CAMERA-BASED TEXTURE MAPPING:

AN APPROACH FOR CREATING 3D DIGITAL ENVIRONMENTS

WITH FOREGROUND FORMS USING 2D PAINTINGS

A Thesis

by

JUWANA NICOLE SAMMAN

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

August 2008

Major Subject: Visualization Sciences

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Approved by:

Chair of Committee,   Karen Hillier
Committee Members,   Ergun Akleman
                          Michael Greenwald
Head of Department,   Tim McLaughlin

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ABSTRACT

Camera-Based Texture Mapping: An Approach for Creating 3D

Digital Environments with Foreground Forms Using 2D Paintings.

(August 2008)

Juwana Nicole Samman, B.A., San Francisco State University

Chair of Advisory Committee: Prof. Karen Hillier

This thesis develops the method of using textures projected from the perspective of a projection camera, in combination with two-dimensional paintings and three-dimensional models, to create digital environments. Past uses have demonstrated effectiveness only for background and midground scene elements with limited camera movement. This work explores how camera animation can be maximized using the projected texture technique onto foreground environment forms. Through several case studies, general guidelines for artists are developed for using camera-based projected textures.

To my family

ACKNOWLEDGEMENTS

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CHAPTER I

INTRODUCTION

Since the beginnings of feature film, artists have tried to capture the imaginary on screen. Many different means have been used throughout the years, including painting on glass, in-camera compositing, miniature sets, and more recently, digitally created environments to trick an audience into believing that unlikely or impossible things existed together on the screen. Advances in technology have allowed the development of new methods. One approach is projecting two dimensional (2D) paintings onto virtual three dimensional (3D) geometry, which allows for some freedom of camera motion, and saves the time and resources of having to construct detailed digital 3D models and shaders.

The relationship between the 2D and 3D elements within the digital environment are generally determined by several factors: proximity to camera, camera motion within a shot, and seconds of screen time. In general, matte paintings have been used for elements further from the camera, as a backdrop, and for shots with minimal or no camera motion. They are an especially effective and efficient way to suggest place, time, and mood within a scene. Compared to the lengthy process of building, lighting, and texturing

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This thesis follows the style and format of *ACM Transactions on Graphics.*

a digital 3D model, they can be created quickly with relatively few resources.

While abundant (yet vague) references online suggest that camera-based texture mapping is a common practice in feature filmmaking, this artist-researcher could find no specific documentation on the methodology and uses of this technique. However, one record of recent research in this area was found. In 2004, Nathan Bowden developed an approach for projecting textures from the perspective of a camera into a scene with camera movement, and then recorded the process for his masters thesis at Texas A&M University. He was able to effectively use this method to suggest complex settings with a minimum of modeled geometry.

1.1   Artistic Intent

This artist-researcher proposes to continue the work that Nathan Bowden started. One of the limitations that he did not address was using this technique with foreground environment elements. Through several case studies, appropriate methods for using camera-based texture projection as an efficient means of integrating camera animation with foreground objects in a scene will be developed.

CHAPTER II

HISTORY

The beginnings of matte paintings and special effects in film can be traced back to magician Georges Méliès during the 1890's (Brosnan 1974). He created hundreds of films, each only a few minutes long. They contain a mixture of stage and photographic tricks, often using elaborate paintings as backgrounds for the set. An American, Norman Dawn, inspired by Méliès work, used the technique of painting on glass for the 1907 film *Missions of California* (Hutchison 1987). Over a pane of glass, set between a static camera and the mission remains, Dawn painted the missing segments of the church and then filmed this newly enhanced church through the glass.

In-camera transparent mattes became a widely copied technique and were used in many classic films. For the jungle scene in *King Kong*, glass plates, layered both in front and behind a miniature *King Kong*, were used to create the illusion of depth (Pinteau 2004). While this technique was effective in certain circumstances, one serious drawback was that the camera and glass had to remain stationary until the shot was complete. Any motion, intentional or otherwise, to this setup, would necessitate a re-shoot of the entire sequence to ensure camera consistency.

An alternate approach was soon developed in the form of a black matte painted on glass to block a portion of the image (Figure 1). The scene could be shot, the film

rewound, and the previously unexposed section exposed to the painted scenery to achieve a composite (with a mask covering the film that had been initially exposed). This technique is known as latent image compositing.

Figure 1.Nicholas Samman. Original Photograph. 2002.

In 1916, Frank D. Williams patented the traveling matte (Wright 2002). To insert characters into a different setting, the actor would first be filmed in front of a blue background, and the silhouette of the actor would be extracted by creating a copy on high contrast film that registered the actor as a white figure on a black background. This allowed the actor to be separated as an element from the background, which was also filmed separately. With an optical printer, frame by frame, the opaque area, defining the actor's position on screen, was inserted into the background miniature scenery. Compositing with an optical printer consisted of placing two or more pieces of film with separate elements of a scene in a projector, and then photographing them together on a new

piece of film. The color blue, now commonly used as a blue screen backdrop, was initially chosen because it did not appear in faces.

The concept of multiple glass planes to suggest depth was pushed further by Disney in 1937, with his multiplane system (Vaz 2002). Layers of painted glass, representing foreground, midground, and background, were each individually lit, animated, and focused to suggest depth and motion. Today digital programs such as Adobe After Effects can achieve a similar effect.

During the 1970's, Industrial Light & Magic (ILM) developed a motion control camera for *Star Wars* (Smith 1986). This computer-controlled system could track camera movements, and repeat them, allowing for multiple takes to be filmed separately and combined later.

Bridging the gap to the present, in 1985, for the film *Young Sherlock Holmes*, an ILM matte painter named Chris Evans became the first to work on a digital matte painting (Dunigan 1996). Since then, leaps and bounds in digital 2D and 3D painting and compositing technology have been achieved.

For recent films, it has become standard practice to include actors shot against blue or green screens. This allows the director complete freedom to film the actors and background separately, and then seamlessly combine them in post-production. There may be few, if any, other objects physically in the scene during the shoot. Advanced techniques for extracting parts of images and combining them with various photographic, painted,

practical, or 3D elements have allowed previously unimagined flexibility (Brinkman 1999).

"By the end of the decade [1990's] the 2-D cut and paste technology was integrating computer graphics" (Vaz 2002). For the 1999 film *The Phantom Menace*, ILM manipulated photographs of textures from the Bay Area and desert locales, and used them with digital 3D rock geometry for the pod race sequence. This mixture of traditional matte painting methods and computer models allowed for realistic imaginary landscapes.

For the movie *Spider-Man* (2002), Sony Imageworks used a combination of film footage, photographic, and painted elements to create the New York landscape. Many of these altered photos and paintings were "glued" onto very simple 3D cubes to create the illusion of a complex landscape (Pinteau). The advantage of recreating the city in this manner allowed complete freedom for a camera to track a flying Spider-Man from any angle (Figure 2). While Spider-Man and Star Wars are specific examples, in recent films, digital environments are widely used to create landscapes that would not otherwise be possible or realistic.

It is interesting to note in that in the gaming industry other techniques are used. A team of researchers introduced a new approach for extreme simplification, a model for representing complex 3D models in real time by reducing them to a few primitives. This representation, which they call billboard clouds, is "composed of a set of planar

Figure 2. *Spider-Man*. Columbia Pictures and Marvel Enterprises.

polygons with texture and transparency maps" (Décoret et al. 2003). The planes are chosen

in a way that represents the geometry of the model, and the visual complexity is captured

through textures. More so, billboard clouds maintain "interesting parallax effects even into

the range of extreme simplification" (Décoret et al. 2003). This technique is closely related

to a wide body of previous work in the area of model simplification, particularly

superfaces (Kalvin and Taylor 1996) and face clustering (Garland et al. 2001; Sheffler

2001). However, one advantage of billboard clouds is that it "does not require connectivity

of the clustered faces" (Décoret et al. 2003), so it can be applied to a larger range of

models, such as vegetation. Although conceptually there are similarities with the use of

projected matte paintings in feature film, these automatic approaches are difficult to use for

hand-painting applications.

When it comes to using paintings to suggest a three-dimensional space, whether they are projected textures or painted backgrounds, limitations still exist. Foreground elements in a shot that calls for camera motion are generally created through the expensive process of modeling, UV mapping, texturing, and lighting 3D geometry. This artist-researcher explores using an alternate method, camera-based projected textures, as a means to achieve the same effect in an efficient manner.

Numerous references to camera-based texture mapping can be found online, which suggest that it is widely used within commercial films and advertising. However, there is no specific documentation to explain where it is used and how. Often, this artist-researcher can only guess whether this technique was employed instead of more conventional means of shading. Even in cases where one can estimate with some confidence that projections were used, the methodology is unknown. This thesis will attempt to document the process with depictions of what situations are good candidates for camera-based texture mapping, as well as the various approaches used to solve individual challenges.

CHAPTER III

METHODOLOGY

This artist-researcher has created five individual case studies to demonstrate the various methods developed. Each of these studies addresses a specific question and contains different challenges. The first two cases are designed to discover how past methods may have been implemented, and where the limitations might arise. The third case study pushes these limitations to their maximum by creating a simple scene with an object very close in the foreground, and an extreme camera move. Its purpose is to compare various methods of addressing the problem through testing, and determine which, if any, is a possible solution. Cases four and five take the form of an establishing shot. They apply the findings from the previous three case studies to two very different digital environments. Through the process, this artist-researcher has developed general solutions for a variety of scenarios, and discovered the flexibilities and limitations of how this method can be applied.

