Appendix A

Prototypes

Throughout the evolution of the ideas in this thesis, several prototypes have been implemented. All the images in this thesis are taken from these prototypes. The following is a chronological list of the prototypes stating briefly what they are and who was involved in their design and implementation. Most of these prototypes were created simply for proof of a concept and visual explanation.

A.1 Minimum Broadcast Graphs (MBG)

Minimum Broadcast Graphs was designed and implemented by M. S. T. Carpendale. The purpose for creating MBG was to provide visual explanations for the theoretical issues involved in the minimum broadcast graph research. It contains several features including:

- a graph library containing approximately two hundred and fifty broadcast graphs (Figure A.1),
- the possibility of animating broadcasting on any of these graphs (Figure A.2),
- a sequential visual explanation of discovering minimum broadcast graphs for hypercubes (Figure A.3),
- animations of gossiping on graphs (Figure A.3), and
- a simple graph editor (Figure A.4).

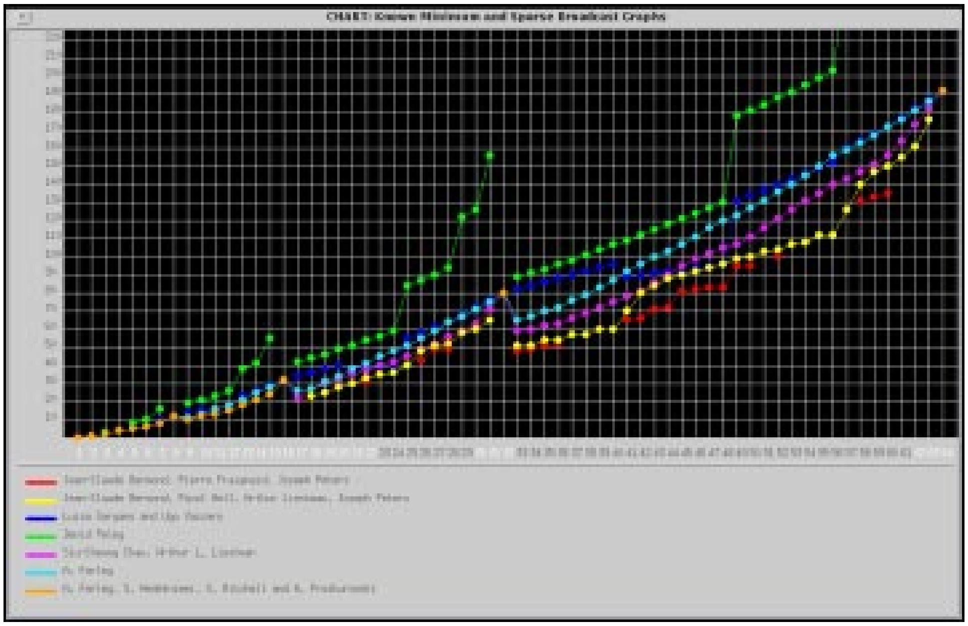

Figure A.1: The interface to the minimum broadcast graph library. Each node represents a graph. They are organized by the number of nodes (horizontal axis) and the number of edges (vertical axis) and linked by colour to the papers that describe them.

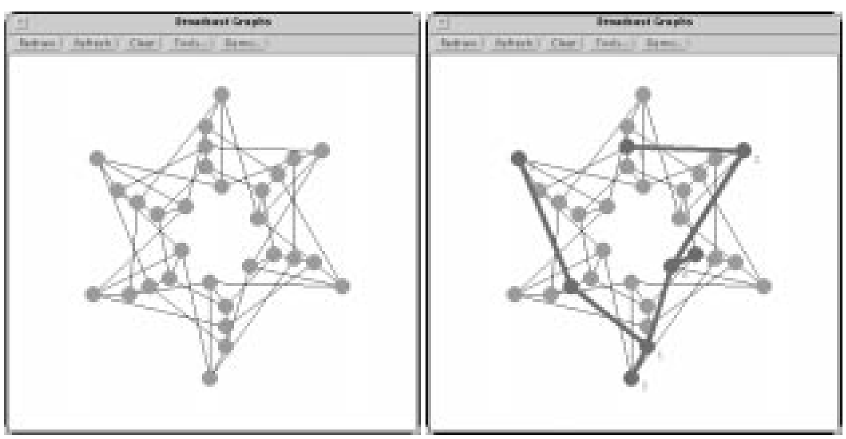

Figure A.2: The left image shows a thirty node graph from the library. The right image shows the same graph after three steps of broadcasting.

Most of the graphs the are used in illustrations in this thesis were created using MBG. Working with graphs in MBG was the motivating factor for this investigation of screen real estate issues.

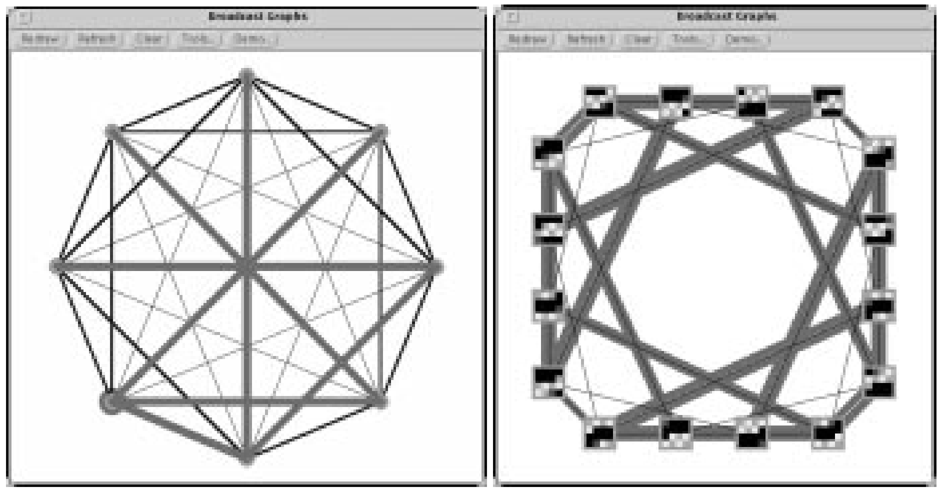

Figure A.3: The right image is part of the storyboard explanation of developing minimum broadcast graphs. The pink shows the edges used for a broadcast scheme for one node. The blue shows the edges needed to be able to use this scheme from all nodes. The red shows those edges which will not be needed. The left images shows the step before last when gossiping with sixteen nodes. The checkerboard pattern in the nodes show positionally which nodes a given node has gossiped with.

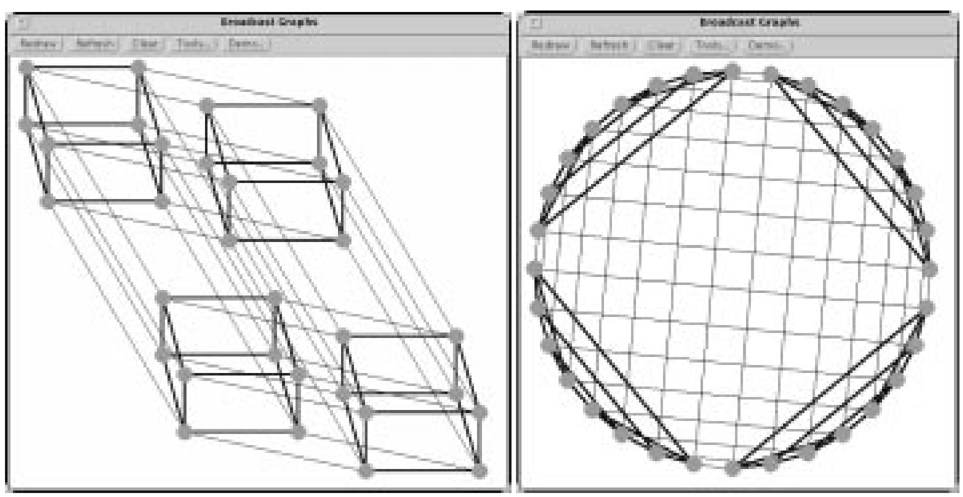

Figure A.4: These two images show two layouts for a five dimensional hypercube.

Through working on MBG I became interested in how computers can be used to support our cognitive processes. I feel that, in general, externalizing problems can help improve understanding [164] and that computers can be used to visually support this externalization. I continue to explore how best to provide visual support that aids comprehension.

