Bringing the Advantages of 3D Distortion Viewing into Focus

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Abstract

Some recent developments in the area of multi-scale viewing have concerned the creation of such views from magnification factors as input. We present an algorithm in which magnification factors are used directly to control the creation of a multi-scale view in a 3D based distortion viewing. Our algorithm relies on the basic geometry of a perspective view volume, the properties of which provide a single step conversion between magnification and transformation.

1 Introduction

Research in effective use of screen space now offers a variety of methods for providing single image multi-scale visual exploration environments [2, 5]. Furnas and Bederson's introduction of Space Scale Diagrams [4] showed how conceptualizing these transformations in 3D facilitates greater understanding. This paper explains how a 3D framework can exploit the properties of a single point perspective projection to create multi-scale views directly from magnification specifications.

Figure 1: Single focus multi-scale view.

In section 2 we outline two mathematical frameworks used for the creation of multi-scale presentations of two-dimensional information. Section 3 derives the exact method we use to allow specification of the magnification factor for a lens. In section 4 we discuss the similarities between different methods and contrast the complexity of our algorithm with that of a previous method. Finally, conclusions are drawn in 5.

2 Creating Multi-scale Views

There are many methods for producing multi-scale views (for surveys see [16, 10, 7]). All of these methods adjust the presentation of two-dimensional representations. For the purposes of this discussion we note one broad distinction. Most [1, 9, 14, 13, 5] make use of transformation functions that are applied in the two-dimensional plane of the representation. A few [8, 12, 2] manipulate the two-dimensional representation in three-dimensions and then apply perspective projection to achieve their multi-scale views.

2D Based Approaches. The two-dimensionally based approaches create a new presentation or view by spatially adjusting a given two-dimensional layout to another two-dimensional layout. A 2D transformation function performs adjustments in x and/or y. The resulting pattern of magnification and compression is the derivative of the transformation function. The reverse, determining the transformation function from the magnification function is non-trivial in 2D.

Keahey and Robertson [6] note that an appropriate interaction method is to allow the user to create multi-scale views by requesting the pattern magnification that suits their task, and describe an iterative approach that achieves this. Their method starts with a grid and a set of desired magnification amounts. The grid is adjusted iteratively, ensuring no grid point overlap until the difference between the magnification provided by the adjusted grid and the desired magnification is sufficiently small. They use 3D images, representing magnification fields as a height field, to illustrate the effect of the transformation function [6].

3D Based Approaches. The three-dimensional based approaches are quite different algorithmically. The plane or surface that holds the two-dimensional representation is manipulated in three dimensions, then viewed through single point perspective projection. The transformation function results from the combination of the manipulation of the surface and the perspective projection of it. As we will show in section 3 this combination simplifies the mathematics of the relationship between magnification and transformation to the geometry of similar triangles.

In a perspective framework the two-dimensional surface is placed on the x, y plane parallel to the viewplane at a distance along the z axis from the viewpoint which defines unit magnification. 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. The scale or magnification factor of planes parallel to the viewplane is a function of the distance from the viewpoint.

The surface manipulation is achieved in this manner. The focal region of a lens is defined positionally and parametrically so that it provides the desired magnification. Visual integration from the focal region into the context is provided by a drop-off function. We frequently use a Gaussian drop-off function since its natural bell curve integrates smoothly into both the focus and the context. Points on the surface are then translated depending on the value of the drop-off function when applied to the distance of the point from the focal region. To ensure full visibility and uniform magnification response the foci are viewer-aligned and the translation vectors are normalized in z, (for complete explanation see [2]). The extent of the spread of the distortion into the context can be user controlled by adjusting the domain and range of the drop-off function. The manipulated surface is then viewed through perspective projection.

