using a virtual counterpart, is a good representative of a direct representation of an imaginary world. Most of the map contents describe geographic elements which, even if belonging to a virtual land, have the same properties of concrete elements of a real land, e.g., a building, a street, or a square. Another example of an imaginary land depicted with great accuracy in Google Maps is the *Middle Earth* map, shown in Fig. 4 [40], related to Tolkien's *The Lord of the Rings* novel. The blog "*Nick's Café Canadien*" has an interesting section on imaginary lands and maps [41].

The lower right quadrant of Fig. 3 contains a map, shown in detail in Fig. 5, of a part of Mount Kaata, in Bolivia, inhabited by the Qottahuaga Andeans. These Andeans communities are united by a common interpretation of Mount Kaata in terms of the human body, using a metaphor linking the elements of the territory to anatomical parts: the lakes for eyes, the river branches for arms and legs, etc. The metaphor is completed by legends and rituals occurring in selected locations and shrines in the mountain's "body" [22,23].

Another example of a metaphor over a real geography is the *medieval garden*, the so-called *hortus conclusus* ("close-lock" garden). It is anchored to the real world, but the elements pictured have a metaphorical meaning: the tree placed in the garden center represents the tree of life; a well or a fountain stand for the source of

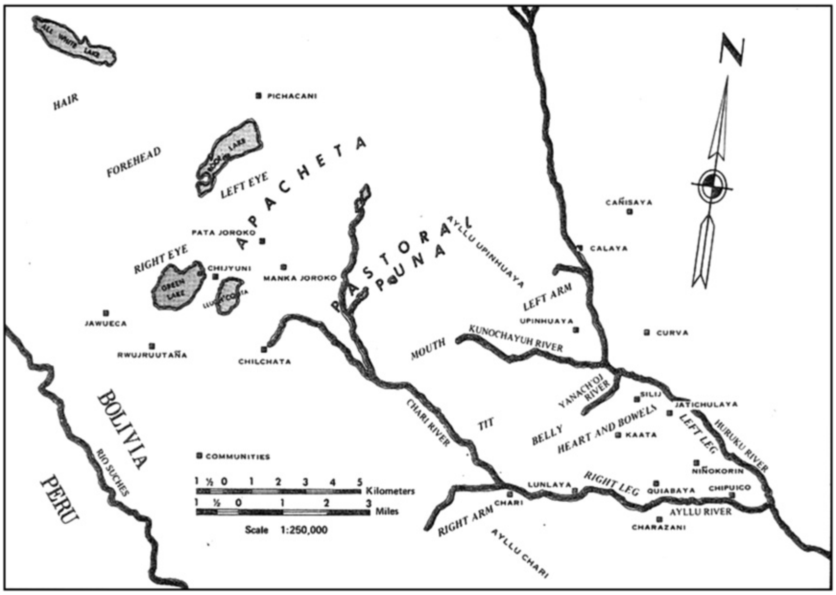

Fig. 5. The anatomy of Mount Kaata in Andeans communities's interpretation (from [22]).

Fig. 6. The map of tenderness.

knowledge; the four paths that divide the garden enclosure in four quadrants represent the four angles of the universe. The garden is therefore a metaphor of the universe and of the spiritual life, represented through concrete land objects [24].

The *Map of Tenderness* (*Carte du Pays de Tendre* in the original French version) placed in the upper right quadrant of Fig. 3 and shown in detail in Fig. 6 is one of the best known and commented metaphorical maps representing with a geographic allegory a different knowledge domain [25,42]. It appears in the novel *Clélie, Histoire Romaine* written by Madeleine de Scudéry in middle XVII century, and represents the "stations of love" along a path of increasing degrees of affection. The path starts at the bottom of the map in the "*New friendship*" town and leads to tenderness through a smooth river and straight paths crossing small villages, each representing a good feeling. The path is also populated by dangerous feelings to be avoided, such as the forbidden "*Rock of Pride*", leading to adverse moods like *indifference* and *enmity*, represented by a lake and a sea at the two sides of the map. The metaphor is very accurate, coherent and impressive on the emotional side; we shall discuss it in some detail in the next section.

The Map of Tenderness has suggested a few variations on different domains, the most notable being the Map of Research Tenderness by Jean-Luc Michael [26,43]. In an essay on research methodology, he proposes a map similar to the one of M.me De Scudéry, but dealing with concepts of scientific research: "The ideal would be to have a Map of Tender of Research, inspired by that of Madeleine de Scudéry, containing the Sea of Speculation, the Lake of the Empirism, the Villages of Cartesianism and Phenomenology as well as route indicators leading a researcher to discovery, bypassing any obstacles or using them to advance in his quest" [43, translation from French by the authors].