A.2 Voronoi Diagrams: An animation of Fortune's plane sweep algorithm

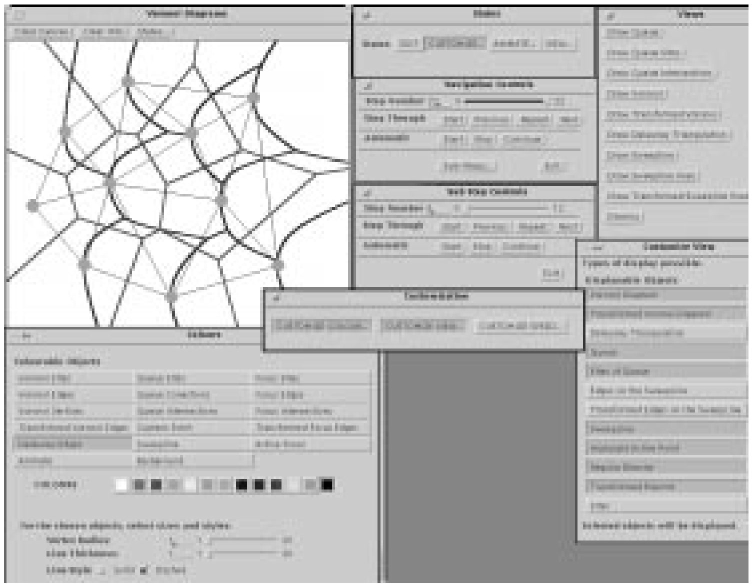

Figure A.5: Animating Fortune's plane sweep with controls for reversing and viewing sub-steps

This program was designed and implemented by M. S. T. Carpendale to animate Fortune's plane sweep algorithm for the creation of Voronoi diagrams. This algorithm animation explores ways of incorporating Piaget's [121] ideas on constructive learning into an algorithm animation (Figure A.5).

A.3 3DPS: Three-Dimensional Pliable Surfaces

3DPS was designed by M. S. T. Carpendale with input from D. Cowperthwaite and implemented by D. Cowperthwaite. Motivated by the space shortage problems such as those encountered in MBG and concerned with creating readable presentations, M. S. T. Carpendale developed a three-dimensional detail-in-context solution for two-dimensional vector representations. Using three dimensions allowed incorporation of visual cues and supported the possibility of folding.

3DPS was first implemented primarily as an algorithm animation. The resulting interface provided visual access to the geometry of the algorithm. All the controls used two levels of indirection to allow the transformations to be viewed without the mouse in the way (Figure A.6). As this was developed as a research tool, the interface is difficult to use. Many of the images in this thesis were

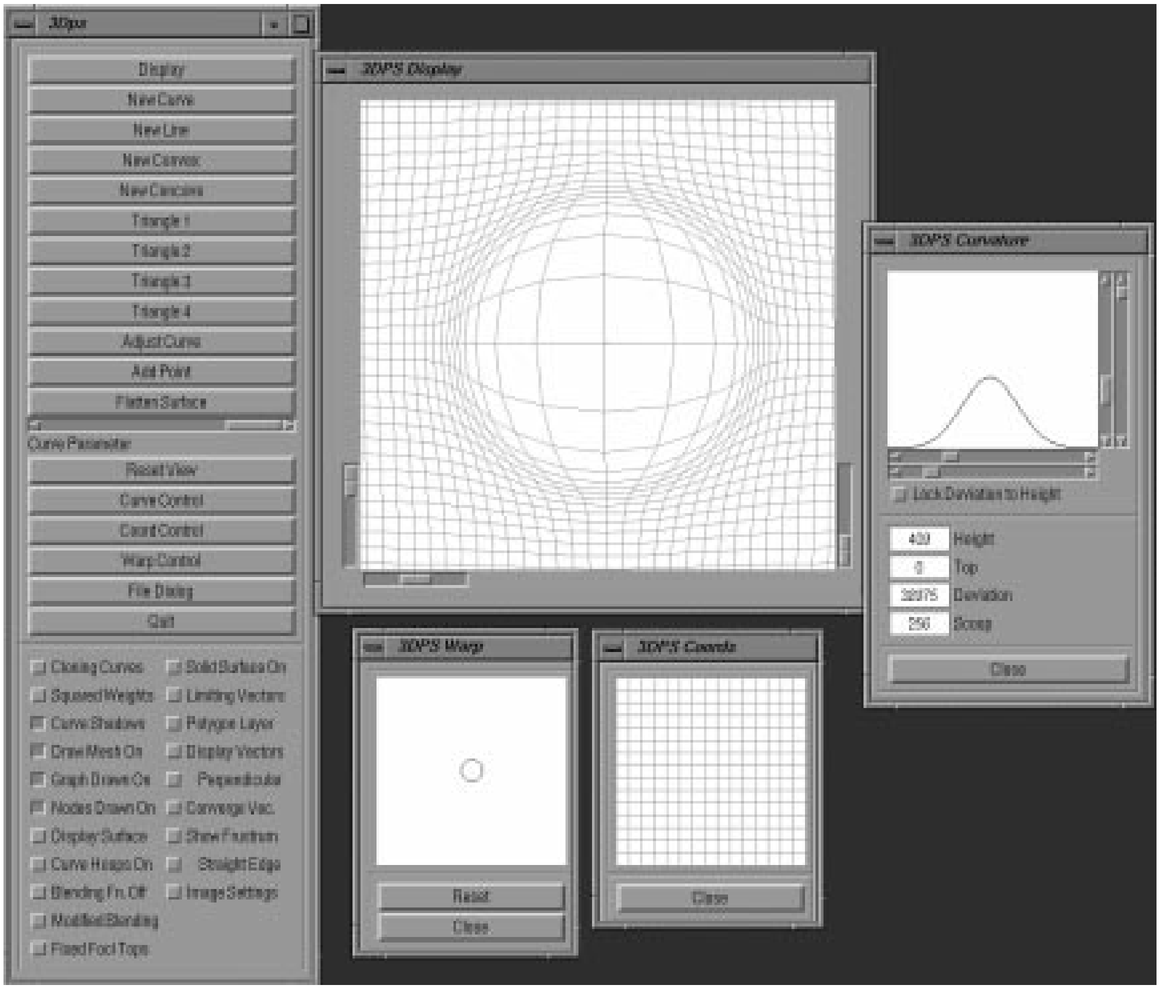

Figure A.6: The interface to the initial prototype, 3DPS. The panel on the left allows selection of what is to be displayed. The control on the right sets the height, the maximum, the width and the amount that the auxiliary curve is used. The two small windows control, on the left, folding and on the right location of the active focus.

taken from this prototype as it supports the display of separate aspects of the algorithm. This type of implementation was chosen to allow further refinement of the algorithm. This refinement was done in conjunction with David Cowperthwaite. For instance, being able to watch exactly happened in the inter-focal regions provided the insight from which the currently used blending method was developed.

A.4 3D-Warp: Three-Dimensional Visual Access

This joint work was originated by David Cowperthwaite and is being extended by David Cowperthwaite. The framework developed through 3DPS was applied to three-dimensional vector representations (Figure A.7). 3D-Warp: Three-Dimensional Visual Access was designed by D. Cowperthwaite and M. S. T. Carpendale and implemented by D. Cowperthwaite.

