Dimensionality of spatial data

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Abstract: *For many GIS application, a key assumption is that all spatial data handled are referenced to a 2-D cartesian coordinate system. This convention restricts the scope for mapping the vertical dimension over terrains or within the earth, oceans or atmosphere, since this third dimension must be covered to an attribute and expressed in 2-D as a line or zone with a constant value. Now, attention is focusing on the design and implementation of 3-D GIS in a range of geoscientific application areas.*

Keywords: *spatial data, G.I.S.,3-D representation, map, visualization*

1. Introduction

Visualization is an important component of any effort to understand, analyse or explain the distribution of phenomena on the surface of the earth.

The development of technology has accelerated capabilities to collect huge volumes of information, particularly geographical information. Visualization can readily be justified throughout since as data collection becomes easier, the volume of available information continues to increase and more sophistication is required to sift through the volumes. Precision and consistency have become increasingly important as well. The efficiency of visual tools (imagery, maps and graphical products) and of the human visual processing system cannot be underestimated in terms of their importance for understanding the complexities of spatial information. Printing, photography, flight, plastics and electronics have facilitated major advances in our ability to collect, manipulate and disseminate spatial information.

More recently GIS has provided a platform for a variety of new graphic and cartographic tools for visualization. With the advent of GIS technology, geographers now have a plethora of graphic and cartographic techniques as their disposal. These include graphic portrayal of temporal data, geographical flows, animated displays and three dimensional imaging techniques. It is important to realize that these graphical products would be difficult if not impossible to generate without computer assistance.

2. Dimensionality of spatial data

Geoscientific spatial data can be represented in two clearly distinct Euclidian dimensional context:

- 2-D – a spatial object or region which is defined in 2-D space by measurements on axes x, y;
- 3-D – a spatial object or domain extending through 3-D space defined by axes x. y. z.

The use of a 2-D representation has generally been to delineate object in the plane or fields of observations, specifically the mapping of spatial pattern and extent. Typical examples of such spatial object would be land parcels, coastlines or fire hydrants which are readily handled in a GIS with an x, y coordinate system.

Many forms of geoscientific analysis seek to collect data about spatial object and domains such as features of the solid earth, oceans or atmosphere which fill or enclose 3-D space. A complete representation of these phenomena requires the definition of each location known within an x, y, z coordinate system. This fully 3-D system allows a direct analogy between the real space and simulated space to be established in the model. It also requires 3-D forms of spatial indexing which are much more difficult to create and manage than the existing 2-D systems.

0-D dimensional visualization

The primitive object with 0-D is the point. Since the x and y values which define a point must store both integer and other coordinates such as UTM easting and northings, and also global coordinates in both latitude/longitude and radian format.

Three special cases of point are given, allowing the point to store an attribute associated with it, either a feature, a label or an area identifier. The final zero dimensional object is the node, which contains both a point and linkages to one-dimensional object connected to the node.

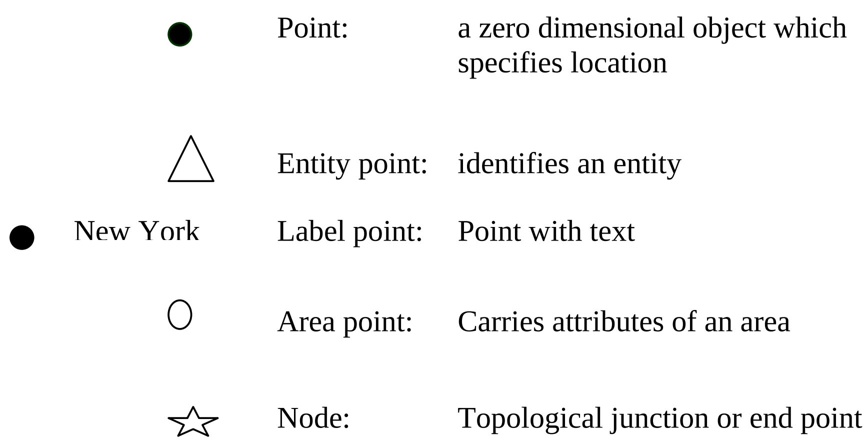

Fig. 1. Zero-dimensional cartographic objects

1-D visualization

The 1-D dimensional cartographic objects are more various, serving a large number of cartographic needs. The generic name for a 1-D objects is a line, which can consist either of a locus of point defined by a function such as a polynomial, or an arc, or as a sequence of connected primitive objects known as line segments. The line segment is simply a straight line connecting two points (two points stored together). The string, a group of connected segments, without any other topological information, makes up the building block for the more complex one-dimensional objects. When a string close upon itself, it is termed a ring and rings can be created from strings, arcs, links or chains. The link is a network primitive, consisting of a single edge of connected graph. The directed link adds the direction of connection and the addition of a string between the nodes forms a chain.

