Exploring Distinct Aspects of the Distortion Viewing Paradigm

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Abstract. This paper separates multi-scale or distortion viewing techniques into their component parts. Possible advantages of applying these distinct component separately are considered.

Keywords: multi-scale viewing, distortion viewing, graph layout

1 Introduction

Various approaches have been applied in the creation of distortion or multi-scale views. These approaches usually combine several techniques to make a chosen section of a graph more readable. In principle this is done by magnifying the selected section or focus while simultaneously adjusting the relative positioning of adjacent sections so as not to cause congestion and/or overlap. This is generally seen as a temporary viewing technique and the original layout is restored when the task at hand is completed. For surveys of this type of work see [9, 14, 18].

Considerable effort is usually placed on creating displays appropriate for a particular type of information or for the information's characteristics. As a result, several distinct distortion aspects are generally combined at a level below the control of the user. There is some recognition in the literature of the usefulness of these distinctions [3, 9, 17, 19]. We gather, illustrate and extend the list of separate distortion components, with the suggestion that these distinct aspects could be usefully added to a semi-automated graph layout tool. While there are other distinctions not mentioned in this paper, for instance discrete or continuous images [2], we have limited the scope to those aspects that most effect positional organization.

This discussion is concerned with two dimensional layouts only. While some of the distortion techniques mentioned were first presented in three dimensions, they all have a two-dimensional projection; notably Document lens [15], Perspective wall [10], 3dps [1] and visual access distortion [2].

2 Distinctions

Usually a multi-scale viewing approach combines perhaps selectively several techniques that work together to create useful information displays. As an initial step towards applying these techniques to graph layout there are several useful distinctions that can be made. This section examines these distinctions that have become part of the distortion viewing paradigm, many of which are closely related alternatives and thus are discussed in contrast to each other.

Adjustment/Creation Distortion viewing techniques are most frequently used to adjust an existing display, however, they can be used to create a layout. Noik [13] 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 [5] he builds the layout bottom up where each node knows the space requirements of its children and so can establish its own needs. This nested layout approach handles requests for spatial emphasis to be allocated to particular nodes. As layouts are created from the graph structure and the selected foci, a change in this selection can create a radically different result. This limits its use as an exploration tool since it could make it difficult to recognize subsequent images as being in fact the same graph. However, it remains one of the few approaches to use a detail in context paradigm to create graph layouts. This separation between adjusting an existing display or creating one from scratch points to the next underlying distinction.

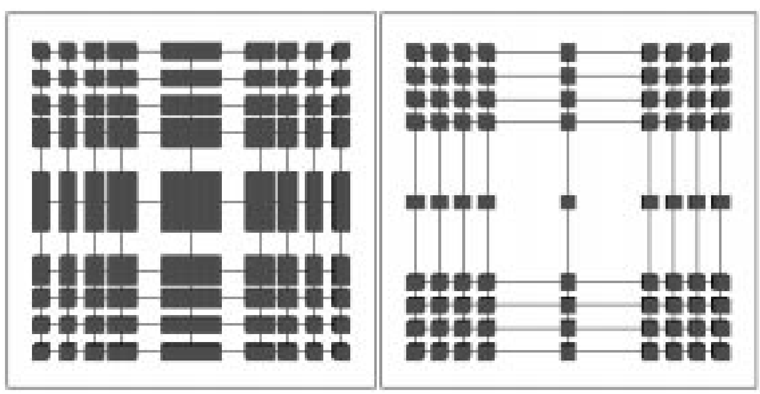

Fig. 1. Magnification/displacement; left, magnification and displacement combined; right, displacement only

Euclidean/Structural Distortion implies that spatial manipulation needs to be applied to some notion of space or type of distance metric. A choice of Euclidean distance requires an existing spatial representation. In contrast the choice of a graph theoretic notion of distance, such as path length, does not. In the former case, since the distance factor is obtained from the existing spatial layout applying distortion will result in adjustment, in the latter it can be used to either create or adjust. Noik [13] creates nested views based on structural hierarchy.

