INFORMATION VISUALIZATION IN THE INTERACTION WITH IDL

Maria Francesca Costabile and Giovanni Semeraro
Dipartimento di Informatica, Università di Bari
Via Orabona 4, 70125 Bari, Italy
costabile, semeraro@di.uniba.it

Abstract

We briefly discuss the state of the art of the research in information visualization. Then, we describe a technique for visualizing meta-information about the content of a networked information system in the context of a digital library, which is being developed at the University of Bari.

1. Introduction and Motivation

The computer technology is providing everybody the possibility of directly exploring information resources. Huge amount of data are becoming available on networked information systems, ranging from unstructured and multimedia documents to structured data stored in databases. On the one side, this is extremely useful and exciting. On the other side, the ever growing amount of information at disposal generates cognitive overload and even anxiety, especially in novice or occasional users.

Nowadays, wide varieties of users access, extract, and display information that is distributed on various sources, which differ in type, form and content. The current user interfaces are usually too difficult for novice users and/or inadequate for experts, who need tools with many options, thus limiting the actual power of the computer. Users need to easily understand what kind of objects are stored in the available sources they have access to, how they can retrieve and organize them along ways that permit to make rapid decisions on what is relevant and which patterns exist among objects. Users also need to manipulate the retrieved information in order to incorporate it in their specific tasks. As a consequence, networked information systems must provide enhanced user interfaces that support this intensive interaction between users and information.

In this context, the conventional interfaces, based on the view of information retrieval as an isolated task in which the user formulates a query against a homogeneous collection to obtain matching documents, are completely out of date. Indeed, this view does not correspond for several reasons to the reality of users working with networked information systems. For example, users are often unable to formulate specific questions, and they realize what they are trying to ask and how to ask it by browsing the system. This process has been called *progressive querying* in [CCL94] and *iterative query refinement* in [RPH95]. Moreover, users often consult multiple sources with different contents, forms, and methods of access.

The same holds for searching in structured relational database system, for which the SQL language has become a widespread standard. With SQL, users perform queries that specify matches on attribute values, such as author, publisher, date of publication. Each document has values for the attributes, and database management methods enable rapid retrieval even with millions of documents. Although SQL is a standard, many form-fillin variants for expressing relational database queries have been proposed to aid novice searchers. However, the diversity is itself an impediment to ease of use. Designers must take into account that users of walk-up kiosks or WWW pages cannot invest hours or minutes to learn each interface. Finding a way to provide powerful search without overwhelming novice users is a current challenge.

We recognize three different needs of people exploring information: 1) to understand the content of the information system, 2) to extract the information of interest, and 3) to browse the retrieved information in order to verify that it matches what they wanted. To satisfy such needs, the user-interface designers are challenged to invent more powerful search techniques, simpler query facilities, and more effective presentation methods. When creating new techniques, we have to keep in mind the variability of the user population, ranging from first time or occasional versus frequent users, from task-domain novices versus experts, from naive (requesting very basic information) versus sophisticated users (interested in very detailed and specific information). Since there is not a technique capable to satisfy the need of all such classes of users, the proposed techniques should be conceived as having a basic set of features, while additional features can be requested as users gain experience with the system.

1.1 Visualizing Meta-information

Several authors agree that users interacting with huge amount of unknown and various information find extremely useful some *meta-information* on the following different aspects of the stored data [RPH95]: 1) *content*, that is, what information is stored in the source; 2) *provenance*, which refers to how the information in the source is generated and maintained, whether it is a public source or a personal archive, how frequently it is maintained, etc.; 3) *form*, i.e. the schemes for the items in the source, including their attributes and the types of values for these attributes; 4) *functionality*, that concerns the capability of the access services, such as the kinds of search supported with their performance properties; 5) *usage statistics*, that is statistics about source usage, including previous use by the same user or other ones.

One of the goals of our work is to investigate effective ways for endowing the interaction environment of networked information system with appropriate representations of the above meta-information, particularly about content, in order to provide users with proper cues for locating the desired data. The various paradigms for representing content range from a textual description of what is stored in the information source to structured representations using some knowledge representation language.

