Geographical Interfaces to Museum Collections

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Abstract

A requirement of the user interfaces of museum information systems is to enable access to information in a geographical context. Some existing user interfaces can locate information by means of place names, and some have scanned images of maps that include interactive fixed links to related images and text. The quality of geographical aspects of user interaction could however be greatly improved in several respects. The use of structured digital map data would enable user interaction with all displayed map features as well as the implementation of a variety of spatial queries based, for example, on spatial neighborhood and on the determination of paths through transport networks. Digital map data can also be used to answer queries by presenting maps that are adapted to user needs with regard to the features displayed, the level of generalization and the annotation. There is considerable potential to enhance the range of spatial relationships that might be stored in geographical thesauri, which can be exploited in processing spatial queries in the absence of geometric data. Other challenges to further development include the maintenance of uncertainty in geographical data, and the processing of user queries that employ imprecise qualitative spatial terminology of natural language.

Keywords

geographical information systems (GIS); place names; imprecision; spatial query languages; spatial reasoning; map generalization; museums; hypermedia; user interfaces

Introduction

When accessing museums information, geography may be regarded as one of several contexts in which a query may be formulated. Much of the material maintained by museums has a geographical dimension, whether it relates to the place from which an object originates or where events took place. The need for geographical access arises therefore both in the context of collections management and in public access. Frequently the available geographical data are in the form of place names attached to objects and contained within documentary records. Some geographical data may also be in the form of maps which record natural or artificial features or the location of events. When present in museums however, maps are rarely available in a digital format that enables their content to be accessed with flexibility from an interactive user interface.

At present, for purposes of information retrieval, place names may be recorded in relational databases and used for matching with names that form part of a query. The processing of database queries that include place names can be facilitated by the use of geographical thesauri (Rahard, 1990; Harpring, 1992, 1997) which assist in translating between different versions of place names or in traversing the different levels of a spatial hierarchy (e.g. country, province, county etc.). Thesauri clearly have an essential role to play in the development of the geographical component of a user interface, but there is still a long way to go in creating comprehensive thesauri, and in encoding and exploiting what could be a rich set of spatial relationships between the named places.

Maps are sometimes employed as part of a user interface in a museum information system, but they are usually quite limited in their functionality. Typically they are in a scanned (raster) format, possibly with some highlighted symbols, or hot spots, superimposed. Clicking on a hot spot may result for example in the display of a related image or video, or a piece of text. This type of map interface appears quite crude and inflexible when compared to the use of digital maps in geographical information systems (GIS). When maps are encoded in vector geometry format, as is usually done in GIS, all features on the map become distinguishable and controllable in their graphic symbology and annotation. Thus it becomes possible to change the content and scale of an individual map and hence adapt it to suit the user's interests. The map becomes a potentially powerful element in the user interface, in that the user interacts with it to ask questions and to receive answers. Commercial GIS often include a range of spatial analytical tools that can provide the answers to queries regarding quite complex spatial relationships of neighborhood, coincidence and accessibility. Such functions could undoubtedly be exploited as part of the user interface of museum information systems, in which user queries could combine specification of subject matter with geographical (and temporal) context.

It may be remarked however that GIS in their current form exhibit several weakness when considered in the context of museum information access. In particular they have limited capacity to exploit geographical thesauri; to maintain information in time; to maintain incomplete and imprecise geographical data; and to process queries that are framed in terms of the imprecise qualitative spatial expressions that we use in natural language. In the remainder of this paper several aspects of the interactive and graphic presentational functionality of current and emergent GIS are reviewed, with regard to their potential for enhancing the capability of museum information systems. Specific topics that are addressed include the current state of spatial query languages; the potential for qualitative spatial reasoning in the user interface; and the capacity for dynamic display and annotation of geographical information at different levels of generalization.

Exploiting Geographical Information Systems Technology

Conventional GIS usually include several information search and query facilities that could be expected to be of use in a museums context. The main types of query that have obvious application in museums include those based on one or more of: location; phenomenon; neighborhood; and paths.

Location-based queries allow the user to ask what phenomena are to be found at a given location. There are several ways in which location could be expressed. Location may be described in terms of a spatial window that may be a rectangular region which the user either specifies in terms of map or geographical coordinates, or creates interactively by drawing, moving and scaling a rectangle on the screen. The assumption is that the display may start with an overview map onto which the user specifies a window of interest. Another way of defining location in a GIS is to give the name of a region, such as a country or a county, the geometric boundary of which may be used to define the region of interest. Alternatively the user might name a settlement on which a rectangular retrieval window (of possibly arbitrary extent) may be centered.