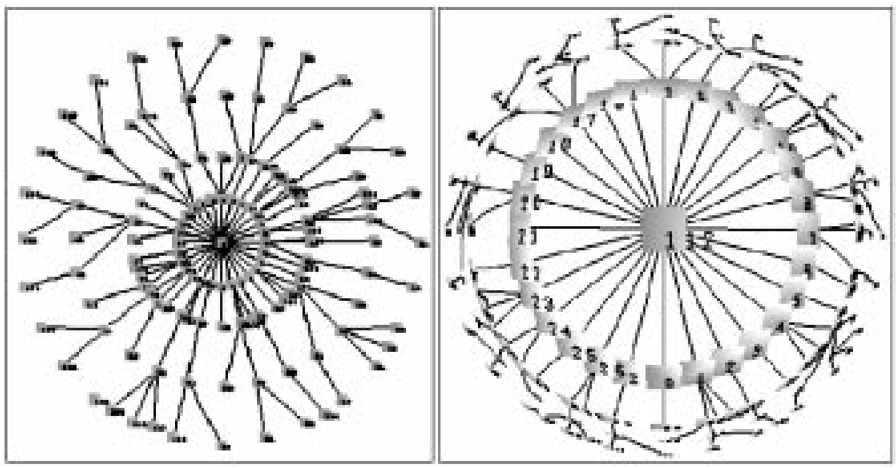

Fig. 2. Right, fish-eye view of a circularly laid out tree: left, curve parameters adjusted to accent the inner ring; note that while the nodes are now quite visible they still overlap

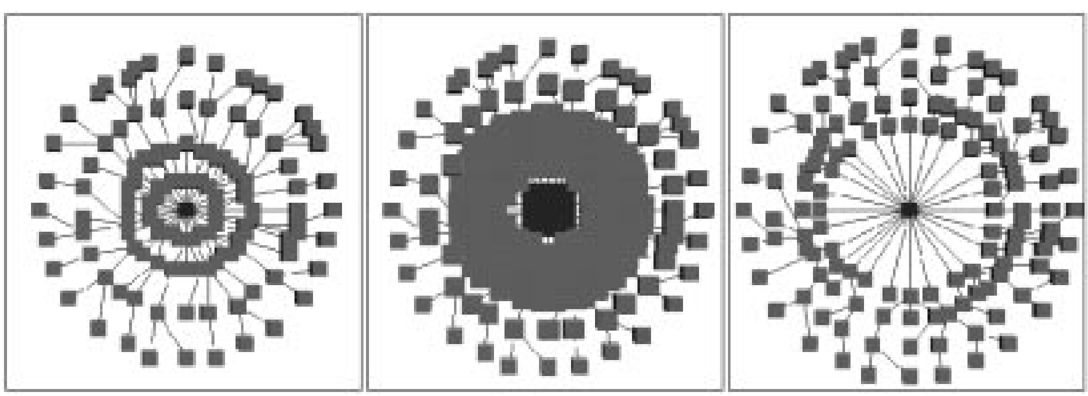

Fig. 3. Left, circularly laid out tree with the inner two circles slightly congested; middle, application of both magnification and displacement exacerbates the problem; right, displacement only makes the distinctions between nodes in the two rings much clearer

Magnification/Displacement Traditionally the distortion techniques of magnification and displacement have been applied simultaneously to create magnified foci in context. This distinction is applied in [3] to create detail in context views for three dimensional graphs. Figure 1 illustrates one distortion technique (orthogonal) on the left applying magnification and distortion simultaneously, and on the right applying displacement only. Combined magnification and displacement create traditional orthogonal fish-eye views [7, 17, 19]. 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 2 shows a circularly laid out tree graph with a single continuous fish-eye applied using both magnification and displacement. Note that while the nodes in the central ring are easier to see they are still over lapping and the outer rings have become quite compressed. In Figure 3 applying magnification with displacement to a similar tree entirely obscures the two central rings while applying displacement only separates the inner ring quite nicely.

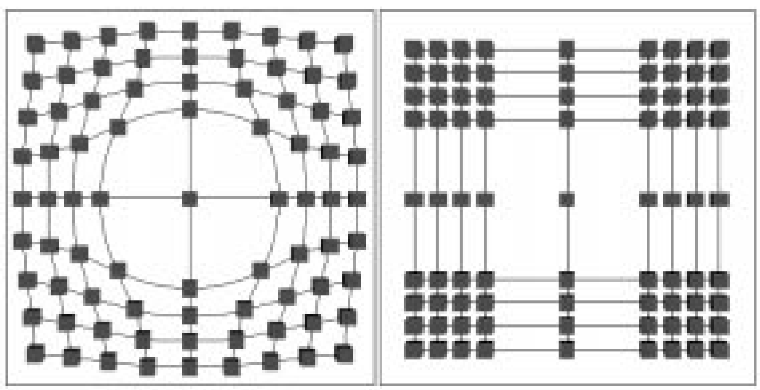

Fig. 4. Orthogonal/radial; left, radial Gaussian displacement; right, orthogonal displacement

