TOWARDS INDIVIDUALIZATION OF MAPMAKING AND MOBILITY OF MAP USE

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Forewords

While the widespread Internet access has been continuously narrowing the distinction between office life and home life, the flourishing wireless telecommunication is creating a growing mobile population in the open air. The mobility requires the shrinking size of computing and display devices, which in turn brings about new constraints on wireless retrieval, transmission, visualization and analysis of spatial data. Two years ago, our colleagues were vehemently talking about the seamless and scalable digital earth, today, the labels leading the hit-list have become "location-based services" and "digital earth moving". Without having time to take a breath, we find ourselves already in the middle of a new era of individualization of mapmaking and mobility of map use. Not surprisingly, the spectacular technical progresses have left behind many unsolved cartographic problems and a number of new research topics.

Internet as a "melting pot" of personal geo-services.

With the development of e-commerce, Internet has been evolved into a global market place where a great variety of wares "flow" among suppliers, brokers and buyers. Unlike the hard commodities that have to be mailed by suppliers or picked up by orderers, spatial data have their intrinsic flexibility to be directly downloaded upon ordering. Since years, geo-data suppliers have been concentrating themselves on the tasks of constructing portal sites to attract buyers, filling "holes" and removing redundancy in their data warehouses, updating and versioning the data items, developing compression methods as well as data structures for efficient transmission and so on.

However, the availability of a digital earth on the Internet is not our final goal, rather the starting point of personal geo-services with Internet as their "melting pot". In order to perform location-based tasks, for instance, netizens have to know what kind of spatial data they should look for, where and how they can find them. Disappointment occurs if

- the spatial queries are difficult to formulate;
- the searching methods are inefficient;
- the found data are inadequate; or
- the found data are oversupplied

Following geo-services are necessary for Internet data acquisition:

Location-based query languages

Unlike the document-based queries that consist of key words connected by Boolean operators, location-based query languages must sufficiently and intuitively describe spatial concepts that are composed of (1) geometrical / topological entities, e.g. geographic regions and their spatial relations, (2) location-related qualities and quantities, e.g. geo-coded thematic layers bound to the geographic regions in question, and (3) theme-related qualities and quantities, e.g. associative information and cross-references that can be linked with the thematic layers. Since there are no crisp boundaries among spatial concepts, the corresponding queries should be enriched by fuzzy operators (e.g.

nearby, around, similar) and non-physical measurements (e.g. distances in terms of driving speed or expenses).

Tolerant search methods for location-based tasks

Technically, the geometry of a particular geographic region can be exactly clipped, yet a rough clipping is more useful for many location-based applications. The reason is rather simple: geometric terms are inconvenient to use. With the exception of a few professionally targeted search, most netizens refer to a geographic region by its place name (or place names of its neighboring regions) instead of the exact bounding coordinates. A rough clipping is usually constrained by certain tolerance values which vary with user tasks and contexts. In mobile environments, for instance, the same fuzzy operator "nearby" may require different proximity values, depending on the moving speed. On the other hand, location-related thematic layers and their cross-references can only be reasonably identified by means of fuzzy matching based on semantic similarity or association. As users are not willing to pay unnecessary bits or suffer unnecessary "traffic jam", the heaped data around a location need to be scaled down to the right level of detail and level of relevance for the particular task and context.

Data mining for the purpose of value-adding spatial data warehouses

The effectiveness of a spatial search is strongly influenced by the accessibility and transparency of the existing databases on the Internet. The accessibility requires that (1) the database as a whole be well-tagged with a summary containing the relevant key words; and (2) the individual data items be indexed with explicit attributes and metadata. The transparency requires further methods to (1) discover the spatial concepts that are otherwise hidden in the database; and (2) describe the discovered concepts using an easily understandable language. An accessible and transparent database allows flexible aggregation and segregation, hence the personal division of the information space. However, personalizing large data inventories is complex and unintuitive. Spatial data suppliers would go insane trying to determine what to offer to whom, especially when they themselves have lost an overview of their own databases. Therefore, such tasks should be performed by automatic spatial data mining systems.