CHAPTER IV

PROCESS

This artist-researcher started by studying past work, looking at Nathan Bowden's thesis, and re-implementing some of his techniques. Through this process, this artist-researcher gained a better understanding of this approach, and a better understanding of where the limitations of using camera motion with foreground elements arise.

By studying past and current work, and developing several unique test cases, this artist-researcher has demonstrated, by example, the successful application of camera-based projection textures as an efficient approach to creating a range of digital environments. Throughout this work, Alias/ Wavefront Maya has been used for creating 3D models, camera animation, and camera-based texture projections. Adobe Photoshop and Corel Painter, in conjunction with a pressure sensitive Wacom tablet were the tools used to create the digital paintings.

CHAPTER V

CASE STUDIES

Camera-based texture projections have already been successfully implemented using a completely static camera. Because of a foreground object's proximity to the camera, distortions appear more quickly than with mid or background elements as soon as camera motion is introduced. For camera-based texture mapping to be practical and time effective, adjustments are necessary. These case studies address some possible solutions to this problem. These solutions are guidelines to working with camera-based projections, general methods that can be used to push the limitations to their max.

A variety of different setups have been created for each of the individual case studies. Through a discussion of the process involved in their creation, this artist-researcher hopes to clarify appropriate uses for camera projection techniques as one more production tool for a 3D digital scene. While this method is a powerful solution for particular cases, these case studies also illustrate that in some cases, other techniques may be better employed.

There are five animation files that accompany this thesis work, one for each of the case studies that follow. They are available for downloading.

5.1   Case Study 1 (Desolate Prairie)

Using Camera-Based Texture Projection to Solve

Perspective Challenges within a Still Matte Painting

As an initial foray into matte painting, this first case study is an exploration of the techniques used to actualize a concept. The premise was simple: to take a central element from an original photograph, and place in within an entirely different context. Considerations for perspective, lighting, time of day, and overall mood of the new scene would need to be taken into account. In addition, this artist-researcher chose to use camera projection as a tool to understand and match the perspective within the original two-dimensional scene.

After much consideration, a photograph of an old shack in a wooded forest was chosen as the starting point (Figure 3). The shack's look suggested an array of interesting options. This artist-researcher made the decision to transport this shack's location to a prairie - desolate and barren, the sky dramatic and ominous. In keeping with this decision, other elements were chosen with an eye towards the intended overall feel of piece (Figure 5). These photographic elements would then be manipulated with respect to light, color, and perspective (Figure 6), and combined with digital paint to integrate all of the pieces into a new setting.

Figure 3. Case Study 1 Original Photograph.

The first step was to determine the proper perspective. First, the shack was placed

in its new position in the image, and perspective and horizon lines were drawn for

reference. In the original picture, the shack is raised above eye level. Since the camera film

plane is not parallel to the plane of the house, it appears as if the front of the house is

falling back into the picture plane. For the prairie, the shack's perspective would be only

slightly raised, looking almost straight on. The distortion in the original shack needed to be

corrected to the perspective of the new film camera. The adjustment of the shack itself was

accomplished using various transform and warping tools in Photoshop. This

artist-researcher tried to manipulate the ground layer using similar methods to match the

perspective angle of the ground to the shack, without much success. An alternate approach

was needed. Enter camera projection.

Figure 4. Case Study 1. Maya Projection Setup.

In Maya, an image plane was created from the original photo. The pencil tool was

used to draw curves mimicking the angle of incline, and these curves were lofted to create

geometry (Figure 4). A projection camera was locked to the viewpoint of the image plane,

and an initial pass was rendered (Figure 7). The render was then taken back into

Photoshop, where this artist-researcher further manipulated the render to match the shack

perspective as closely as possible. One area that needed special attention was the path

leading to the door. Distortions and stretching were especially apparent in the tall grasses. On top of the rendered image, patches of grass and portions of the path area were digitally painted to provide an acceptable result (Figure 8).

The resulting painted render was then projected as a ground texture from the perspective of the projection camera back onto the geometry. While this method proved to be a useful solution for this case, it has disadvantages. The perspective angle of the initial ground plane can only be roughly approximated when using only one photograph as a reference.

After the correct perspective and horizon lines had been established for the painting, the next step was to paint out the trees overlaying the shack. This was necessary as the new location would be in a grassy area rather than a wooded one. An additional level of detail was added into the newly treeless shack by painting decaying moss onto the wood, and adding a slight warping to simulate age and weather damage (Figure 9).

A contact shadow now needed to be painted under the shack to give it the appearance of lying on the ground plane. Portions of the shack, in particular the roof ledge, were also painted to simulate the light streaming down from between the clouds. This same

technique was applied to the ground area to create bounce light. As a final touch, a wheelbarrow was added into the foreground to give a sense of scale (Figures 10 and 11).

In summary, this case study was an exercise in some basic matte painting techniques using photographic elements. Special consideration was given to integration of the various painted and photographic elements, and proximity cues. This was especially important for the horizon area, which is fully painted. To integrate the horizon line with the sky, the hue and saturation levels were closely matched, and the border itself was diffused. As the painting moves further into the distance, the contrast and saturation levels decrease, and the grass becomes smaller and less defined. Warmer tones were used in the foreground, and the cooler tones for areas farther away help create the illusion that they are receding (Figure 12). The use of both reference images and observation from life were tools this artist-researcher regularly relied upon to confirm the validity of choices made while creating this piece. A juxtaposition of the original photograph and the final matte painting has been included for comparison (Figure 13).

Figure 5. Case Study 1. Unaltered Photographic Elements.

Figure 6. Case Study 1. Color Adjusted.

Figure 7. Case Study 1. Projected Ground Layer.

Figure 8. Case Study 1. Painted Path and Grass.

Figure 9. Case Study 1. Trees Removed, Weathering Added.

Figure 10. Case Study 1. Bounce Light on Shack, Contact Shadow, Wheelbarrow.

Figure 11. Case Study 1. Wheelbarrow Scale and Perspective, Ground Shadow.

Figure 12. Case Study 1. Painted Horizon and Depth Adjustments.

Figure13. Case Study 1. Top Original Photo. Bottom Final Matte Painting.

5.2   Case Study 2 (Cityscape)

Camera Projection from One Perspective Using a 2D Painting

The purpose of this case study was to take a simple digital painting and animate a camera through the scene. This artist-researcher wished to devise a case that would clearly illustrate the areas that could potentially be problematic when camera motion was introduced.

The parallax method, which creates the illusion of depth by placing separate viewing planes at a distance from each other, was implemented for the Cityscape. Layers of a still painting in Photoshop were used as the individual planes for this case study. Each layer was projected as a texture onto simple 3D geometry from the perspective of a fixed camera, the projection camera. A separate filming camera was then animated through the scene.

With camera projection, a large part of the solution is determining an ideal location for the projection camera. Depending on the motion of the animation camera, a well-chosen location for the projection camera can minimize or remove the need to paint additional textures. In a general sense, the more the perspective of the projection camera deviates from that of the animation camera, the more distortions, stretching, or holes will appear. A simple scenario was used for this case study to familiarize this artist-researcher

with the practical implementation of camera projection in a shot with a moving camera, and to reveal potential problem areas for future work.

The process for this piece began with observing the skylines of various cities at night. Common geometric shapes and lighting color cues emerged, and a simple sketch was created as the basis for a painting (Figure 14). The intention of this artist-researcher was to create a simple, stylized design for a nighttime cityscape using a luminous and saturated color palette. The architecture was intentionally designed to have a slightly warped perspective with curved distortions. Initially, this was created as a still painting in Corel Painter in one layer (Figure 15). As such, it was not usable as a layered projection onto multiple pieces of geometry. Therefore, the piece was brought into Photoshop, and each building was then exported as a separate layer with an appropriate alpha channel.

The second step was to bring the painting into Maya. An image plane could be used as a reference for modeling very simple geometry from the viewing perspective. Using a locked projection camera, one for each building, a texture for each individual building was projected back onto its respective geometry (Figures 16 and 17).
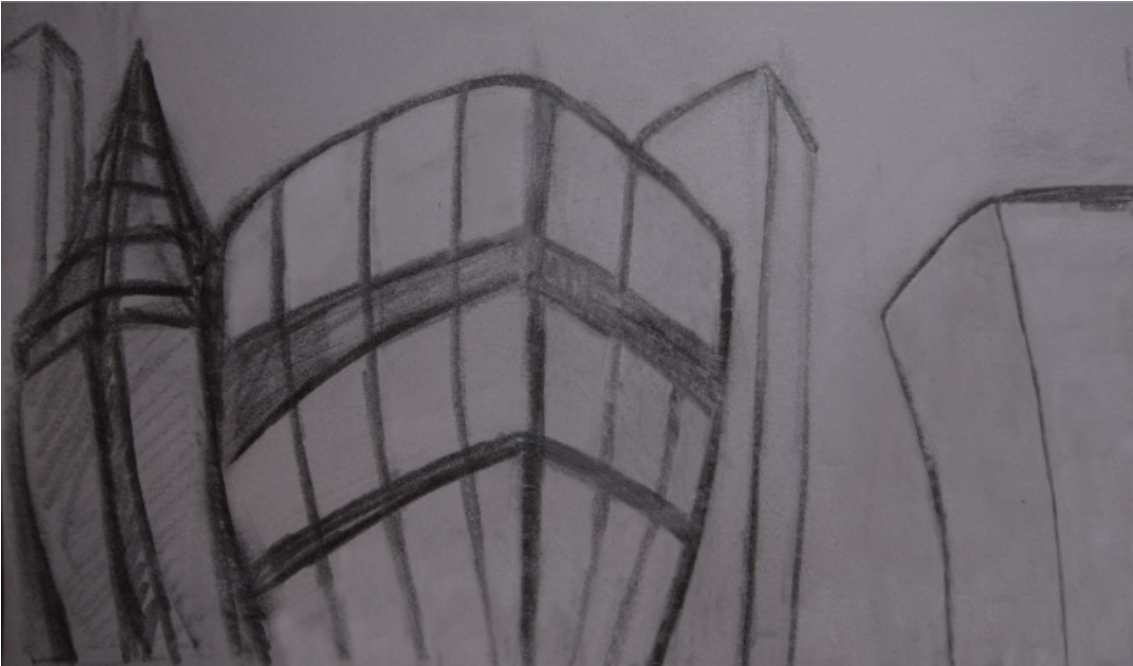
Figure 14. Case Study 2. Concept Sketch for Cityscape.