Orthogonal/Radial Any given distortion can be either applied orthogonally or radially creating significantly different layouts (Figure 4). This distinction frequently noted in previous work is often provided as an option [7, 12, 17, 19]. Misue et al. [11] consider the issue of a user needing to be able to recognize that a given graph or display in fact contains the same information across changing fish-eye views. They suggest three spatial factors that may aid in preserving a user's mental map thus helping this recognition. These factors are orthogonality (that objects maintain relative right/left up/down positioning), proximatey (that adjacent objects remain that way) and topology (that containment relationships are preserved). Both Sarkar et al. [17] and Storey and Hausi [19] discuss this or-

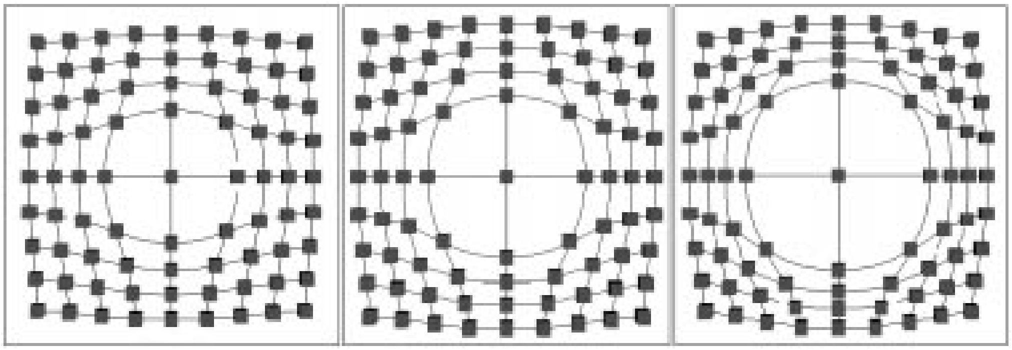

Fig. 5. A progression of Gaussian displacements

thogonal/radial distinction in relation to these three factors, noting that while an orthogonal distortion preserves orthogonal relationships in the display it creates new perhaps artificial clusterings. Storey and Hausi [19] in particular notes that a radial approach is better at preserving proximatey relationships which may be more important to the information (Figure 4). This choice allows layouts to reflect those aspects of the information displayed which are currently important to preserve. Figure 5 shows the progression of a radially applied Gaussian distortion using displacement only. Note that only in the most magnified image on the right of Figure 4 is the clustering that occurs in orthogonal distortion starting to become apparent.

Expansion/Compression Expansion and compression have become common place with most visual display tools allowing some method of 'zooming' in and out. There are two points to be made of relevance to with the present discussion. First, distortion viewing has focused on expansion using compression only to compensate for the extra space required by the magnification. This perspective may reverse when the purpose is positional reorganization. It is possible to imagine deciding to compress a section of sparse layout just as likely as choosing to expand a particularly dense section. Second, zooming provides magnification to scale for all aspects of the image so that relative relationships remain unchanged. As previously discussed this can be an important consideration. However, in some situations, for example wanting to distinguish between nodes, separation is more important than magnification. Application of the earlier distinction between magnification and displacement allows such variations as expansion without accompanying node magnification, which can be used to separate nodes in congested areas, conversely compression without shrinking node size would allow inter-node space to be minimized without nodes themselves becoming single pixels or disappearing.

