Interactive Manipulation Of Projections With a Curved Perspective

Abstract

The concept of "curved perspective" has been used by artists such as M.C. Escher in order effectively convey a sense of three dimensional space while being restricted to a two dimensional canvas. We present an interactive system to create and manipulate projections with a curvilinear perspective. Our system presents the user with a set of intuitive screen-space perspective primitives that control the vanishing points of the scene. This allows the user to generate diverse projections having curved perspective.

1. Introduction

Traditional computer graphics uses linear perspective to project 3D scenes onto the 2D image plane. In classical perspective, points at infinity are projected to vanishing points on the 2D plane. Thus, lines tending toward infinity in the real world converge at the vanishing points of the scene. This is an approximation of our perception of the real world. In reality, our perception of the real world is not so linear. Our overall view of a 3D scene is an aggregation of several individual views. Thus, converging lines in the 3D world are not perceived as straight lines but are instead perceived as converging curves. This leads to the concept of "curved perspective".

A scene viewed in curved perspective has curves converging at its vanishing points rather than straight lines. The advantages of curved perspective over linear perspective are several. Curved perspective produces perceptually accurate projections. It can be used to emphasize the importance of certain parts of the scene over others since the viewer is naturally attracted to these curved lines. It can also be used to communicate a sense of three-dimensional space on the 2D image plane.

We present an interactive method to create projections with a curved perspective. Our interface allows the user to modify the vanishing points of the scene in order to control the curved perspective. This is analogous to an artist moving around the vanishing points on the canvas to change the overall projection of the scene.

2. Related Work

Previous work has been done in constructing non-linear projections of scenes from multiple linear perspectives [AZM00] , [Sin02]. These mainly deal with integrating individual linear perspective views of a 3D scene in a coherent manner and are not concerned with applying a different type of perspective to the scene.

Previous methods also require detailed manipulation of the internal camera parameters of several cameras placed in the scene in order to control the non-linear projection of the scene. This is quite daunting for the novice user. Our interface consists of simple GUI primitives to manipulate the vanishing points of the scene without requiring any knowledge of the inner workings of the graphics camera.

3. Methodology

In order to vary the perspective across a single 3D model we automatically assign a unique camera to each vertex of the 3D model. The vertex camera is found by varying the center of projection of a default scene camera. The new center of projection is a function of the position of the projected vertex with respect to the vanishing points defined in the scene. We will refer to this function as the warp function from here on.

4. Mathematical Model

If M represents the linear perspective projection matrix then the transformation of a world space point P into the corresponding camera space point c is given by the equation:

$$c = MP \tag{1}$$

M is a function of 11 camera parameters, one of them being the center of projection of the scene.

$$M \;=\; f(COP) \qquad (2)$$

We define a warp function g, which represents the amount of warp c is subjected to, given the current set of vanishing points in the scene. Thus, g takes in the camera point c and the vanishing points of the scene. The range of g is the interval $[0,1]$. g can be any monotonically increasing function. In the simplest case, g is a constant function resulting in linear perspective. The examples in this paper set g to be a sinusoid. Given n vanishing points in the scene we can define the new center of projection for c as:

$$COP' \;=\; \text{OldCOP} + \sum_{i=1}^{n} w_i g(c, V_i)\vec{v} \qquad (3)$$

V_i : i^{th} vanishing point in the scene.
$\vec{v}$: Vector from V_i to c.
w_i : Weight of the i^{th} vanishing point in the scene. $w_i \in [0,1]$.

The new projection matrix $M^{'}$ is then defined as :

$$M' \;=\; f(COP') \qquad (4)$$

The world space point P is then reprojected using the new projection matrix M' resulting in a new camera space point c'.

$$c^{'} \;=\; M'P \qquad (5)$$

This concept can be extended to defining multiple curved cameras on a single 3D model. This feature is useful when the user wants to define multiple warps in order to highlight certain local features on the model. Given m curved cameras defined on a model, equation(3) can be rewritten as:

$$COP' \;=\; \text{OldCOP} + \sum_{j=1}^{m} w_j \sum_{i=1}^{n} w_i g(c, V_i)\vec{v} \qquad (6)$$

w_j : Weight of the j^{th} curved camera. $w_j \in [0,1]$.

5. User View

Perspective primitives are GUI primitives defined for one or more vanishing points in the scene and are analogous to the primitives that artists sketch to layout 3D scenes on a 2D canvas. The user can click and drag a GUI handle on these primitives to modify that particular vanishing point. The handles are reset after a vanishing point is modified. Thus it is possible to place vanishing points outside the image plane just as artists do on a real canvas.

In the case of multiple curved cameras defined over a 3D model, the user can pick a region on the model to place the camera. Currently, a curved camera is represented by a circle whose radius represents the region of influence of the camera and the gray scale color represents the weight of the camera. The position, size and weight of the curved camera are all user controlled.