Figure 15. Case Study 2. Original Matte Painting in One Layer.
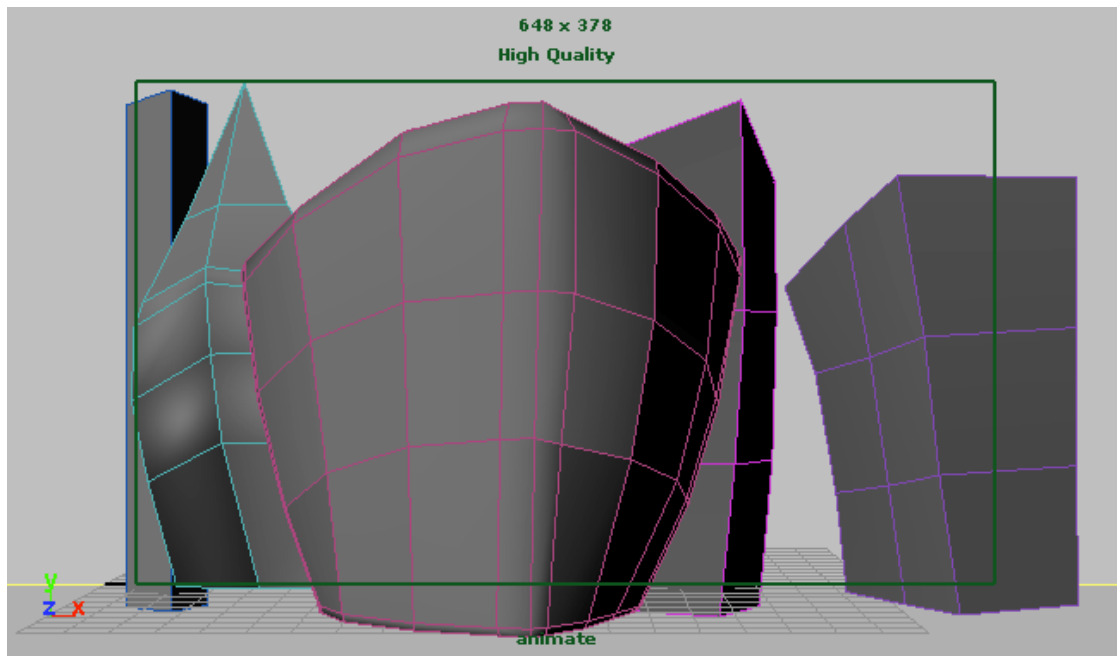
Figure 16. Case Study 2. Maya Scene With Simple 3D Geometry.
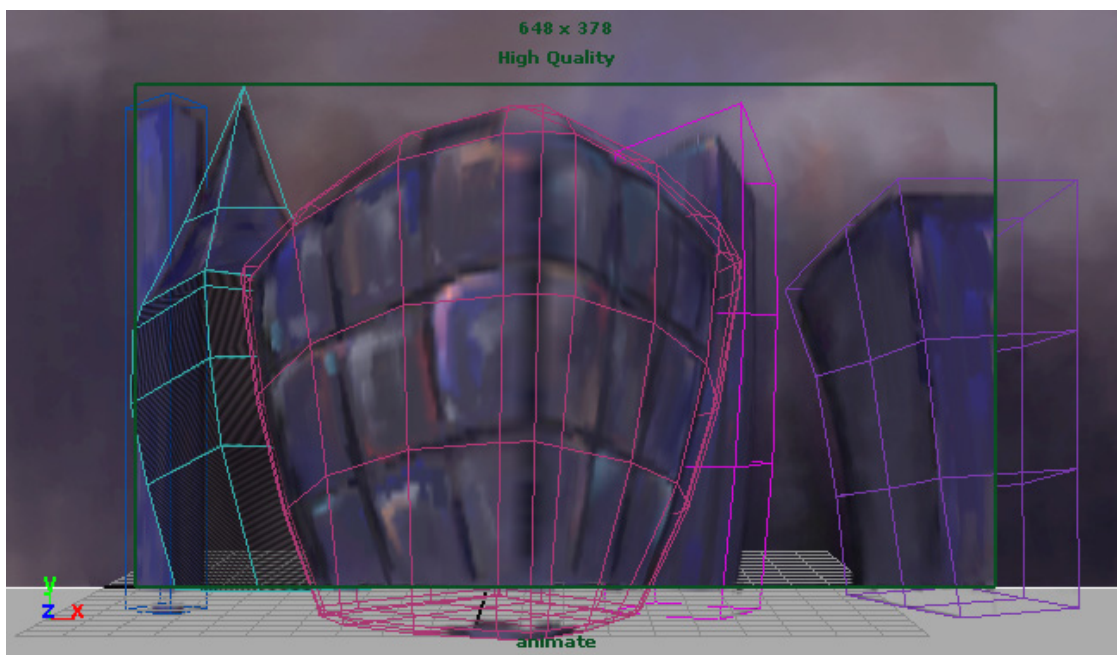
Figure 17. Case Study 2. Textures Projected onto 3D Geometry.

A simple animation test revealed holes in the textures of the background buildings. These empty patches became more apparent the more extreme the camera movement. Another issue was the size of the sky plate. On both the right and left sides empty space was revealed. To fix this would require the sky plate to be a larger resolution than the rendered image. This would account for the changes in viewing area that became visible with the changes in camera orientation. For future reference, this artist-researcher also tested the scene with alternate camera motion paths to determine how far the illusion of a three-dimensional scene could be pushed without painting additional projection images.

Using this case study as a test, this artist-researcher determined that the parallax method was a reasonable solution for simple camera motion, primarily zooming. For the more complex case studies that follow, different preproduction considerations would be needed. Ideally, the process would begin by first blocking out simple geometry and camera motion for a given shot. A frame would be rendered from the point of view of the projection camera, and used as a reference layer in the Photoshop painting to capture the appropriate perspective. It would also be beneficial to add a key light as reference when creating the render to help keep the light direction consistent.

5.3   Case Study 3 (Multiple Camera Test)

Using Camera-Based Texture Projection for

Foreground Geometry with Camera Motion

The third case study is perhaps both the simplest and the most complex of the test

cases. It is simple, because the target geometry is a cube, and the texture is a photograph of

a building. It is complex, because the animation camera is extremely close, the degree of

motion is substantial, and the texture has an unforgiving grid-like pattern on one side, a

brick wall. Using this simple case, this artist-researcher has chosen six different tests.

Through them, the limits and the effectiveness of camera-based texture projection for a

simple foreground element with extreme camera motion can be seen.

As preparation for the various tests, a particular corner of a house was chosen. One

side of the house was laid with regular brick, and the other, white paint over wood. From

eye level (looking straight on), photographs were taken from orthographic views, as well

as from regularly measured intervals along a circular path (Figure 18). The total rotation of

the animation camera is 90 degrees, or one fourth of the way around a circle.

Test one consisted of three static projection cameras set at regular intervals along

the path (Figure 19). For each projection camera, a new Lambert shader was created, and

the reference photograph corresponding to the same viewpoint (angle) as the camera, was

then attached to the incandescence channel of the shader. For this case, three
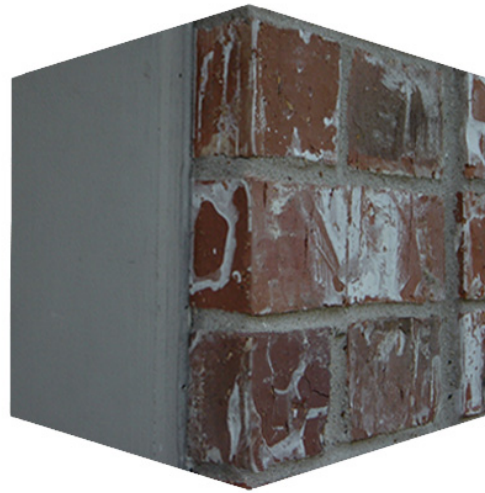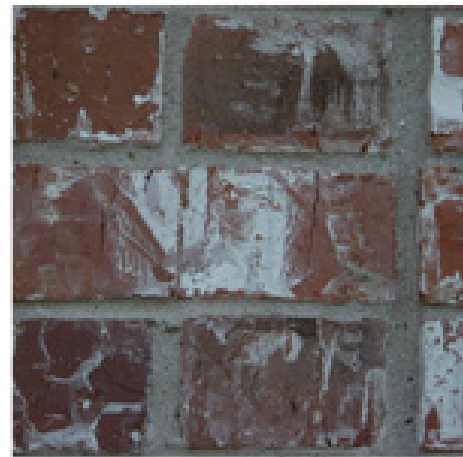
Figure 18. Case Study 3. Clockwise from Top Left:

