Interactive interfaces for knowledge-rich domains

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SUMMARY
Timelines represent a familiar means for representing the relationship among historical events. When incorporated into the context of electronic documents, the timeline provides the basis for implementing an interface into an event space, relying particularly on hypertextual-style links. Generalizing timelines also permits the flexible representation of many different kinds of relationships beyond the temporal. This paper includes examples of such representations, showing examples from prototype implementations.

1   INTRODUCTION

The key characteristics of documents are that they present selected information and they structure that information to be comprehended readily. Documents are written by an author for a purpose—presumably to communicate some set of concepts to a reader. Inherent with the concept of communication is the concept of structure. Documents long have been used to organize diverse material related to common themes. They provide a powerful metaphor that can be used to organize temporal, spatial, relational, and even unrelated data. In the digital world, interactive documents potentially are useful as interfaces for digital libraries and large, complex on-line systems [1]. Specifically, a document interface can provide context, encapsulation, and links to related information.

In an interactive environment, the opportunity exists to define new document forms— documents that aid in the organization of information, in the presentation of relationships among information elements, and in the flexible reformulation of structure highlighting different information space aspects. For instance, Allen [2] has demonstrated how an interface may be applied to digitized videotapes, effectively making them interactive documents.

In this paper, we explore the use of interactive documents as interfaces to historical data, starting with the basis of the well-known representation of a timeline. Because the documents are electronic and interactive, we can use them to display events and their relationships from different perspectives. The abstraction mechanism of knowledge representation techniques provide the reasoning capability necessary for displaying user specified

information at a desired level of detail. In most of this work, time is used as the underlying structuring dimension. Time is one effective dimension for organizing information. A number of authors and commercial systems have implemented electronic timelines of varying complexity, for example, Yankelovich, *et al.* [3], and Plaisant, et al. [4]. Allen [5] demonstrated highly interactive timelines, such as graphical timelines linked to text descriptions and timelines in which items were selected to be be displayed based on attributes. In addition, Allen proposed that timelines could be used as information system interfaces. This work follows and extends that suggestion. As we will show, traditional timeline displays are a special case of this mechanism in which the temporal dimension alone is shown. For instance, we show linking across temporal events.

To illustrate these concepts, we have implemented user interfaces that permit the specification and visualization of events and their relationships. In the prototypes, a reader can choose to display subsets of events, reference events, browse an event hierarchy and rearrange the information space along other dimensions such as temporal, spatial, causal and subset. The point and click restructuring capability helps the user prepare better mental model of the content of a document. Effectively, this is a data viewer for semantically related events (e.g., [6,7]).

2 PRESENTATION

Interactive documents also allow manipulation of their presentation (i.e., changes to the display that are independent of the document's semantic structure). Abstractions can be mapped to the screen display using one of the several available display representations. As illustrative examples we examine variations of the following techniques: non-linear representation of timelines; distortion-based techniques to integrate detail and context; and the use of lines and texture to display related objects. Examples of these, taken from our prototype presentations, are given later in this paper.

3 GENERATING PRESENTATIONS AND DOCUMENT SEMANTICS

Document semantics is the information conveyed by the author to the reader. An author can convey the same information to the reader using more than one representation. In paper-based document representations, the document semantics are frozen by the presentation medium. The reader, however, may find one representation better than another for understanding the meaning conveyed by the author. The advantage of purely electronic delivery, over other mediums, is that the reader can manipulate and restructure an electronic document interactively.

One example of differing representations possible in electronic documents can be found in the context of hypertext and hypermedia. A standard model of hypertextual documents is graph-based. In this representation, content is contained in the graph's nodes and links are modeled by intentionally-authored graph edges [8,9]. A traditional hypertext representation is to associate the content elements with embedded anchors (i.e., 'hot spots'). Links, in turn, are associated with the anchors.