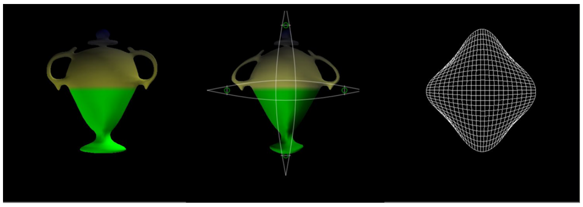

Figure 1: ***Case Study 1a:*** *(a)Linear Perspective of a vase. (b)Corresponding curved perspective of the vase. (c)Curved grid corresponding to the perspective view in (b).*

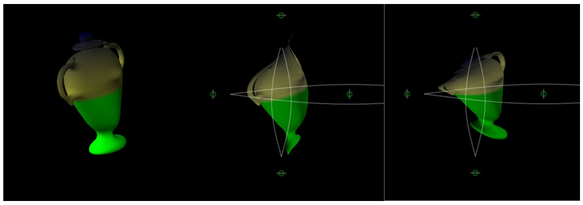

Figure 2: ***Case Study 1b:*** *(a)Side view of the vase in linear perspective. (b)Heavy weighing of vertical vanishing points. (c)Heavy weighing of horizontal vanishing points.*

6. Case Studies

Case Study 1a : We begin with a linear perspective view of a vase as shown in Figure 1(a). The curved perspective of the vase is shown in Figure 1(b). The perspective primitives are drawn as sinusoids whose ends represent the vanishing points of the scene. Thus there are 2 perspective primitives : one controlling the zenith and nadir of the scene, the other controlling the left and right vanishing points of the scene. Note how the handles of the vase have curved inwards and the bottom of the vase has become narrow. Our method retains the original lighting of the vase even after re-projection of the vase using curved perspective.

Case Study 1b: The side view of the vase is shown in Figure 2(a). Figure 2(b) shows the curved perspective of the vase obtained by assigning very heavy weights to the zenith and nadir. The zenith and nadir are very close to the vase itself resulting in the lid of the vase almost disappearing. Figure 2(c) shows the curved perspective of the vase obtained by assigning very heavy weights to the left and right vanishing points. Note how the right vanishing point is located outside the picture. This is equivalent to placing a vanishing point very far away or in the extreme case, at infinity. Thus the right-side of the vase is not as warped as the left side of the vase.

Case Study 2a: Figure 3(a) shows the side view of a building in linear perspective. Figure 3(b) shows the curved per-

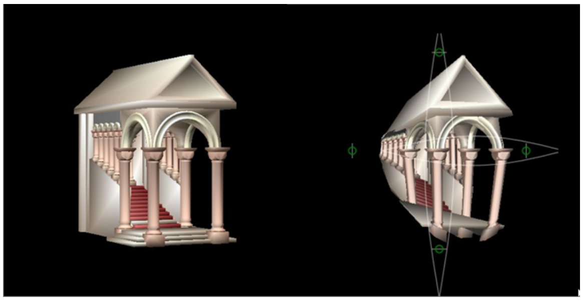

Figure 3: ***Case Study 2a:*** *(a)Linear perspective of a building. (b)Curved perspective of the building. (c)Heavy weighing of vertical vanishing points. (d) Heavy weighing of horizontal vanishing points.*

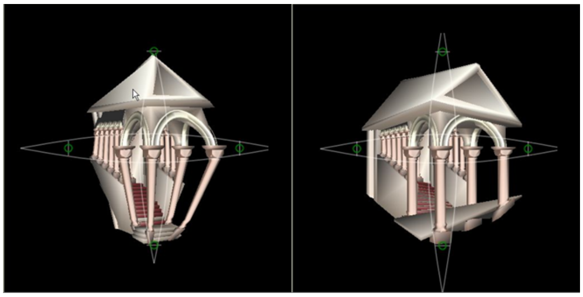

Figure 4: ***Case Study 2b:*** *(a)Heavy weighing of vertical vanishing points. (b) Heavy weighing of horizontal vanishing points.*

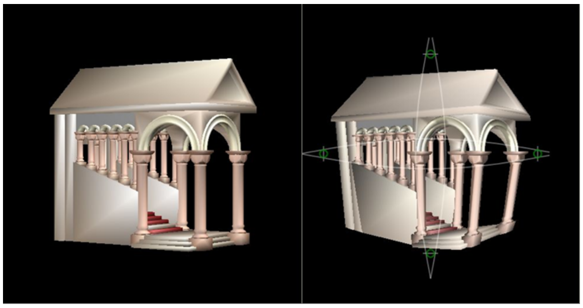

Figure 5: ***Case Study 3:*** *(a)Linear perspective view of the building. (b) Curved perspective view of the building applying the global warp function.*

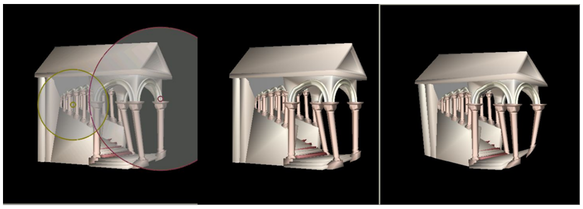

Figure 6: ***Case Study 3:*** *(a) and (b) Local curved perspective by applying only 2 local cameras. (c)Combining the global and local curved perspective.*

spective view of the building with an equal weighing of all 4 vanishing points. Note that the left vanishing point is within the building which results in the side pillars converging to that point.