a. Front Orthographic View (0 degrees) b. Corner View (45 degrees),

c. Three-Quarters View (67.5 degrees) d. Side View (90 degrees).
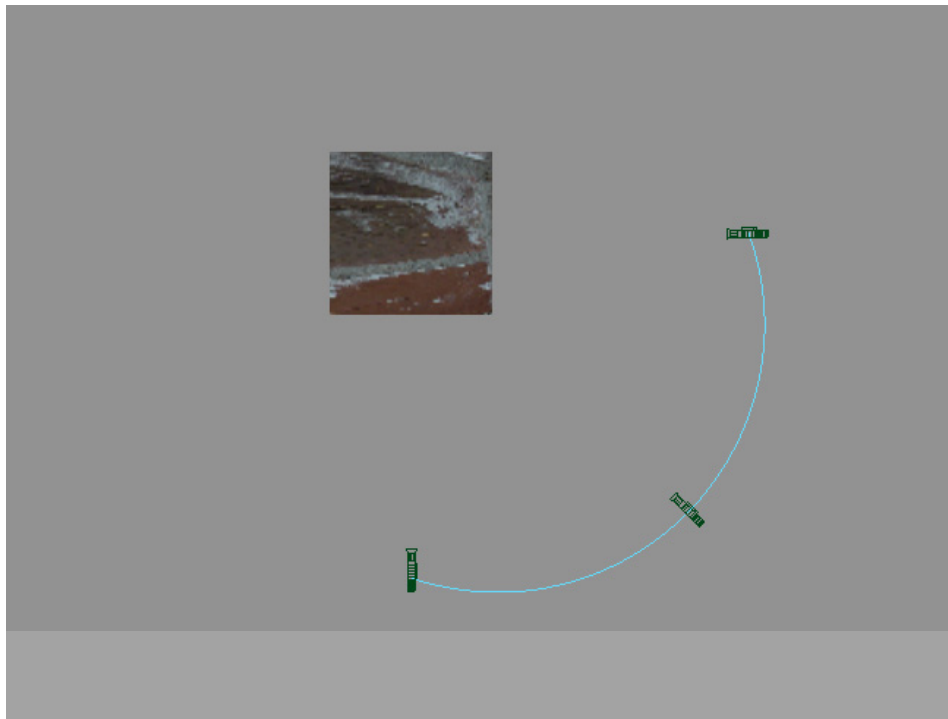
Figure 19. Case Study 3. Camera Path and Placement.

shaders were created: front (0 degrees), middle (45 degrees), and side (90 degrees). In

Maya, a layered shader was created with each layer consisting of one of the previously

created shaders. The opacity of each of the layers was animated to correspond to the

position of the animation camera. For this first test, consisting of 240 frames, the three

layers were blended using linear interpolation.

The results for frames 0-120 were acceptable (Figure 20). For frames 121-240, the

opacity of the side brick starts to show through the wood on the front (Figure21). As a

check, this artist-researcher made sure that the geometry was not double-sided. While this

can cause double projection errors, that was not the problem in this case.

It was very interesting to note the difference between the success of the first half of the test, and the less than acceptable results of the second. This can be reasonably attributed to the inherent difference between the patterns of the textures on the two sides of the building.

Figure 20. Case Study 3. Test 1 Frame 60.
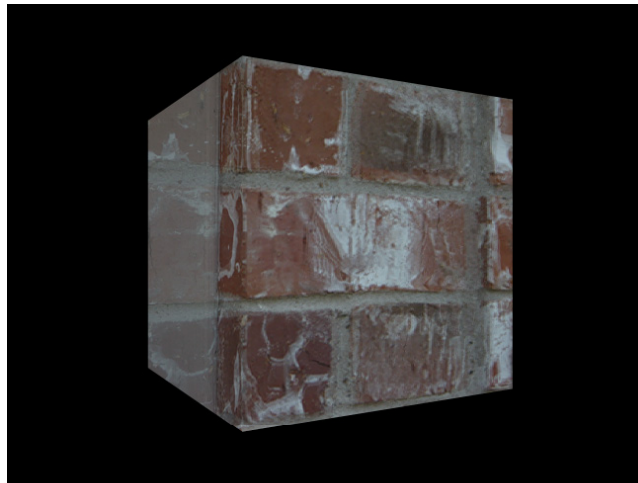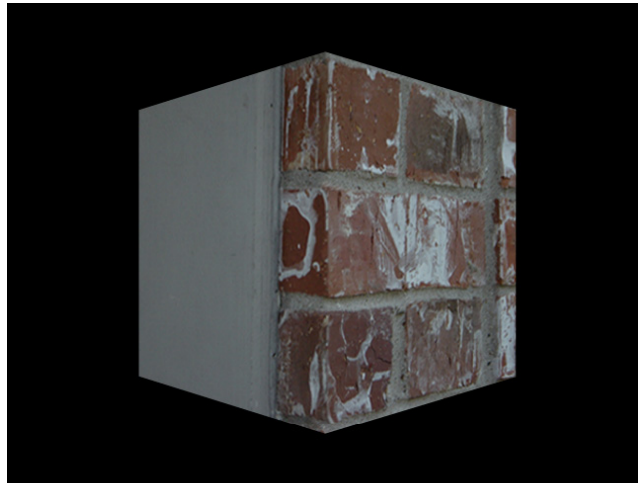
Figure 21. Case Study 3. Test 1 Frames 121, 140, 160.

While the front is covered with white paint over wood, the side is laid with brick. The linear nature of the bricks is especially unforgiving; even slight distortions that may go unnoticed on the paint become glaringly obvious. This observation is very important to understanding what cases are ideal candidates for camera projection, and those that may be better solved using alternate methods. For the remaining tests, this artist-researcher focused on the last 120 frames, attempting to find a reasonable solution to the stretching and opacity problems.

In test two, a fourth projection camera was created. It was placed halfway between the middle and the side, at 67.5 degrees, along the circular path. Again, linear interpolation was used from frames 120-240. And again, the results were not satisfactory. In fact, artifacts were even more obvious than they were with test one. Instead of trying to blend between two textures, now there were three separate perspectives to blend between. No matter how well this artist-researcher attempted to align the individual textures in Photoshop, the distortion persisted (Figures 22 and 23). This is due to the fact that there is an inherent perspective change from the corner (frame 120) to the side orthographic view (frame 240). A specific pixel location in each of the projected textures will then correspond to a different location on the cube geometry. Therefore, the brick pattern appears to stretch as the cube rotates.
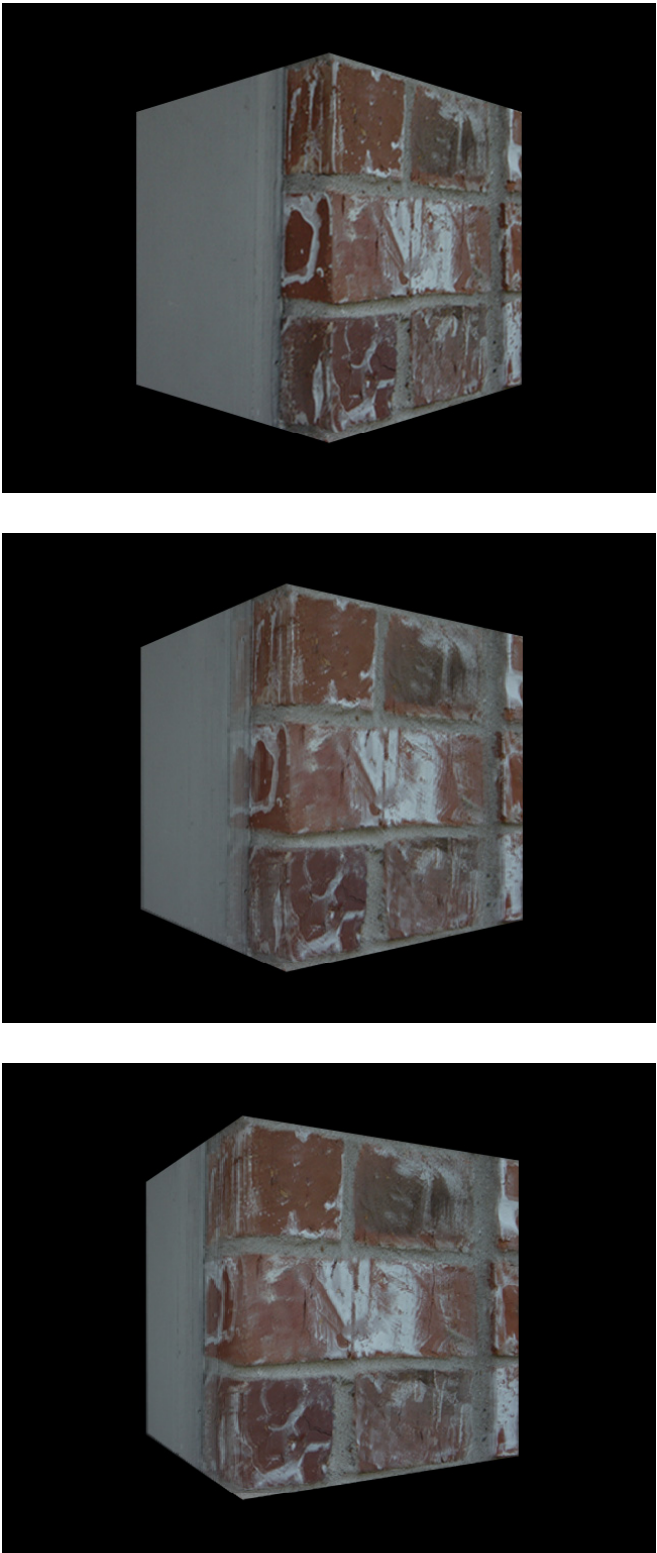
Figure 22. Case Study 3. Test 2 Frames 120, 140, 160.
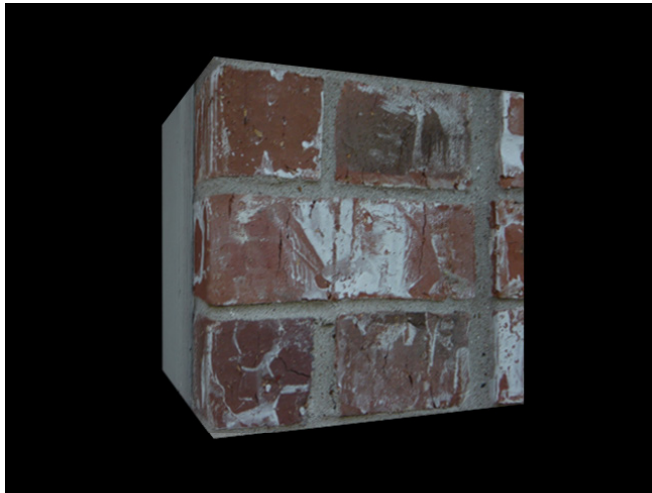
Figure 23. Case Study 3. Test 2 Frames 180, 200, 220.