Some projects have investigated alternatives to the node/link hypertext model. One alternative is to represent the relationships among content elements spatially. For example, VIKI [10] allows positioning of elements in two dimensions with no explicit representation of anchors or links. Pad [11] and Pad++ [12] take this a step further representing the

Figure 1. Styles of composers

information space in three dimensions. Another alternative is found in other systems, which include models of different kinds of relationships beyond those reflected by traditional hypertext links. Trellis [13] includes modeling of the temporal relationships that exist during presentation of document. An electronic, interactive document allows the reader to select any of the alternative representations of relationships.

3.1 Granularity of abstraction

We adopt an object oriented methodology to define objects, attributes, and their behavior. Even in a simple case, the number of objects is quite large, therefore a judicious choice of abstraction granularity is necessary to provide a balance between the number of objects and the level of document semantics to be conveyed. For example, Figure 1, taken from a exploration of musical history, assigns a 'place of origin' attribute to each music composer. It is possible to assign a value at a very coarse (country or continent) or a very fine (house or street) level of granularity. Sometimes the author may have no choice but to use the coarse granularity, as the value at finer levels of granularity may be unknown.

4 PRESENTATION ISSUES

4.1 Displaying objects

Figure 2 shows the similarity of music styles between different classical composers in a timeline format. A very simple graphical display of objects consists of rectangular shapes tagged with object identity. The same data can also be presented in a tabular or textual format. First, the similarity of style stands out more clearly in the timeline display [5]. In addition, the graphical representation allows easy association of ancillary information such as predecessor/contemporary relationship. Also, in our prototype, clicking on a composer's box displays more detailed information on him/her. In addition, graphical representation lends itself to many different kinds of presentation. As an example Figure 5 shows a
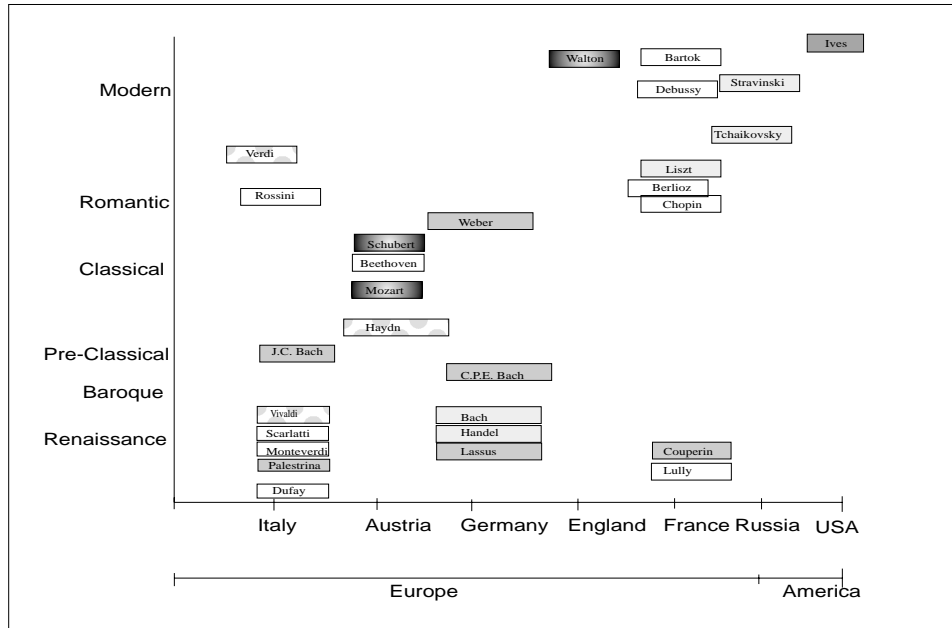
Figure 2. Composers by country, era, and style of music

restructured version of the document displayed in Figure 2. This is not to say that a graphical display is always better than a tabular display. For example, when screen space is at a premium, a compact table may be the best display method.

4.2   Displaying attributes

Each document element may have some attributes of interest to the readers. For example, a music composer has a particular style, was born in certain country, belonged to a certain musical era, etc. As described below, two issues of importance related to attributes are the domain of the attribute values and the number of attributes to be displayed.