Our choice is to exploit visual techniques, whose main advantage is the capability of shifting load from user's cognitive system to the perceptual system. Indeed, information needs to be visualized in an information space in order to be retrieved by users. This visualization can either be carried out by the users in their own mind, in which case it is essentially the users' conceptualization of that information, or it could be accomplished by the system, in which case the visualization is generated on the display screen. The latter is actually called *information visualization*, and is defined as "a process of transforming information into a visual form enabling the user to observe information" [CEG97]. Recent research has proved that a suitable visualization can reduce the time to get information, and to make sense out of it. In the information system context, visualizations have a wide range of applications, they can be used for visualizing various types of meta-information, as well as queries and retrieved results.

In Section 2 of this paper, we briefly report on the state of the art of the research in information visualization. In Section 3, we illustrate a technique for visualizing meta-information about the content of a prototypical digital library service, that is currently being developed at the University of Bari. Conclusions are given in Section 4.

2. Information Visualization

As McCormick et al. say in [CDB87], "Visualization is a method of computing. It transforms the symbolic into the geometric, enabling researchers to observe their simulations and computations. Visualization offers a method for seeing the unseen. It enriches the process of scientific discovery and fosters profound and unexpected insights".

We are now all familiar with direct manipulation interfaces; their success testify the power of using the computer in a more visual manner. Direct manipulation is based on some fundamental concepts, such as the visualization of actions and objects of interest, the use of fast, incremental and reversible actions, and the immediate visualization of the result. Visual displays give the possibility of showing relationships by proximity, containment, connected lines, color coding, etc. Highlighting techniques, like blinking, brightening, reverse video, can be used to focus the attention to specific items among thousands of items. Rapid selection can be performed by pointing to a visual display.

By visually presenting information, we exploit the potentiality of visual perception of human beings. Visual presentations are particularly useful since they allow users to activate perceptual procedures to quickly obtain the desired result. Such procedures substitute the logical inferences the user should perform without a visual presentation. Moreover, by allowing dynamic user control of the visual information through direct manipulation principles, it is possible to traverse large information spaces and facilitate comprehension with reduced anxiety. In a few tenths of a second, humans can recognize features in mega-pixel displays, identify patterns and exceptions, recall related images. The use of proximity coding, color coding, size coding, animated presentation, and user-controlled selections enable users to explore large information spaces rapidly and with fun.

2.1 Information Visualization Prototypes

In our work, we are particularly interested to designing visualization tools that provide users with a rapid overview of the content of an information system. Recently, many visual query systems have been developed [CCLB97]; such systems use visual representations to depict the domain of interest and express related requests. Indeed, exploring large multi-attribute databases is greatly facilitated by presenting information visually. Among different visualization techniques of databases proposed in the literature, Ahlberg and Shneiderman have proposed starfield displays [AS94], that plot items from a database as small selectable spots (either points or small 2D figures) using two of the ordinal attributes of the data as the variables along the display axes. The shown information can be filtered by changing the range of displayed values on either axes. If this is done incrementally and smoothly, the result is zooming in and out on the starfield display, and the user can track the motion of the spots without getting disoriented by sudden, large changes in context.

The values of other attributes of the database can also be varied by the user through appropriate widgets that allow to perform dynamic queries [SWA92]. This is a very interesting visual query formulation technique (see [CCLB97] for a classification of such techniques), based on range selection, i.e. it allows a search conditioned by a given range on multi-key data sets. The query is formulated through direct manipulation of graphical widgets, such as buttons, sliders, and scrollable lists, with one widget being used for every key. The user can either indicate a range of numerical values (with a range slider), or a sequence of names alphabetically ordered (with an alpha slider). Given a query, a new query is easily formulated by moving the position of a slider with a mouse; this is supposed to give a sense of power but also of fun to the user, who is challenged to try other queries and see how the result is modified.

Higher usability is ensured if the query results fit on a single screen and are displayed quickly, i.e. within a second [AWS92]. Moreover, input and output data are of the same type and may even coincide. As a consequence, dynamic query applications typically encode multi-attribute database items as dots or colored polygons on a starfield display.

An application of dynamic queries is shown in [SWA92] and refers to a real-estate database. There are sliders for location, number of bedrooms, and price of houses in the Washington, D. C. area. The user moves these sliders to find appropriate houses. Retrieved ones are indicated by bright points on a Washington, D. C. map shown on the screen. Another interesting application that combines dynamic queries and starfield displays is FilmFinder [AS94]; it allows information about movies to be retrieved by providing names of actors, actresses, or movie directors through alphasliders, or values of other attributes through appropriate range sliders and buttons. The user can select some values by using a slider, and this first choice determines the set of values that can be selected with the remaining widgets. For example, if the user has selected a specific movie director, only names of actors and actresses who worked with that director can be selected next. This strategy is called tight coupling and it is aimed at preventing users from specifying null sets. In other words, query widgets and their related query formulation mechanisms are designed to interact with each other to avoid empty query results; this is achieved by restricting users to specify query criteria that lead to non-empty results. A tightly coupled query is then a series of filters selecting a subset of a database. For each new filter that is set, users can only select values of the remaining filters that let through at least one database object still existing after the last filter.