In comparison to statistical methods, data mining strategies have a number of advantages. On the one hand, they are capable of discovering knowledge based on noisy and incomplete samples. On the other hand, they provide quantitative criteria that guide the optimization of a database. At the Technical University of Munich, a data mining system has been developed to explore the road database maintained by NAVTECH. In the original database, each road element is described by ca.150 attributes. Two algorithms on the basis of the entropy theory and the rough-set modeling technique have been applied to rank the individual attributes and detect the dependencies among attributes based on their values in an arbitrarily selected region. Other algorithms are devoted to extracting routes based on road geometry. With the knowledge of relative importance of the individual attributes, users are given the flexibility to buy a local road database with truncated attribute list. By observing the ranking list and correlation matrix calculated for different regions, information that reflects the regional differences of a road network can be extracted. Likewise, the changes in ranking list and correlation matrix of the same region after removing or adding a route imply the relative importance of this particular route. However, there are still very few spatial data mining methods that can process the geometric and semantic attributes in a well-integrated manner. While the separate treatment of geometry and semantic data of spatial objects might be sufficient for many GIS applications, it is not able to create a reasonable description of spatial patterns that occur as outcome of the interplay between geometric and semantic attributes.

Navigational guide and autonomous search agent

A personal data retrieval on the Internet for location-based tasks is characterized by a series of queries combined with selections and browses that successively approach a goal. The efficiency of such a search task depends on how smart the queries are formulated, in which order the queries are processed and how the searcher reacts upon the intermediate results prompted by the search engine. Due to the complexity and fuzziness of spatial concepts, every search step may results in a number of ramifications as possible moving directions. Facing multiple choices, the searcher may need an orientation service such as personalized navigational guide or autonomous search agent - a computer program that helps him avoid deadlock and select the most promising direction in the information space.

On-demand map production

Early maps mostly originated from direct observations of the happenings in the reality or they were transcriptions of mental images obtained from direct human-environment interactions. The liberalization of data acquisition techniques has now made it possible to digitize the real world including its finest object details, share and maintain the digital records in distributive data warehouses. Due to its task-neutrality and objectivity, every digital earth regardless of its resolution is regarded as an unbiased object model of the reality (primary model). The digital object models constitute the central part of research and development of GIScience, at the same time, they become the new origins of mapmaking. It seems that the realm of mapmaking is shrinking and cartographers are being pushed into the corner of picture making. While an early mapmaking process began with field observation and ended up with map products, the majority of modern maps have been "simply" derived from the available object models. However, the condensed field of mapmaking has raised a number of new challenges concerned with on-demand map production.

On-demand map production is an approach toward the individualization of mapmaking. The term "on-demand" reminds us of following facts:

- User demands determine the contents to be selected from the object model (e.g. above mentioned located-based date retrieval on the Internet), the levels of details, the presentation styles (e.g. photorealistic, symbolic), the purposes (e.g. communicative, explorative), the production methods (e.g. on-the-fly, predefined), the access modes (e.g. view-only, interactive) and output forms (e.g. screen display, hardcopy).

- On-demand produced maps represent cognitively processed views of the reality (secondary models). Meanwhile, they are graphically generalized for the selected output medium. The essential cognitive and creative activities of map design are embedded in the understanding and visualizing the object model based on the individual user requirements.

- Although certain procedures such as selection of personal mapping contents, calculation of projection, conversion of printing format and digital color management may have good chance of full automation, it is so far impossible to automate the whole process of on-demand map production. On the one hand, mapmaker's understanding of a digital object model is limited to what is explicitly described. On the other hand, what a mapmaker can infer from user requirements is merely a coarse framework composed of non-exhaustive guiding rules and constraints. Style-sheets, scene-graphs or individual symbols can be predefined in an object model, however, their automatic implementations often end up with unacceptable graphic displays. For this reason, the mapmaker has to make many own decisions interactively in order to create a correct-looking map product.