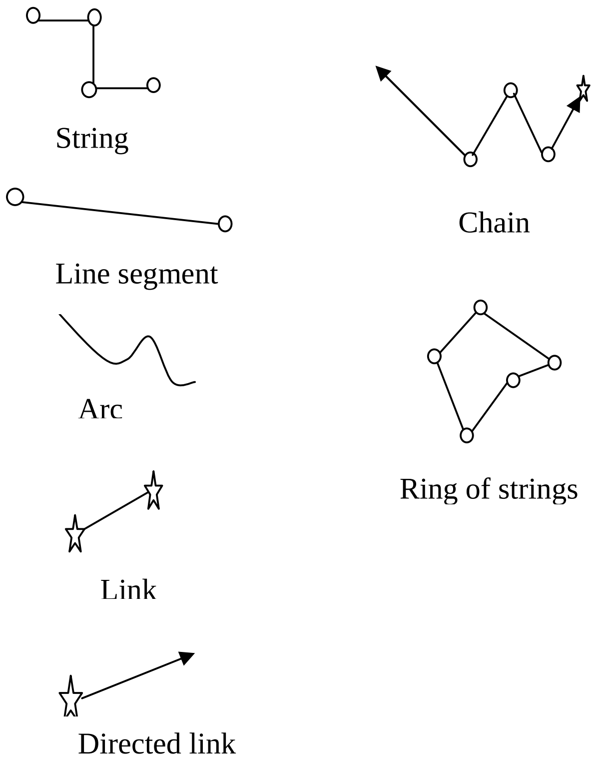

Fig. 2. One–dimensional cartographic objects

2-D visualization

A 2-D visualization is a graph or raster where the z valua defining a surface is projected on to a 2-D plane and 0-D, 1-D and 2-D objects can be displayed. Since z is usually a continuously varying value on the ratio scale the value of z is usually grouped into a class and the class boundaries shown.

Fig. 3. A 2-D isoline map

2,5-D visualization

A 2,5-D visualization is a an isometric model where the z attribute associated with an x, y location is projected onto an x, y, z coordinates references system and all three axes displayed. This operation transforms the map of z attributes for an x, y position so that each z attribute defines a position on the z axis, creating a surface with no thickness visualized within 3-D space. This approach simulates the view that would be seen by a human observer from a point within the 3-D space. Hence, a 2,5-D visualization is still limited by the basis of a 2-D representation.

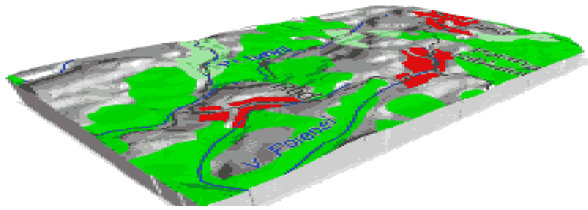

Fig. 4. A 2,5-D representation

3-D visualization

A true 3-D visualization is a full 3-D model where many x, y, z observation are structured into a solid structure and visualized in perspective view, complete with multiple occurrences of z. This kind of view is a precise analogue for the physical space inhabited by human observers and allows the full specification of 3-D operations on the observed phenomena within the limits of the geometrical model employed.

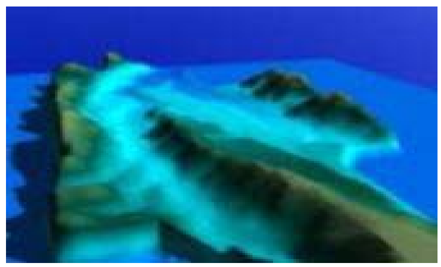

Fig. 5. 3D visualization

3. Conclusions and proposals

Within contemporary geoscientific analysis only 2-D and 2,5-D visualization of 3-D representations of reality are in common use, specifically, surfaces visualized in 3-D space. For such visualization, 2,5-D techniques offer the opportunity to view the model and are popular since they are calculated easily and match certain application requirements well. The role of visualization have been presented from the fields of geography, statistics, cognitive science, robotics, database management, cartography and cybernetics, all which contribute to visualization of spatial information.

Future directions in visualization research will likely address improvements in access and manipulation of larger volumes of spatial data, the development of multidimensional (three dimensional and higher) data structures such as voxels and the implementation of GIS capabilities for temporal analysis and display

4. References

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