Another good example of a metaphorical journey in an imaginary land is in the novel *The Pilgrim's Progress* a Christian allegory written in the 17th Century by John Bunyan; the protagonist of the novel moves from his hometown, the "*City of Destruction*" to the "*Celestial City*" on the mount Zion, traversing several places with allegoric names. Maps of the journey drawn with different shapes appeared in several printed editions of the novel; the Wikipedia entry for the novel has a quite complete section on the geographic allegory [44].

2.2. *Tuning map information details*

The map space displayed in Fig. 3 is focused on reference world and knowledge classification. We can introduce a further dimension representing the map detail level, taking into account different subsets of the spatial relations that characterize the reference world, e.g., topological, directional and metric relations. In many cases the adoption of a limited but meaningful subset can help the understanding of the relevant map information. Well known examples of this situation are the maps of the underground urban transport systems (the so-called *metro-maps*), which are a highly schematic representation of the transport lines, the stations and the exchanges, but do not follow the exact geographic placement. They were initially drawn superimposing the path of the railways to an accurate geographic representation of the metropolitan areas. In 1931 Harry Beck [27], an employee of the London underground transport company, realized that the accurate rendering of the physical locations of the railway stations was irrelevant to the traveler, and the crowded areas of the map did not allow sufficient detail or would have requested the use of very large canvas. He proposed a diagrammatic representation of the underground, where the geographical representation of the metropolitan area was erased and replaced by a simplified picture of the transport network consisting only of stations, straight line segments preserving the network topology and a distilled subset of simplified geographical elements (e.g., the Thames river), helpful to perceive the approximate location of the stations in the city. Such simplified representation was so successful that gradually became a standard basis for the underground transport maps for every city of the world.

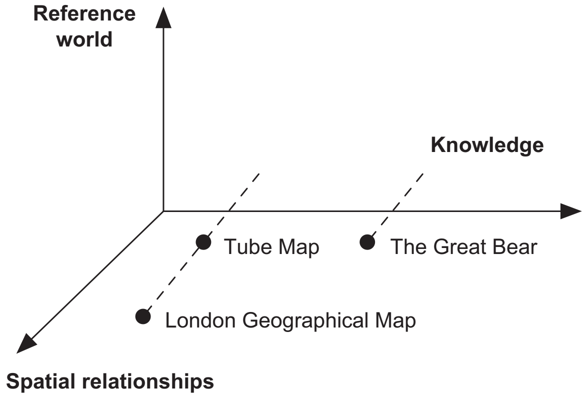

Fig. 7. The extended map classification space.

The style initiated by Harry Beck has also been used metaphorically to represent history, trends and relations of facts and themes of different domains. In particular, the topology of the first 1933 edition of the London tube map was used by the artist Simon Patterson in a work named *The Great Bear*. In this work the artist superimposed to the Tube topology the information related to categories of famous people, such as scientists, saints, philosophers, comedians and explorers [28]. In 2006 the Guardian published a re-labeled version of the same map for showing the relations between musicians and musical genres in the 20th Century [45].

The use of different subsets of the spatial relations that characterize the reference worlds might be explicitly represented by an additional dimension, as suggested by Fig. 7. The third axis represents the use of the different types of spatial relations. In the figure a complete map of London, the original Tube map by Harry Back and the *Great Bear* map by Simon Patterson are located according to their properties: a direct world representation for the London map and the Tube map vs. a metaphorical world representation for the *Great Bear* map; on the other axis, a topological representation for the Tube map and the *Great Bear* map vs. a geographical representation of the London map.

3. Metaphor structure, definition and interpretation

Metaphoric maps contribute to knowledge organization and sharing by matching the human ability to perceive space and environment with the relations linking entities and concepts in the represented domain. Knowing the composing elements of the map (the base vocabulary of the metaphor) and their layout we are able to interpret the knowledge subsumed by the geographical metaphor. It is worth to note that the correspondence between a representation and the represented knowledge is not unique, and can be satisfied at different degrees of details and consistency; consequently, the interpretation of the metaphor can be more or less easy and safe, as art and literature (mainly the classical poetry) put into evidence. To cite a simple case, Dante's *Comedy* is full of metaphors and allegories that have engaged critics for centuries, in many cases without coming to a common interpretation.

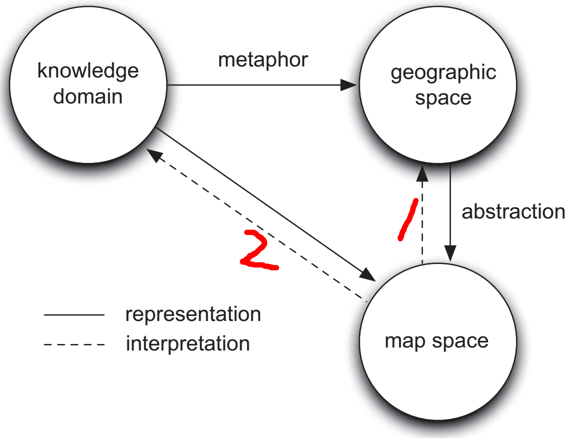

Fig. 8. Metaphoric map construction (solid lines) and interpretation (dashed lines).