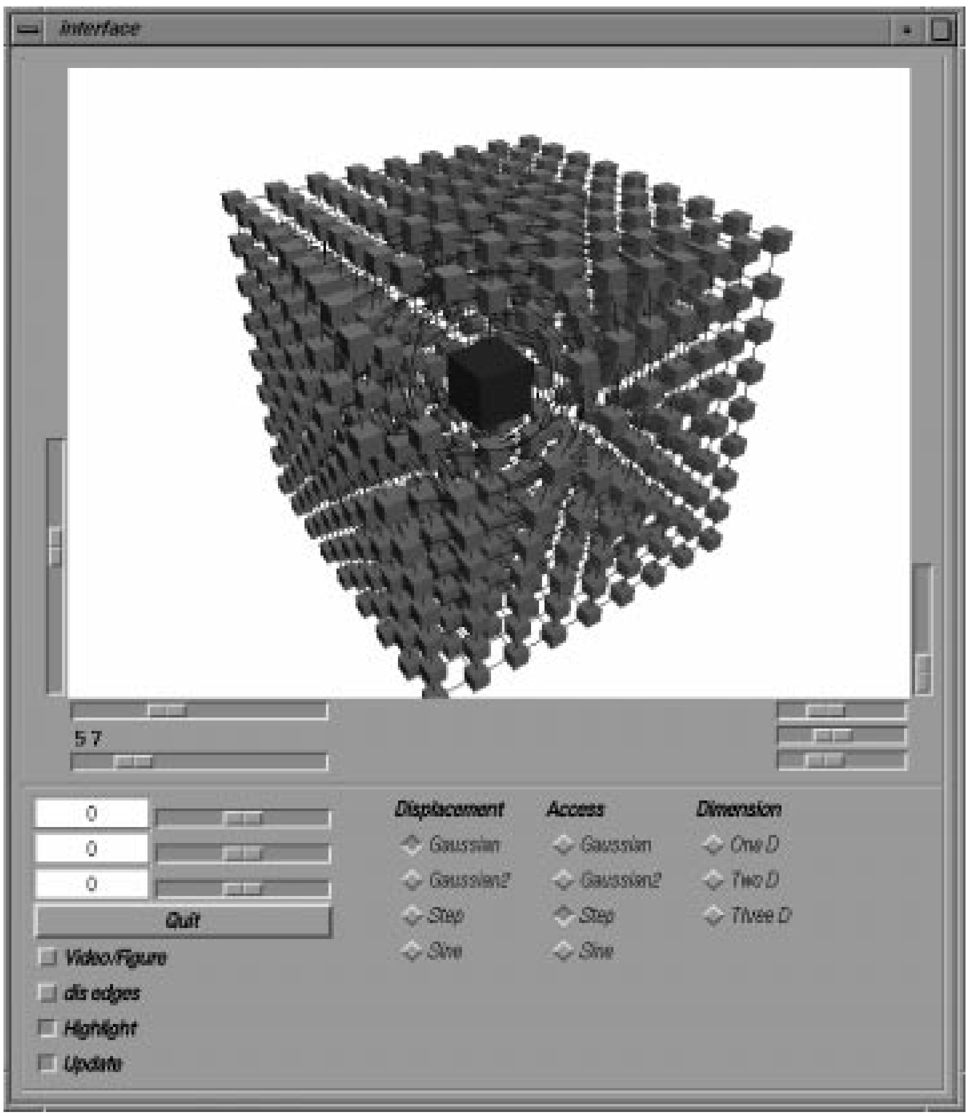

Figure A.7: The 3D-Warp prototype

A.5 Varying Dimensionality in 3DPS

This prototype variation was designed by M. S. T. Carpendale and implemented by C. Pantel. The purpose was to extend 3DPS to include one and two-dimensional distortions. C. Pantel extended D. Cowperthwaites 3DPS code to include more of M. S. T. Carpendale's basic framework. In particular, the possibility of applying the distortion only in the x direction was included. This prototype included the first scroll lens.

A.6 3D-Pliable for image data

This version of 3D-Pliable was designed by M. S. T. Carpendale and D. Cowperthwaite and implemented by D. Cowperthwaite to extend 3DPS detail-in-context functionality to raster image data.

A.7 3DPS for 2D+ Representations

This version of 3DPS was designed by M. S. T. Carpendale and protoyped by M. S. T. Carpendale modifying D. Cowperthwaite's 3DPS code. It is a prototypical exploration extending concepts in 3DPS for application to discrete information representations that make partial use of the third dimension.

A.8 Temporal Access

The version of 3D-Warp was designed by M. S. T. Carpendale and prototyped by M. S. T. Carpendale using D. Cowperthwaite 3D-Warp code. This began the investigation in applying 3D-Warp to real data.

A.9 Detail-in-context for H-curves

This 3D detail-in-context approach for viewing the DNA representation H-curves was designed by M. Lantin and M. S. T. Carpendale and implemented by M. Lantin. This prototype compared user and information needs with EPS presentation possibilities to design a specialized 3D zooming approach for H-curves.

A.10 MR Image presentation

This detail-in-context presentation for viewing MR Image data was designed by J. van der Heyden and M. S. T. Carpendale and implemented by J. van der Heyden. This research has involved extensive user studies conducted by J. van der Heyden and is contained in her masters thesis. Since the user studies indicated a fairly close match with the SHriMP algorithms capabilities, SHriMP [150] was used as a starting point. The EPS framework was used in developing variant layout strategies to better suit radiologists needs.

A.11 SEED

The FRBC project SEED (Simulating and Exploring Ecosystem Dynamics) has both a simulation and visualization component. Those involved in this project are: Dr. F. D. Fracchia, Dr. K. Lertzmann, Dr. T. Poiker, M. S. T. Carpendale, Dr. A. Fall, D. Cowperthwaite, and J. Fall. The visualization component is primarily the work of M. S. T. Carpendale and D. Cowperthwaite and has utilized several aspects of the EPS framework. Also involved in implementing some visualization aspects are M. Tigges, D. Kennett, and D. Pullara.

Fugures A.8, A.9 and A.10 show some of the progression of the development of visualization components of the SEED project.

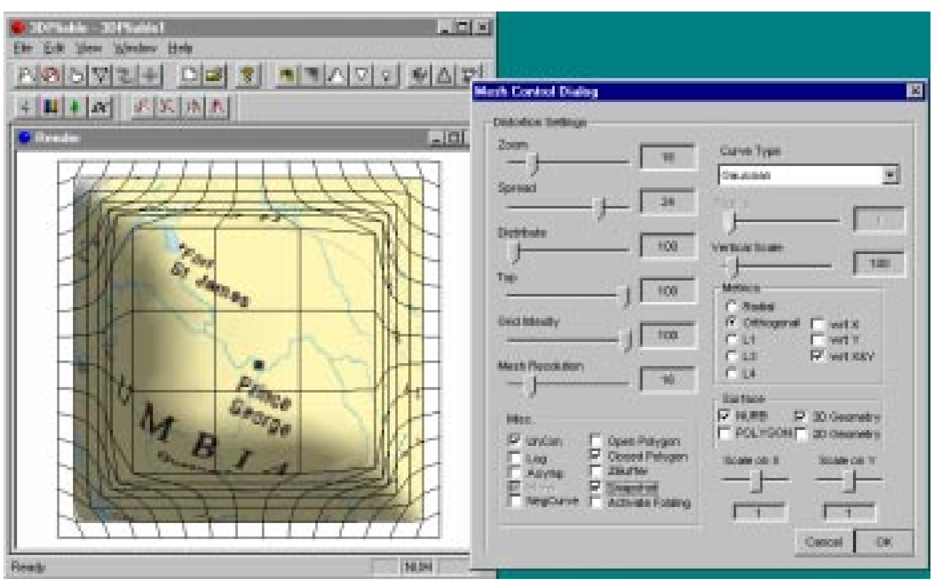

Figure A.8: This version includes several drop-off variations and some L-metric variations