Test three brought a return to using three projection cameras, meaning that from frames 120-240 there would be blending between only two textures. In the graph editor in Maya, the animation curves were edited to interpolate non-linearly. So starting from frame 120, the animation slows in to frame 240. The results for this test were better than the previous two, but distortions at test frames 200 and 220 were still unacceptable (Figure 24).

Three projections were also used for test four. The use of non-linear interpolation was also repeated, but instead of starting the blending at frame 120, it was shifted to frame 180 with hopes of lessening the perceptible stretching that was occurring towards the end. This test yielded the best results thus far, but by no means were the problems gone (Figure 25).

Another approach was needed. With the idea that sometimes the simplest solution is the most effective, only two projection cameras were used for test five. One was placed at the front, and one at the side. Because there would be no blending between textures, theoretically there would also be no distortions or stretching. This theory proved to be correct, but of course new problems were introduced. A test of frame 120, directly in the middle, showed some alignment issues with the two textures. Granted, this could be adjusted in Photoshop, but a more disturbing problem was the sharp CG crispness of the corner (Figure 26). Obviously, this was not desired.
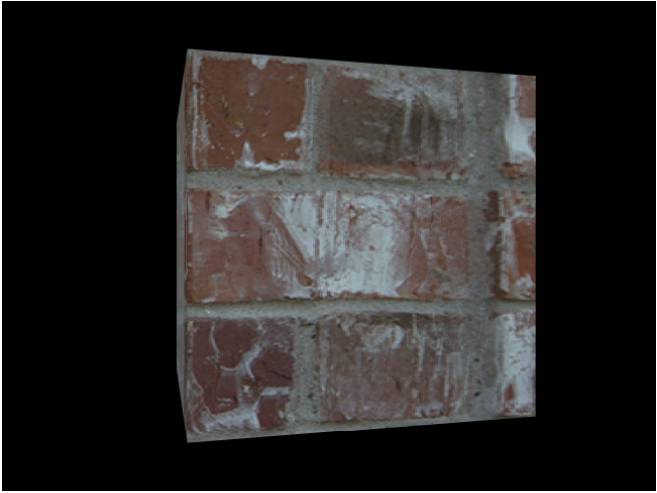
Figure 24. Case Study 3. Test 3 Frames 140, 200, 220.
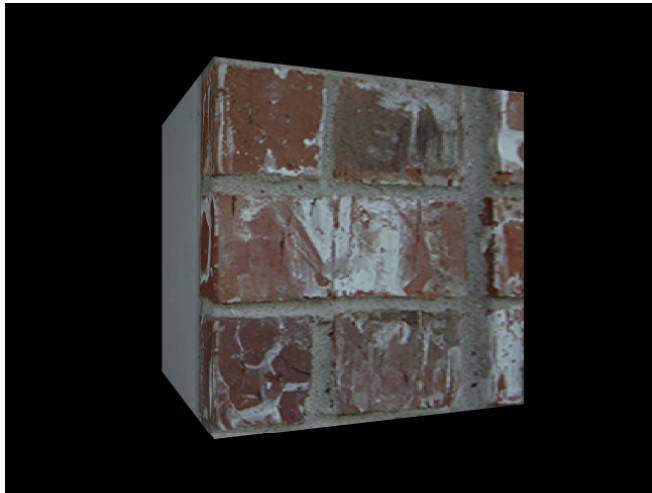
Figure 25. Case Study 3. Test 4 Frames 180, 200, 220.

Figure 26. Case Study 3. Test 5 Frame 120.

For the final test, a completely different method was employed. This artist-researcher

became aware of a feature based morphing program written by a fellow Visualization

student named Alex Timchencko. The software worked by interpolating between two

different images based on feature lines set by the user. An algorithm would then calculate

the difference between the two, and attempt to find a mid ground. The success of the blend

depended on several things, amongst them the similarity between the two images, and the strategic placement and number of user-set feature lines.

Twenty-eight separate feature lines needed to be set on both the source and destination images (representing frames 120 and 240) to get an even somewhat reasonable result. This is obviously not a reasonable approach, as the amount of work it would take to UV map and shade the geometry would be substantially less. Also, despite the ridiculous number of guides set, the results were less than satisfactory. There were still calculation errors that created holes in the geometry, and floating texture remnants (Figure 27).

In conclusion, this study, as such an extreme case, proved to be a valuable resource for testing various camera projection approaches. However, in general, this artist-researcher would not consider using this technique for an element so close to the foreground in a shot with such extreme camera motion. One exception might be if the shot had extensive motion blur or significant depth of field, with a large area out of focus. While the results were quite successful using a brick texture in such a close shot, there would be greater flexibility with a more forgiving texture, such as stucco.
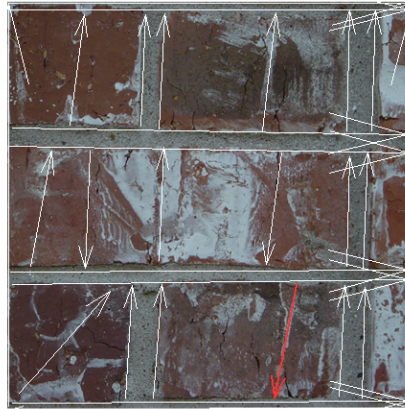
Figure 27. Case Study 3. Test 6
Source, Destination, and Output Images.

5.4   Case Study 4 (Sand Dunes)

Dramatic Fly Through a Completely Digital Landscape

with Foreground Elements

The fourth and fifth case studies differ from the preceding three because they can be seen as establishing shots for a scene as opposed to merely tests. Various techniques for using camera-based projections have already been tried in a range of circumstances using both painted and photographic elements. Now it is time to apply what was learned to more complex scenarios to see whether these techniques are successful.

Sand dunes - simple, elegant, dramatic - are the subject for case study four. To gather inspiration, this artist-researcher browsed through photographs of many types of sand dunes from all parts of the world. Attention was focused on their different shapes, colors, and lighting at various times of the day, from dawn till dusk. Since the intention was to create a complete environment, including lighting and shadows, with only a matte painting, the time of day was important. It would need to be baked into the painting, and therefore would be much more difficult to change than a virtual lighting set-up.

Another decision made early in the preproduction process was to create the digital 3D geometry and lock the camera motion in Maya first. An appropriate location for the projection camera would be chosen based upon that. By using a rendered reference frame, the projected matte painting would align to fall onto the actual scene geometry.

Since the design was of importance to the overall feel of the piece, this artist-researcher created a number of sketches both from reference and from imagination (Figure 28). These studies were helpful to understand the shapes and curves of the different types of dunes. In the end, inspiration was taken from sand dunes found in Namibia, which have a distinctive shape, sharp angles, and a reddish-orange coloring. A stylized version would fit well with this artist-researcher's artistic intention. To add to the drama of the rich color of the dunes, a dusk lighting palette was chosen. Purplish shadows and a warm sky would complete the desired effect.
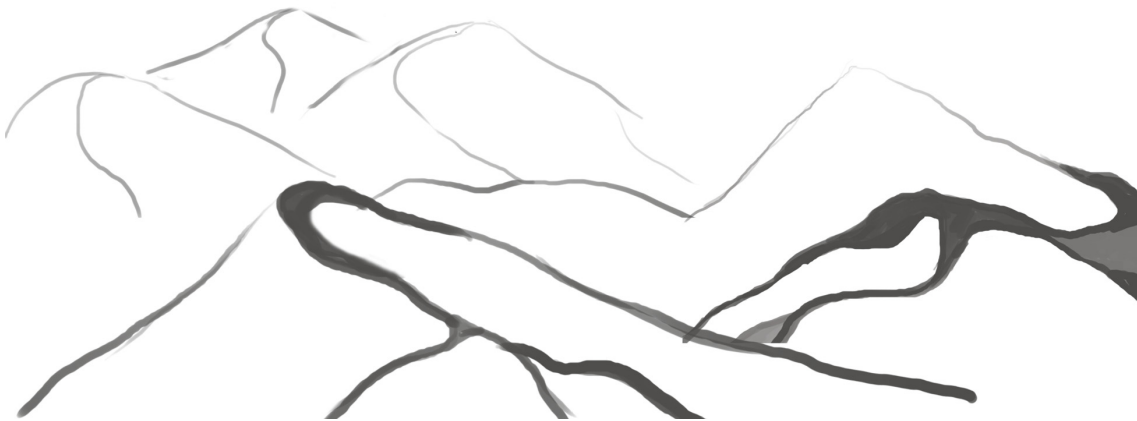
Figure 28. Case Study 4. Sketch Idea.