4.2.1   *Domain of attribute values*

Attribute values can be of two types, namely, qualitative (or categorical) and quantitative. For example, a music composer can be from classical period (categorical) or from the period 1750 AD–1850 AD (quantitative). Attributes with categorical values can be represented by using color, texture or shapes. In Figure 1, three levels of gray are used to represent the styles of composers. In Figure 2, shape has been used to represent music style of the composers. Texture can also be used instead of (or in addition to) shape to obtain the similar effects. In Figure 2, two additional attributes are shown by spatial placement of elements on the two-dimensional map. The X-axis represents the country that had the greatest influence on the composer and the Y-axis represents the musical era associated with the composers. 3D display techniques will allow us to add an additional attribute.

It is harder to represent the attributes in the second, quantitative, category. These attributes are associated with a numerical value, which is difficult to represent visually.
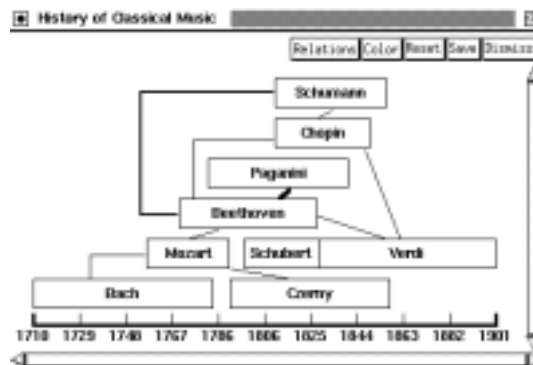
Figure 3. Direction of influence on composers

We have used color gradients and rectangle size to approximate the value. The efficacy of such approaches however, is not clear. Representing such attributes accurately almost requires use of a numerical value tag. It is possible to classify numerical values manually into range intervals and to a certain extent this process of classification can be automated [14]. Applications of such techniques are numerous, e.g., statistical graphics, spreadsheets, and visual database query systems.

4.2.2   Number of attributes

It is to be emphasized that a user can switch from one representation of the document to another easily. The mechanism described above, color, shape, texture can also be combined together and more attributes can thus be displayed. It may, however, reduce the clarity and thereby the readability of the document.

Care must be taken in limiting the number of categories also. Too many categories will clutter the screen and will limit the comprehensibility of the document. For example, Figure 1, with only three categories, is easy to follow, while Figures 2 and 3, with eight and five categories respectively, seem to approach the limits of comprehension. Note, it is easy to keep a limited number of shapes and textures in the database and apply them to the elements on demand.

4.3   Displaying relationships

Relationships among elements are important pieces of a document. Representation display techniques can be divided into two broad categories: explicit and implicit.

4.3.1   Explicit representation

In the explicit form, lines typically are used to connect the two elements involved in the relationship. Arrow-headed lines are used for directional relationships. Figure 3 illustrates the influence on composers of their predecessors and contemporaries using arrow-headed lines. This form is most common in paper and electronic documents as in entity-relationship diagrams [15], object-oriented analysis diagrams [16], and hypertext and Web structure displays [17].
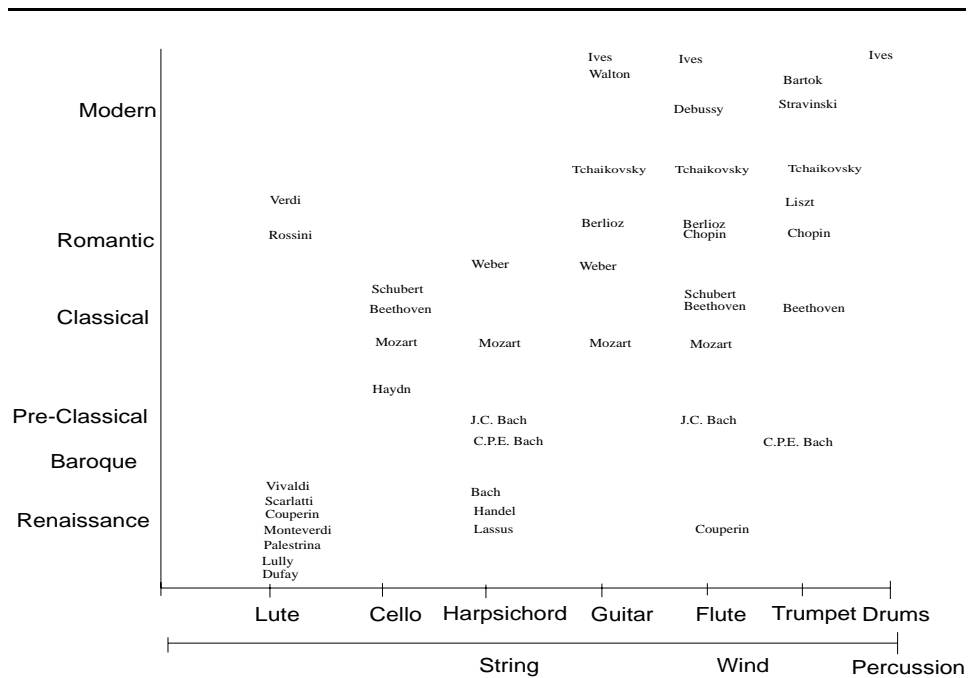
Figure 4. Composers by period and use of musical instruments