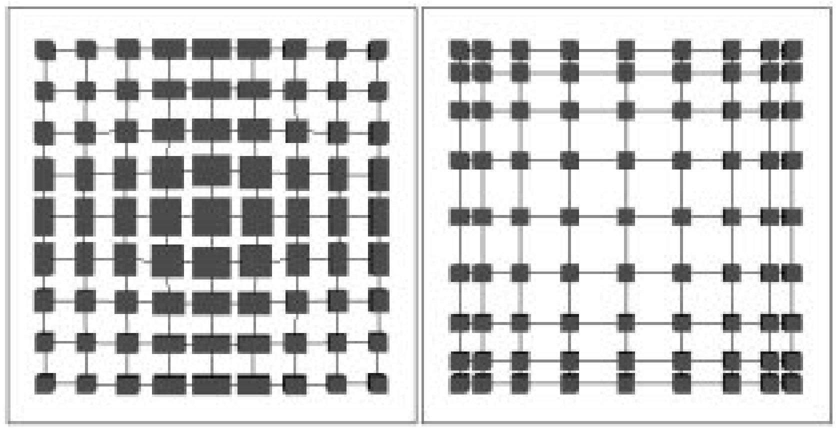

Fig. 6. Uniform/non-uniform; left, non-uniform scaling; right, uniform scaling

Uniform/Non-Uniform As discussed above, scaling or uniform expansion and compression are common capabilities. However, distortion viewing techniques add several non-uniform possibilities. The basic idea of integrating a focal area with its context has led to a great variety of non-uniform approaches. The next two sections to follow further sub divide such distortions. Figure 6 shows a gradual decrease in node size on the left in contrast to the image on the right which uses an orthogonal scaling only approach. The latter image has a central section of uniform expansion, four corner sections of uniform compression and four non-uniform sections, two compressed in x and expanded in y and two reversed.

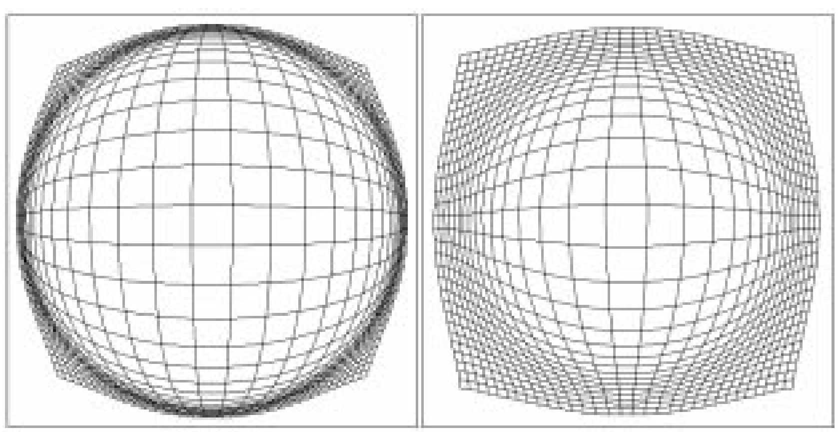

Fig. 7. Two variations in resulting pattern for non-linear distortion

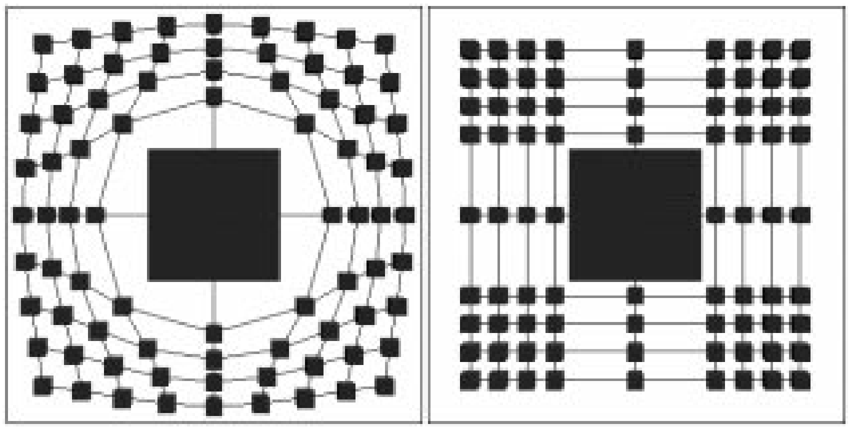

Fig. 8. Step magnification with on the left radial distortion and on the right orthogonal distortion

Linear/Non-Linear Distortions The distinction between linear and non-linear distortions is discussed in [9] as a constant or varying rate of decrease; the reader is referred to the appendix in this paper to find the mathematics behind most of the distortion approaches in the literature. Linear non-uniform distortions are the simplest type and involve a regular rate of increase/decrease which can be interpreted as the slope of a straight line. However, discussions in multi-scale viewing often take the attitude that the compression needed to allow for extra focal space should ideally be gradual enough to provide good visual integration between the focus and its context. This combined with varying information dependent needs such as areas of secondary interest [4] and reasonable magnification of the immediate surrounds of the focus [16], has led to exploration of functions that provide varying rates of compression. At the present time there are an increasing number of choices in the literature in this regard. They include the use of information specific degree of interest functions [4, 17] as well a great variety of curves, notably arctan [7, 12], hyperbola [8], hemisphere [17] and Gaussian [1]. 3dps [1] extends the single curve approach by: allowing the user to control the curves parameters, interactively affecting the distortion patterns, and by introducing a secondary curve (half sine) that is also used interactively to modify the basis curve (Gaussian) allowing the user choice of resulting distortion patterns. Figure 5 shows a simple displacement only, Gaussian progression, Figure 6 on the left, side shows a half sine curve applied orthogonally for both magnification and displacement, and Figure 7 illustrates two distinctive distortion patterns resulting from modifying a Gaussian curve with a half sine curve.