After the initial design was locked, the next step was to create the 3D geometry in Maya. Using a sketch as a guide, curves were drawn for both the top and the bottom edges of the dune, and then lofted. A lattice deformer was applied to one half of the geometry so the sides would not be symmetrical, with additional hand sculpting to refine and add more detail, such as the crater. This artist-researcher then extruded the bottom edges to have a gradual slope that connected with the ground plane. Despite all of this, the model itself was deliberately created to be simple, allowing for the real detail to come from the painted texture that would be projected onto it. As a final step in the modeling process, smaller, additional dunes were added further in the distance. The entire model was combined to be one continuous piece of geometry for the sake of simplicity (Figure 29) so that only one shader would need to be applied.

After the geometry was complete, the animation camera was moved along a carefully designed route. A slow reveal of the landscape was planned to add an initial sense of mystery about the location. The image starts out as an abstract, almost 2d view, looking down at the front of the top ridge. It slowly swings over to the side to reveal a three-dimensional view of the environment.
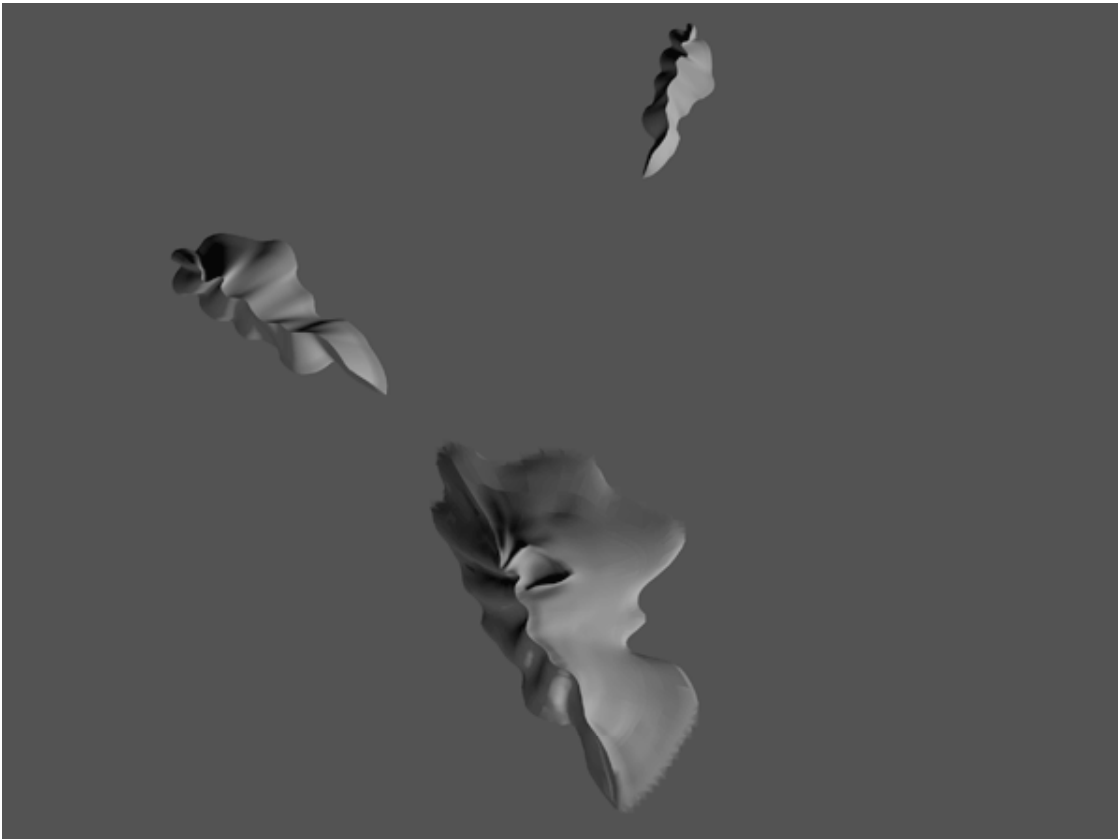
Figure 29. Case Study 4. Maya Model.

Several things were taken into account to make the decision about the camera path

and location. Some of considerations were artistic, such as using the camera to tell a story.

Others motivations were connected to the purpose of this research, which is to push the

limitations of camera projection as a technique. This influenced both the extent of the

motion of the animation camera, and the proximity of the camera's placement to the

geometry. Choosing to place the front ridge of the dune so close in the foreground had the

added advantage of allowing appreciation of the full level of detail in the painted texture.

After the animation was locked, the location of the projection camera needed to be determined. In general, the more the perspective of the projection camera deviates from that of the animation camera, the more stretching and distortions will be apparent. Since the perspective of the animation camera changes so dramatically throughout its course of motion, attempting to match the projection camera to one of the points along the animation path did not seem like it would work well. A different approach, or angle in this case, was needed. Through the process of brainstorming and some quick initial tests, this artist-researched happened upon the idea of placing the projection camera directly above the scene. A top orthographic view, at a substantial distance away, seemed a feasible solution.

Once this was decided, a frame was rendered from the perspective of the projection camera, and a rough painting was created with just planes of color, and lines defining boundary areas, such as the ridge of the dune (Figure 30). By projecting this rough painting back onto the geometry and creating a quick low-resolution render of the scene from the vantage point of the animation camera, problematic areas could be revealed without too much time being spent on details.

Figure 30. Case Study 4. Initial Color Planes.

The rough projection worked much better than this artist-researcher had initially

expected in the first test. Due to the degree of camera motion, it was initially suspected that

two or three separate and full-sized paintings might have been needed, which would have

been blended together as in the previous test case. Happily, the only area that posed

immediate problems was the top of the ridge, along the left side. The model has a very

steep slope along the ridge, and when painting from a top view, no matter how closely

zoomed in, it is not possible to account for all of the geometry area. Therefore, when

projected, the pixels along that section of the painting were being stretched in an unsightly

manner (Figure 31).

The solution for this distorted area was to create an additional projection camera, aimed towards the side of the dune at eye level. A few select faces along the top, near the ridge, were chosen to receive the new projected texture. To create a seamless blend between the two paintings, a reference frame was rendered out from the side projection camera, with the painting already mapped onto the geometry from the top projection camera. In this way it was possible to exactly match the color placement within the secondary painting. An alpha mask was created as well, so that only the selected faces would be affected (Figure 32).

After the foreground and midground elements were in place, a decision needed to be made regarding the background area. While a more conventional approach would have been to create a perpendicular plane for the sky, this artist-researcher wanted to see if it would be possible to create a convincing sky as part of the same flat painting. Therefore, the sky was painted from the perspective of the top projection camera, and after a few iterations, a believable sky and horizon line were achieved (Figure 33).
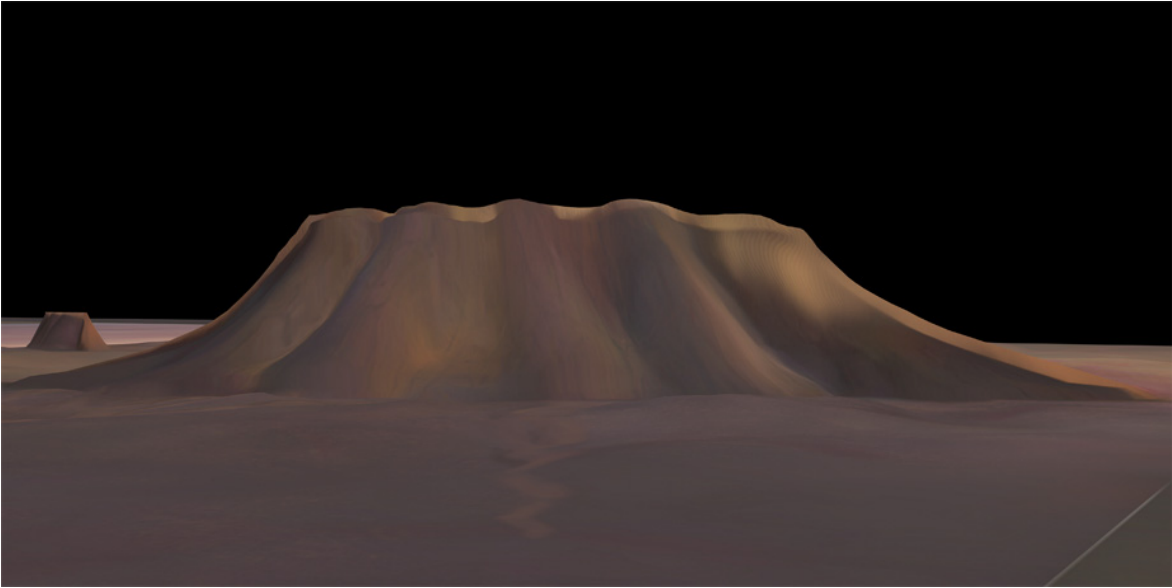
Figure 31. Case Study 4. Before Paint Fix. Side Projection Camera.
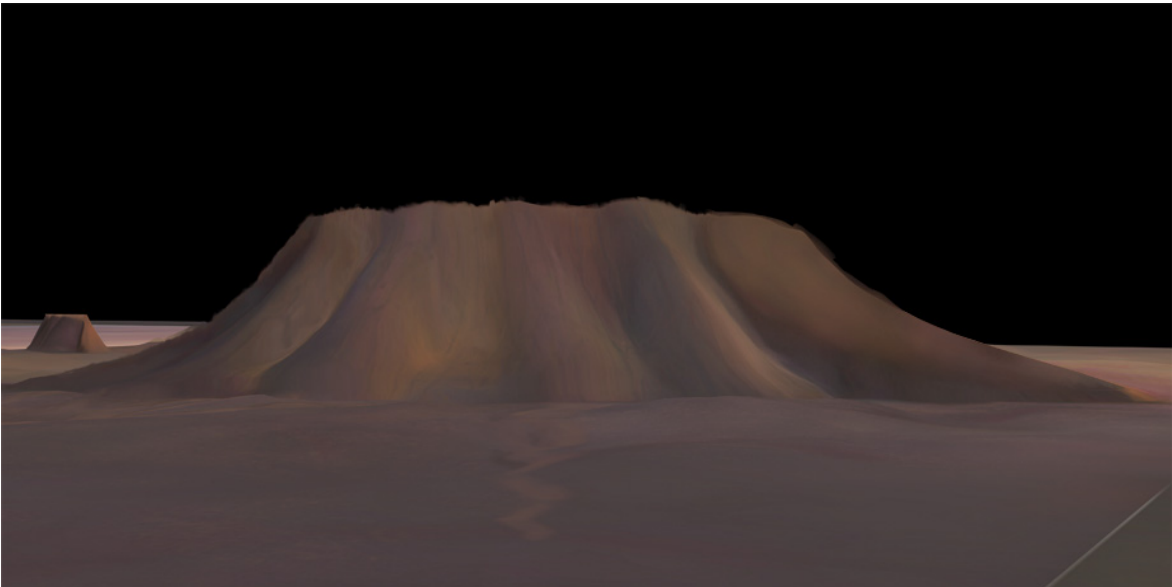