Phenomenon-based queries allow the user to specify categories of information that are of interest. The GIS then retrieves the locations of all occurrences of those phenomena. At its simplest level the user could specify a single phenomenon, such as 'iron-age hill forts', in which case all stored occurrences of them might be retrieved and displayed on a map. Alternatively a more complex retrieval expression may be formulated, in which the user expresses interest in a combination of phenomena that are coincident. For example 'bronze-age sites on south facing slopes with chalk geology above 500 meters elevation'. Phenomenon-based queries appear similar to the type of query that may be formulated with a conventional (non-spatial) database, in which it is possible to specify a logical combination of categories with constraints upon their values. The difference is that locational data are retrieved, and they may be constrained by spatial relationships.

Phenomenon-based queries are often combined with a specification of neighborhood or proximity. Neighborhood queries are typically defined either in terms of distances from a given phenomenon or in terms of adjacency with regard to a given phenomenon. Taking the former case, the user may ask for all objects of a particular category that are within 5km of a specified place such as a settlement, or a specified point (coordinate) on a map. For example 'retrieve all recorded occurrences of roman coins found within 10km of the center of Cirencester'. Distance-constrained neighborhood searches are usually implemented with respect to stored features represented geometrically by points, lines or areas. They are sometimes referred to as *buffer queries* because they involve constructing a geometric buffer representing the region of space within the specified distance of the given spatial object.

The other main type of neighborhood query is one based on adjacency or connectivity with a given object. For example 'retrieve the location and the owners of the land bordering property owned by the Duke of Norfolk in 1838'. Efficient processing of such queries depends upon the storage of topological data encoding the connectivity between lines, and the areas that are bounded by linear features (such as property boundaries).

The main type of path-based query is that in which the user wishes to find the 'least-cost' route between two or more specified places. Assuming that the route is via a network of roads, such queries depend upon the existence of a topologically structured network, in which the connectivity between each segment of the network is explicitly recorded. Network data structures can be exploited to answer particular types of neighborhood query, in which distance is to be measured along a transport network. Network distances can also be transformed to travel times, so that the user could ask to 'retrieve the locations of all settlements within 12 hours travel on horse back'.

QUERY INTERFACES IN GIS

Implementation of query interfaces that provide access to geographical information is distinguished by the need of the user to refer to regions of space and to spatial relationships between phenomena of interest. Some commercial GIS and a number of experimental GIS provide the user with a command language that resembles, to varying degrees, the SQL query language available with most relational databases. By itself this provides a purely command-driven interface, based on the SELECT, FROM, WHERE construct of SQL. The commands may be issued either by typing text or selecting elements of the query from menus, perhaps within a fixed sequence of operations. The GIS command languages differ from standard SQL however in providing constraints within the WHERE clause that are based on spatial regions and spatial relationships. Thus it may be possible to specify a rectangular spatial window and relationships such as *inside*, *adjacent* and *distance* may be supported. An example of the use of this style of spatial query would be the following, based on facilities available in Egenhofer's (1991a) SpatialSQL, which is an experimental system:

```
SELECT site.name, site.geometry
FROM site, county
WHERE site.type = roman and
        county.name = 'Gloucestershire' and
        site.area > 1000 and
        site.geometry inside county.geometry.
```

The results of such a query might be displayed on the computer screen and the user would also normally expect to be able to specify the graphic symbology that was to be used.

Some GIS provide a query mode which mixes the use of a textual, or menu-driven, command language with interactive graphics in which the user is able to select objects of interest that are displayed, and then to include those objects within a query. At the simplest level, this would enable the user to select a displayed object by pointing to it, then to enquire about its attributes, perhaps including the display of an associated photograph, or running of a video. For a more geographical example, the user might point to a river displayed on the screen and then formulate a query to search for objects of a given class (say finds of flint tools) that were recorded at locations within a given distance of the currently selected object (i.e. the river). Having answered the query, the results might then become the currently selected objects, which could themselves be referred to in a subsequent query.

It may be noted that the latter type of interaction, which is currently available in some commercial GIS, may be regarded as a significant enhancement to the relatively familiar style of hypermedia interface in which the user selects one of what may be a very limited number of hot spots, and is then given an associated piece of information, the content of which they may have no control over. Note that in the GIS-style interface, all displayed features could be expected to be subject to interactive interrogation and manipulation.