4.3.2   Implicit representation

The implicit form of representation uses visual cues to emphasize the relationship. Figure 1 uses two such cues. Shades of gray identify the related composers and placement of the composer objects on the timeline determine the direction of influence. Note that Figure 1 provides the same meaning as Figure 3. As another example, Figure 2's X-axis shows a hierarchical relationship between countries and continents. Figure 4 shows a similar relationship between instrument and its type.

There are some advantages of using an implicit representation. For example, the above hierarchical relationship, also known as 'is-part-of' relationship, can be extended to any depth without loss of readability. In addition, the display looks less cluttered with the use of the implicit technique.

5   VIEWS AND INTERFACES FOR MANIPULATING DOCUMENTS

In this section, we describe several techniques that have been applied in the presentation of interactive documents. Each technique alters the spatial presentation of the document. A user can experiment with these techniques on electronic documents until he/she finds a display that best conveys the document semantics.

5.1   Graphical fisheye views

A graphical fisheye view, a distortion-based technique first described by Furnas [18], allows one to focus on a specific area of the screen while keeping the context visible. Figure 5 shows how fisheye views can be applied to the document represented in Figure 2. Here the
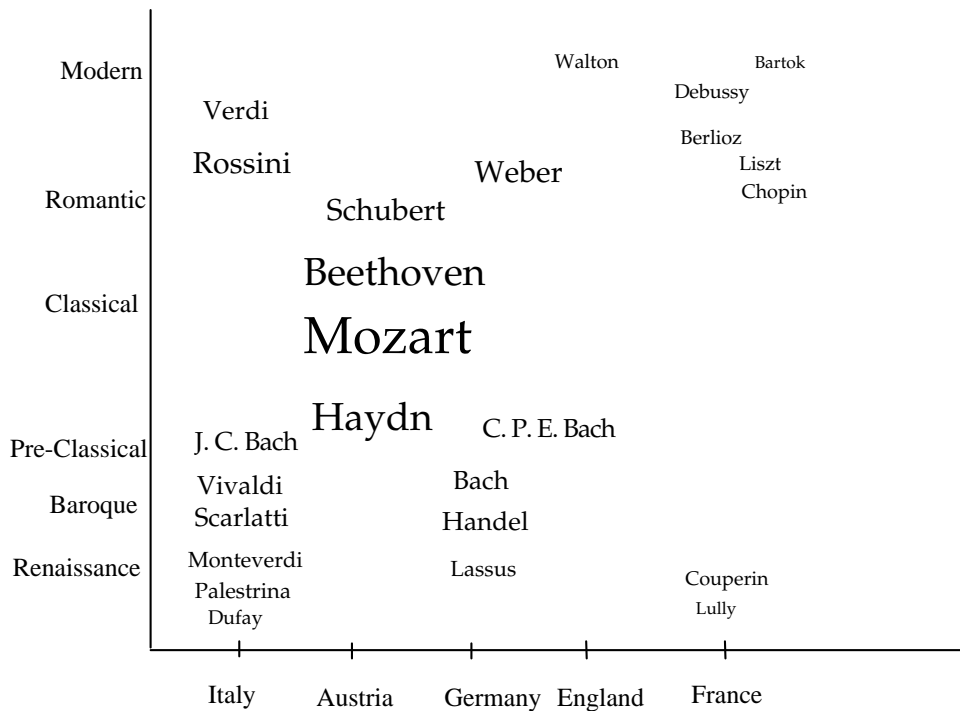
Figure 5. Fisheye view of the document in Figure 2, with focus on Mozart