Dynamic queries are also called direct-manipulation queries, since they are based on the same fundamental concepts of direct manipulation illustrated above. One of the big advantages of such interaction technique is that it allows focusing the attention on the task users have to perform. Objects of interest are all displayed so that actions occur in the high level semantic domain. Each command is a comprehensible action in the problem domain whose effect is immediately visible; this relieves the user from the burden of decomposing tasks into syntactically complex sequences, thus reducing user load in problem-solving. The sliders are a good metaphor for the operation of entering a value for a field in the query: changing the value is done by a physical action instead of entering the value by a keyboard. Such action is easily reversible by moving the drag box, if the obtained results are not what users expected. No action is illegal, hence error messages are not needed. More references to work on dynamic queries can be found in [Shn94].

At Xerox PARC in the last years a group of researchers has developed several information visualizations, with the aim of helping the users understand and process the information stored into the system [RCM93, RPH95, CRY96, Car96]. They have created the "information workspaces", i.e. computer environments in which the information is moved from the original source, such as networked databases, and where several tools are at disposal of users for browsing and manipulating the information. One of the main characteristic of such workspaces is that they offer graphical representations of information that facilitate rapid perception of the overall patterns. Moreover, they use 3D and/or distortion techniques to show some portion of the information at a greater level of detail , but keeping it within a larger context. These are usually called *fisheye* techniques [Fur86], or alternatively *focus* + *context*, that better gives the idea of showing an area of interest (the focus) quite large and with detail, while the other areas are shown successively smaller and in less detail. Such an approach is very effective when applied to documents, and also to graphs [SB94]. It achieves a smooth integration of local detail and global context. It has more advantages of other approaches to filter information, such as 1) zooming or 2) the use of two or more views, one of the entire structure and the other of a zoomed portion; the former approach shows local details but looses the overall structure, the latter requires extra screen space and forces the viewer to mentally integrate the views. In the *focus* + *context* approach, it is effective to provide animated transitions when changing the focus, so that the user remain oriented across dynamic changes of the display avoiding unnecessary cognitive load. A good example is provided by the Perspective Wall [RCM93]. For other techniques developed at Xerox PARC see [RPH95].

Numerous prototypes have been proposed for information visualization. The ones mentioned above are among those providing the most novel ideas. Shneiderman provides in Shn98 a very good survey. Other useful references are [CEG97, CC96, Cru96, GB96].

2.2 Supported Tasks in Information Visualization

There are many visual design guidelines. A central principle for information visualization might be summarized in the Shneiderman's Visual Information Seeking *Mantra "Overview* first, *zoom* and *filter*, then *details on demand*" [Shn96].

The overview allows the user to grasp the content of the application and its distribution across the different attributes. Providing an overview is particularly useful in WWW interfaces for information systems, that give users direct access to the content and interconnections within an information domain. WWW navigation should be stimulating and attractive for the users; unfortunately, due to the large amount of accessible information, the search of some detailed information can often become a long and complex activity for the user. One of the main problem is the difficulty users have in generating their mental model of the system they are interacting with; it can be difficult for them to grasp the kind of information stored and the modality for managing it. Such a problem is particularly serious since WWW interfaces are mostly used by occasional users, who are not willing to perform an in-depth study, but need to easily grasp the kind of information they can have and want to get it quickly.

Zooming is another interesting task, since users typically have an interest in some portion of a collection, and they need tools to enable them to control the zoom focus and the zoom factor. A satisfying way to zoom in is to point to a location and to issue a zooming command. Smooth zooming helps users to preserve their sens of position and context. Another popular approach for keeping the context while zooming some areas of interest is the already mentioned fisheye strategy [Fur86]; the fisheye distortion magnifies one or more areas f the display.

Users may filter out uninteresting items, so that they can quickly focus on item of interest. Dynamic queries applied to the items in the collection constitute one of the key ideas in information visualization [AS94]. Sliders, buttons, or other control widgets coupled to rapid display update are used for the filter task.