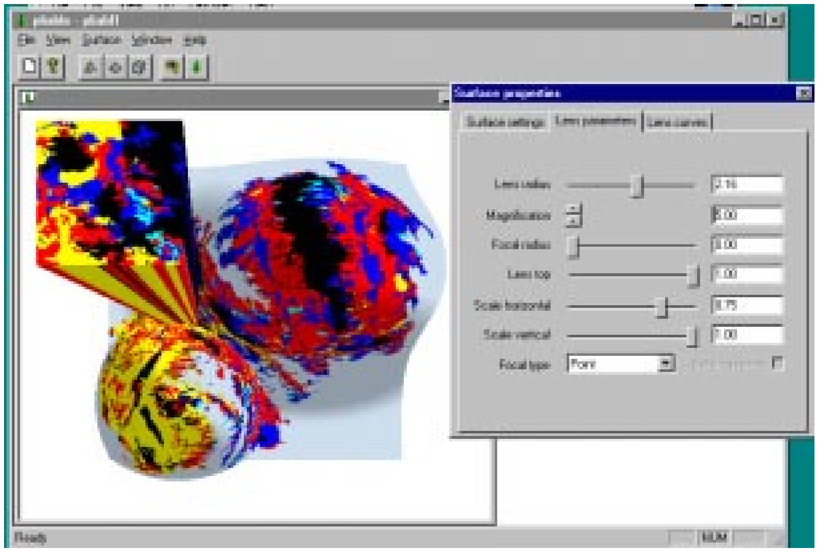

Figure A.9: This version includes Gaussian, linear and Manhattan lenses

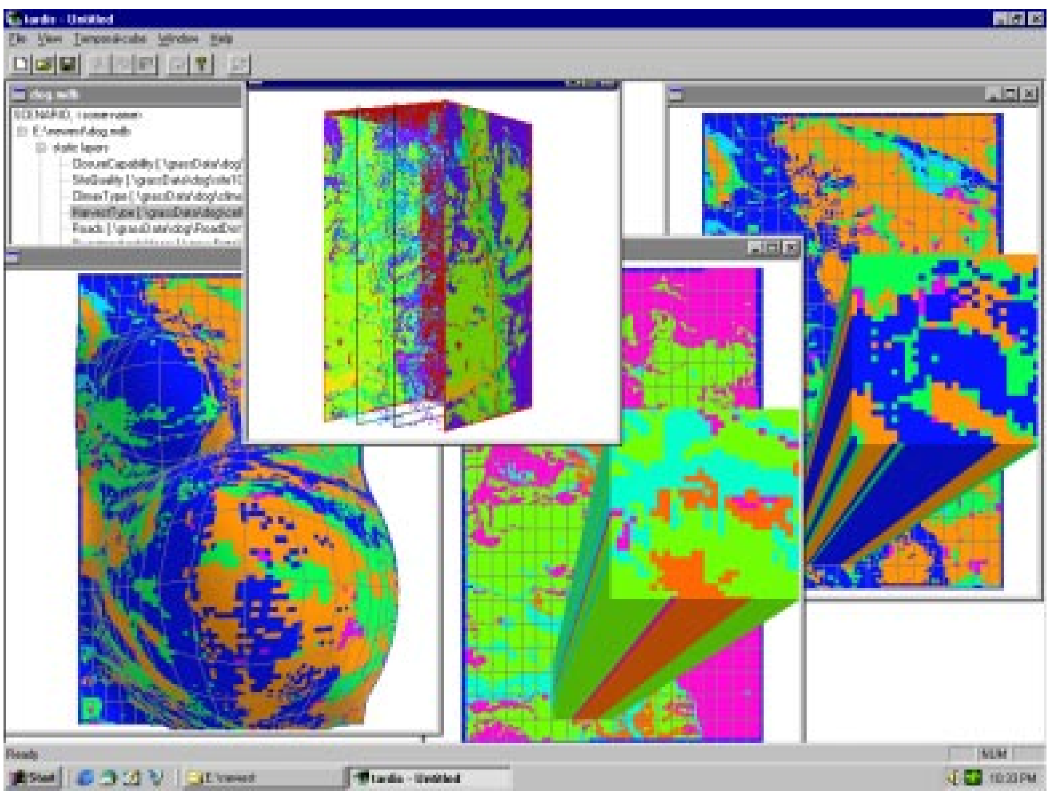

Figure A.10: This is the Tardis visualization environment. It includes visual exploration methods for both 2D visual representations and 3D visual representations

Appendix B

Perspective Projection

Perspective as developed or re-discovered in western art during the Renaissance is often referred to in artistic circles as ‘artificial’ or ‘linear’ perspective because it depends on a single fixed viewpoint, which could only correspond to one eye, is projected onto a flat plane and is worked out mathematically. As such it only approximates the complex ‘natural’ perspective that is perceived with two eyes in motion. A computer graphic implementation of perspective tends to be even more precise mathematically than an artistic interpretation of perspective. While this precision may give a ‘stiff’ version of reality, its mathematics can be used to affect presentation.

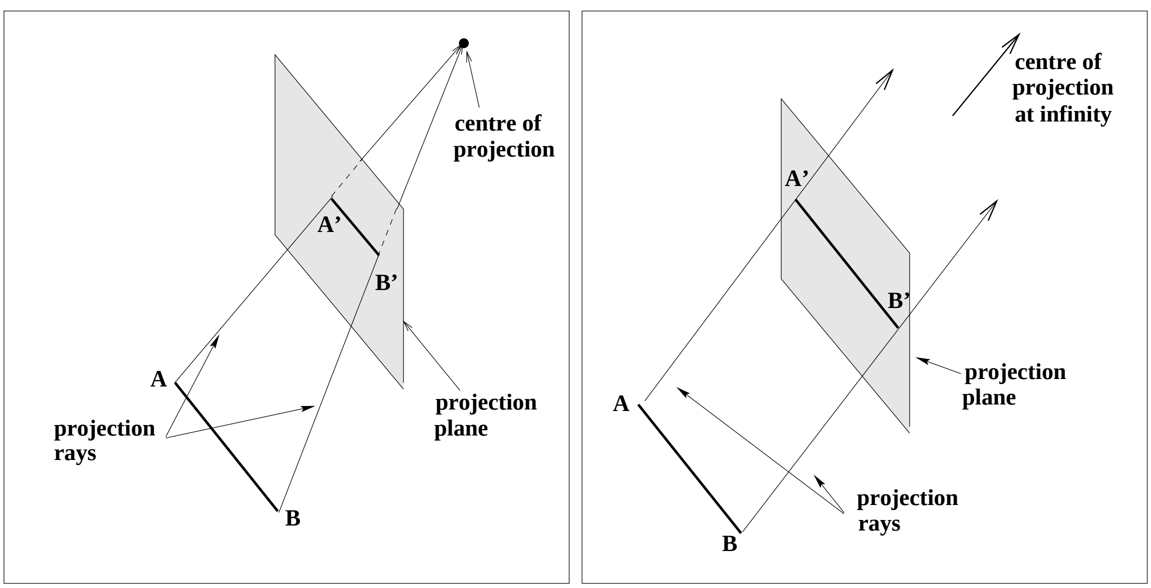

Figure B.1: Planar geometric projections: left, perspective; right, parallel

Since EPS makes extensive use of perspective geometry, a brief overview is included here. For a more detailed explanation see a graphic text, such as Foley et al. [49] or Hearn and Baker [65].

B.1 Basic Projections from 3D to 2D

Perspective projection is a system for representing three-dimensional space on a two-dimensional plane. A *projection* maps points between spaces of differing dimensions; in general a projection "transforms points in a coordinate system of dimension n into points in a coordinate system of dimension less than n" [49]. Two basic projections from three dimensions to two dimensions are *perspective* and *parallel* (Figure B.1). A perspective projection passes straight *projection rays* from each point of each object, through a *projection plane* to a single point that is the *centre of projection* (Figure B.1, left). The configuration resulting from the intersection of the projection rays with the projection plane is the 2D result. In a parallel projection the projection rays are parallel (Figure B.1, right). The distinction between perspective and parallel projection is established by the distance between the centre of projection and the projection plane. If the distance is finite the projection is perspective and the projection rays converge to the centre of projection. If the distance is infinite, the rays do not converge and the projection is parallel.

B.2 Perspective Foreshortening

Line segments of the same length that are oriented in the same way but are different distances from the centre of projection appear the same length in parallel projection. In perspective projection the line segment of the same length, oriented in the same way and further from the centre of projection will appear smaller when projected (Figure B.2). In perspective the projected size of an object varies inversely with its distance from the centre of projection. This is known as *foreshortening* and is one of the main visual effects of perspective projection. As the closer objects occupy a greater percentage of the viewing space they appear larger, while those further away appear smaller and smaller until they disappear in the distance. As a result of foreshortening, in general, parallel lines do not remain parallel, and angular and distance relationships are not preserved when projected. With perspective projection only the lines that are parallel to the projection plane remain parallel after the projection. Geometric relationships such as angles and proximity are only be preserved when they are on planes that are parallel to the projection plane.

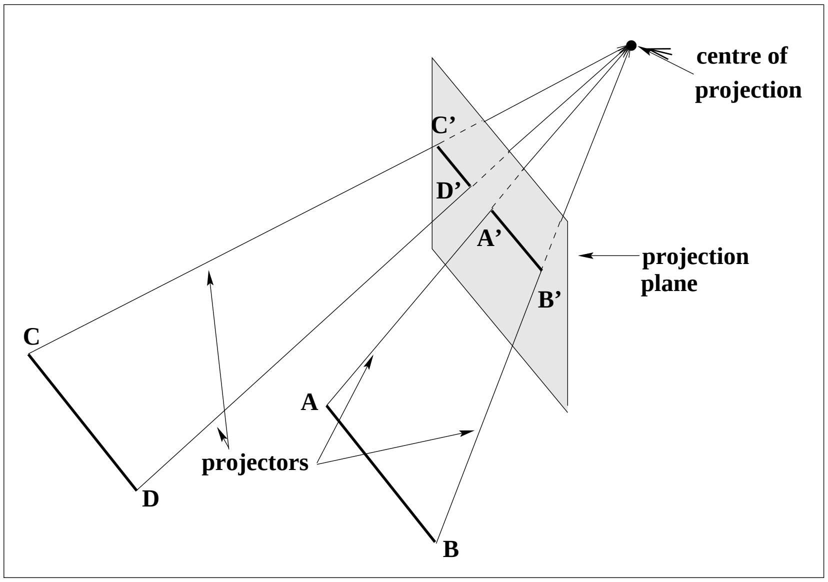

Figure B.2: Perspective foreshortening; lines AB and CD are the same length, CD’s greater distance from the centre of projection creates a smaller projection

B.3 Perspective Viewing

While the principles of perspective stay as outlined above, the terminology commonly used when discussing perspective viewing on a computer is slightly different. The projection plane can be infinite, however, on computer only a certain portion of it can be visible in the final presentation. The visible portion of the projection plane is called the *view plane*. The centre of projection is located approximately where the user is presumed to be looking from and is called the *viewpoint*. Together the viewpoint and the view plane define the *view angle*. The *central axis* passes through the viewpoint and is orthogonal to the view plane. Any point within the field of view can be projected onto the view plane, and all points outside will be projected onto other areas of the projection plane and consequently will not form part of the visible presentation. The *view volume* is the 3D space defined by the viewpoint and the view plane. Together these items establish the general appearance of the perspective view. The view volume is usually truncated by the establishment of *front* and *back clipping planes* forming the *viewing frustum* (Figure B.3).