focus is on Mozart. As we go farther from the point of focus, a progressively reduced view of other items is shown, displaying significant amounts of context.

5.2   Perspective wall

A perspective wall [19] allows wide data such as long timelines to be effectively displayed on the limited screen space. We have implemented the perspective wall on a 2D display. A user can use forward and backward buttons to navigate through the document space. The disadvantage of this technique is that if the data are equally spread on both X and Y dimensions, then it is difficult to display the Y-dimension.

5.3   Log transforms

Many events of interest include long periods in which not much happens followed by increasing activity. Logarithms scales can be used to position information effectively in such cases. This technique is commonly used for traditional timelines of geologic or evolutionary history. Figure 6 shows the birth of various musical styles. Each interval on the time axis represents exponentially larger time periods, allowing displays of events that happened 10,000 years ago in the perspective of the events that happened one year ago. This same idea could be extended to the spatial axis as well, allowing events to be presented in the nearby zones as well as in remote areas. In addition, because these are electronic presentations, the scale could be adjusted interactively by the user.
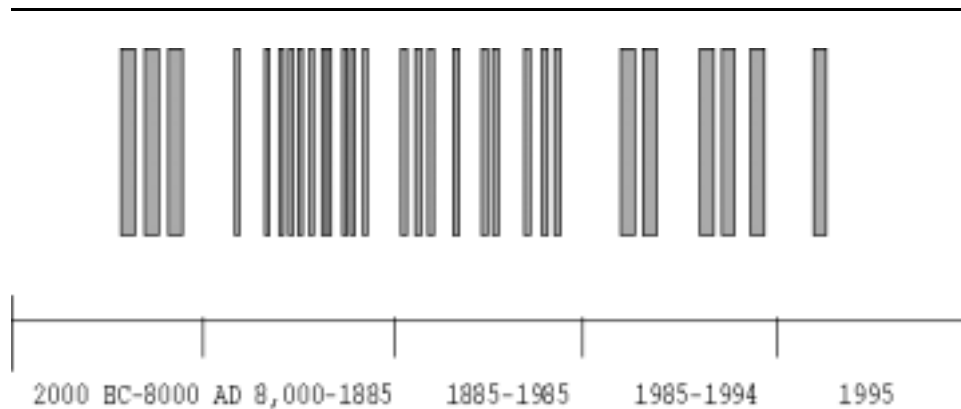
Figure 6. Birth of musical styles on a log scale

5.4 TOCs and Overviews

A table of contents [2] allows a user to click on any topic to display the subsections of that topic by expanding the hierarchy rooted at the topic. A second click collapses the hierarchy. A useful extension of this approach is a graphical table of contents [20]. The 'overview' from the Visible Human project [21] lets users skim through large amount of text or graphic material while keeping the overview visible and tracking location in the overview. The overview technique is suitable for showing hierarchical relationships such as the 'is-part-of' relationship. Figure 7 displays the location and description of musical centers of the word. Each successive column from right to left, narrows the choice to a smaller area. By clicking on any element the user can see the hierarchy rooted at that location. The user can then navigate to any leaf node for details.

