Chapter 8

Conclusion

Creating computer visualizations poses problems specific to computers both in terms of developing appropriate information representations and presenting those representations in a manner that is meaningful to the user. As in any visual field, an understanding of the medium has a bearing on the success of the resulting presentation. In the world of computers, this understanding is still in a generative stage. We make a contribution towards this growing understanding by exploring one specific aspect of information visualization, *elastic presentation space*.

The computer offers a new type of presentation space with new potential and new problems. We examined one identified presentation problem, the screen real estate problem, focusing in particular on the difficulty of supporting detail-in-context readings. The perceptual discontinuities that can result from the computer presentation of visual information are significant in terms of conveying data accurately and in an accessible form.

We define presentation as distinct from representation and delineate the dimensions of computational presentation space. We develop a framework, Elastic Presentation Space (EPS), developed independent from specific applications and formulated to respect cognitive principles, for the exploration of the distortion dimension of computational presentation space. We test the usefulness of this framework by:

- using it to develop a detail-in-context method,
- using it to explain and extrapolate between previous presentation methods, and
- extending its use to three-dimensional representations.

8.1 Contributions

8.1.1 Defining Presentation Space

We divided the display problem into two components: representation and presentation. Representation is the act of creating a basic image that corresponds to the information, such as creating a drawing of a graph. Presentation is the act of displaying this image, emphasizing and organizing areas of interest. This distinction has netted several benefits. It has allowed the exploration of presentation space independent of information specifications other than the dimensionality of the representation. The resulting methods can be applied to any two-dimensional visual representations; in particular, this includes raster image data. At the onset of this research, methods for viewing raster image data did not include the possibility of detail-in-context viewing.

Presentation space consists of possible transformations from one presentation to the next. These possible transformations can be grouped into *presentation dimensions*.

1. *Partition* is the act of dividing a given presentation into components or regions.
2. *Aggregation* is the act of changing a given presentation by collecting components or regions of a presentation into a groups.
3. *Distortion* is a spatial re-organization that changes the original proportions.
4. *Simplification* is the act of removing some aspect of the representation.
5. *Augmentation* is selective visual addition intended to increase the clarity of the presentation.
6. *Motion* is the act or process of changing position.
7. *Illumination* is the use of various kinds of lighting (from none or little to ambient, directional, and specular effects).

8.1.2 Providing a Detail-in-Context Method

Our first test of the usability of EPS was to develop a detail-in-context prototype 3DPS [20]. 3DPS provides the desirable features as suggested in the literature. Previous research recognized the detail-in-context problem and delineated the functionality that might exist in an ideal detail-in-context approach. In comparison with the suggested list all previous solutions had caveats. Furthermore, through use of EPS we were able to extend detail-in-context capabilities to include: arbitrarily shaped foci (Section 3.4), exact specification of magnification (Section 3.5), distortion control (Section 4.1) and folding (Section 4.3).

8.1.3 Describing Elastic Presentation Space

One of the hallmarks of a useful framework is its ability to explain and/or relate previous research. Chapter 5 shows how EPS can explain previous methods and their inter-relationships. Existing presentation solutions such as windows, full zooming environments and various distortion approaches create visual displays that vary considerably, both visually and algorithmically. EPS provides a way of understanding how these seemingly distinct solutions relate to each other. Also, it provides a method of relating them algorithmically, allowing the inclusion of more than one presentation solution in a single interface. Furthermore, EPS supports extrapolation between the methods it explains.

Being able to relate previously distinct presentations methods has allowed creation of solutions that exist in the spaces between the current point solutions. In fact, a range of presentation methods exist: between insets and detail-in-context presentations, between re-positioning in separate views and detail-in-context presentations, between full-zoom and detail-in-context presentations, and between radial and orthogonal detail-in-context presentations .