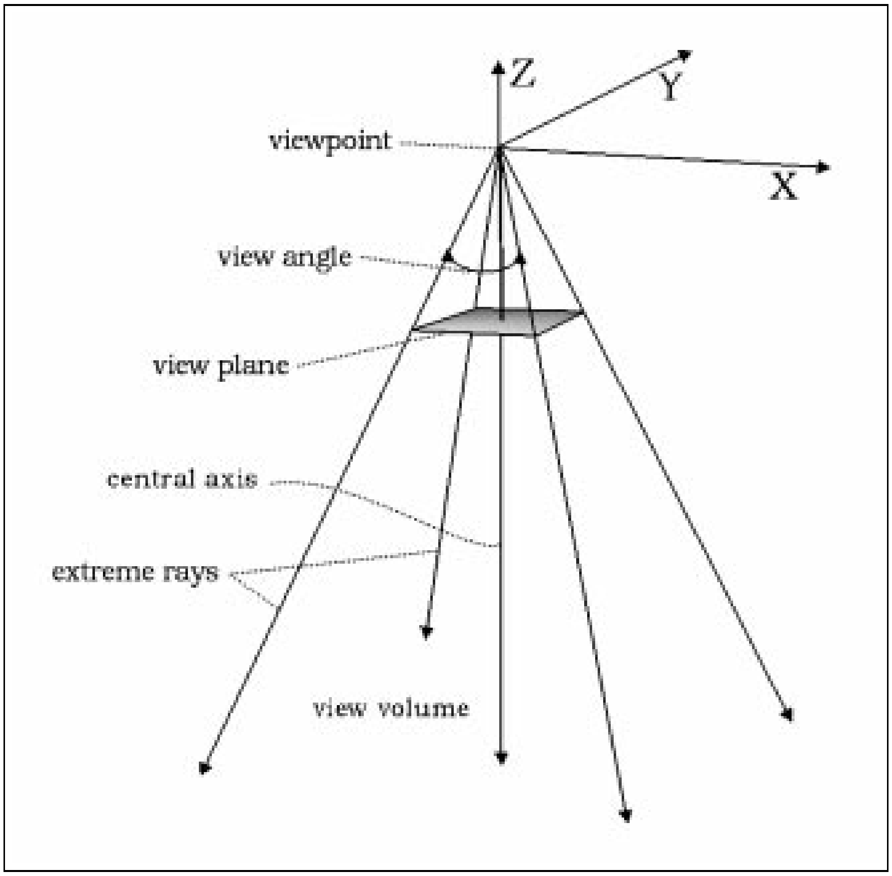

Figure B.3: The 3D viewing volume

B.4 Perspective Projection Geometry

The geometry of single-point perspective projection is quite simple. Assuming the viewpoint to be the origin, given a point $P(x, y, z)$ and a central axis to the z axis at a distance d_b from the viewpoint, similar triangles can be used to calculate the projected point $P_v(x_v, y_v, z_v)$. The distance d_v, is to x_v as d_b is to x as follows (Figure 3.1):

$$\frac{x_v}{d_v} = \frac{x}{d_b}; \qquad \frac{y_v}{d_v} = \frac{y}{d_b}$$

$$x_v = \frac{d_v \cdot x}{d_b}; \qquad y_v = \frac{d_v \cdot y}{d_b}$$

For the projected point $P_v(\frac{x}{d_v/d_b}, \frac{y}{d_v/d_b}, d_v)$, the ratio d_v/d_b operates as a scaling factor. During a translation of objects in a common plane geometric relationships such as angle, parallelism, relative

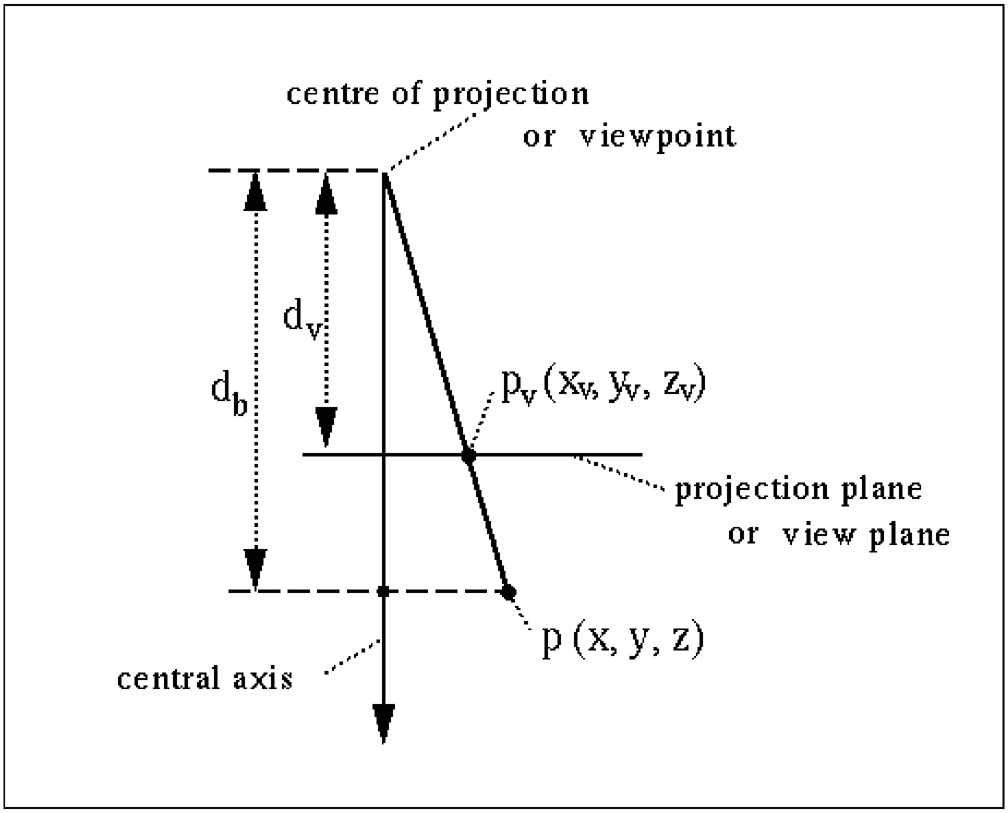

Figure B.4: Similar triangles used to calculate single point perspective

proximity, orthogonality and topology are preserved, providing the plane's orientation to the view plane is maintained.

B.5 One, Two and Three Vanishing Points

In perspective projection any set of parallel lines on any plane that is not parallel to the projection plane will converge to a *vanishing point*. As parallel lines can be oriented in an infinite number of directions there are an infinite number of possible vanishing points.