5.5 Elision

In the description of log transformations earlier, the time scales were adjusted to compress periods when there were few events. Another approach is simple elision in which users can

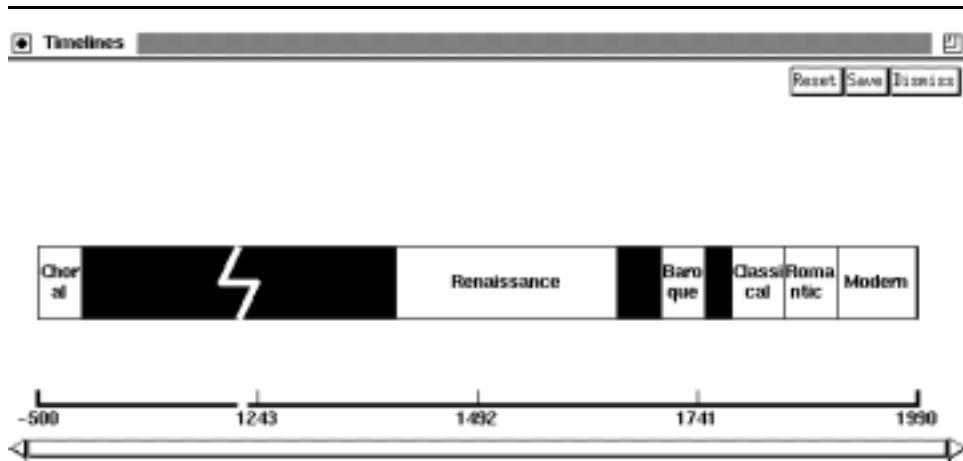*Figure 7. 'Overview' of musical centers around the world*

Figure 8. Musical eras

simply drop out the uninteresting sections of a graphic. In a general implementation, the user can cut out as many sections as desired. Figure 8 shows an example of this technique. In a pop-up dialog box the user can specify the value at which elision is to occur. The unit of this value is same as the units of X-axis. Here, the user has skipped the period between 400 AD and 1200 AD leaving the rest of the timeline intact.

5.6   Bar charts

This age-old technique is effective both on interactive documents and on static documents. Figure 9 shows dates of major pieces of music by composer. Clicking on a work displays more details in a popup window. This is useful for displaying objects that have numerical attribute values. Bars also can be color/texture coded to show additional attributes.
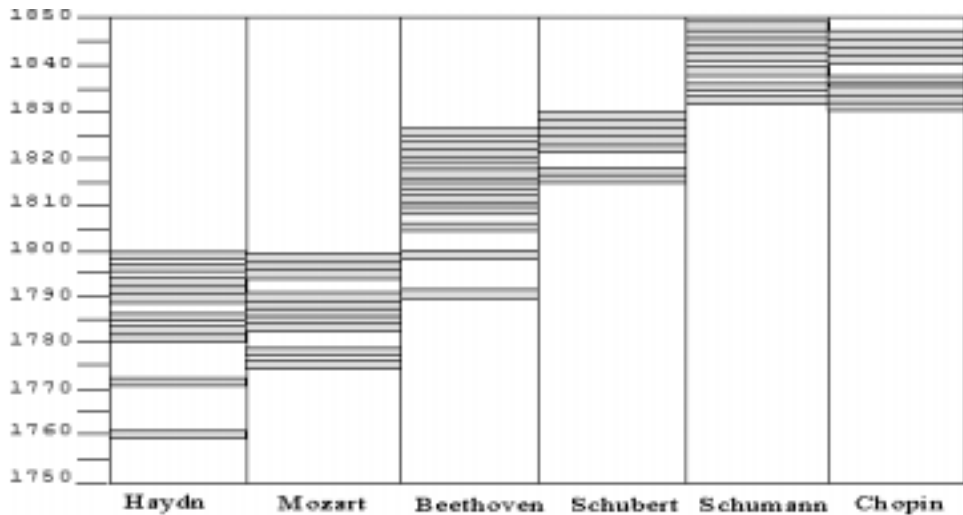