The basic entities of a knowledge domain are *entities* (or *concepts*) connected by *relations*. Concepts can be organized in classes representing their common aspects. In drawing a metaphorical map the author of the metaphor establishes a relationship from the concepts of a different knowledge domain (the *object* according to Peirce) with the entities of a geographical space (the *representamen*), identifying features on the geographical side (the metaphor *syntax*) as explanations of features on the other knowledge side (the metaphor *semantics*, i.e. the Peirce's *interpretant*), preserving the relations between them. A reader of the map interprets it by first trying to associate the map elements to geographical entities and then to derive the author's view on the original knowledge domain.

We discuss as an example the relationships between the metaphorical meaning of the *Map of Tenderness* and its geographical representation.

In the description of the knowledge domain of love and affection contained in the novel *Clélie, Histoire Romaine*, examples of concept classes (in italics) and instances (in parentheses) are:

- *origin of tenderness* (new friendship);
- *cause of tenderness* (disposition, esteem, gratitude);
- *success of tenderness* (tender by disposition, by respect, by gratitude);
- *failure* (enmity, danger, indifference);
- *good feeling* (kindness, submission, attentiveness, …);
- *bad feeling* (negligence, inequality, oblivion, …);
- *obstacle* (pride, …).

These concepts are related by connections in causal chains: some examples are:

- *cause of tenderness* flows from *origin of tenderness* to *tenderness*;
- *cause of tenderness* leads to *tenderness* through *good feeling*;
- *cause of tenderness* leads to *failure* through *bad feeling*;
- *good feeling* connects *origin of tenderness* to *tenderness*;
- *bad feeling* connects *origin of tenderness* to *failure*.

The author of the novel associates the above concepts with a geographic metaphor with the aim to describe the many ways to reach love from friendship, as in a journey, but also the obstacles on the path that can lead to different destination.

The entities of the metaphor are the geographic elements relevant to describe a journey: *cities* (starting and ending points of a journey), *communication lines* (rivers to navigate or roads to walk), *villages* traversed during the journey, *obstacles* like dangerous rocks, and natural elements causing an interruption of the journey when the right path is lost, like *lakes* and *sea*.

The relations between the metaphor and its geographic representation are described by the author in her novel: the *tenderness causes* flow across increasing feelings, leading from a new friendship to three types of tender, three different affection states. *Tenderness causes* have a behavior similar to a flow of water, a river, while the different affection states are represented by solid, large cities where the evolution of feeling may stop for a while or even forever. Some feelings are smaller cities, which are not meant as destinations but as intermediate steps leading to tenderness. Indeed, the disposition river flows smoothly and directly, because natural disposition naturally moves towards tenderness. Gratitude and esteem, on the contrary, are grown by intermediate feelings that increase the tenderness, but also reveal risks to deviate from the right path with bad feelings, leading to indifference and enmity. Tenderness is the spiritual destination of good feelings, but since the human nature is not only spiritual, it must be controlled, otherwise an excess can lead, through the dangerous sea of senses, to the unknown lands of the passion.

The interpretation of a metaphoric map requires an inverse reasoning: a reader looks at the map and interprets the symbol, first relating them to known meanings in the geographic space and analyzing their properties. By interpretation, the observer infers that in the representation of the metaphor the author conceived a river named *Disposition*, leading to the town of *Tender by Disposition*, and two main roads crossing villages labeled with names of feelings, leading to the towns of *Tender by Esteem* and *Tender by Gratitude*. A natural interpretation of the difference between navigating a river and moving on a road is that the river naturally flows toward the estuary (hence the destination is easily reached, as by disposition) while a road must be traveled being careful at the crossroads and deviations. Deviations from the main paths, indeed, go through villages labeled with names of bad feelings, leading to unwanted destinations, such as the waters of *Indifference* and *Enmity*.

The diagram in Fig. 8 illustrates, in general terms, the relations between the knowledge domain, the geographic domain and the cartographic representation (map space). The solid lines represent the process of metaphor definition, the dashed lines the metaphor interpretation.

4. Building and browsing metaphorical interactive maps

Maps evolve from mute displays of a geographic reality to digital interactive and pro-active tools not only because they depict a changing reality whose content develops in time, but mainly because they are the workbench on which the information needs of a set of users meet and mutually evolve, as the social interactions between the users evolve. Often, depending on the tools used, the physical appearance can be determined on the fly at use time.

Users themselves become (co-)authors of the map, directly contributing to its evolution through shared applications. Google Map Maker [46], a web application available in over 180 countries, allows users to improve the vectorial geographic information available in Google Maps, signaling modifications to existing roads, evidencing new pathways or bikeways or drawing spatial limits of buildings and areas such as a park or a university campus.