The three-dimensional space has three principle axes, x, y and z. If a vanishing point exists on these principle axes it is called a *principle vanishing point.* Perspective projections can be characterized by the number of principle vanishing points. The viewpoint and view plane can be positioned to cause one, two or three principle vanishing points based on which axes they intersect respectively. Figure B.5 shows two views of single point perspective where the single principle vanishing point

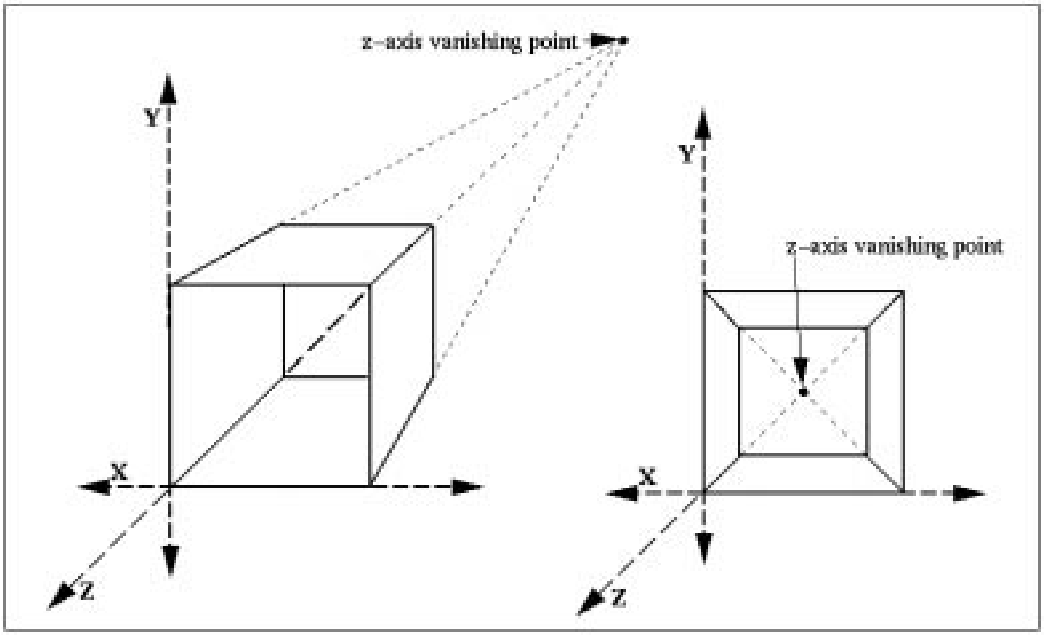

Figure B.5: Two views of single point perspective

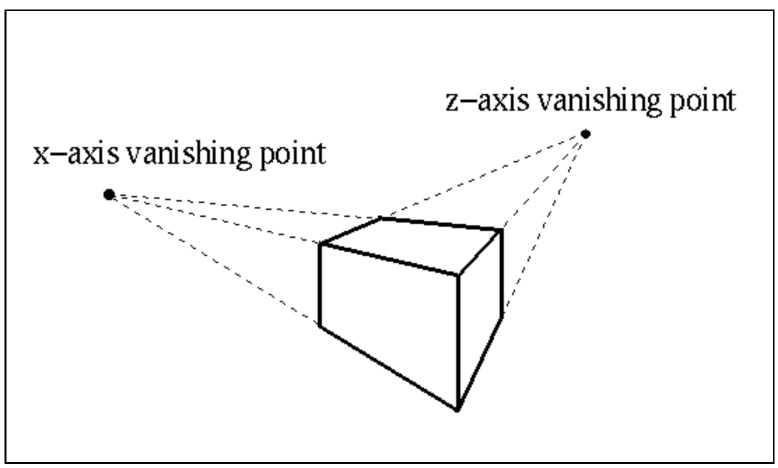

Figure B.6: Two point perspective

is on the z axis and the projection plane is parallel to the x, y plane. Single point perspective projection in this orientation preserves angles, proximity, and parallelism on all x, y planes and has visual realism from the perspective foreshortening in z. Figure B.6 shows a two-point perspective view. Note that the lines parallel to the y axis stay parallel. Figure B.7 shows a three-point perspective view.

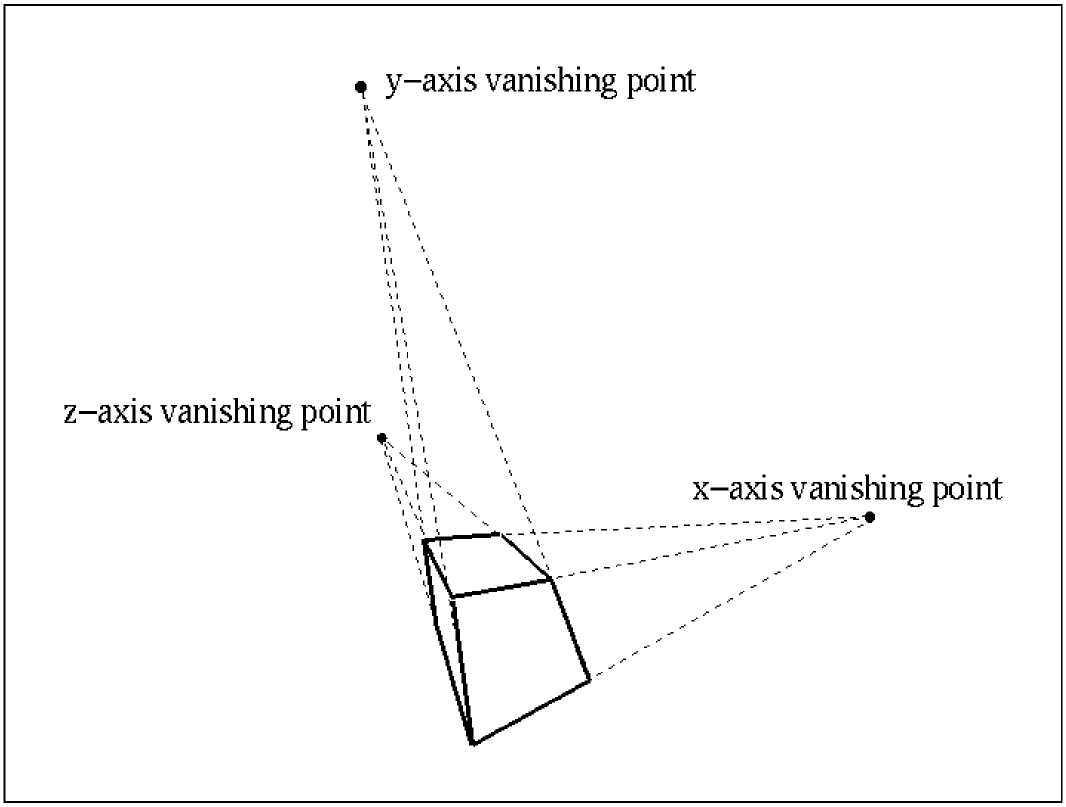

Figure B.7: Three point perspective

B.6 Occlusion in Perspective Projection

If two points are projected onto the same location in the view plane, the point that is visible will be the point that was closest to the view plane. Once a three-dimensional representation has been projected onto the two-dimensional screen, objects in front occlude those further back. This has led to discussions as to whether there is inherent benefit in use of 3D or if there is any more effective display space through the use of three-dimensional representations [171]. However, it is in keeping with normal vision in that a closer object will hide those behind.

This has created the possibility of an infinite number of layers at a given z location. The effect is the same as that common to drawing tools and windows. Apparently people did not initially find it intuitive that windows could slide over and under each other on essentially the same plane. However, the behaviour is now familiar.

Appendix C

Image Credits

Though this framework for elastic presentation space (EPS) was developed independently of a specific application, several 2D visual representations have been used to illustrate the ideas. This appendix is included to acknowledge the sources of the 2D visual representations that have been used. Here each image is displayed undistorted with its credits.

C.1 Land Cover Map of Champaign, Illinois

This land cover map of Champaign, Illinois (Figure C.1) was created by Illinois Natural History Survey Geographic Information System from satellite imagery. This map is part of the Critical Trends Assessment Project (CTAP) authored by Donald Luman, Illinois State Geological Survey, Mark Joselyn, Illinois Natural History Survey, and Liane Suloway, Illinois Natural History Survey.

It can be found at the Illinois Department of Natural Resources web site:

$$http://www.inhs.uiuc.edu/igis/illinois/counties/champaig.html$$

As part of their web site ($http://dnr.state.il.us/cpyrited.htm$), the Illinois Department of Natural Resources states that:

"The Illinois Department of Natural Resources will not knowingly post copyrighted material on the Internet without permission from the copyright holder."