As indicated previously, conventional GIS do however lack some features that are important for museum information access. Notably, they are not able to exploit geographical thesauri to raise the intelligence of the user interface with regard to recognizing alternative versions of place names, or place names at different levels of spatial generalization. An essential requirement of GIS in museums is that information be located in time as well as space. At present most GIS do not provide explicit control of the temporal dimension, as has been emphasized by Signore et al (1995). In an effective spatio-temporal geographical database, all representations of geographical phenomena would be associated with a temporal interval. It may also be necessary to distinguish between 'real world' time (or 'valid time') that relates to when documented events took place, and 'database time' (or 'transaction time'), which records the time at which updates to an information system take place (Snodgrass, 1992).

GIS are also weak with regard to their capacity to process qualitative descriptions of spatial relationships. Thus, although as we have seen above, certain spatial relationships such as *inside* and *adjacent* may be supported, other less precise relationships are not available. These include terms such as *between, north, in front* and *in the vicinity*. The ability to process such descriptions could be useful in user interfaces and as part of data input procedures for historical, non map-based, records.

GEOGRAPHICAL THESAURI AND QUALITATIVE SPATIAL RELATIONSHIPS

In the GIS research community, the problems of reasoning with qualitative spatial and temporal relations have been the subject of investigation for several years (Mark and Frank 1991; Frank and Kuhn 1995; Egenhofer and Mark 1995; Jones and Luo 1994). In the museum domain it may envisaged that developments in this area could be exploited in the creation of highly versatile geographical thesauri that could store proximal, directional and adjacency information in addition to the present, usually sole, spatial relationship of containment, as expressed in hierarchies. The development of such a thesaurus is a considerable challenge, particularly due to the need to handle the uncertainty associated with some types of qualitative relations, and the uncertainty in the nature of historical geographies (Signore and Bartoli, 1990).

The motivation is considerable however, since having created a spatially-rich thesaurus it could be employed both in command-driven query languages and in interactive hypermedia. In command-driven queries the thesaurus would assist in translating between the user-provided description of a place and similar names stored in the information system, and in retrieving associated places that were related through a variety of spatial relationships. Such retrieval might be performed in the absence of geometric map data, while providing some of the functionality associated until now only with GIS technology. It may be envisaged that different levels of spatially-constrained geographical functionality might be provided depending upon the presence or absence of digital map data. In a hypermedia interface the geographical thesaurus could be used to provide typing of the links between stored objects, both with regard to different versions of the same name and to spatial relationships with other names. On selecting a displayed object, the user could then qualify their interests with regard to particular spatial relationships with the selected object.

An example of an experimental implementation of spatial relationships of containment and of adjacency, in the context of hypermedia, is to be found in the Semantic Hypermedia Architecture (SHA) described in Taylor et al (1994) and Jones et al (1995a). Here these spatial relationships were combined with conceptual and temporal relationships and were implemented as implicit links maintained in a semantic database. The approach has assisted in implementing navigation strategies that support imprecise matches between the user's specification of their interests, and the identification of the stored media items (Tudhope et al, 1995; Tudhope and Taylor, 1997).

TYPES OF QUALITATIVE SPATIAL RELATIONSHIP

Spatial relationships can be categorized broadly into those based on topology, proximity (or neighborhood) and orientation. A further category of size is sometimes also included. It may be envisaged that ideally all of these types of spatial relationships could be supported for purposes of geographical information access.

Topological relationships

Topological relationships are concerned with concepts of connectivity between the boundaries of spatial objects. They are independent of orientation. If a distinction between the interior, boundary and exterior of an object is established, it is possible to enumerate a set of possible topological relations between a pair of objects based on the intersection of their respective interior, boundary and exterior. These relations are *inside, covers, equivalent, meet, overlap* and *disjoint*. Inside is the case in which both the interior and the boundary of one object are entirely enclosed by the boundary of the other. Covers is an inside situation in which the boundary of the contained object coincides in part with that of the containing object. Equivalent refers to the case where the two boundaries are exactly the same. Meet is the situation in which there is no intersection between the interiors of the two objects, but part of their boundaries are coincident. Overlap is the case in which the boundary of one object crosses the boundary of the other, such that part the interior of one object is inside the other while the other part is outside. Disjoint is the case in which the objects are entirely separate such there is no intersection of either their interiors or their boundaries. This description of topological relationships is referred to as the 9-intersection model and is described in Egenhofer (1991b) and Egenhofer and Franzosa (1991).