While the user suggestions specified through Google Map Maker are subject to review before being introduced in the cartography available to all users, a totally user-driven approach is introduced by Waze [47]. In Waze people may be involved at different levels in the live creation and editing of the cartographic elements and in the specification of the road live conditions, such as traffic. Many editing operations can be exploited on the field through GPS-aware applications on several mobile platforms, enabling users to draw new roads simply by driving through them, or to highlight the features and the problems of the currently visited location. As a result, maps become a medium to update and enrich knowledge.

If we focus our attention on the interactive tools allowing users to transform static maps into proactive representations, we note that most of them manage different classes of objects focusing on specific map types in the classification of Fig. 3. For example, a G.I.S. is usually focused on the (*direct*, *real*) case, and permits to place different classes of vector objects in places denoted by the geographical coordinates of a real territory. At the other end, authors of maps belonging to the (*metaphorical*, *imaginary*) case might use generic illustration tools to draw a land and place virtual objects on it.

A relevant exception to this dichotomy is represented by the Google Maps environment, which can be used to build interactive maps belonging to any map type. Most of the maps built with Google Maps belong to the (*direct*, *real*) case because they represent real objects on a georeferenced map. There are notable exceptions, already introduced in previous sections: for example, the site Slurl.com uses Google Maps to present a preview of interesting locations available in the Second Life world, belonging to the (*direct*, *imaginary*) case, which has its own tools for mapping and visualizing the world's geography when a user enters.

Google Maps can be used also for managing maps containing objects that have been built with a metaphorical aim and therefore belong to the (*metaphorical*, *real*) case. For example, the *maze* has been often used in the Christian tradition as a metaphorical representation of the pilgrimage to Jerusalem. Most mazes are represented in the pavement of famous cathedrals, such as Chartres, but there also gardens representing mazes, such as the one in the Norwich Cathedral in UK. A collection of outdoor mazes from different parts of the worlds is available on Google Maps as a collection of placemarks [48].

These examples show that Google Maps, originally conceived as a tool for displaying real geographical objects without any metaphorical aim, can be profitably used also for creating and managing metaphorical maps. The adoption of similar components by other Web map applications such as Yahoo Maps! and Microsoft Bing Maps is a confirmation of their suitability by ordinary users, who are not trained in geographical information systems. While these tools do not represent an end point for research, they are anyway an interesting starting point for the building of an expressive visual language, suitable for the representation of the different map types discussed above, able to express structural properties, capable of representing all the different types of interactive maps, and of a unified map space that might be browsed with a single tool, shifting among the different levels (imaginary and real, direct and metaphorical), according to the user needs.

5. Towards a language for cartography based knowledge organization

Fig. 9 shows the mapping between the entities of the knowledge domain and the entities of the geographic domain as discussed in Section 3. We may distinguish different

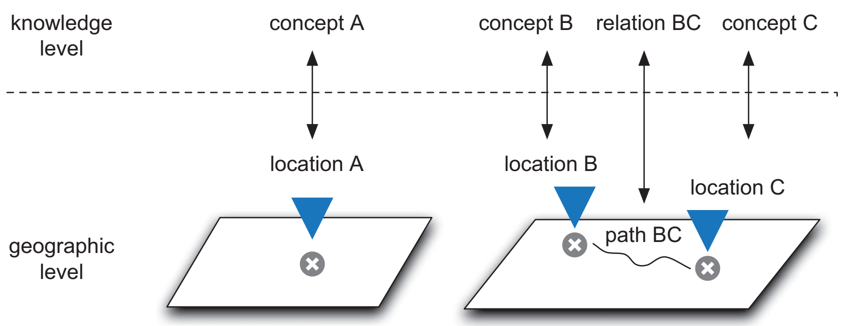

Fig. 9. Mapping between the geographic and the knowledge domains.

expressivity levels, according to the type and the aggregation of the geographic symbols. The mapping displayed on the left, which uses only geographical locations, can express concepts corresponding to a complete verbal sentence. The mapping displayed on the right enhances the expressivity introducing also paths connecting different locations. Such addition permits the author of the metaphoric map to build more sophisticated verbal sentences using the cartographic elements.

Fig. 10 displays two examples related to the different expressivity levels described above. The illustrations and the texts are a re-elaboration from the *Pilgrim's Progress* novel by John Bunyan, mentioned in Section 2 as an example of a metaphor built on an imaginary land. The example on the left describes a metaphor based on a single location. At the knowledge level, the geographic symbol may be translated as a single verbal sentence: *the world is condemned to the destruction*. The example on the right describes a metaphor based on two locations and on the path connecting them. A wicket gate and a beautiful palace are connected by a steep road. They represent respectively the uneasy start of the pilgrim's interior travel, the support of the Christian community and the difficulty of maintaining the direction toward the salvation. At the knowledge level the three geographic entities can be translated into three connected verbal sentences, described in Fig. 10.