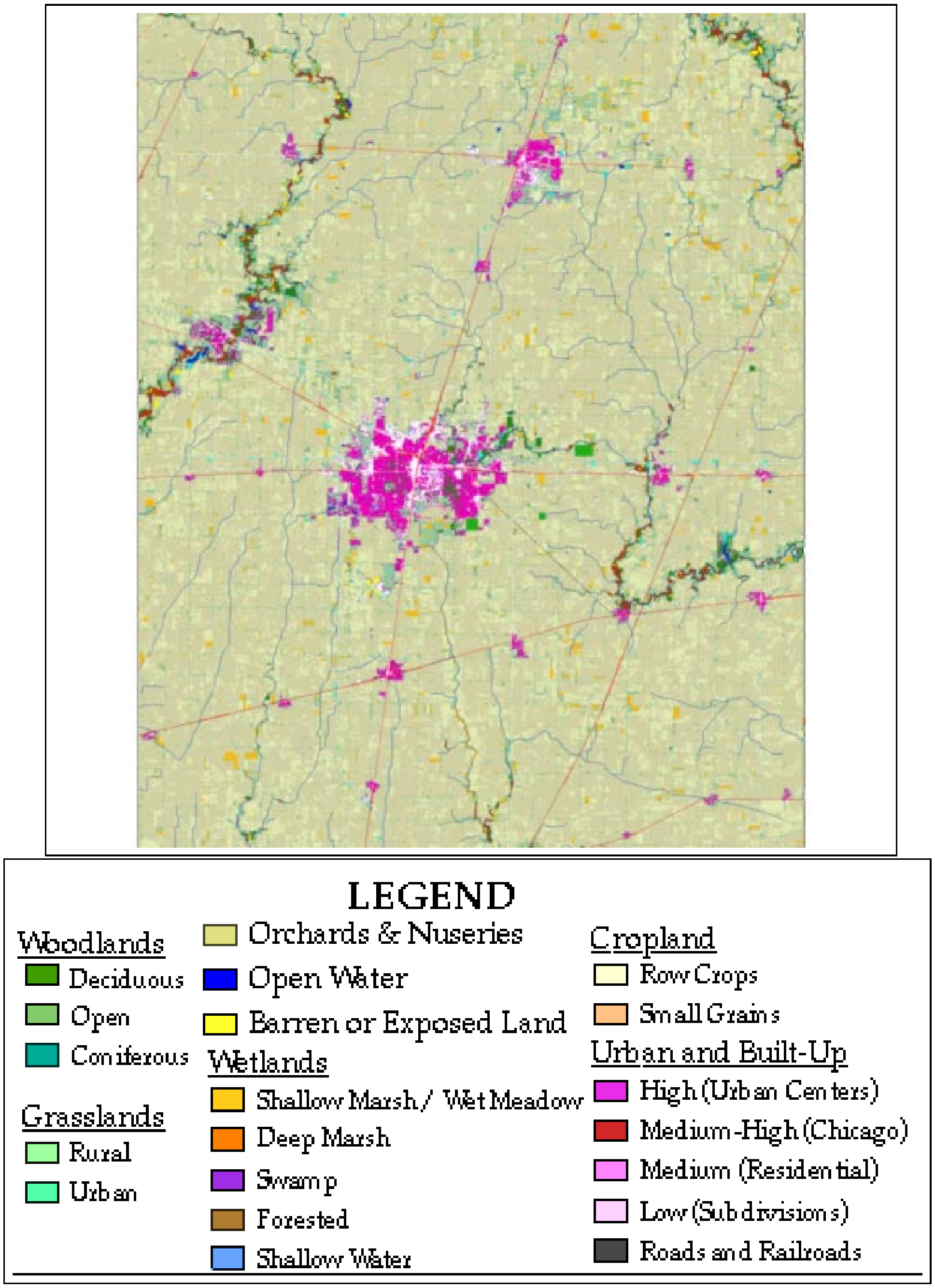

Figure C.1: Land Cover Map of Champaign, Illinois

C.2 Map of British Columbia

Figure C.2: Map of British Columbia

This map of British Columbia (Figure C.2) is from National Atlas of Canada, Ministry of Natural Resources Canada. It can be found at the National Atlas Information Service (NAIS) web site:

$$http://alert.ccm.NRCan.gc.ca/wwwnais/select/base/english/html/ebase3.html$$

The copyright information regarding this map can be found at
($http://alert.ccm.NRCan.gc.ca/wwwnais/wwwmisc/english/html/copyright.html$) and reads as follows.

C.3 Orion Nebula

Figure C.3: Image of the Orion Nebula

This Hubble image of the Orion Nebula (Figure C.3) shows a closeup of “Proplyds” or Protoplanetary Disks. The press release text reads; “Hubble Confirms Abundance of Protoplanetary Disks Around Newborn Stars (PR94-24 June 13, 1994)”. It can be found at the following web site:

$$http://oposite.stsci.edu/pubinfo/pr/94/24.html$$

This NASA Hubble Space Telescope image of a region of the Great Nebula in Orion was created by Space Telescope Science Institute, operated by the Association of Universities for Research in Astronomy Inc., from NASA.

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C.4 Surface of Mars

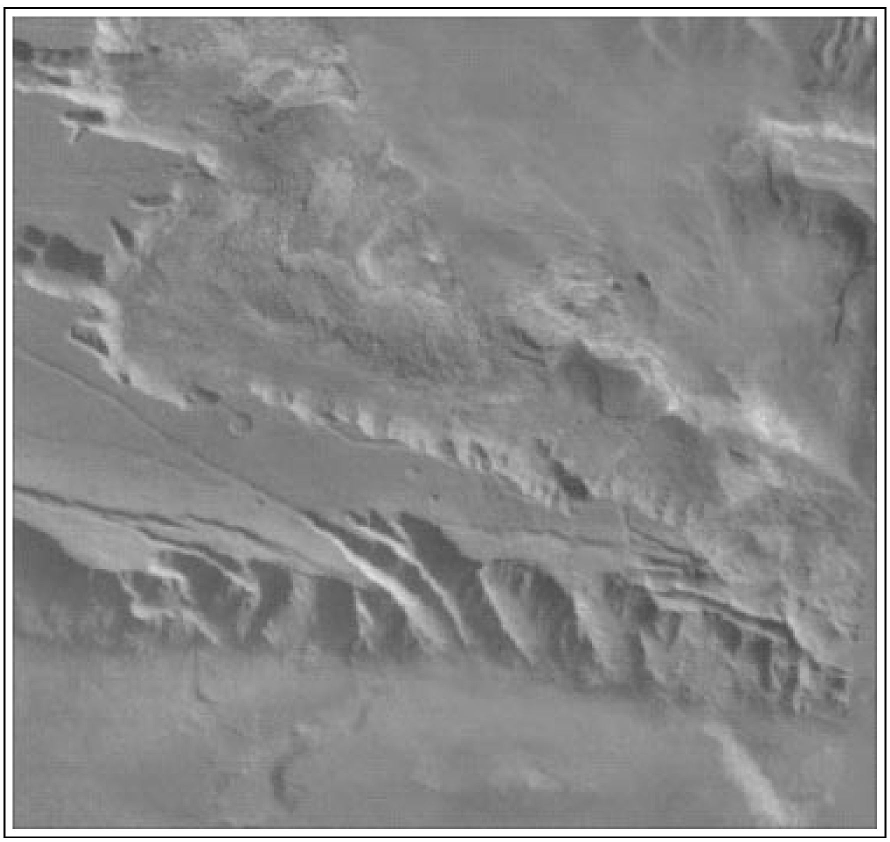

Figure C.4: An image of the surface of Mars

This image of the surface of Mars (Figure C.4) is used with the permission of Jonathan Bradley. This image was developed by Calvin Hamilton and Jonathan Bradley at Los Alamos National Laboratory and the technology has been licensed by LizardTech (*www.lizardtech.com*). The image data was created by NASA and the USGS with support of Space Telescope Science Institute, operated by the Association of Universities for Research in Astronomy, Inc., from NASA contract NAS5-26555. (*http://www.c3.lanl.gov/ cjhamil/Browse/mars.html*)"

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C.5 Forest Species: Rocky Mountain Trench

This image (Figure C.5) is of the dominant forest species for the White and Lusser River Valleys in the Rocky Mountain Trench. This data was taken from a SELES [44] modeling project in the Invermere Forest District of British Columbia.