- *insets and detail-in-context presentations*. In EPS terms an inset is a detached lens with a described focal region. A *Manhattan lens* connects the focal region of the inset directly to the surface in normal position. The advantages of Manhattan lenses are: magnification of focal region is to scale, freedom of re-positioning is provided, interactive visual connection is available. However, while adjacent context can be seen in a visually connected manner not all of it can be seen simultaneously (Section 5.2.1).
- *repositioning in separate views and detail-in-context presentations.* Separate views provide freedom of re-positioning. EPS extends detail-in-context presentations to include re-positioning of foci or *folding*. Folding allows spatially separated focal regions to be repositioned while maintaining their information content and without disconnecting them from their context. We know of no other work that examines the repositioning of foci within a detail-in-context view (Section 4.3).
- *full-zoom and detail-in-context presentations*. The drop-off function that establishes the distortion region of the lens depends on a distance function. Basing the distance function on only x or y (or partial x or y) creates a *scroll* (or partial scroll). A scroll (with distance function x only) provides full-zoom in y and detail-in-context in x (or vice versa). Adjusting the degree to which x and y affect the distance function provides interactive alternation between a detail-in-context lens, a scroll, a viewer-aligned full-zoom and back again (Section 7.3).

- *radial and orthogonal detail-in-context presentations* Basing the distance function on L-metrics can provide a continuum between radial and orthogonal layout. In practice we find that L-one (diamond shaped), L-two (radial) and L-∞ (orthogonal) are of most interest (Section 4.2).

8.1.4 Extending to Three-Dimensional Representations

EPS was developed for two-dimensional representations. In Chapter 7 we investigated removing this limitation and discovered that EPS could be usefully applied to visual representations with other spatial dimensions. In particular, the ideas from this framework have been applied to three-dimensional representations creating a novel visual access method that deals effectively with occlusion and is capable of providing three-dimensional detail-in-context views. This visual access method solves the problem of occlusion in internal regions of a three-dimensional layout by clearing a line of sight to any chosen regions of interest (Section 7.5).

8.1.5 Looking at Comprehension Issues with Elastic Presentation

For an information presentation to be useful it is essential that the information can be understood. If the distortions are read as part of the information this may lead to false interpretations [160]. It is important to provide support to allow one to perceive the distortions as distinct from the information. We addressed this problem with the introduction of *visual cues*. Visual cues provide meta-information about the distortion, with the intention of allowing the user to perceive the distortion as distinct from the information. We identified four classes of visual cues.

- Pre-attentive abilities
- Acquired skills
- Visual formalisms
- Constructions

These distinctions between types of visual cues indicate places to look for relatively well-understood visual cues, and help identify which aspects of our interfaces may be cross cultural [169], and which are culturally tied and thus require learning (Chapter 6).

8.2 Future Directions

There are several directions indicated by this research:

1. using these results in developing applications,
2. continuing the exploration of issues involved in creating comprehensible presentations,
3. investigating interaction issues, and
4. continuing with the theoretical exploration.

8.2.1 Application

Application work has been started in three areas. With applications we believe that it is important to focus on potential users, identifying the specific features of the information and the specific nature of the tasks. Each application has involved working with users in different ways. Our H-curves [61] application was conducted in consultation with the developer of H-curves, Hamori. For MR-Image presentation a preliminary field study was conducted, observing radiologists at work. The Tardis project is an ongoing collaboration with researchers in the Resource and Environment Management Lab.

H-Curves

We have applied our understanding of presentation space to provide improved visual access to long DNA sequences represented as H-curves [60, 62]. An H-curve is a graphical representation of sequence data capable of displaying very large sequences ($> 100,000$) in a compact form. At low resolutions (high compactness), global sequence features such as codon bias become visually apparent, while higher resolutions display local details down to the individual residues. H-curves have been used to display entire genomes and to detect features in sequences such as a change in the DNA template-strand transcribed, overlapping genes, and repetitive sub-sequences. They are also quite suited to comparing global features among sequences, as sequences from similar genome families are expected to have similar codon biases [61]. Although very long DNA sequences can be plotted with H-curves, micro-features are lost as sequences get longer.

In consultation with biologists (in particular Hamori) we identified the following salient features of H-curves that are important to preserve: These are: global context (compression only), sequential display (no reversal), 'drift' as a sequence holds different meanings at different resolutions (all regions should have locally constant scale), 3D positional information (3D visual access), and the end points of the curve (and any segment within the curve). What is desired is a 3D detail-in-context technique [92] that utilizes a step magnification/compression function and provides geometric continuity between the sections of differing but constant scale.

This preliminary work on applying distortion viewing to H-curves could be extended to provide more complete visual exploration methods for DNA. We look forward to working with molecular biologists in such an endeavour.

