HIERARCHICAL CELLS COMPLEXES

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Multipurpose Geographic Information Systems (GIS) offer considerable cost savings due to the sharing of data acquisition and maintenance efforts among several user groups. However, the requirements for such GIS become more complex as the system has to satisfy the demands of more than one user group. Typically, in multipurpose GIS very small spatial objects (e.g. parcels) coexist with very large ones (e.g. nations). Queries will therefore be asked over a large range of scales. A system satisfying these requirements must be able to handle spatial objects efficiently independent of their size and must support the modeling of objects in several spatial resolutions.

Topological data structures have become an accepted method for modeling spatial objects, with cells being the fundamental units of which objects are composed (8), (14), (11), (4), (10). Known topological data structures offer only a single degree of spatial resolution for modeling objects (5). Displaying objects in different resolutions is therefore difficult. In topological data structures, relatively large objects are typically composed of a large number of cells and their representation therefore requires a large amount of data. This causes their handling to be slow and inefficient (12). For these reasons, present topological data structures need to be improved for the implementation of multipurpose GIS with their large range of object sizes.

While the detail of present topological data structures is necessary for small scale queries, a multipurpose GIS has to include additional representations that reflect certain properties of the objects in less detail in order to provide for efficient medium and large scale queries. In these representations, the amount of data describing an object is typically small. The objects can therefore be handled efficiently. If the query processing accesses the most appropriate representations, the system response time is independent of the size of the objects.

Additional representations are normally tailored to a specific set of queries. Its data can be derived from the original representation and is therefore redundant. This situation is a special case of multiple representations. The National Center for Geographic Information and Analysis (NCGIA) currently undertakes a research initiative to investigate problems of multiple representations (6).

An example for such an additional representation are lattice structures which organize the spatial inclusion relationships between objects (13). This paper introduces the concept of additional topological data structures.

The structure consists of a set of topological data structures which form a tightly ordered structure. This ordered structure can be thought of as a number of graduated, step-like levels forming a pyramid-like topological representation. The lowest level contains all spatial objects and thus corresponds to a present topological data structure. Higher levels contain only subsets of objects of the next lower levels. Thus, the number of objects, the number of topological cells, and the amount of data per spatial object decreases with increasing level. The position of an object within the pyramid is determined by its size and importance. The top level contains only the largest and most important objects. The

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decision concerning an object's placement within the pyramid can be made for classes of objects, as well.

The structure is managed by a query optimizer which accesses the highest levels possible for a specific query. Because the number of cells per object is much smaller on higher levels, all the queries can be processed much faster. Queries such as "find all neighboring states of Maine" or "display the state of Maine" can be processed approximately in the same time as the same queries involving small objects such as parcels.

Of course, the redundant structure automatically has to be kept consistent. For this reason, topological cells (edges, areas, volumes in 3-d) of adjacent levels are related hierarchically. In contrast to formerly proposed applications of hierarchical structures in GIS, the spatial objects themselves do not have to be hierarchically related (7), (2), (3). Looking at 2-dimensional cells, i.e. edges, the hierarchical structure is very similar to that of a strip-tree and is therefore very well suited for modeling objects (i.e. their boundaries) in several spatial resolutions (1). In smaller resolution, a polygonal line is approximated by a straight line segment. A "strip" around this line segment encloses the polygonal line. Its dimensions indicates the maximal error introduced by the approximation. Using this possibility to model objects at different spatial resolution provides for fast display of relatively large objects in appropriate detail.

The proposed structure extends the potential of topological data structures, such that a large range of object sizes can be handled efficiently. The objects can be modelled at different spatial resolution. The structure is therefore very well suited for the implementation of multipurpose GIS.

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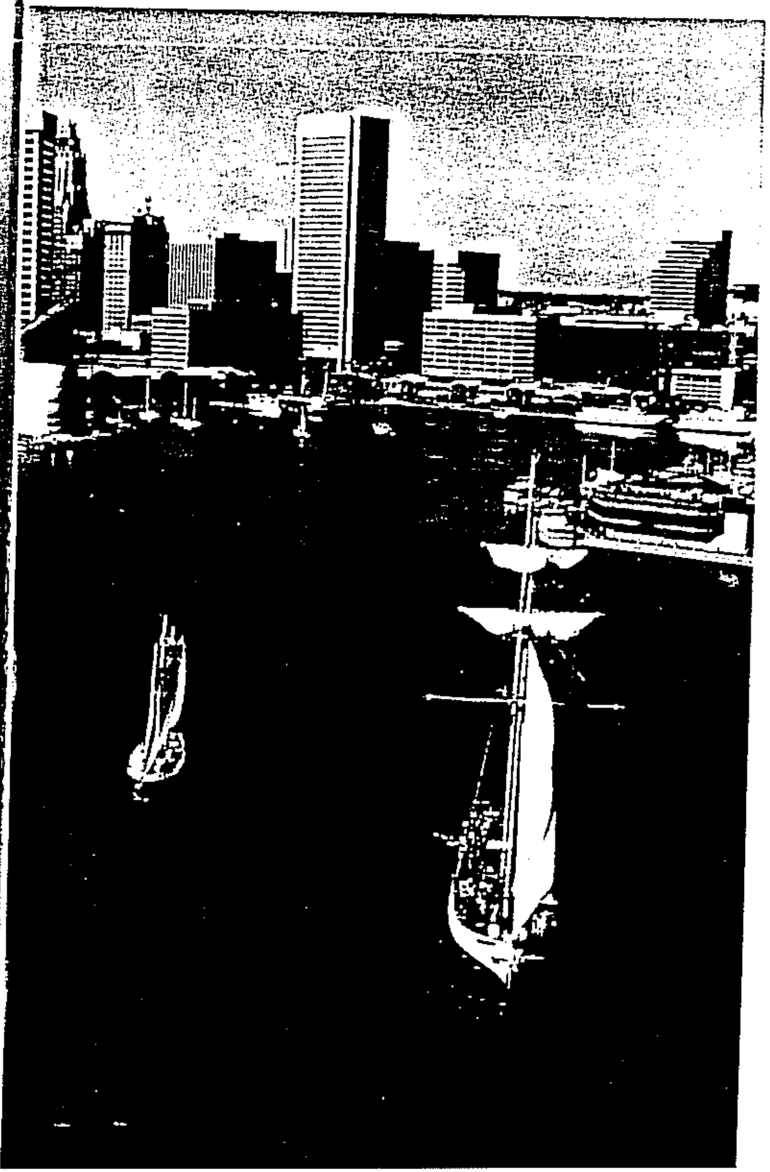

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