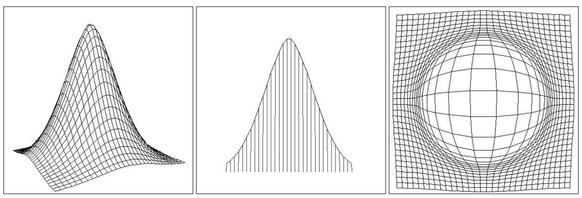

Figure 2: 3D surface manipulation and resulting transformed view.

In our explanations of 3D based transformations, we have used 3D images that show the manipulated surface (Figure 2, left). Though these images have visual similarities with the images of 3D magnification fields, they are representing step one in a two step algorithm instead of the result of the transformation. Figure 2, centre is a cross section showing the viewer-aligned translation vectors, and Figure 2, right, is the apparent transformation viewed through perspective.

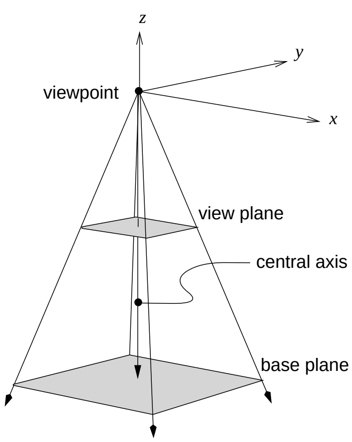

Figure 3: The perspective view-volume.

3 Magnification and Transformation in a Perspective Framework

In the 2D based approaches there are two factors; transformation and magnification. In our 3D perspective framework there are three factors; the apparent translation in x and y, the actual translation in z and the perceived magnification. As illustrated in Figure 3 the viewpoint is centred directly above the surface along the z-axis, at an established distance d_v. Translating a section of the surface to a height h in z creates a change in magnification mag. Perspective projection appears to move a point from its initial location at (x_i, y_i) to (x_m, y_m).

Both the apparent transformation in x and y and the resulting magnification factor, mag, can be readily calculated from the surface height, h. Additionally, the height can be derived given either the magnification factor or the x and y translations. Figure 4 illustrates this for x_i.

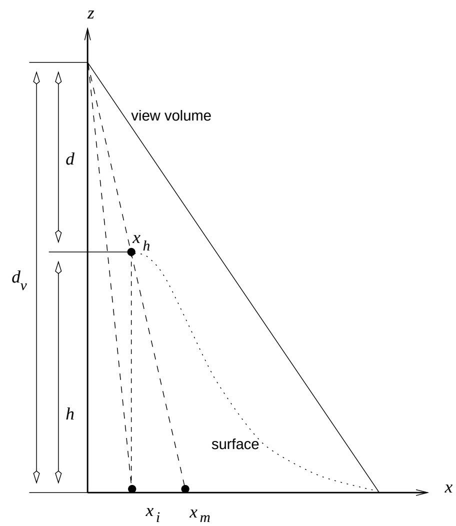

Figure 4: Similar triangles show the relationships between z-translation and magnification in single point perspective. The lateral distance between the projections of x_i and x_h at the surface position is the magnification of information at P_i.

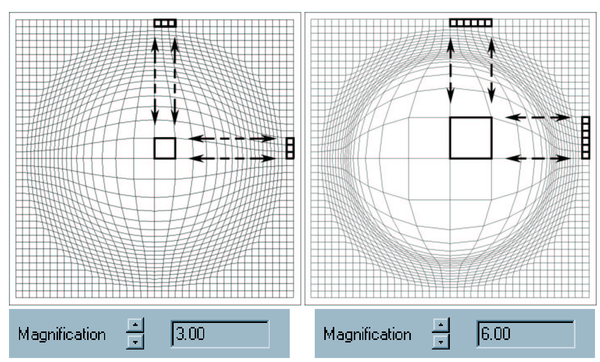

Figure 5: Magnification of a uniform grid by 3 times and 6 times respectively.

Given: Surface Height. A point P_i on the base plane (refer to Figure 4) is translated a z distance, h, to locate it at P_h, $(x_i, y_i, (z_i + h))$. The projection of P_h on the view plane is distance x_m away orthogonally from the view axis on the base plane. Therefore the magnification is the perceived translation $x_m - x_i$.