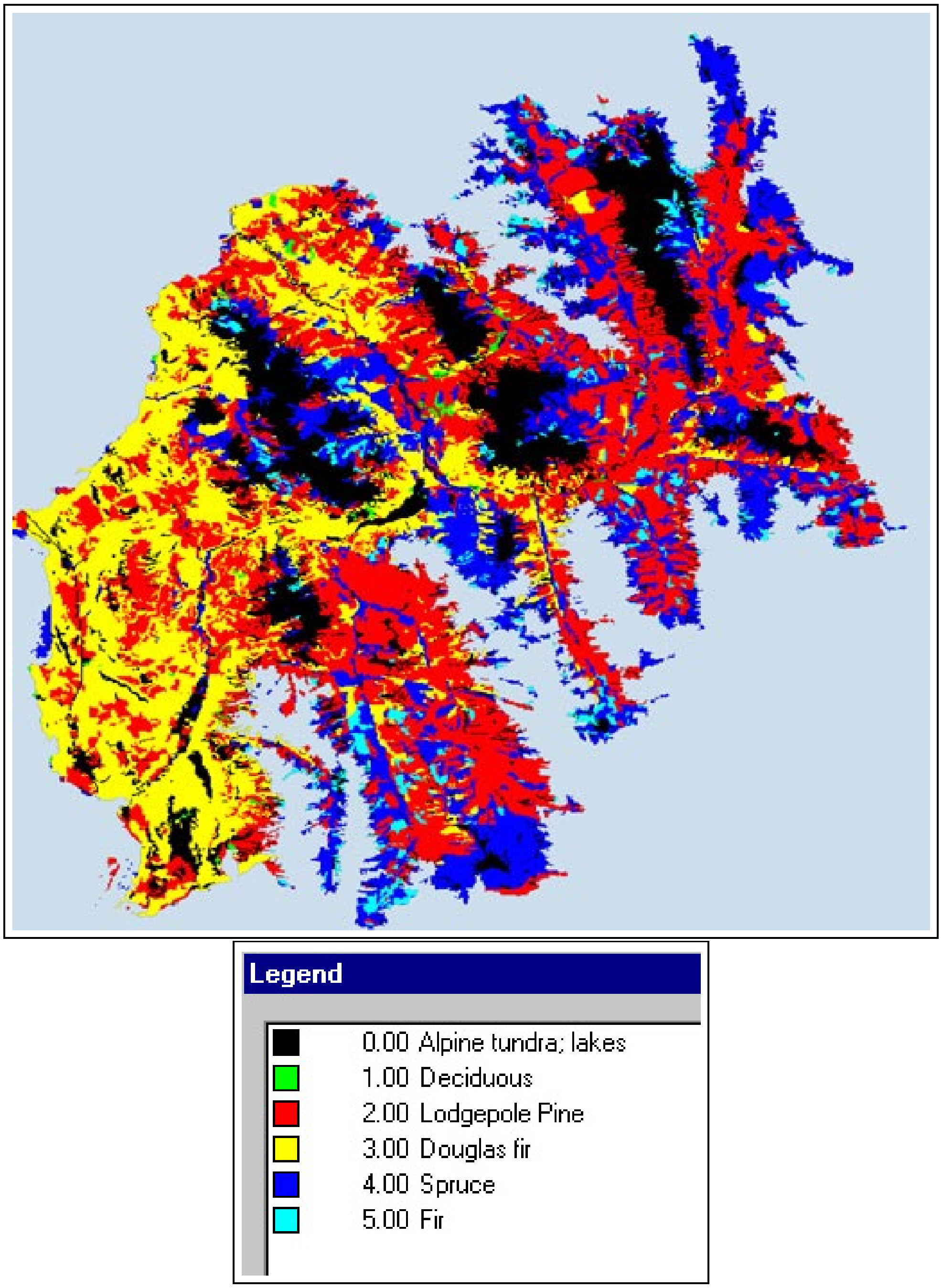

Figure C.5: Forest Species: Rocky Mountain Trench

C.6 Coastline Map of Vancouver British Columbia

The coastline map of Vancouver (Figure C.6) is used with permission from James Strickland who first created this map for use with his master's thesis [156].

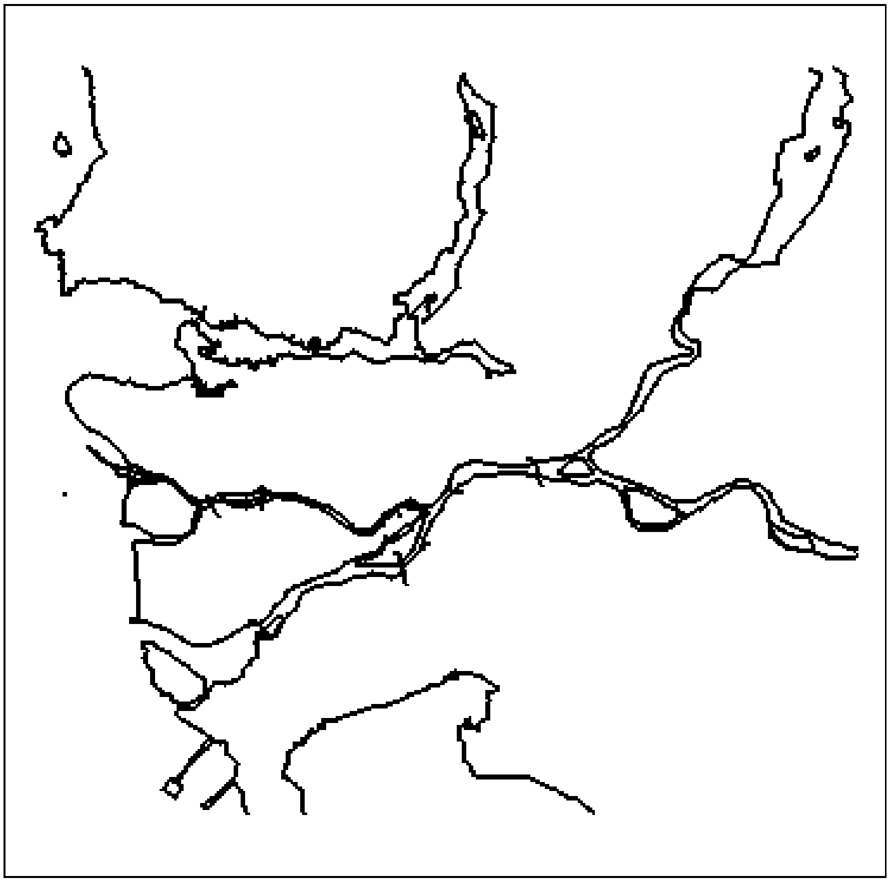

Figure C.6: Coastline Map of Vancouver British Columbia

C.7 CATGraph Image

Figure C.7 is taken from Figure 2 in:

K. Kaugars, J. Reinfelds and A. Brazma. A Simple Algorithm for Drawing large Graphs on Small Screens.In Roberto Tamassia and Ioannis G. Tollis, editors, *The Proceedings of the DIMACS International Workshop on Graph Drawing*, pages: 278-282, Princeton, New Jersey, USA, 1994.

It is volume 894 in the series Lecture Notes in Computer Science published by Springer-Verlag

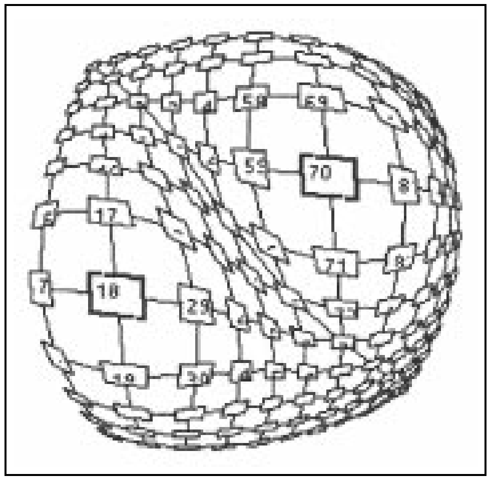

Figure C.7: Arctan Fisheye from CATGraph

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C.8 Non-linear Views Image

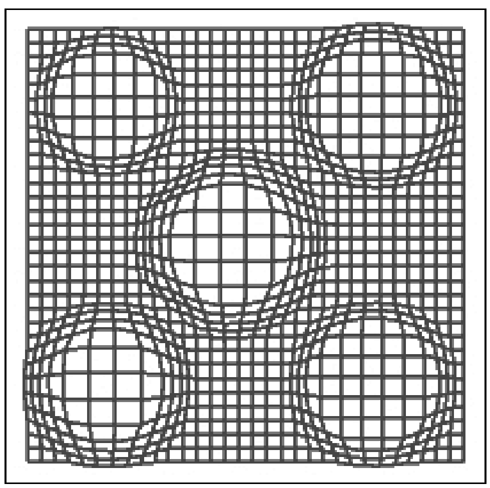

Figure C.8: Non-Linear Views [84]

Figure C.8 is used with permission from Alan Keahey and can be found at the top of the his web page on non-linear magnification.

$$http://www.cs.indiana.edu/hyplan/tkeahey/research/nlm/nlm.html$$