As discussed in the previous section, a representation of all the types of maps considered in this work with a single mapping tool is possible; the examples displayed, anyway, are results of individual experiments. Besides, often information is represented as a part of a single raster level that does not permit the automatic identification and manipulation of the symbols and of the labels represented. We make a step further, using the interactive widgets available in most web mapping applications for representing in a standard and automatically processable fashion the geographic symbols, the concepts, the relations and the mapping between the different entities.

In particular, we rely on two popular widgets, as displayed in Fig. 11(a); the *placemark*, that identifies a place characterized by a specific geographic location, and the *balloon*, that permits to associate to a place identified by a placemark a chunk of information. We define a structure for the content of the balloon, which allows us to annotate the properties related to the geographic and knowledge domain, including their mapping.

During the authoring phase, the use of the placemark and of the associated data structure for the balloon content allows the map's author to define geographic symbols and to associate them to the knowledge domain through a well-defined set of textual labels. During the browsing phase, the users will be enabled to browse the geographical entities and to access the knowledge level available in the balloons, using standard interaction modalities.

From a cognitive point of view, the authors can build sentences characterized by the first expressivity level (i.e., Fig. 9, left part). The additional expressivity level described in the right part of Fig. 9 cannot be reached directly, because the path widget available in most mapping applications cannot be associated directly to a structured description. However, for reaching such goal it is possible to rely on the functionalities available with a suitable data structure.

A structured definition of the information contained in a balloon permits to obtain also a complementary goal, i.e., the automatic creation – through a back-end software architecture – of a network of relations between different maps belonging to all the cases described in Section 2. The ways to build such a network will be described in Section 6.

The data structure referred to the placemark and stored in the associated balloon is organized into three main sections describing geographic, temporal and metaphoric data.

Table 1 details the fields of the data structure associated to the placemarks. Data are split into three different categories, related to their geographic, temporal or metaphoric nature.

Geographic data include the *location coordinates* for identifies the location, the *location name* for specifying the

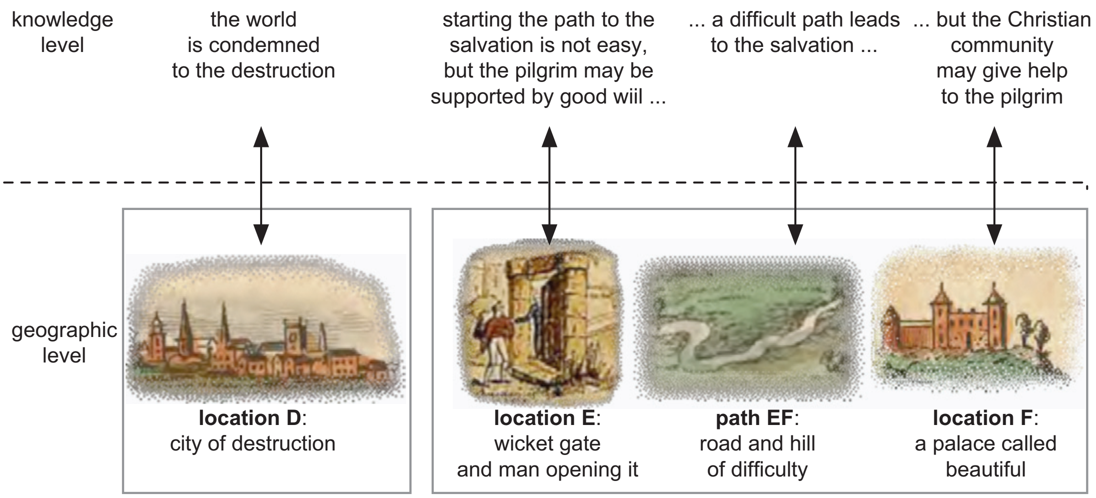

Fig. 10. Two examples of mapping between the geographic and the knowledge domains.