Proximity relationships
Proximity relations when expressed quantitatively consist of a distance relative to a specified object. The distance may be regarded as measured in straight lines, which corresponds to the buffer zones referred to earlier in the context of GIS. Alternatively it may be measured along a network. In natural language we frequently use qualitative descriptions of distance, chiefly through the use of the terms *near (or close)* and *far* and qualifications thereof. Clearly these proximity terms are context dependent. They depend upon the scale and the distribution of the phenomena to which we are referring and the means by which we may travel from one place to another. For example we may be referring to phenomena at the scale of a single room, a building, a neighborhood, a city, a state, a continent, the earth or the universe. If phenomena are distributed sparsely, we may regard an object as nearby because it is nearer than most other objects. Given a different density of distribution, the same object might appear distant. This effect results in the possibility of perceived distances between two places becoming asymmetric, depending upon the place in which the observer is located.

ORIENTATION

The interpretation of descriptions of orientation, unlike topology, and to some extent proximity, depends critically upon the frame of reference. Three types of frame of reference may be distinguished: *extrinsic*, *intrinsic* and *deictic* (Hernandez, 1991). Extrinsic frames of reference are external to the objects being referenced. Probably the most common external frames of reference are magnetic north and north relative to the earth's axis. They give rise to the cardinal directions of north, south, east and west and their combinations. Intrinsic frames of reference refer to inherent properties of an object that are used to orient it. Thus objects such as houses and cars are regarded as having a front and a back that depend upon the form and structure of the object and they do not change when the orientation of the object changes with reference to an external frame of reference. Intrinsic frames of reference give rise to orientation terms such as *front, back, behind, side, above* and *below*.

Deictic frames of reference are determined by the orientation of an observer. Thus in describing the location of objects in a scene, an individual may use terms such as in front, left, and above and they must be interpreted relative to the current orientation of the observer of the scene. Note that in a description of a scene, both intrinsic and deictic terms could be employed. For example 'The stone was on the left hand side of the square, in front of the white house'.

AUTOMATED REASONING WITH QUALITATIVE SPATIAL RELATIONSHIPS

If we create a geographical thesaurus in which place names are associated with each other by a set of spatial relationships, then the thesaurus may be used to deduce spatial relationships that are implied by the explicitly stored relations. This facility is provided by existing thesauri in which hierarchical relationships of spatial containment are stored. Thus if we know that place A is inside place B and place B is inside place C then we can deduce that place A is also inside place C. Hence if the user enquires about place C, they may be provided with information about the contained places, which include place A. If the relationship of meet or adjacency were also to be recorded, between regional features, such as 'D adjacent to C', then an enquiry about places nearby to D could deduce that places A and B may be of interest because they are contained within the adjacent region C. Given the set of topological relationships, it is possible to build a composition table (Egenhofer, 1991b) which records the definite and possible relationships that may be deduced about A and C, given a pair of topological relations R(A,B) and R(B,C).

The potential for spatial reasoning has been demonstrated at a theoretical level at least for topological relationships. The qualitative orientation and proximity relationships also lend themselves to automated reasoning. For example, if A is north of B and B is north of C then A is north of C. Unfortunately, such rules cannot be guaranteed to work since, as discussed in more detail below, our understanding of the meaning of these relations is rather imprecise, such that composing pairs of relationships that may themselves be at the limits of certainty, may result in deduced relationships that are quite unreliable. For descriptions of some techniques for spatial reasoning with proximity and orientation relations see for example (Frank, 1992; Freksa, 1992; Hernandez, 1993).

Imprecision and Uncertainty in Spatial Objects and Spatial Relationships

It appears in principle at least to be desirable to allow users of a museum information system to express queries to the system in terms of named places and of qualitative spatial relations. These might be employed in a formal query, requiring a specific item of information, or in the course of browsing through the information space, in which the user wished to control the navigation with regard to geographic space.

Effective implementation of a user interface that recognized a variety of qualitative spatial relations would however need to take account of the imprecision associated with the naming of places and of the imprecision in many of the commonly used qualitative spatial relationships. When uncertainty is taken into account, the description of topological relationships provided above appears somewhat simplistic in that it appears to assume that it is possible to make a clear distinction between interiors and boundaries of geographic phenomena. In the case of much geographical information this is not so. There are several reasons for this.

Boundary uncertainty

Many geographical phenomena do not have precise boundaries. Thus areas defined by vegetation types tend to merge into each other, as one species starts to dominate over another. Topographic regions that we may often refer to, such as the Rocky Mountains or South Wales, can be defined quite subjectively with no universally agreed boundaries.