The extent of cartographic products

Since ancient times maps have been serving as favorite communication tools to help people construct or adjust their personal mental images (tertiary models) of their living environment. Modern maps have evolved from naturalistic depiction and photorealistic documentation of the reality. With the successive transition of map design techniques from naturalism to abstraction, mapmakers have won more and more freedom to integrate the graphic presentation of invisible or hidden aspects of spatial concepts in map products. Being characterized by spatial reference, representative scale, generalization and symbolization, maps are generally considered as the peak of cartographic science and art. However, recent developments in cartography tend to oppose the "holy" tradition of cartography. More and more professional cartographers are turning away from standard maps and experimenting with new expression forms. On the one hand, in favor of intuitive reading, abstract map symbols are distorted, elaborated or concretized by applying anamorphosis, multimedia and animation techniques. At the end of successive morphing, abstraction entirely gives way to photorealism or naturalism. On the other hand, in favor of spatial data analysis, design elements of map symbols are reduced or minimized so that finally only a topologic skeleton remains as a graphic presentation. Many cartographic information systems offer interactive maps that can smoothly change their appearances to map-related presentations or vice versa. For example, during a simulated "fly-through", users can comfortably observe and steer a landscape that successively transits from vertical, oblique to horizontal view.

Map-related presentations are distinguished from maps in aspects such as geometric properties (e.g. bird-eye view), dimensions of projection surface (e.g. relief presentation on a globe), design styles (e.g. photorealism), presentation media (e.g. image map) and perception modes (e.g. audio-visual). The connection between map-related presentations and maps is characterized by the likeness or comparability with regard to spatial reference, mapping contents and their scale range.

Map users have learnt to appreciate various cartographic products. They are rather insensitive to the boundary between a map and a map-related presentation. Whether map symbols look similar to the original scenes or not does not bother map users either because every well-designed cartographic product can invoke their curiosity in a special way. The truth is that cartographic products have their own values as graphic art even if the presented data are useless or out of date.

A visualization dedicated to anamorphosis with functions such as value-by-area, polyfocal projection or dynamic lens makes its users selectively attentive to mapped contents. Personal views can be created if the areas of personal interest can be interactively defined by users. Anamorphosis is indeed an excellent way of using deceiving tricks to help us find truth. By reproducing the visual impression of the original scenes (or creating a visual impression for those non-visible scenes), a photorealistic presentation renders an immersive atmosphere to its users. It can thus direct users' attention to the geometric aspects such as form and size of the spatial objects or concepts. To the other end, a highly abstract graphic presentation draws users' attention by intentionally introducing an apparent distinction between each symbol and its referent. The distinction creates a psychological distance that isolates users from the geometric aspects of the individual scenes, thus, forces them to look for further information beyond the visual appearance. In fact, what users expect from a digital earth is much more than what they could see by simply riding on a "magic carpet" in the air. The combined use of maps and map-related presentations has proved efficient in assisting users to go through pictures of the reality to the reality of pictures.

In pre-computer times, map-related presentations played only a marginal role due to their small production volume and/or limited scientific value. Occasionally, they were called paramaps, a term that implies their somewhat inferior position in cartography. However, this situation has been dramatically changed in digital cartography, especially since the introduction of multimedia technology. The rapid penetration of explorative cartography has resulted in a constantly increasing number of map-related presentations. In interactive cartographic information systems, map-related presentations have been accepted among users as being at least equally valuable to standard maps. The fact that well-designed map-related presentations are better eye-catchers than standard maps is particularly important for screen design that should be adaptive to the characteristics of screen medium. For example, the rule that a passive paper map must simultaneously ensure the visibility and legibility of its symbols is no longer applicable to screen medium. Taking the user behavior of screen-reading into consideration, a screen map, in particular, an Internet map, must try to immediately arouse attention of its intended users by offering eye-catching visibility and real-time rendering speed. Only when users show their interest is it meaningful to provide the necessary legibility to enable the further reading. This may well be one of the major reasons for the wide-spreading application of techniques such as animation, multidimensional multivariate visualization, successive rendering, dynamic graphic clipping, sensitive symbolization, integrated legend, adaptive name placement etc.

The expanding market of map-related presentations requires our new insight into the extent of cartographic products and their evaluation. Investigating the map typology or tupu (graphic spectrum) as called by Chinese colleagues has the tasks to:

- study the impacts of GIS and multimedia mapping on cartographic vocabulary and quality issues (e.g. We need to seek answers for the open questions such as what kind of acoustic variables have their practical use in cartography, how the map-related presentations should be suitably positioned and termed, for what each map-related presentation is good etc.)
- develop cartographic theories and methods for the design of screen maps and interactive cartographic information systems (e.g. Topographic screen maps need a different look from their paper counterpart. Graphic user interface should be regarded as an inseparable part of a screen map.)
- extend the application field of cartographic visualization (e.g. Maps are not only efficient in communicating spatio-temporal information, but also a favorite tool for the visualization of non-spatial structures such as cyberspace. The potentials of multimedia maps in visualizing and verbalizing complicated events need to be discovered.)