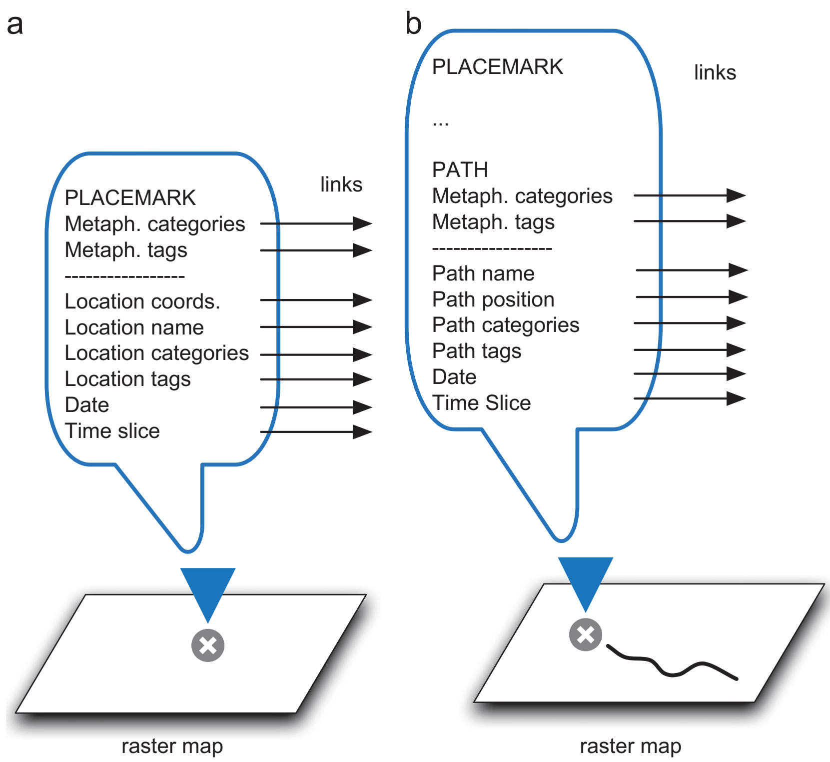

Fig. 11. Structured geographic and metaphoric description of cartography elements.

Table 1
Summary of the metadata associated to the map placemarks.

Category	*Type*	*Content*
G1 geographic data	Location coordinates	Longitude and latitude of the location
G2 geographic data	Location name	Name of the location
G3 geographic data	Location category	Category of the location according to a controlled vocabulary
G4 geographic data	Location tags	Qualitative features of the location through a list of free tags
T1 temporal data	Date	Date of execution of the map
T2 temporal data	Time slice	Interval of validity of the data drawn on the map
M1 metaphoric data	Metaphor categories	Keywords defining the metaphor according to a controlled vocabulary
M2 metaphoric data	Metaphor tags	Definition of the metaphor through a list of free tags

identity of the place (e.g., Unity Square) and complementary top–down and bottom–up annotations (i.e., the *location category* and the *location tags*). Top–down annotations are chosen from a set of predefined keywords identifying the type of location (e.g., building, square, etc.); the use of a controlled vocabulary helps to match them consistently with data describing other placemarks. Bottom–up annotations are free tags arranged in a list, as usual for the user-generated Web 2.0 information. Free tags greatly enhance the expressivity of the notation and are complementary to the top–down closed annotation style. Anyway, expressivity based on an open vocabulary may prevent content matching with other information because of the homonymy, synonymy and polysemy problems that are typical of free tag annotations (unless fuzzy similarity match and web resources such as WordNet are used [49]).

Temporal data include both the specification of the *date* of creation of the map and of the *time slice* for which the entities represented are valid.

Metaphoric data include a set of keywords (*metaphor categories*) and tags (*metaphor tags*) that are mapped to the geographical information associated to the placemark. As for the geographic data, metadata include both top–down and bottom–up annotation styles, for coupling the precision of the description with the enhanced expressivity provided by the use of tags.

Through the introduction of a set of associated metadata we modify the simple Chartesian nature of the placemark, that expresses the localization through a tuple of geographic coordinates, coming to an empowered notion of place that puts in evidence its qualitative properties and may be associated to the presence of significant artifacts.

In such case the placemark becomes a *landmark*, an easily recognizable entity of the territory. Landmarks in metaphorical maps are the key entities for the building of the metaphor itself, connecting the conceptual world to the geographical one.

An important part of a map is the set of paths connecting different locations. Unfortunately, in most of the available web mapping tools paths are available only as part of the raster background or as vector entities with no processable bounding to interactive structures such as the balloons. Such limitation, which has no conceptual reasons but is simply an implementation feature, prevents the association of annotations, references and in general hypertextual data that characterize the path and that might be used for connecting it to entities in other maps.

A solution is the association, illustrated in Fig. 11(b), of path data to placemarks representing significant locations of the path itself, e.g., the starting and end locations, and other key locations along the path. The data structure is enriched with an additional section collecting data related to the path, still organized in three subsections for geographic, temporal and metaphoric information.

6. From map classification to map networks

The definition of the data structure anchored to the placemark represents also the basis for the definition of a network of maps belonging to different types, allowing the user to switch between reality, imagination and metaphor in exploring a knowledge domain. The network relations may be automatically computed on the basis of the matching of the values stored in the different fields of the data structures associated to relevant placemarks. In this context the metadata values associated to the placemarks may be considered as input keywords for a software searching component capable of retrieving all the occurrences of the same keywords and of generating a set of hypertextual links for connecting these keywords to the relevant placemarks belonging to the network of maps. Of course, the search component may be specialized for taking into proper account the specific nature of the category and type of metadata. For example, given that different map authors may specify a given location with different levels of accuracy, the matching of the location coordinates may tolerate a definable level of error. Again, the matching of the values of the location or of the metaphor tags may take into account, for augmenting the number of the results, the optional use of a fuzzy similarity matching or the use of the already mentioned Wordnet lexical database of English.