Geometric data error

An associated problem is that the geometric components of geographical data defining the boundaries of phenomena are invariably subject to error. This arises for a variety reasons that includes error in the source of information, which is often in the form of a map, and error in the process of digitizing the data. A consequence of these errors is that any topological relationships that may have been derived from geometric digitized data must be subject to error. Blakemore (1984) has highlighted the very serious errors in spatial containment that can arise when using a GIS to determine which areal regions contain each of a set of point locations. The problems are a direct consequence of the error in the boundaries of the digitized regions, such that if a point is located within one of the bands of error associated with the linear boundaries, there is a high probability of the point being allocated to the wrong region because the boundary is not correctly located in its digital representation.

Temporal Change

The problem of uncertainty in the definition of specific phenomena is compounded by the fact that the extent of natural and man-made phenomena is subject to change over time, due for example to change in the dominance of vegetation species or to urban growth or degeneration. It could be envisaged that the user might make an enquiry using their current understanding of the geographic extent associated with a place name, where that extent had changed significantly over time. For example "tell me about Celtic crosses found in Dublin". It is quite possible that finds of Celtic crosses might in the past have been recorded with a place name of a settlement, which is now a part of Dublin, but which was not at the time of the find. Geographical thesauri as described by Harpring (1997) can be expected to include hierarchical relations of containment, that would allow this particular query to be processed successfully.

Ambiguities could arise however if it is not made clear whether the user is referring to the modern extent of a topographic place or the extent at the time of an historical event. For a thesaurus with containment relationships to be used reliably for historical information retrieval, all spatial relationships such as contain (inside) and adjacent, would need to be qualified with their temporal extent. This could be in the form of a temporal interval, recording the start and end dates over which the spatial relationship was known to be valid. Hence there would need to be multiple representations of spatial relationships to reflect their change over time.

UNCERTAINTY IN ORIENTATION AND PROXIMITY

As was indicated above, qualitative descriptions of proximity are essentially imprecise, partly due to their contextual dependence upon scale and the pattern of distribution of phenomena. Similarly, the terminology of orientation and direction is imprecise. When we express an interest in things to the south of a town, we may be referring to a zone which is at least as wide as the town and extends both east and west with increasing distance from the town. Implicit in the expression of interest may be a sense of proximity which might be determined approximately by the size of the town. When we express an interest in locations *between* two named towns, it may be envisaged that we are interested in locations within a sausage-shaped zone the width of which is related to the size of the towns, and which might be somewhat wider in the middle distance between the two towns.

There have been several efforts to formalize the definition of qualitative spatial relations for purposes of interpreting them in information system queries. See for example Dutta (1991) and Gahegan (1995) who have used fuzzy set theory to provide interpretations of topological and of proximity terms respectively. Abdelmoty and El-Geresy (1994) have presented a scheme for defining the meaning of the cardinal directions in a manner which adapts to the extent of the objects of interest.

Such quantifications may well assist in providing an initial interpretation of a user query. If a graphical, map-based user interface is employed, ambiguity can be resolved by prompting the user to modify the geographical extent of an enquiry by pointing to features on the map, which may become the subject of a further query, and by changing the scale and the extent of the displayed map features. Currently displayed features may thus be used as part of a process of query refinement.

DYNAMIC MAPS AND MULTISCALE ACCESS TO GEOGRAPHICAL INFORMATION

The ability to zoom in and out of a map and to change the contents in response to user interaction has the potential to enhance greatly the degree of interactivity and the efficiency with which the user is able to locate information of interest. In most existing GIS, a request to change the scale of a map results in a purely geometric operation, whereby the map is shrunk or blown up, depending on the direction of scaling. In some systems a facility is provided to control which features should appear at particular scales, in an effort to avoid the clutter that may result from reducing the scale of the map without changing its content.

Published maps at different scales are the outcome of a manual process of cartographic generalization. This involves modifications to the level of detail and the choice of features that are to appear, which are in turn determined by the scale of the map (and hence the space available) and the purpose of the map. Cartographic generalization is a relatively complex process of information abstraction in which the symbolization of displayed features may be modified to ensure clarity and legibility.