Interactive user interface

Understanding a cartographic product is always a personal experience. The cognitive expenses of a user by interpreting cartographic symbols can be considerably reduced if the mapped contents are exactly what he needs (personal data access) and presented in his favorite fashion (personal view). However, personalization does not mean that the spatial data warehouses should be partitioned into numerous individual fragments or the cartographic market should be flooded with individual but ugly products. Rather, users should be given necessary geo-services that help them find their wanted data and create their personal expressions of the data. So far both the personal data acquisition and the personal data visualization are supported by human-computer interaction. This implies the importance of developing an effective and efficient user interface. A good interface should be able to provide users with necessary interactive tools, at the same time, minimize their mental efforts in getting along with these tools.

Most of current graphic user interfaces are developer centered. Although developers are humans too, they themselves and their assumed users do not truly represent actual user requirements. Many function-rich, but performance-poor interfaces have been designed according to add-on design principle. That is, new interactive functions are constantly inserted into the system as soon as there is a requirement. In order to accommodate the heaping functions, the system appearance has to be frequently changed. Consequently, the oversupply of interactive functions causes confusion among users and many available functions remain unused. Often a system is obsolete or upgraded before a user has learnt the most fundamental system functions. In fact, the design of a user interface reaches its perfection, "not when you have nothing more to add, but when you have nothing more to take away" (*Exupéry* in *Gloor* 1997).

One of the key issues for optimizing a user interface deals with user modeling by tracking dynamic user behavior and constructing user profiles. User modeling can only be as good as the algorithms and the relevancy of the behaviors they measure (Greening, 1999). Theoretically, a user model is composed of numerous facets, with each corresponding to an individual user. However, tracking the user behavior is a never-ending dynamic process. Every user has his own learning history, experiences, preferences, intelligent level and social environment. His psychophysical and emotional state varies from one moment to another. Moreover, his information need is influenced by task and context. It might be wasting resources to identify every individual user by investigating all possible demographic and personality features due to two major difficulties: (1) the try to generate all the possible relationships may result in a combinatorial explosion that can hardly be handled by most machine-learning algorithms; and (2) the individual user evidence (explicit or implicit) that can be collected during limited interactive sessions is often too meager and volatile to form a facet with sufficient certainty.

In fact, many individual users do share a lot of common characters. Despite the fashion of "be yourself", many "self" users choose to look and think like their friends, neighbors or colleagues. Keeping this in mind, clustering general user behaviors based on the most representative features would be more useful because it helps avoid drowning us in details on the one hand and improve system's general conformity of user expectation.

Equally important is to enhance the interface transparency that is characterized by the system ability of self-description, self-organization and self-navigation. Self-description with its services such as on-line help and sensitive symbols aims at assisting users to detect and fill their knowledge "holes". Self-organization has the goal to optimize interaction performance. For example, adaptively structuring interactive functions based on the dynamic logging history of a special user may lead to an increased learning efficiency. Finally, self-navigation is a necessary aid that protects a user from being disoriented and at the same time rationalizes system resources. One of the research tasks, for example, is to develop autonomous agents for map reading. An autonomous agent is active throughout the interactive sessions. By continuously analyzing the actual user action (e.g. query, eye-movement, mouse click or pause), it predicts the next likely moving step or suggests a next action to the user without forcing him to follow. Thus a user has always his choice in addition to the advice made by the agent.

Summary

The development towards individualization of mapmaking is an extension of mapmaking for general public, while the mobility of map use is in essence a revolution with the potentials to unite the advantages of paper maps, wireless data access and interactivity. In order to satisfy the diversified user requirements, there is an urge need to develop spatial data mining methods for the purpose of value-adding spatial data warehouses and discovering user stereotypes. Meanwhile, the typology of cartographic products needs to be enriched by extending cartographic theories for screen design and interface design.

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