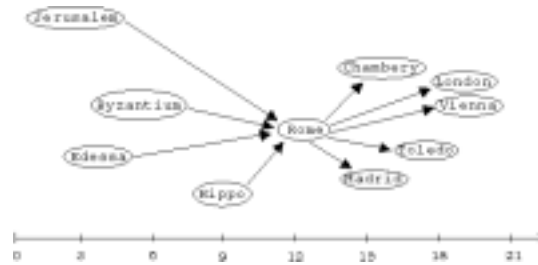*Figure 9. Bar chart of dates of famous musical works by composers*

Figure 10. Direction of influence of music: Relationships with the focus on Rome

6   SIMPLE INFERENCES BASED ON DATA RELATIONSHIPS

Limited 'discovery' of causality can be illustrated using simple transitive inference mechanisms. An example of this is shown in Figure 10. Here the user wants to see all the elements that are directly related in some way to the city Rome. This is clearly a small subset of all relationships that exist in the document. By double clicking on the node labeled Rome, the user can also see the extended relationships in which Rome is involved, this provides contextual information to the reader as shown in Figure 11. Similarly, we could seek to discover information about our composer's teacher-student lineage and perhaps even investigate in the potential for chance meeting among composers, as reflected in overlapping lifespans and work locations.

7   IMPLEMENTATION DETAILS

The prototypes described in this paper for displaying objects, attributes and their relationship were implemented in Tcl version 7.4 and TK version 4.0 [22] on Sun SPARCstations under Solaris 5.4. Some techniques for interactive manipulation of documents were implemented in the Java language [23], also on the Solaris platform. The prototypes remain under development.

8   DISCUSSION AND CONCLUSION

Electronic document representation enables presentations that borrow familiar forms from the past coupled with unprecedented flexibility. The interactive document metaphor, combined with a graphical user interface, permits the reader to tailor information presentation
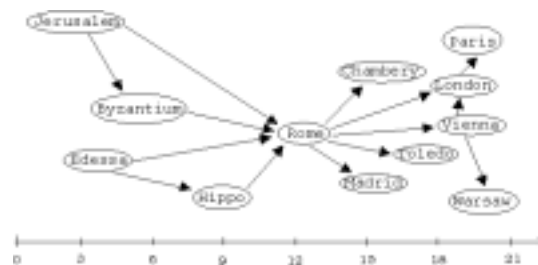

Figure 11. Direction of influence of music: Extended relationships with the focus on Rome

to enhance understanding. We have presented an object-oriented methodology for implementing abstractions and reasoning mechanisms that enables use of innovative presentation techniques in mapping abstractions onto displays.

In this paper we focused on presentation issues involved in pure electronic delivery of documents. Document specification systems such as ODA [24] and SGML combined with DSSSL [25,26] provide a strong logical structure for printed documents, which is separated to a degree from their physical appearance. Our system extends this work to electronic documents by allowing one to alter the visual or graphical presentation of the document without affecting its logical structure—in other words, the presentation can be tuned to its desired application without altering the 'database.'

The approaches described here also provide implementation of some kinds of general interfaces for information systems. A number of specific approaches using an interactive document metaphor have appeared in the recent literature [2,4,27]. Our approach generalizes the specific approaches by providing a domain-independent abstraction mechanism. This abstraction mechanism underlies our prototypes that implement interaction methods such as fisheye views [18] and the perspective wall [19].

While time provides a strong underlying dimension, it does not solve the problem of selection and structuring information as a coherent whole. There are many open and difficult challenges ranging from effective formatting to generation of descriptions of the events presented. Nevertheless, timelines can be effective and novel organizers for digital libraries of historical information.