We can select an item or a group of items to get details. Once we have obtained a few dozen of items, it should be easy to browse the details about the group or individual items. The usual approach is to simply click on an item to get a pop-up window with values of each attributes. In Spotfire [IVEE], the details-on-demand window can contain HTML text with links to further information.

Besides the four tasks explicitly mentioned in the Shneiderman's Mantra, three other tasks are very useful in information visualization, namely *relate*, *history*, *extract*. Referring to the first, users can view relationship among items. In the FilmFinder details-on-demand window [AS94] users could select an attribute, such as the film's director, and cause the director alphaslider to be reset to the director name, thereby displaying only films by that director. The Table Lens emphasizes finding correlations among pairs of numerical attributes [RPH95].

We can keep a history of actions to support undo, reply, and progressive refinement. Information exploration is inherently a process with many steps, thus keeping the history of actions and allowing users to retrace their steps is important. Currently, mostly prototypes fail to deal with this requirement.

It is also useful to allow extraction of sub-collections and of the query parameters. Once the users have obtained the item or the set of items they desire, it would be useful for them to be able to extract that set and to store into a file in a format that would facilitate other uses, such as sending by e-mail, printing, inserting into a presentation package. As an alternative to saving the result set, they might want to save the settings for the control widgets. At the moment, few prototypes support this extract task.

3. An Approach to Visualizing Information Content

The work reported in this section refers to a WWW-based user interaction environment, focusing on a novel technique for visualizing the content of the information system of a digital library, called IDL, currently developed at the University of Bari [SEMF97, EMSF98]. More details on the overall interaction environment of IDL can be found in [CESF98].

A first prototype of IDL has been equipped with a WWW interface exploiting a typical form fill-in interaction style. That interface is powerful and flexible since it permits a search by a combination of fields, but it is more appropriate for users who are already acquainted with the library structure, and also have some information about the library content. By observing casual users interacting with the IDL prototype, we realized that often users performed queries whose result was null, just because they did not have any idea of the kind of documents stored in the library. Therefore, we decided to enrich the IDL interaction environment by developing some novel visual tools, that aim at allowing users to easily grasp the nature of the information stored in the available sources and the possible patterns among the objects, so that they can make rapid decisions about what they really need and how to get it.

3.1 The Topic Map

One of the new features of the IDL environment, that users appreciate the most, is the possibility of getting a rapid overview of the content of the stored data through the *topic map*. Such a visualization is actually an *interactive dynamic map* (interactive map for short), as it has been proposed in [ZB95]. An interactive map gives a global view of either the semantic content of a set of documents or the set of documents themselves. The semantic content reflects the topics contained within the set of documents and the way they are organized to relate to each other; it is represented by a thesaurus that is built automatically from a full-text analysis.

Interactive maps exploit the metaphor of exploring a geographic territory. A collection of topics, as well as a collection of documents, is considered to be a geographical territory that contains resources, which metaphorically represent either topics or documents; maps of these territories can be drawn, where regions, cities, and roads are used to convey the structure of the set of documents: a region represents a set of topics (documents), and the size of the region reflects the number of topics (documents) in that region. Similarly, the distance between two cities reflects the similarity relationship between them: if two cities are close to each other, then the topics (documents) are strongly related (for example, documents have related contents).

Topic maps are very effective since they provide an overview of the topics identified in a collection of documents, their importance, and similarities and correlations among them. The regions of the map are the classes of the thesaurus, each class contains a set of topics represented by cities on the map. Roads between cities represent relationships between topics. In this way, topic maps provide at a glance the semantic information about a large number of documents. Moreover, they allow users to perform some queries by direct manipulation of the visual representation.

Document maps represent collections of documents generated from a user query, that may be issued on the topic map by selecting regions, cities, and roads. The cities of these maps are documents, and they are laid out such that similar or highly correlated documents are placed close to each other.

In order to generate the topic map in IDL, we need to identify the set of topics or descriptors defining the semantic content of the stored documents; such topics constitute the IDL *thesaurus*. There are several thesauri used in the information retrieval literature; most of them are built manually and their descriptors are selected depending on specific goals. An example is the Roget's thesaurus, that contains general descriptors. When building the IDL thesaurus, we have used standard techniques, also taking into account the type of documents currently stored in IDL. They are scientific papers that have been published in the journal IEEE Transactions on Pattern Analysis and Machine Intelligence (*pami*), in the Proceedings of the International Symposium on Methodologies for Intelligent Systems (*ismis*), and in the Proceedings of the International Conference on Machine Learning (*icml*). Therefore, we have used the INSPEC thesaurus containing specific terms in the field of Artificial Intelligence. This thesaurus contains 629 keywords, that are either single words or expressions made up of more words (up to five).