Disjoint/Continuous Distortions The section above discussed the use of continuous curves to create the distorted sections. The idea of non-uniform distortion also includes various types of step functions [9]. These can be disjoint, piecewise continuous and can be composed of sections of scaling only combined with linear or selected non-linear curves. The results in Storey and Hausi [19] can be thought of as a scaling only disjoint step function. Figure 8 shows a magnification step function combined with first a radial Gaussian displacement and then an orthogonal displacement. See [19] for discussion of applying this result for layout adjustment.

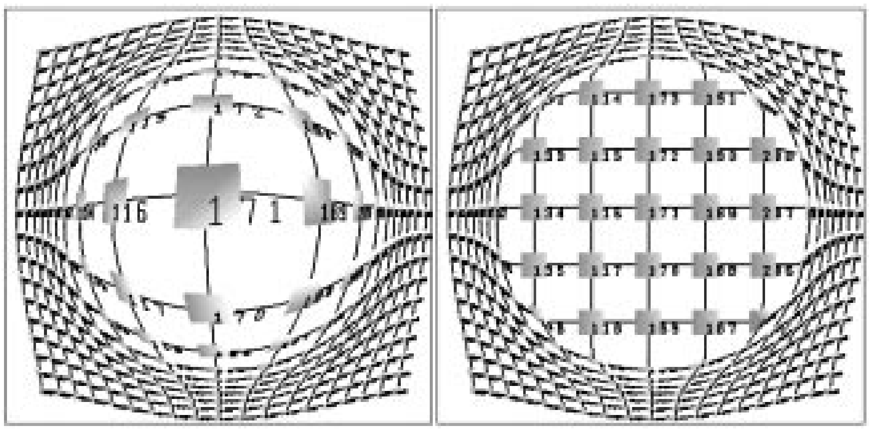

Fig. 9. Global/excluded; left, global distortion; right, focus excluded from distortion

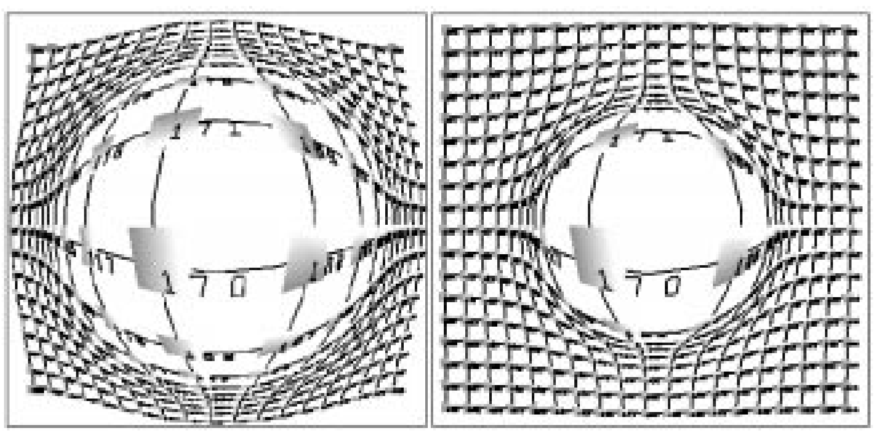

Fig. 10. Global/constrained: left, global distortion; right, locally constrained distortion