MR Images

Medical image analysis is shifting from current film-oriented light screen environments to computer environments that involve viewing and analyzing large sets of images on a computer screen. Magnetic Resonance Imaging (MRI) studies, in particular, can involve many images. This research examines how best to meet the needs of radiologists in a computational environment [166]. To this end, a field study was conducted to observe radiologists' interactions during MRI analysis in the traditional light screen environment. Key issues uncovered involve control over focus and context, dynamic grouping of images and retrieval of images and image groups. We applied our understanding of presentation space to choose the most appropriate presentation method, matching task and information requirements learnt from field studies to presentation possibilities. There is ongoing research in this regard, working with radiologists to establish the right balance in the presentations between white space, limiting the number of different levels of scale, and preserving orthogonal relationships.

Tardis

An ongoing application is a collaboration with resource and landscape managers in the development of the SEED (Simulating and Exploring Ecosystem Dynamics) project. The project aims to create of a suite of tools that facilitate the process of building and examining simulations of spatially explicit models of landscape dynamics. This research has a dual focus, the simulation of landscape dynamics (SELES [44]), and the visualization of the information that these simulations produce (Tardis [27]).

In consultation with potential users we have selected and incorporated many presentation variations according to specific information and task needs. Of special concern in this research is the extent of the data and its inter-relationships that need to be understood over multiple scales, and across many information dimensions (spatial, temporal, attribute and run-replicate), and the challenge inherent in implementing viewing methods to facilitate understanding.

The concepts in the visualization environment have developed iteratively in conjunction with the development of the SELES simulation engine. Researchers, developing increasingly realistic models with SELES, have provided motivation for support of more complex dynamics. This in turn has driven the need for more flexible visualization tools. We are continuing to investigate the possibilities and new challenges this data presents. For instance, the visualization environment can been used to verify individual aspects of a SELES model during development.

Of particular current interest is the development of an extension to the concept of a lens that we are calling *analytical lenses*. Analytical lenses are being developed in direct response to user requests to combine the ability to do analysis work with the visualization environment. We are exploring the integration of simple analysis methods with the existing magnification lenses.

8.2.2 Comprehension Issues

While the consideration of comprehension issues was an important factor in the development of EPS, the work presented here is only a beginning. Having provided the ability to include visual cues to support a user's interpretation, there is extensive investigation still to be done in regards to its success. We are interested in such questions as: are comprehension issues dependent on the type of representation? when are visual cues needed? do visual cues help users interpret distortions? to what extent? do they all work equally? can users learn to read distortions? do visual cues support this learning? etc.

Currently two studies are underway and another is planned. The two current studies address the questions: do readability issues vary across representation types? and given that a user can not interpret a distortion, which cues help? The planned study will start to investigate whether a user's ability to read distortions improves with practice.

In the first study, we looked at five representation types: a coastline map of an unknown area, a coastline map of an known area, a topological photograph of an unknown area (the surface of Mars), a grey-scale photograph of an unknown area (the Orion Nebula), and a map with text labels of a known area (British Columbia). Preliminary results indicate that though there is a distinction between the known and unknown coastline maps, it is small, and these types of representations seem very difficult to read. The photograph was also difficult while the distortions were identified relatively easily in the familiar map. In contrast it seems users are relatively capable of reading the grey-scale photograph of the Orion Nebula.

In the second study, preliminary results seem to indicate that the grid is pretty consistently successful and there seems to be at least one representation type where shading is not only not useful but is problematic.

8.2.3 Interaction Issues

A very important but largely untouched area of research is the question of how best to interact with elastic presentations. Which aspects of the lens should response to mouse action? Should there be different interaction modes? Should folding be controlled from the lens' top or base? How much complex control is useful to a user? Could a subset of lenses be sufficient? Do Manhattan lenses provide a bridge allowing a user to develop an appreciation of detail-in-context within a reasonably familiar paradigm? and so on. There are many new interaction issues that need to be resolved.

8.2.4 Theoretical Exploration

Presentation/Adjustment/Creation

We have explored within presentation space in that we have limited our exploration to reversible adjustments that do not effect the representation. However, the types of ideas discussed in this thesis can be used for layout adjustment and actually reorganize the representation itself. Furthermore, they can also be used to create a spatial organization or layout. Noik [116] notes that distortion approaches usually require an existing layout, and proceeds to use these ideas to provide an initial layout. In a manner analogous to Interactive Graph Layout [68] he builds the layout bottom up by providing each node with knowledge about the space requirements of its children so that it can establish its own needs. This nested layout approach handles requests for spatial emphasis to be allocated to particular nodes. Applying the expanded palette of presentation methods to both layout creation and adjustment can be investigated.