We have represented documents and keywords (topics) by vectors, that is a common practice in information retrieval [SG83, Lar91]. The coordinates of the document vectors and those of the topic vectors are computed in the following way: the coordinate d_i of the vector representing document D is 1 if the topic T_i was found in D, and 0 otherwise; the coordinate t_i of the vector representing topic T is 1 if document D_i contains T, and 0 otherwise.

In the IDL maps, we have implemented some color based coding techniques and we have added several widgets to the original project described in [ZB95], in order to obtain a more effective visualization and to provide some mechanisms appropriate for a flexible interaction in a data-intensive context, such as a digital library. Details on the map visualizations and on the user interaction with them are in [CESF98].

3.2 Some Related Work

The IDL visual interaction environment has been influenced by recent research on information visualization, which turned out to be a way of improving the intensive interaction between users and information [CEG97, CC96, Cru96, GB96]. In [RPH95], a variety of studies, tools, and systems developed at Xerox PARC illustrates the style of rich interaction that users will have with digital libraries. The technique we have proposed is a contribution in that direction.

The topic map has been designed with the aim of assisting those users who are unable to formulate specific questions, and that can realize what they really want and how can retrieve it only by browsing the system. The process of formulating a query progressively, i.e. step by step, by first asking general questions, obtaining preliminary results, and then revisiting such outcomes to further direct the query in order to extract the result the user is interested in has been called *progressive querying* in [CCL94]. The idea is similar to the *iterative query refinement* in [RPH95]. It is an interesting feature a query system should have, and it has been exploited by the visual query tools implemented in IDL.

The interactive dynamic maps proposed in [ZB95] were the main source of inspiration for the topic map, as we have described above. However, in the IDL environment we have improved the visualization by exploiting some color-based coding techniques and added several widgets with the aim of providing interaction mechanisms suitable for a data intensive context, such as that one of online digital libraries. Furthermore, in our system the topic map allows users to perform queries by direct manipulation, a facility that was not very well developed in [ZB95].

The interaction through the topic map is in accordance with Shneiderman's Visual Information Seeking Mantra "Overview first, zoom and filter, then details on demand" [Shn96]. We have implemented mechanisms for zooming and filtering working on the overview provided by the topic map. Once some documents have been retrieved, a simple click on a document icon in the document map will provide detailed information on that document, up to a complete view of the whole document.

4. Conclusions

Networked information systems pose several demands due to the large number and variety of its users, and also to the nature of the stored data, that is distributed on autonomous information sources that differ in content, form, and type. One of the consequences is that they must be equipped with environments that permit a new style of rich interactions with such information-dense systems. The work presented in this paper is a contribution in this direction.

We are aware that usability is an extremely important requirement for applications having a large variety of users, such as digital libraries. The testing should be done with representatives of each of the primary user communities and of as many of the secondary communities as time and money allow. Some preliminary usability evaluation of the IDL interface has been already performed, and the topic map has been designed in order to overcome some problems detected while observing the interaction of novice users. We are currently planning more accurate usability testing to be performed in the near future.

References

[AS94] Ahlberg C., Shneiderman, B., «Visual Information Seeking: Tight Coupling of Dynamic Query Filters with Starfield Displays», *Proceedings ACM CHI'94*: Human factors in computing systems, pp. 313-317.

[AWS92] Ahlberg C., Williamson C., Shneiderman B., «Dynamic Queries for Information Exploration: An Implementation and Evaluation», *Proceedings ACM CHI'92*: Human Factors in computing Systems, pp. 619-626.

[BRS92] Botafogo R., Rivlin E., Shneiderman B., «Structural analysis of hypertexts: Identifying hierarchies and useful metrics». *ACM Trans. Inf. Syst*. 10, 2, 1992, pp. 142-180.

[Car96] Card S.K., «Visualizing Retrieved Information: A Survey», *IEEE Computer Graphics and Applications*, March 1996, pp. 63-67.

[CC96] Catarci T., and Cruz I.F., «Special Issue on Information Visualization», *ACM Sigmod Record*, 4, 1996, p. 25.

[CCL94] Chang SK, Costabile M.F, Levialdi S., «Reality bites – progressive querying and result visualization in logical and VR spaces», *Proc. Of IEEE Symposium on Visual Languages*. St. Louis, 1994, pp 100-109.