Depending on the specific type of map, not all the data fields may be meaningful, hence filled with content. For example, a (*direct*, *real*) map probably will not contain metaphoric information, even if it can have relations with information residing in a metaphoric map. A map of an on-line game often lacks a specific temporal localization, e.g. because placed in an imaginary timeless space.

As stated in [29], the finding of web information is usually based on two different but related activities: search and navigation. Currently the finding of entities belonging to web maps is based mainly on the search of locations and on the following navigation of the neighbors through zooming and panning operations. Besides, often the hypertextual content of the balloons points to web resources different from the map, such as web pages containing detailed information about a specific location. What we aim to obtain through the introduction of an automatically computed network of relations is an enhancement of the hypertextual navigation between different maps, driven by associative mechanisms. Such mechanisms are typical of the serendipitous exploration of information, where a specific target is not fixed from the start and may be influenced also by the information found in the previous navigation steps. The final goal is to enhance the overall findability of map-related information.

An example of logical connections between maps of different types is illustrated in Fig. 12, where four map types are sketched with the information associated to a few relevant placemarks. The map of the Cathedral of Chartres is representative of the (*metaphorical*,*real*) type, because it contains a labyrinth representing metaphorically the pilgrimage towards Jerusalem. The label *labyrinth* is associated to placemarks in other two maps: the imaginary map of the labyrinth of the King of Goblins, from the movie *The Labyrinth* (1986), representing metaphorically the path towards adulthood, and the imaginary map of a maze designed by the game software house Nintendo.

The map of the Chartres cathedral is related to the map of Jerusalem, a (*direct*,*real*) map, twice: once through the chronological localization and once through the label *Jerusalem*.

In some cases a match may occur between labels belonging to different sections of data, e.g., metaphoric and geographic. In the example, Jerusalem represents the metaphorical counterpart of the center of the labyrinth of the Chartres cathedral, but it represents also one of the geographic dimensions of an historical map of the city.

Fig. 13 illustrates the structure of a web interface for exploring a network of maps resulting from the automatically computation of the relations between the geographical entities. The interface preserves the simplicity of the web map tools, permitting to the user that interacts with the map (panel 2 in Fig. 13) the ordinary panning, zooming and selection operations. The selection of a specific placemark evidences the associated balloon with data. Labels are triggers to start a query for retrieving all the placemarks, available in the map network, that share the same content.

The results are listed in panel 4 and may be selected by the user for replacing the current content of the map panel. A *Best match* button on the top of the balloon triggers a query that uses as parameters all the labels available in the balloon. The result appears in panel 4, ordered according the matching score. The user may use a pull-down menu, from panel 3, for changing the order of visualization of the results, privileging for example the metaphoric matches instead of the geographic ones. Panel 5 is used for visualizing the steps of the cognitive path of the user navigating through the different maps of the network, enabling him/her to return back to previous steps.

Finally, panel 1 integrates the search function into the interface. The panel permits the user to search – as an