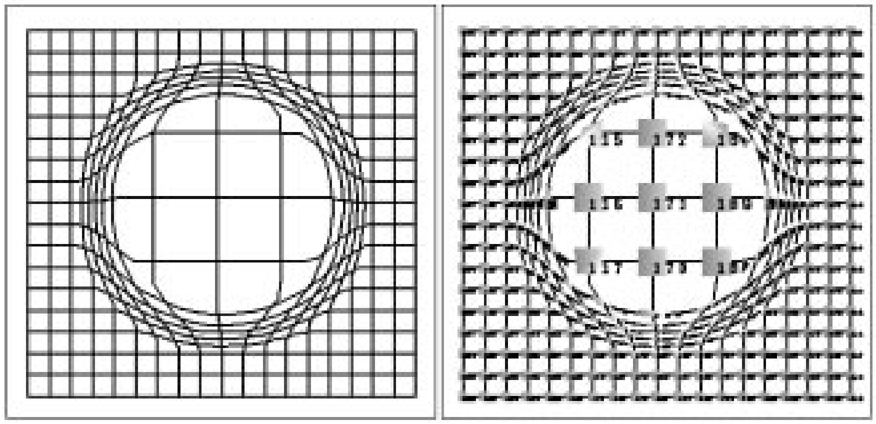

Fig. 11. Piecewise application; two sections scaled only connected by a Gaussian curve

Global/Excluded Most detail in context techniques are global in that they affect the entire display. The basic idea of step or piecewise functions introduces the possibility of limiting the techniques to chosen sections. The initial application of this idea was to keep focal areas clear of distortion. Sarkar [17] guaranteed magnification to scale only in convex focal areas, essentially excluding the distortion from the specified areas. 3dps [1] extended this to arbitrary focal areas (Figure 9). This ability to control the area that is affected by the distortion is central to using distortion techniques to enhance semi-automated layout. A useful extension would be the selection of non-focal areas that could be also excluded from the distortion. Figure 9 shows a focal section that is scaled only surrounded by radial Gaussian distortion.

Global/Contained The previous section is concerned with the exclusion of a region or regions from an otherwise global distortion. This section discusses limiting the extent of the distortion. The idea of contained application of a distortion technique was presented in 3dps [1] and is also used in visual access distortion [3]. The user is allowed to interactively affect the bounds the distorted area by adjusting of the curve parameters. Figure 10 shows a single contained distorted section that integrates smoothly into the undisturbed background. This notion provides freedom to expand or shrink a small section and adjust different sections with different distortion patterns. Currently limits are controlled by curve parameters, this can be extended by placing limits through defining Cartesian areas, certain substructures, or neighbors of particular distance. Constraining distortions can be combined with the afore mentioned possibility of excluding sections. Figure 11 shows one of the choices in 3dps [1] that links two sections of uniform scaling with a blended Gaussian radial distortion.

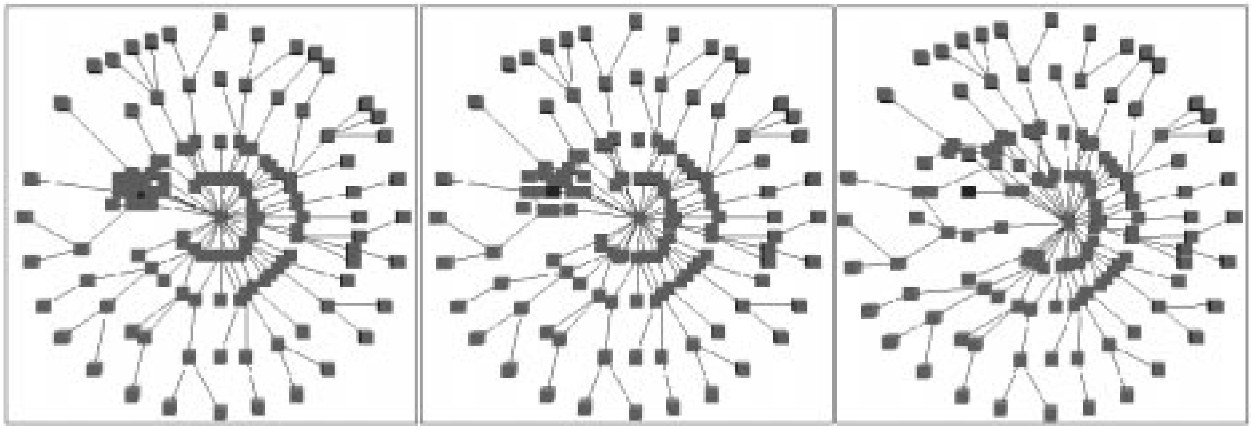

Fig. 12. Left, a tree with a clumped group of nodes; the middle and right, progressive application of Visual access distortion, effectively separating this grouping