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REFERENCES

1. R. Furuta, 'Concept and models for structured documents', in *Structured Documents*, eds., J. André, R. Furuta, and V. Quint, 7–38, Cambridge University Press, (1989).
2. R. B. Allen, 'Interface issues for interactive multimedia documents', in *Forum on Research and Technology Advances in Digital Libraries*, ed., N. Adam, et al., Springer-Verlag, (1995). Also Proceedings Digital Library Forum, May 1995, McLean, VA, pages 133-141.
3. N. Yankelovich, B. J. Haan, N. K. Meyrowitz, and S. M. Drucker, 'Intermedia: The concept and the construction of a seamless information environment', *Computer*, **21**(1), 81–96, (January 1988).
4. C. Plaisant, B. Milash, A. Rose, S. Widoff, and B. Shneiderman, 'Lifelines: Visualizing personal histories', in *Proc. ACM CHI'96*, (April 1996).
5. R. B. Allen, 'Interactive timelines as information systems interfaces', in *Symposium on Digital Libraries*, 175–180, (August 1995).
6. D. Swayne, D. Cook, and A. Buja, 'Interactive dynamic graphics in the X window system with a link to S', in *Proceedings of the Section on Statistical Graphics of the American Statistical Association*, 1–8, (1991).
7. M. E. Lesk, 'What to do when there's too much information?', pp. 305–318. ACM Hypertext, (November 1989).
8. R. Furuta, 'Documents in the digital library', in *Proc. Digital Libraries '95*, (1995).
9. O. Picher, E. Berk, J. Devlin, and K. Pugh, 'Hypermedia', in *Hypertext/Hypermedia Handbook*, eds., Berk and Devlin, McGraw Hill, (1991).

10. C. C. Marshall, F. M. Shipman, and J. H. Coombs, 'VIKI: Spatial hypertext supporting emergent structure', in *Proceedings European Conference on Hypermedia Technologies (ECHT'94)*, 13–23, (1994).

11. K. Perlin and D. Fox, 'Pad: An alternative approach to the computer interface', in *Computer Graphics Proceedings, Annual Conference Series*, 57–64, (1993).

12. B. Bederson and J. Hollan, 'Pad++', in *Proc. ACM UIST: User Interface Software and Technology*, 17–26, (November 1994).

13. P. D. Stotts and R. Furuta, 'Petri-net based hypertext: Document structure with browsing semantics', *ACM Transactions on Information Systems*, **7**, 3–29, (1989).

14. E. Tufte, *The Visual Display of Quantitative Information*, Graphics Press, Cheshire, CT, 1983.

15. E. F. Codd, *The Relational Model for Database Management: Version 2*, Addison-Wesley, Reading, MA, 1990.

16. J. Martin and J. J. Odell, *Object Oriented Methods: A Foundation*, Prentice Hall, Englewood Cliffs, New Jersey, 1995.

17. T. A. Keahey and R. Rivenburgh. HyperLINK: Visualization of WWW navigation, 1996. HyperText'96 demonstration, `http://www.c3.lanl.gov/~keahey/navigate.html`.

18. G. W. Furnas, 'Generalized fisheye views', in *Proc. ACM SIGCHI*, pp. 16–23, (1986).

19. J. D. Mackinlay, G. G. Robertson, and S.K. Card, 'The perspective wall: Detail and context smoothly integrated', in *Proc. ACM CHI'91*, pp. 173–179, (1991).

20. X. Lin, 'Graphical table of contents', in *Proc. ACM Conference Digital Libraries*, 45–53, (1996).

21. C. North, B. Shneiderman, and C. Plaisant, 'User controlled overviews of an image library: A case study of the visible human', in *Proc. ACM Conference Digital Libraries*, 74–82, (1996).

22. J. Ousterhout, *Tcl and TK Toolkit*, Addison-Wesley, 1994.

23. Sun Microsystems Inc. The Java language environment: A white paper. `http://www.javasoft.com/whitePaper/java-whitepaper-1.html`.

24. International Standard Organization. Text and office system—office document architecture (oda) and interchange format, 1989. International Standard 8613.

25. International Standards Organization. Text and office systems-standard generalized markup language, October 1986. Document Number: ISO 8879-1986(E).

26. International Standard Organisation, *Final Text, ISO/IEC CD 10179, Information Technology—Text and Office Systems—Document Style Semantics and Specification Language (DSSSL)*, 1991. ISO/IEC Draft International Standard 10179.

27. R. B. Allen, 'Two digital library interfaces which exploit hierarchical structure', in *Proceedings of Electronic Publishing and the Information Superhighway*, 134–141, (May 1995).

28. C. Harman, *A Popular History of Music*, Dell Publishing Co., New York, NY, 1969.