Expansion/Compression

While both expansion and compression have been used, the primary purpose has been to expand a region with the compression used to compensate for the increased size of the expanded region. This can be reversed. In the real world we organize objects by bringing those we are interested in closer and by moving those of less interest further away. Compression presentation possibilities can be explored. For example, it is possible to imagine deciding to compress a region of sparse layout instead of choosing to expand a particularly dense region.

Focus Line [59, 106] creates distortions according to the relative significance of the data. This indicates another possibility that arises from considering choice of placement for relative expansion and compression. That is to investigate anisotropic lenses.

Magnification/Displacement

Traditionally the distortion techniques of magnification and displacement have been applied simultaneously to create magnified foci in context, and are considered related or even derivative of each other. For instance, a certain amount of displacement opens up a certain amount of space which allows for that amount of magnification. However, these concepts can be usefully applied separately. We used this distinction in 3D visual access [22]. Magnification only would have limited use because of the introduction of occlusion, however, displacement only can be used for adjusting layout (perhaps more usefully than in combination).

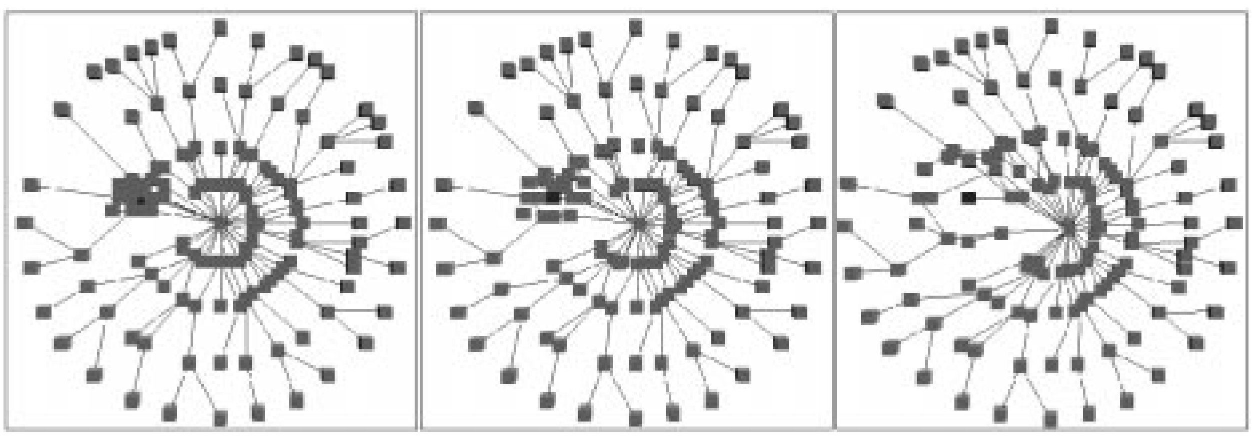

Figure 8.1: Left, a tree with a clumped group of nodes; middle and right, progressive application of visual access distortion, effectively separating this grouping

Problems of occlusion also occur in 2D layouts. For example, sometimes a particular layout can have areas of high density where nodes overlap and occlude one another. The ideas in visual access distortion [22] can be applied to separate the clusters. Figure 8.1 shows a circularly laid out tree with a group of nodes to the left of center. By selecting a node in the centre of the cluster and applying visual access distortion one can ”open up” this cluster. Figure 8.1 left, shows a graph, initially laid out using a spring algorithm in GraphEd [69], with a cluster. The centre and right images in Figure 8.1 show a constrained application of visual access distortion that shifts the nodes, opening up these clusters with minimum effect on the remaining layout. This example illustrates