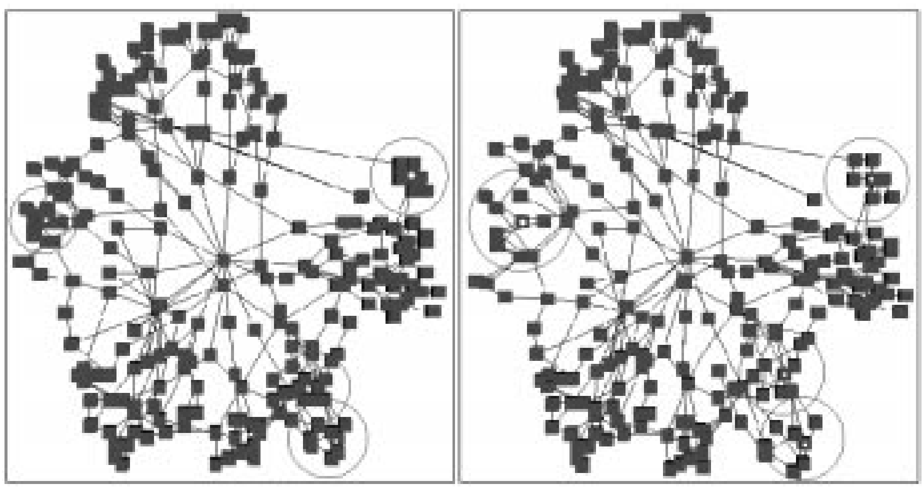

Fig. 13. Left, graph with four marked congested areas; right, same graph with technique in visual access distortion used to spread these areas

Occlusion The discussion of adjustment to this point has focused on spatial reorganization while maintaining chosen properties of the existing layout. It is possible to use similar ideas to actually reorganize relative positioning. For example, sometimes a particular layout can have areas of high node density where nodes are actually overlapping and occluding one another. The visual access distortion [3] uses the same techniques to clear a line of sight to a node or focal area in a 3D display. This can be applied to move the nodes that are obscuring a selected node. Figure 12 shows a circularly laid out tree with a group of nodes

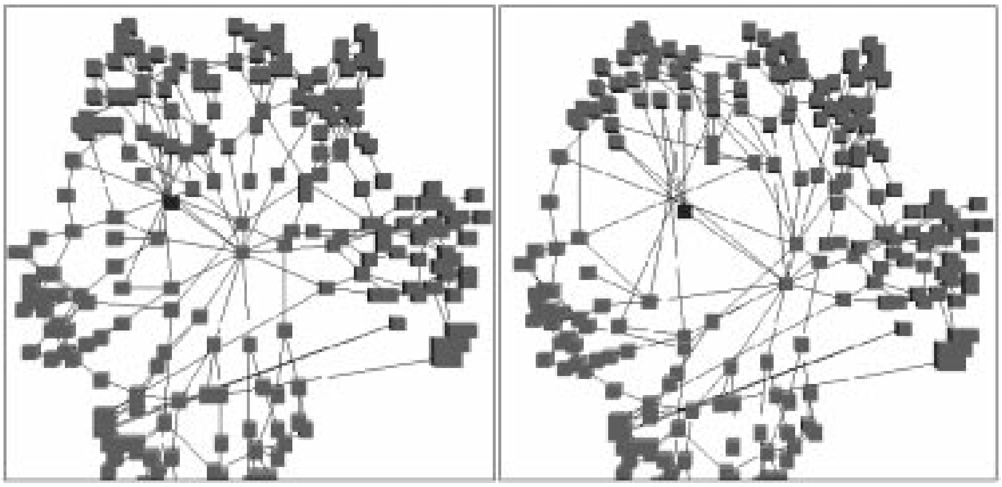

Fig. 14. Left, graph with considerable edge confusion in central left; right, application of radial Gaussian distortion centered on a single node in that region