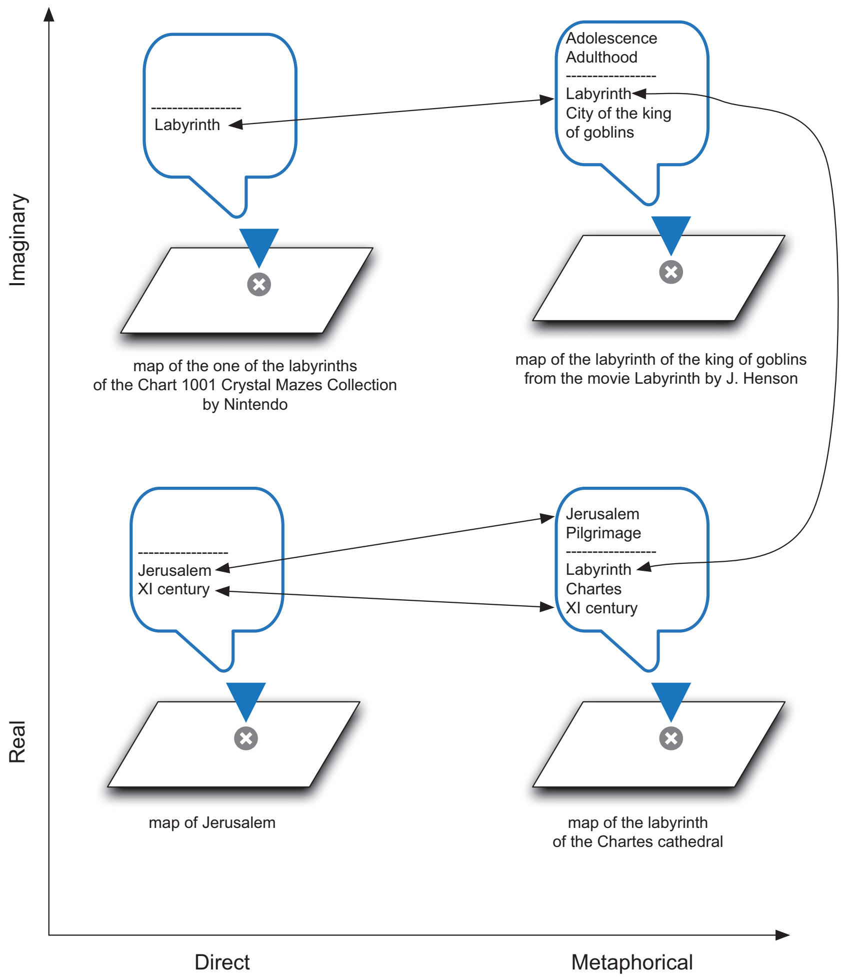

Fig. 12. Connecting maps in networks.

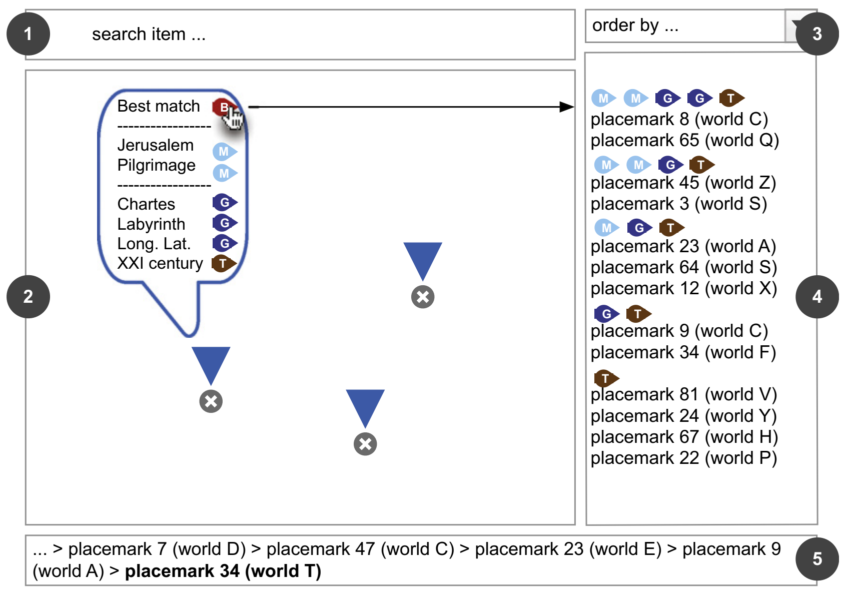

Fig. 13. A browsing interface for a network of map-related information.

alternative to navigation – any metadata specified in the placemark balloons. The results are visualized in panel 4, ordered according the number of occurrences of the same keyword in the different maps. The pull-down menu available in panel 3 may be used for changing the order of visualization of the results, privileging the different metadata categories according to the user choices.

7. Conclusion

Maps are representations of the real geographic space and – through metaphoric mappings – of other domains of human knowledge. They are useful tools to travel in the real world as well as to metaphorically navigate other domains: the travel from *New Friendship* to *Tenderness* in the map of Fig. 6 is a clear example. The rise of new technologies, such as Google Maps and other geographic mapping systems, opens the way to the creation of interactive maps which become new media for knowledge representation, sharing, navigation and incremental creation. In this paper we defined the basic components of a visual language for knowledge management with geographic metaphors, based on the most basic widgets available in web mapping applications: the placemark and the balloon. The key component of the language is a data structure associated to the balloon, collecting metadata about the placemarks, thus permitting to annotate the properties related to the geographic and the knowledge domain, including their mapping. Such definition enables the map author to define geometric symbols and to relate them to the knowledge domain through a set of standardized labels. During the browsing phase the users are enabled to access the geographical entities and the related knowledge level.

The definition of the data structure and its use during the creation of maps belonging to the different types categorized in this work (e.g., real and imaginary, direct and metaphoric) can be also the basis for the automatic creation of a map-based knowledge network. The associated definition of a software back-end for automatically generating and updating such network of relations would permit a full exploitation of the potential of the map-based representation, opening the exploration currently limited to the single maps and to the prevailing use of the search mechanism to the serendipitous navigation of a network of related maps.

Acknowledgments

This paper is dedicated to the memory of Piero Mussio, with whom we started the investigation of metaphorical maps as a shared knowledge organization model. The first three sections are a revised and extended version of a part of a paper co-authored by him, presented at the DMS 2008 Conference [30].

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