The coordinates x_m and y_m are calculated as shown for x_m:

$$x_m = x_i \cdot \frac{(d_v)}{(d_v - h)} \tag{1}$$

The magnification factor is:

$$mag = \frac{(d_v)}{(d_v - h)}$$

These coordinates allow the option of performing transformation directly by translating the point in x and y or through perspective by adjusting its height. This corresponds to displacement, respectively laterally to the view axis and parallel to the view axis. The x and y translation corresponds directly to other transformations that operate in the plane [9, 13, 5].

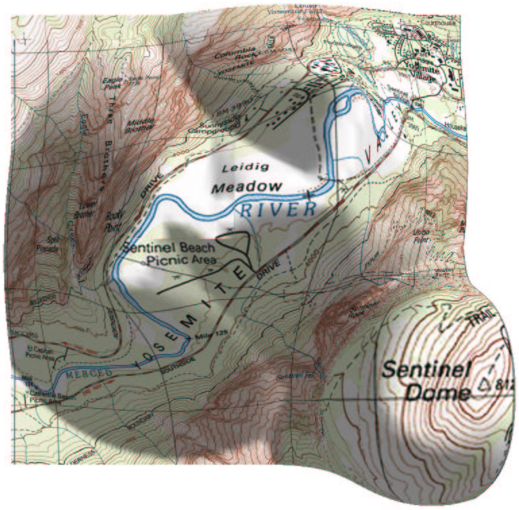

Figure 6: Two in context magnification zooms of the Merced River and Sentinel Dome in Yosemite National Park. The lens following Merced River uses a poly-line focus with a 2x magnification factor and linear drop-off, for Sentinel Dome there is a 3x magnification with a point focus and a Gaussian drop-off.

Given: Magnification Factor.

Given a magnification factor mag, the z displacement h is obtained from d_v.

$$d = \frac{d_v}{mag} \qquad\qquad h = (d_v - d)$$

The coordinates x_m and y_m are calculated as above.

Given: Transformed coordinates.

In the projected view, the transformed image is the result of apparent lateral translations, x_m and y_m. If the known quantities are the transformed coordinates x_m and y_m of the apparent lateral translations, the initial coordinates x_i and y_i can be obtained from h as follows:

$$x_i = x_m \cdot \frac{(d_v - h)}{d_v}$$

The magnification factor is the same as noted above. To obtain either the the magnification factor or the initial coordinates, both the transformed coordinate and the height are needed.

The simplicity of the relationships between magnification and displacement is one of the major advantages of basing our framework on perspective projection. We use the magnification factor to compute the height to which the surface should be maximally displaced, the drop-off function interpolates the magnification smoothly into the context where there is unit magnification. This allows direct specification of focal magnification. Figure 5 shows magnification of a grid by two factors, three times and six times respectively, and figure 6 shows a similar magnification inspecting a topographical map.

4 Discussion

The use of 3D perspective projection to provide multi-scale viewing accomplishes equivalent results to the 2D transformations, as shown in Figure 7. The left image as printed in this paper is, of course, 2D. When it was snapped from the screen it was a 3D manipulated surface viewed through perspective. The centre and right image show the 3D surface and the equivalent 2D transformation respectively. When viewed from above the right image appears equivalent to the left image.

A significant distinction is the 3D presentation of our approach. This has allowed inclusion of user support for the interpretation of the distorted views [3] by providing perceptual cues to the three-dimensional shape. However, the final presentation can be in either two or three dimensions and interactively exchanged (see figure 7). Changing between the two or three dimensional presentation is achieved by applying equation 1. Note that if our method only supplied us with x_m and y_m, the transformed coordinates as with other 2D transformations, the same situation would result. The magnification factor would be equivalently difficult to retrieve. However, as h (or the z coordinate) of each point is known, the relationships remain as described above. This is an important advantage of dividing the algorithm into two steps.