There is considerable interest in automating the process of cartographic generalization, but at present only limited degrees of automation have been demonstrated (Muller et al, 1993; Weibel, 1995). In GIS applications in which there is a need to display information at very different scales, several versions of the map data may be stored, having been derived by digitizing manually-generalized maps. As the user specification of scale changes, so the presented map data may swap from one representation to another. As a consequence there may not be a smooth transition between all scales, and the content of the map may not be well adapted to the particular user's need because it is based on a prior process of generalization. There is therefore considerable motivation in developing multiscale geographical data access schemes in which the generalization process is performed on the fly in direct response to user needs.

Implementation of a flexible multiscale access scheme may be regarded as a combination of processes of data retrieval, and of online simplification and conflict resolution. A number of multi-resolution spatial data access methods have been developed (van Oosterom, 1993; Becker et al 1991; Jones et al, 1996). They are in general based on the principle of categorizing the constituent point geometry of spatial objects according to differing levels of scale significance or priority. Provided the original ordering of the geometric points is maintained, a subset of points may be retrieved and a simplified version of the object generated. For linear features, the selection of points of differing levels of priority is carried out by means of line generalization algorithms such as the Douglas and Peucker (1973) algorithm, which can be used to label points in terms of their local perpendicular displacement from a higher level approximating line.

The geometric processes of manual generalization consist of a set of operations that include line simplification, areal object simplification and the elimination, amalgamation and displacement of map objects. The existing multi-resolution data structures encode the results of line simplification, but not the other tasks. An important characteristic of map generalization is that the appropriate transformations of the map features depend upon the particular combination of features. Thus areal objects of similar class that are too close to each other may need to be amalgamated, while for example linear features of different class that are too close may need to be displaced away from each other to maintain graphic clarity. If the content of a map in terms of the classes of phenomena and the annotation are to be selected in direct response to user actions, then the actual combination of graphic elements can only be known at the time the map is created, and hence processes such as amalgamation and displacement should ideally only be performed as the map is being displayed.

Efficient execution of these tasks on the fly will depend upon rapid evaluation of local graphic conflicts. This requires fast search procedures to find the nearest neighbors to displayed objects and to determine the separation distances between neighbors. Spatial indexing methods, such as those based on quadtrees (Samet 1990a, 1990b), are designed to support fast computation of neighborhood relations from geometric data, though they do not in themselves contribute to the implementation of the individual generalization operations such as amalgamation and displacement. Recent work on the use of triangulated spatial data structures appears to hold promise in implementing dynamic automated map generalization since the triangulation can be used both for efficient proximal search and for determining solutions to the graphic transformations required in the process of generalization (Jones et al, 1995b).

AUTOMATED LABELING OF MAP DISPLAYS

An aspect of map generalization which is sometimes isolated as a problem in its own right is that of labeling the map automatically in a manner that ensures legibility. Until recently it has been a major shortcoming of most GIS that, though they can be used to create maps consisting of arbitrary combinations of map features, the associated labels have been generated in a way which does not attempt to preserve legibility. Frequently labels will overlap each and overlap other important map features obscuring both the labels and parts of some map features. Automated labeling requires a search procedure to find positions for the labels such that they do not overwrite each other and that they do not obscure important graphic features (Freeman and Ahn, 1984; Jones, 1990; Christensen et al, 1995).

Automated text placement has particular importance in public museum information systems. Not only does it allow the display of legible maps that are adapted to user interests, but it allows the possibility of changing the language used in map annotation, while maintaining legibility. This is clearly relevant to cultural heritage information systems, that should ideally be able to address the needs of users in several different languages.

CONCLUSIONS

Because so much of the data maintained by museums has a geographical dimension, there is a strong motivation to provide facilities at the user interface of museum information systems that allow the user to frame queries in terms of named geographical phenomena and of spatial relationships between them. At present the facilities for geographical information access are largely confined to limited exploitation of place names and of relatively static map images that may provide fixed link associations with other text or images.

Several types of geographical query facility that would be of use, both for collections management and for public access, are to be found in current geographical information systems technology. Most commercial GIS employ digital map data in which all features are individually identified and represented by geometric data. This provides flexibility in the user interface, in which all displayed features may be subject to user interrogation and in which the user may employ a query language with spatial extensions to enable them to specify their interests in terms of spatial relationships to named, or interactively selected, places and features.

A characteristic of much of the existing geographical data in museums is the emphasis upon the use of place names to reference information. GIS are at present limited in their capacity to recognize different versions of place names and in their capacity to answer queries expressed in terms of imprecise qualitative spatial relations. In particular there is a need to take account of the change in the associated form and the geographical meaning of place names over time. Geographical thesauri have considerable potential to maintain information on different versions of place names and on the associated spatial relationships. They may be used therefore both in conjunction with GIS technology and in support of hypermedia.