Case Study 2b: Figure 4(a) shows the curved perspective view of the building weighing the vertical vanishing points more heavily than the horizontal vanishing points. Note how the upper pyramid of the building converges exactly at the zenith since there is very little influence exerted by the horizontal vanishing points. Figure 4(b) shows the curved perspective of the building with a heavy weighing of the horizontal vanishing points. Note how the the pillars remain straight even though the stairs tend toward the horizontal vanishing points.

Case Study 3: Figure 5(b) shows the curved perspective view of the building obtained by applying a global curved camera. Figure 6(a) and 6(b) shows the building having a global linear perspective and local curved perspective. This is obtained by defining two local curved cameras represented by the circles. The radius of the circle defines the influence of a curved camera and the intensity of the circle represents the weight of a camera. Thus the right side camera influences a larger number of vertices of the model and has a slightly larger weight than the left side camera. Note how the edges of the building remain the same as in the original model but the side pillars curve inwards as do two of the large pillars. The rightmost pillar remains straight since it lies exactly along the central axis of the right side camera. Figure 6(c) shows the image obtained by combining the global camera of 5(b) and the local cameras of 6(a). Note that the curving of the side pillars is retained from 6(b) while the curving of the rightmost pillar is introduced from 5(b).

7. Implementation

Currently our method computes the lighting and the projection in software. If our method was implemented using vertex shaders there would be a clear increase in speed.

8. Conclusion

Our goal is to easily create and manipulate projections with a curved perspective. Our intention is not to try to model every possible non-linear perspective projection, but instead to provide a simple and easy-to-use interface that effectively encapsulates an interesting class of projections. The warp functions provide a flexible and powerful framework to define interesting projections. The perspective primitives provide an intuitive and simple interface for manipulating these

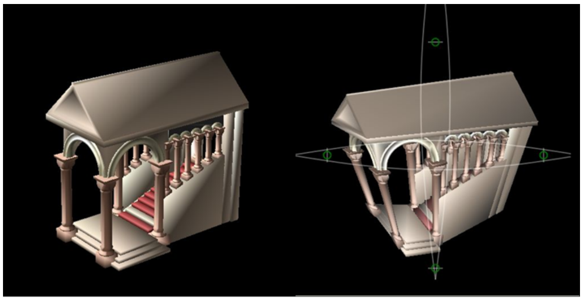

Figure 7: ***Curved Perspective of Building:*** *(b)Vertical vanishing points are weighted heavily. The nadir is very close to the model, while the zenith is further away.*

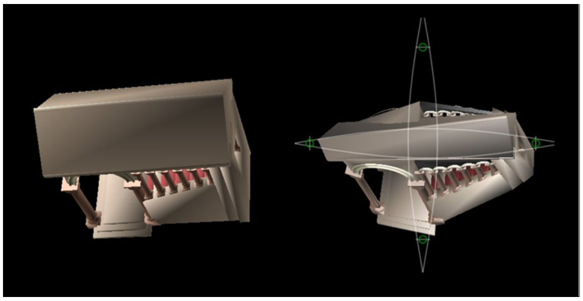

Figure 8: ***Curved Perspective of Building:*** *(b)Horizontal vanishing points are weighted heavily. Notice the outward curve of the walls.*

projections. It is easy to extend our framework to multiple curved cameras over a 3D model. This allows the user to generate images that have a global linear perspective but local curved perspective in specific regions of the model.

References

[AZM00] AGRAWALA M., ZORIN D., MUNZNER T.: Artistic multiprojection rendering. In *Eurographics Rendering Workshop 2000* (2000), Eurographics, pp. 125–136. 1

[CBGS02] COLEMAN P., BARRET L., GRIMM C., SINGH K.: Sketching 3d projections. In *Washington University Tech Report* (2002), pp. 17–24.

[FB87] FLOCON A., BARRE A.: *Curvilinear Perspective: From visual space to the constructed image*. University Of California Press, 1987.

[FvDFH93] FOLEY J., VAN DAM A., FEINER S., HUGHES J.: *Computer Graphics: Principles and Practice*. Addison Wesley, 1993.

[JKB98] JR. C. O., KIER T., BURGHY D.: *Perspective Drawing and Application*. Prentice Hall, 1998.

[Sin02] SINGH K.: A fresh perspective. In *Graphics Interface 2002* (2002), pp. 17–24. 1