While the simple mathematical relationships based on similar triangles as described in section 3 are easy to use it is important to also consider computational complexity issues. Multi-scale views of discrete layouts are created by adjusting the individual points. If the transformation is applied to a grid, the grid points can be used to adjust a surface which can hold any 2D information or image. As each point in the grid must be visited, the size and resolution of the grid is the factor that primarily affects the complexity of the algorithm. The grid sizes we have been using (which allow interactive rates) vary from (10x10) to (30x30). Our method, and all other approaches with the exception of [6], are also dependent on the number of foci. At every grid point a calculation is made to determine the influence of each focus. Considering the literature that indicates that humans tend to hold seven plus or minus two [15] static objects in memory, or Pylyshyn's studies [11] indicating that this number is closer to four plus or minus one for moving objects, in normal use the number of foci will rarely exceed ten. This means that for each point in the grid we generally will not exceed ten focal operations.

In contrast, the direct use of magnification fields by Keahey et al causes iteration through the grid for each point. The number of these iterations is influenced by the degree of magnification requested, with more iterations as magnification increases. The iteration continues until the achieved magnification is within some error tolerance.

5 Conclusion

We have presented a method for direct control over multi-scale views through specification of the magnification for focal areas. The advantages of the method outlined in this paper are as follows. The relationships involved in magnified areas are extremely simple, given a perspective view volume they contain nothing more complex than the geometry of similar trian-

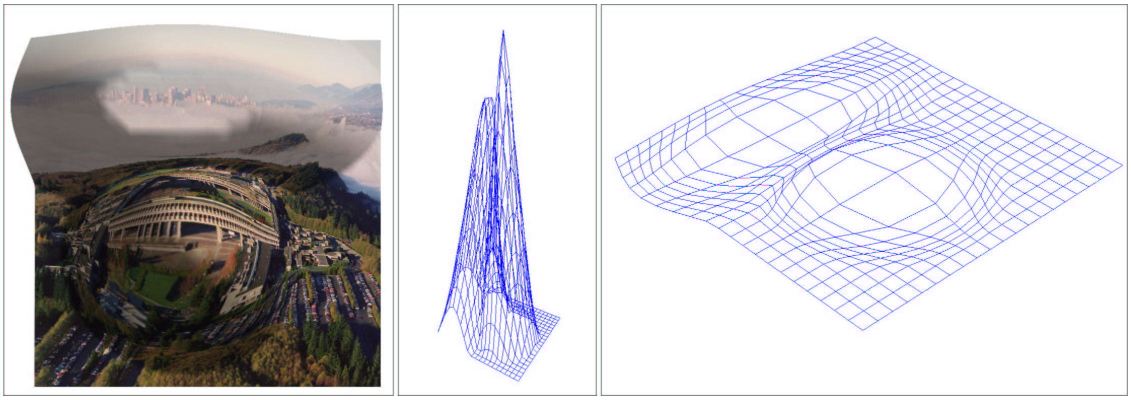

Figure 7: Example of the multi-scale view, the three dimensional surface accomplishing the view and that surface projected back into the original plane of the surface with equation 1. The view applied to the SFU campus, the foci zoom in on downtown Vancouver and the academic quadrangle at our campus.

gles. The magnification is precise within focal regions, previous methods [6] have computed the magnification to within some error tolerance. The interaction is minimal and intuitive, the user needs only place the focus and specify the magnification factor. The calculation for providing the magnification is computationally simple adding only one divide and one subtract per focus.

Acknowledgments

This work was supported by a grant from Forest Renewal B.C. and a postgraduate scholarship from the Natural Sciences and Engineering Research Council of Canada. We also acknowledge resources provided by the Graphics and Multimedia Research Lab at Simon Fraser University and Intel. The authors are grateful for helpful and insightful suggestions from Dr. T. Shermer.

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