It is suggested here that there is considerable potential to build upon the idea of a geographical thesaurus by expanding the range of qualitative spatial relationships between named places. Thus in addition to containment relationships, it is possible to envisage supporting other topological relationships of adjacency and overlap between different types of map features, as well as orientation relationships. The latter could include the directions of north, south, east and west, and perhaps, in the context of large scale phenomena, relationships such as in front, behind, above and below. Such thesauri could then be exploited to implement more intelligent geographical user interfaces with greater flexibility in deducing spatial information, ideally taking account of the imprecise nature of topographic names and of qualitative spatial relationships. The presence of sophisticated geographical thesauri would thus assist in the implementation of spatially-directed navigation of information in the absence of stored geometric map data.

It is envisaged that, when digital map data are employed, greater emphasis may be placed on the use of dynamic map displays in which the quality of user interaction could be greatly enhanced compared with existing facilities. To do this requires further improvement in the technology for online modification of the level of generalization with which cartographic data are displayed. It also requires that full advantage is taken of facilities for automated labeling of map displays to ensure that the text content is clearly legible and is adapted both to user interests and to the user's language.

REFERENCES

Abdelmoty, A. I. and B. A. El-Geresy, "An intersection-based formalism for representing orientation relations in a geographic database", *Second ACM Workshop on Advances in Geographic Information Systems* (Gaithersburg, Maryland, ACM Press, 1994), 44-51.

Becker, B., H.-W. Six and P. Widmayer, "Spatial priority search: an access technique for scaleless maps", *ACM SIGMOD* 20(2) (1991), 128-137.

Blakemore, M. , "Generalization and error in spatial databases," *Cartographica* 21 (1984): 131-139.

Christensen, J., J. Marks and S. Shieber (1995), "An empirical study of algorithms for point-feature label placement," *ACM Transactions on Graphics* 14(3): 203-232.

Douglas, D. H. and T. K. Peucker (1973), "Algorithms for the Reduction of the Number of Points Required to Represent a Digitized Line or its Caricature," *The Canadian Cartographer* 10(2) (1973): 112-122.

Dutta, S., "Qualitative spatial reasoning: a semi-quantitative approach using fuzzy logic", In A. Buchmann, O.Gunther, T. Smith and Y. Wang (eds), Symposium on the Design and Implementation of Large Spatial Databases, *Lecture Notes in Computer Science*, 409 (Springer-Verlag, 1989), 345-364.

Egenhofer, M. J., "Extending SQL for cartographic displays," *Cartography and Geographic Information Systems* 18 (1991a): 230-245.

Egenhofer, M. J., "Reasoning about binary topological relations", In O. Gunther and H.-J. Schek (eds), Advances in Spatial Databases: Proceedings of the 2nd Symposium on the Design and Implementation of Large Spatial Databases (SSD'91), *Lecture Notes in Computer Science*, 525 (Springer-Verlag, 1991b), 143-160.

Egenhofer, M. J. and R. Franzosa, "Point-set topological spatial relations," *International Journal of Geographical Information Systems* 5(2) (1991): 161-174.

Egenhofer, M. J. and D. M. Mark, "Naive Geography", In A. U. Frank and W. Kuhn (eds), Spatial Information Theory A Theoretical Basis for GIS. 988 (Berlin: Springer, 1995), 1-15.

Frank, A. U., "Qualitative spatial reasoning about distances and directions in geographic space," *Journal of Visual Languages and Computing* 3 (1992): 343-371.

Frank, A. U. and W. Kuhn, (eds), Spatial Information Theory A Theoretical Basis for GIS, *Lecture Notes in Computer Science*, 988, (Berlin: Springer, 1995).

Freeman, H. and J. Ahn, "AUTONAP - an expert system for automatic name placement", *First International Symposium on Spatial Data Handling*, (Zurich, International Geographical Union, 1984), 544-569.

Freksa, C., "Using orientation information for qualitative spatial reasoning", In A. U. Frank, I. Campari and U. Formentini (eds), Theories and Methods of Spatio-Temporal Reasoning in Geographic Space. *Lecture Notes in Computer Science*, 639, (Berlin: Springer-Verlag, 1992), 162-178.

Gahegan, M., "Proximity operators for qualitative spatial reasoning", In A. U. Frank and W. Kuhn (eds), Spatial Information Theory A Theoretical Basis for GIS, *Lecture Notes in Computer Science* 988, (Berlin: Springer, 1995), 31-44.