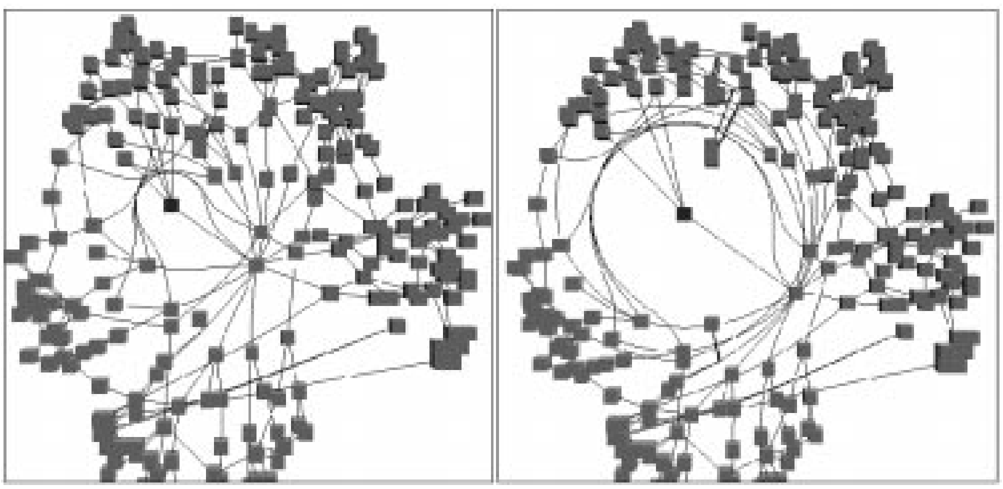

Fig. 15. Graph in Figure 14 with visual access distortion applied progressively to clarify which edges are attached to this node

to the left of center. By selecting and in effect anchoring a node in the center and applying visual access distortion one can "open up" this cluster. Figure 13 shows a the graph, initially laid out using spring algorithm in GraphEd [6], with four marked clusters on the left and on the right a constrained application of visual access distortion nicely shifts the nodes, opening up these clusters with minimum effect on the remaining layout. In the examples above we presented node congestion problems, however, similar situations arise with edges. Figure 14 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 15) 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. Visual access distortion [3] used here for 2D layouts was initially developed to solve issues of occlusion in three dimensions (Figure 16).

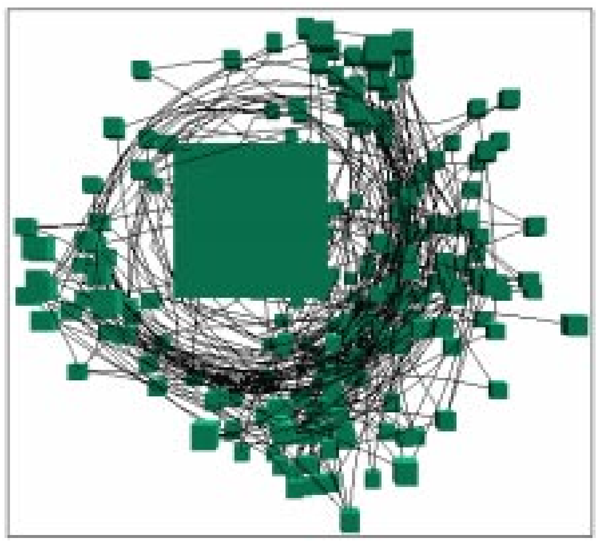

Fig. 16. Step magnification with radial Gaussian distortion applied both nodes and edges

3 Future

This discussion has focused on the layout adjustment possibilities inherant in distinct aspects of distortion viewing techniques. Of particular note in this respect are the abilities to use displacement solely to create separations, the application of visual access distortion which deals with occlusion as effectively in 2D as in 3D, and the possibility of limiting the application of distortion allowing local layout adjustment.

Possible extension into layout creation includes investigation of the ideas behind interactive graph layout [5] which closely parallel those in multiscale viewing. Though the primary concern of each is user control of emphasis in a generating a view of a graph, they are not often discussed in the same context. Interactive graph layout is based on two assumptions; one, that good graph layout is a difficult problem and two, that often the best judge of an appropriate layout is the user, who knows both the information at hand and the motivation for the layout. Similarly multiscale viewing has developed largely from a desire to be able to enhance the display of particular details within their global context. Again it is often (though not always) the user controlling the task at hand who is in the best position make choices about tradeoffs between magnification and compression of different regions.

The interactive graph layout solution is based on partition, or perhaps to phrase it another way, user controlled divide and conquer. Distinct but simple layout algorithms are applied to small sections of the graph. These sections are bounded by a convex hull and further positioned as a group. The overall layout is built in a bottom up manner so that the size and shape of the components are always known. Using a simple row/column based algorithm Henry [5] creates useful layouts that reveal different types of subgraph structure depending on the groupings and the order of application. Given the relative success of this simple method in the bottom up construction of a layout it is possible to forsee how the judicious application of the wide variety of these elemental tehniques, drawn from distortion viewing and discussed here, may lead to still more effective layouts. It is the spatial limiting properties of these distortion techniques, combined with the ability to exclude specific areas from their effects which makes the inclusion of these techniques possible.

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