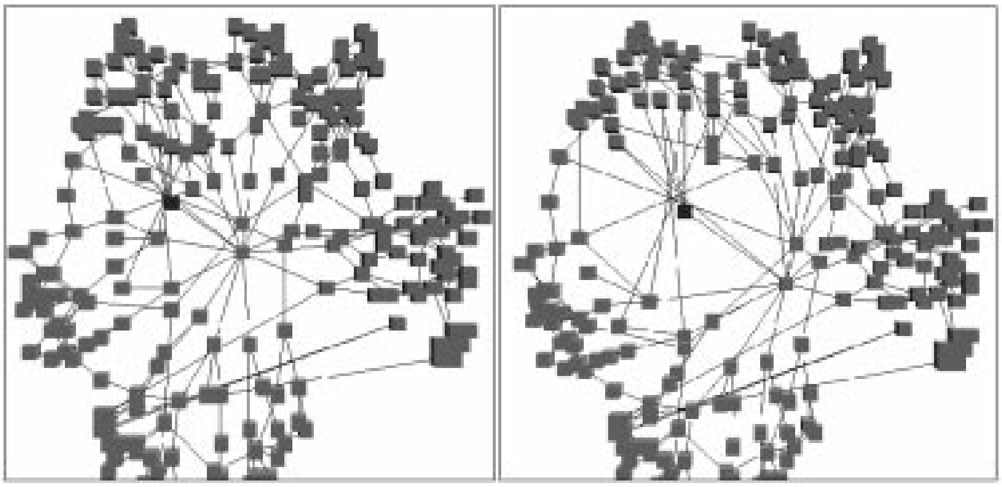

Figure 8.2: Left, graph with considerable edge confusion in central left; right, application of radial Gaussian distortion centered on a single node in that region

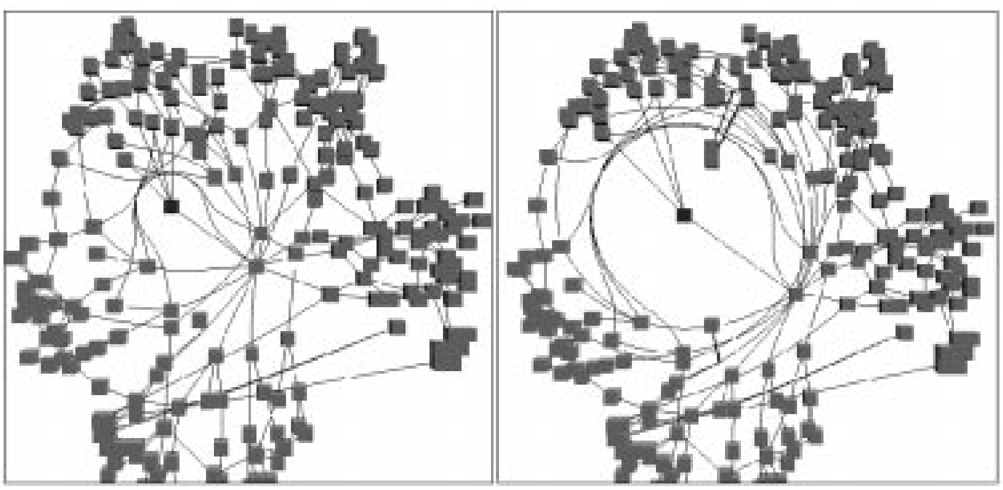

Figure 8.3: Graph in Figure 8.2 with visual access distortion applied progressively to clarify which edges are attached to this node

node congestion problems. Similar situations arise with edges. Figure 8.2 shows a graph (also positioned by spring layout) in which it is unclear whether all the edges passing a node (central left) are attached or merely crossing it. The image on the right applies radial Gaussian distortion in an attempt to clarify this. While the resulting image is an improvement, the application of visual access distortion to the edges (Figure 8.3) deflects crossing edges around the selected node making it easy to see which edges belong to this node. However, since all these edges passed across the node the amount of displacement is approximately the same for all of them. Therefore separating these edges is still an issue.

8.3 Concluding Thoughts

The computer is fast becoming the information medium of choice. Consequently there is an enormous amount to discover about how to make effective use of the fact that computational presentation is changeable and adjustable, or in our terms elastic. A method of developing one's ability to be effective when presenting in a particular medium is to understand the components with which one can work. To this end, in this thesis we describe a taxonomy of presentation transformation dimensions and expand the palette of elastic presentation possibilities. We hope that the contribution in this thesis will be considered an elementary step in a move towards creating an environment in which effective presentation aids thought.