Harpring P., "The Thesaurus of Art-Historical Place Names (TAP)", *Visual Resources Association Bulletin*, 19(3) (1992): 26-32.-

Harpring P., "Proper words in proper places: the Thesaurus of Geographic Names", *MDA Information* 2(3) (1997): 5-11.

Hernandez, D., "Relative representation of spatial knowledge: the 2-D case", In D. M. Mark and A. U. Frank (eds), *Cognitive and Linguistic Aspects of Geographic Space* (Dordrecht: Kluwer Academic, 1991), 373-385.

Hernandez, D., "Maintaining qualitative spatial knowledge", In A. U. Frank and I. Campari (eds), Spatial Information Theory (COSIT'93). *Lecture Notes in Computer Science,* 716, (Berlin: Springer-Verlag, 1993),36-53.

Jones, C. B., "Conflict resolution in cartographic name placement," *Computer-Aided Design* 22(3) (1990): 173-183.

Jones C.B., P. Beynon-Davies, C. Taylor and D. Tudhope, "GIS, Hypermedia and Historical Information Access", *Proceedings Seventh International Conference of the MDA*, (The Museum Documentation Association, 1995a), 109-113.

Jones, C. B., G. L. Bundy and J. M. Ware, "Map generalization with a triangulated data structure," *Cartography and Geographic Information Systems*. 22(4) (1995b): 317-331.

Jones, C. B., D. B. Kidner, L. Q. Luo, G. L. Bundy and J. M. Ware, "Database design for a multi-scale spatial information system," *International Journal of Geographical Information Systems* 10(8) (1996): 901-920.

Jones, C. B. and L. Q. Luo, "Hierarchies and objects in a deductive spatial database", *SDH'94 Sixth International Symposium on Spatial Data Handling, Edinburgh*, Vol 1, (International Geographical Union, 1994), 588-603.

Mark, D. M. and A. U. Frank, (eds), *Cognitive and Linguistic Aspects of Geographic Space*, (Dordrecht/Boston/London: Kluwer, 1991).

Muller, J.-C., J.-P. Lagrange and R. Weibel, (eds), *GIS and Generalization Methodology and Practice*, (Taylor and Francis, 1995).

Rahard M., "Developing and using a geographic names thesaurus for a multidisciplinary database", in D.A. Roberts (ed) *Terminology for*

Museums (The Museum Documentation Association, 1990), 159-162.

Samet, H., *The Design and Analysis of Spatial Data Structures* (Addison-Wesley, 1990a).

Samet, H., *Applications of Spatial Data Structures: Computer Graphics, Image Processing and GIS* (Addison-Wesley, 1990b).

Signori O. and Bartoli R., "A case study for historico-geographical authority", in D.A. Roberts (ed) *Terminology for Museums*, (The Museum Documentation Association, 1990), 150-158.

Signore O., G. Fresta and M. Loffredo, "A distributed hypermedia on archaeology in Tuscany", *Proceedings 3rd International Conference on Hypermedia and Interactivity in Museums: Multimedia Computing and Museums* (ed. D. Bearman), (San Diego, October, 1995), 1-18.

Snodgrass R.T. "Temporal databases", in A.U. Frank, I. Campari and U. Formentini (eds) Theories and Methods of Spatio-Temporal Reasoning in Geographic Space, *Lecture Notes in Computer Science* 639, (1992) 22-64.

Taylor C., D. Tudhope, and P. Beynon-Davies "Representation and manipulation of conceptual, temporal and geographical knowledge in a museum hypermedia system", *Proceedings ACM European Conference on Hypermedia Technology* (Edinburgh, 1994), 239-244.

Tudhope D., C. Taylor and P. Beynon-Davies, "Taxonomic distance - classification and navigation", *Proceedings 3rd International Conference on Hypermedia and Interactivity in Museums: Multimedia Computing and Museums* (ed. D. Bearman) (San Diego, October, 1995), 322-334.

Tudhope D. and C. Taylor, "Navigation via Similarity: automatic linking based on semantic closeness", *Information Processing and Management*, 33(2) (1997), 233-242.

van Oosterom, P., *Reactive Data Structures for Geographic Information Systems* (Oxford, Oxford University Press, 1993).

Weibel, R. (ed), Map Generalization. Special Issue of *Cartography and Geographic Information Systems*, 22(4) (1995).