[CCLB97] Catarci T., Costabile M. F., Levialdi S., Batini C., «Visual Query Systems for Databases: a Survey», *Journal of Visual Languages and Computing*, Vol. 8, 1997, pp. 215-260.

[CDB87] McCormick B.H., DeFanti T.A., Brown M.D., (Eds) «Visualization in Scientific Computing and Computer Graphics», *ACM SIGGRAPH*, 21, 6, 1987.

[CEG97] Card S., Eick S. G., and Gershon N., (1997) «Information visualization», *CHI97 Tutorial Notes*, Atlanta, GA, March 1997, pp. 22-27.

[CESF98] Costabile M.F., Esposito F., Semeraro G., Fanizzi N., Ferilli S., «Interacting with IDL: The Adaptive Visual Interface», in C. Nikolaou and C. Stephanidis (Eds.), *Research and Advanced Technology for Digital Libraries, Lecture Notes in Computer Science 1513*, Springer, Berlin, 1998, pp. 515-534.

[Cru96] Cruz I.F., «Taylorable information visualization», *ACM Computing Surveys*, 28A(4), 1996.

[CRY96] Card S. K., Robertson G.G., York W.,«The WebBook and the Web Forager: An Information Workspace for the World-Wide Web», *Proceedings CHI'96*, April 13-18, 1996, pp. 111-117.

[EMSF98] Esposito F., Malerba D., Semeraro G., Fanizzi N., Ferilli S., «Adding Machine Learning and Knowledge Intensive Techniques to a Digital Library Service», *International Journal on Digital Libraries*, Springer-Verlag, Berlin, 2, 1998, in print.

[Fur86] Furnas G.V., «Generalized Fisheye Views», *Proceedings CHI'86 Conference*: Human Factors in Computing Systems, ACM Press, New York, pp. 16-23.

[GB96] Gershon N., and Brown J. R., «Special Report on Computer Graphic and Visualization in the Global Information Infrastructure», *IEEE Computer Graphics and Applications*, 16(2), 1996, pp. 60-75.

[IVEE] IVEE Development, «Spotfire», Goteborg, Sweden, `http://www.ivee.com/pict/Spotfire-film1.gif`.

[Lar91] Larson, R.R., «Evaluation of retrieval techniques in an experimental on-line catalog», *JASIS*, 43, 1991, pp. 34-53.

[RCM93] Robertson G.G., Card S.K., Mackinlay J.D., «Information Visualization Using 3D Interactive Animation», *Communications of the ACM*, 36 (4), 1993, pp. 7-71.

[RPH95] Rao R., Pedersen J.O., Hearst M.A., Mackinlay J.D., Card S.K., Masinster L., Halvorsen P.-K., and Robertson G.G., «Rich interaction in the digital library», *Communications of the ACM*, 38 (4), 1995, pp. 29-39

[SB94] Sarkar M., Brown M.H., « Graphical Fisheye Views», *Communications of the ACM*, 37(12), 1994, pp. 73-84.

[SEMF97] Semeraro G., Esposito F., Malerba D., Fanizzi S., "Machine Learning + On-linr Libraries = IDL", in C. Peters and Thanos (Eds.), *Research and Advanced Technology for Digital Libraries, Lecture Notes in Computer Science 1324*, Springer, Berlin, 1997, pp. 195-214.

[SG83] Salton G., and McGill M.J., «Introduction to Modern Information Retrieval», New York, NY, McGraw-Hill, 1983.

[Shn94] Shneiderman B., "Dynamic Queries for Visual Information Seeking", *IEEE Software*, 11, 1994, pp. 70-77.

[Shn96] Shneiderman B., «The eyes have it: A task by data type taxonomy for information visualization», *Proceedings of 1996 IEEE Symposium on Visual Languages*, Boulder, Colorado, September 1996, pp. 336-343.

[Shn98] Shneiderman B.: «Designing the User Interface». Addison-Wesley, New York, 1998.

[SWA92] Shneiderman B., Williamson C., Ahlberg C., "Dynamic Queries: Database Searching by Direct Manipulation", *Proceedings ACM CHI'92*: Human Factors in computing Systems, pp. 669-670.

[ZB95] Zizi M., and Beaudouin-Lafon M. ,«Hypermedia exploration with interactive dynamic maps», *International Journal on Human-Computer Studies*, 43, 1995, pp. 441-464.