Figure 32. Case Study 4. After Paint Fix. Side Projection Camera.
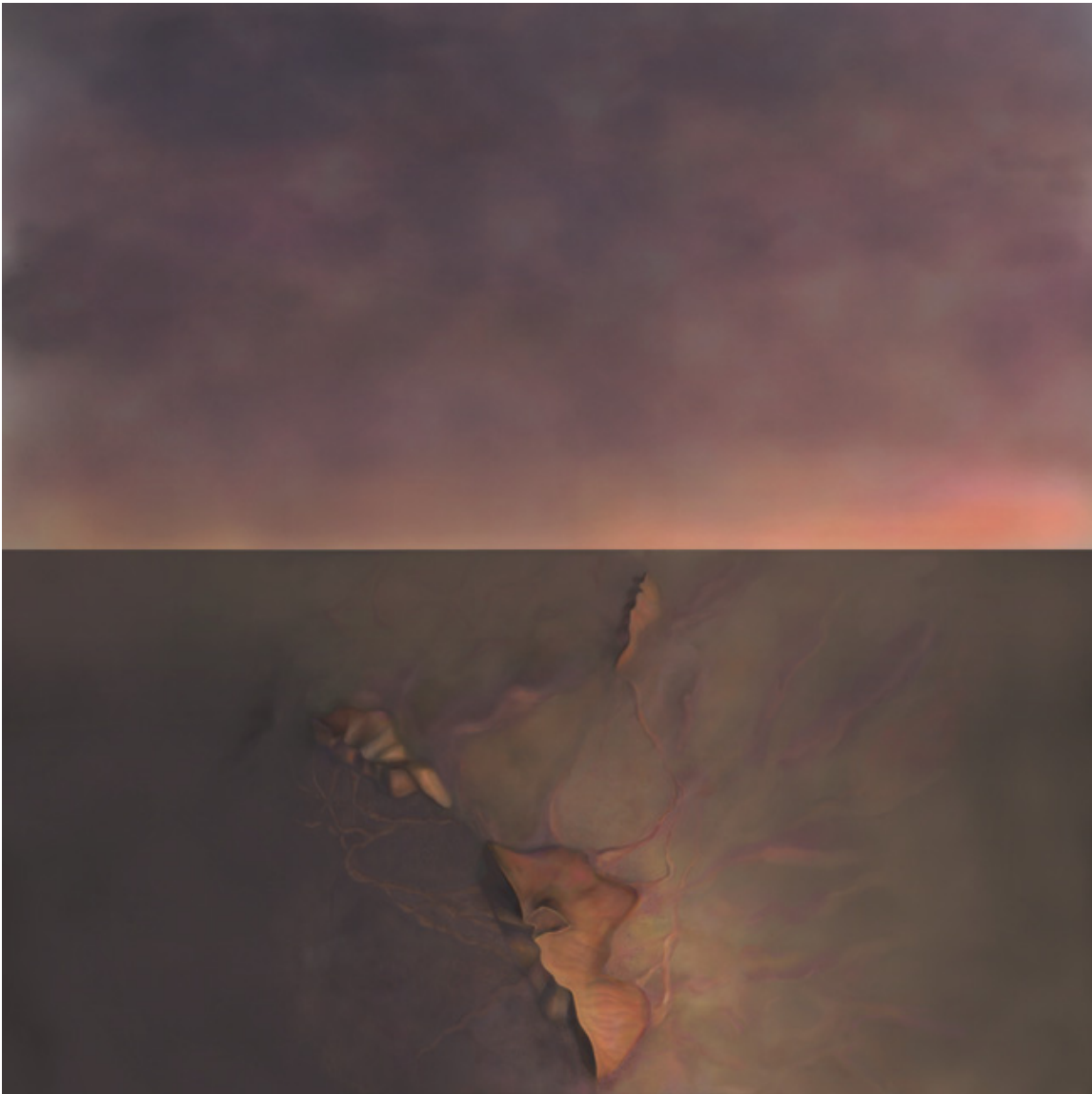
Figure 33. Case Study 4.

Top Projection Camera Final Painting.

A higher level of detail was needed where the animation camera was close up. Now that the projection camera was locked, it was possible to add detail into certain areas. Displacement ridges on the dune and bumps on the ground are in fact a painted illusion. Additional texturing, rocks, and more general details were added to the ground and dune as well, especially to define shadow and highlight areas (Figure 34).

An important issue to discuss at this point is the resolution of the texture. The scale of the painting needs to be created such that the image is at full resolution when the camera is at its closest point to the geometry, but still covers the entire main dune and the immediate surroundings that are visible from the animation camera. Obviously, areas in the background do not need the same level of detail that the foreground does, and in a scene of this size, the resolution of the image can be prohibitive. In fact, including the desired detail and still maintaining the image as one unit proved to be more than Maya could handle (tests showed a maximum supported size of 8150 pixels across).

The ridge area at the very beginning of the animation needed a much higher level of detail than the rest of the environment (Figure 35). When the animation camera is very close, the middle ridge was not sharp enough. To address this issue a new projection camera was created, matching the perspective of the top projection camera as closely as possible, but more zoomed in. Unfortunately, the perspectives could not be exactly matched, and the textures did not align properly. As another option, an attempt was made to map only specific faces along the ridge with this new texture, but due to the proximity
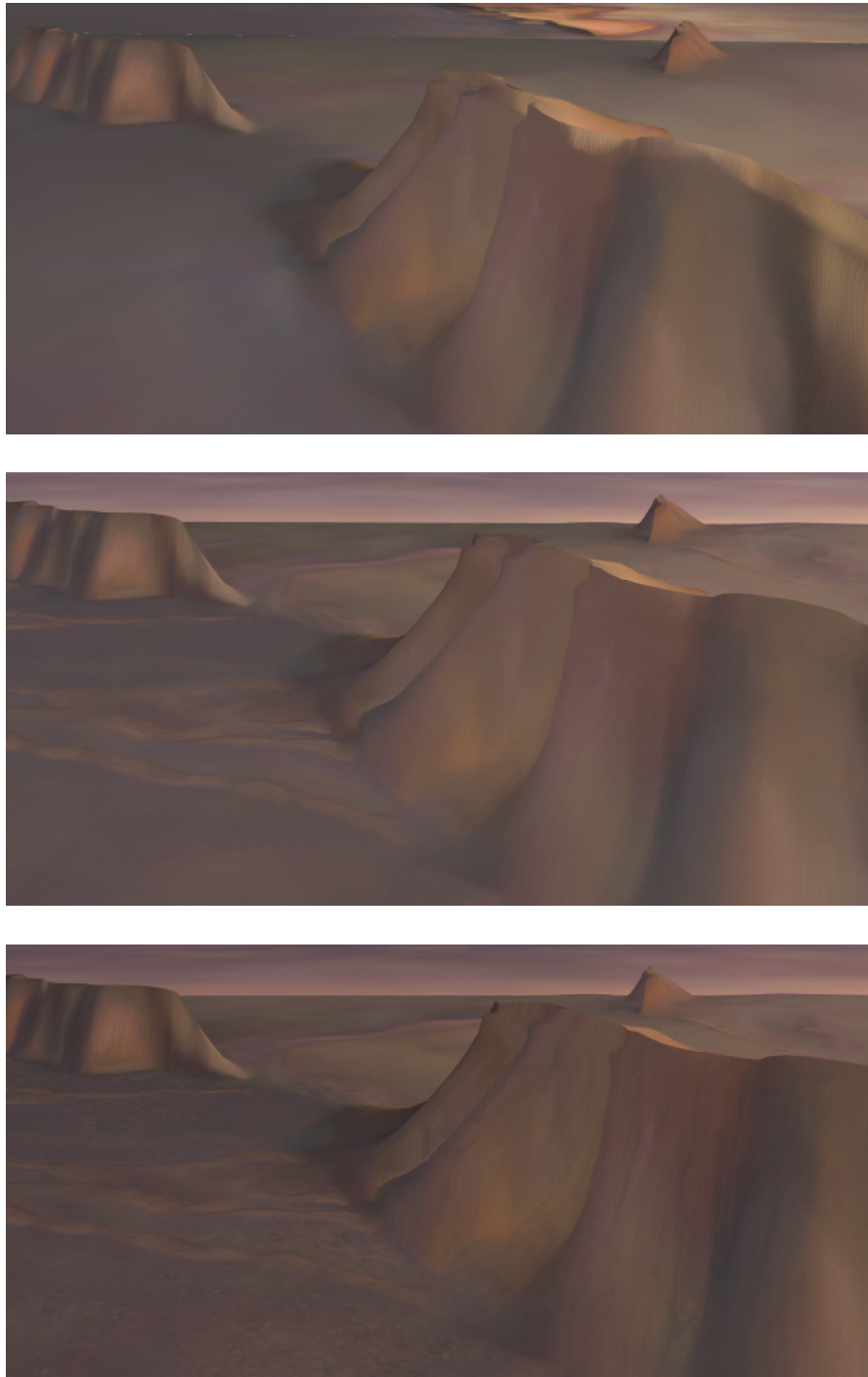
Figure 34. Case Study 4. Increasing Levels of Paint Detail:

Dunes Only, Dunes Plus Ground Ridges, Ground and Ridge Details.

of the camera, there were visible seams. This artist-researcher believes that with further iterations, the two textures could have been more closely matched, but this would have required extensive repainting. Since Maya's maximum resolution was not high enough for the crispness needed when close, the final solution was to keep the original projection camera to avoid misalignment, and the texture was halved widthwise. A 2d node transform node was then used to place it accordingly.

While using the top projection camera exclusively remained a better solution for the beginning of the shot, using both the side and top views was necessary for the rest of the piece. As the animation camera swings over and around the dune, the side-projected painting solved the stretching problem near the ridge. Since the top view of the painting begins to break somewhere between frames 270-275, blending between the two options was the solution. For this frame range, a render was created both with and without the side projection camera, and After Effects was used to dissolve between the two versions. This
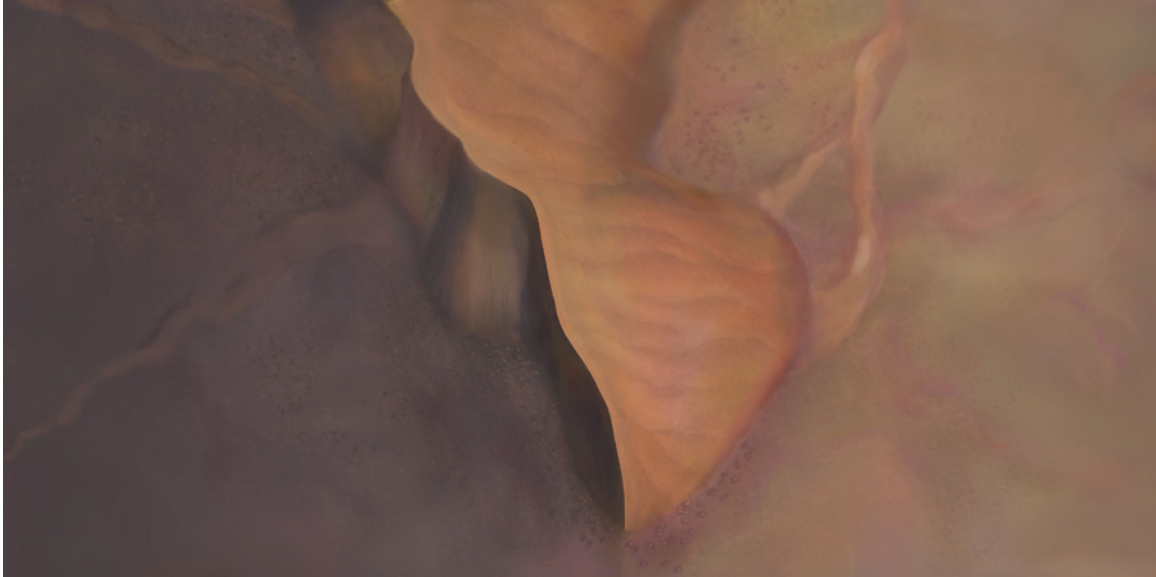
Figure 35. Case Study 4. Top Projection Camera Close Up.
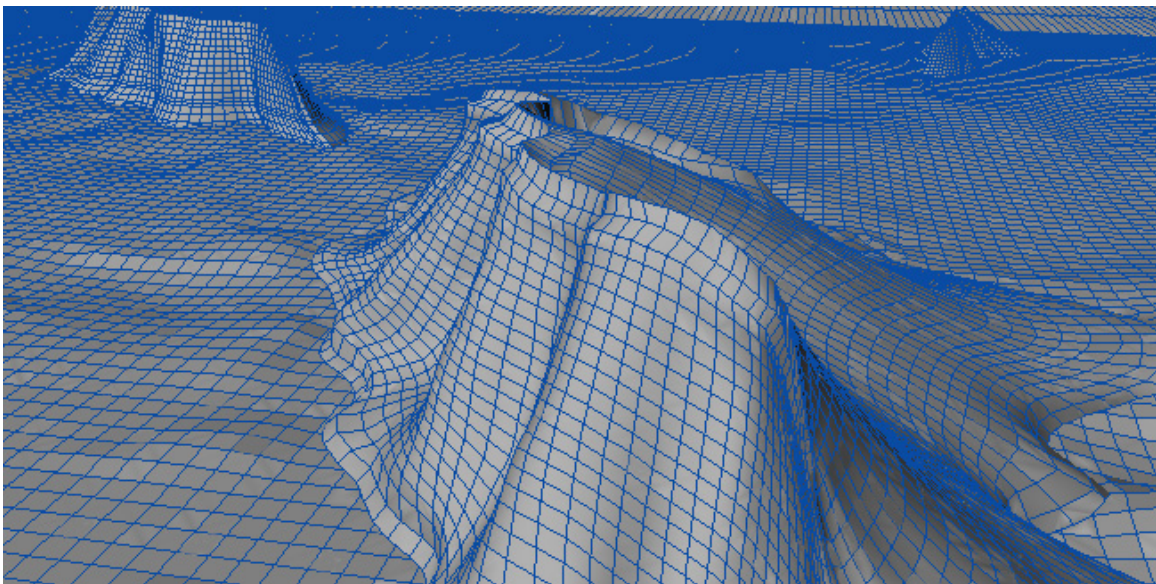
Figure 36. Case Study 4. Geometry Topology Detail.

blending also affected the sand simulation (which was created by Chris Root and is not discussed further here as it does not apply to the topic of camera projection). To keep the transition between the two rendered versions consistent, the simulation needed to be prerendered and cached.

A final but important step was to add environment fog. Rather than create expensive particle and lighting environment effects, the look was painted directly into the finalized matte painting, and then blurred slightly to create the illusion of depth and to unify the sky and ground.

By carefully selecting the location of the projection camera, this artist-researcher maximized the efficiency of the camera projection method by painting as few textures as possible. Lighting is explicitly defined within the painted textures, eliminating the need to add virtual lights to the scene, and the topology of the 3D model remains simple (Figure 36). Finally, the blowing sand atmospheric effects create subtle motion within an otherwise static environment.

5.5   Case Study 5 (Abandoned Room)

Creating a Digital Environment Using Camera Projected

Photographic Elements

Just as with the sand dunes, this case study can be seen as an establishing shot. It combines many of the techniques learned from the first three studies, but unlike the dunes, which were entirely painted, the abandoned room uses a combination of photographic elements and paint. In that sense, it is more similar to the techniques discussed in the desolate prairie case study.

The first step of the process was to find a location that fit the intended subject matter: an old room, in a state of abandoned disrepair. This artist-researcher spent several afternoons walking through the old downtown area of Bryan, Texas. A number of buildings there had the desired feel. One site in particular was chosen, and photographs were taken at various times of the day to determine when the lighting would be most fitting as an initial starting point for this piece. Unfortunately, the chosen site was closed off. This artist-researcher was unable to gain inside access to the location, so all of the reference shots were taken with a zoom lens from the vantage point of a broken window on the far side of the room.

Since orthographic shots of the room were unavailable for mapping onto simple geometry, the possibilities for potential camera motion would be limited. This meant that

by necessity, the matte painting would have to work from only one perspective. An initial

test was set up in Maya with a simple cube, projecting the unaltered photograph onto the

inside of the cube. By using only one projection angle, the panning of the animation

camera would need to remain limited to maintain the illusion of a three-dimensional

environment with a minimum of noticeable distortions. Therefore, the primary motion of

the camera would be a slow steady zoom inwards. More detail could be painted into the

original photograph, which would allow the camera to move closer to the far wall than the

unaltered photograph would allow.

After the initial Maya setup and animation were locked, the photograph (Figure 37)

was brought into Photoshop, where some of the less desirable elements were removed and

other details were painted in. The color palette, saturation, brightness, and contrast levels

were edited (Figure 38). The original backlit sun direction was maintained, but the initial

lighting was faint, with a cool, dismal bluish tone. This artist-researcher wanted to create a

warm glowing feel, so yellow and pink tones and highlights were painted onto the floor,

walls and additional props (Figures 39 and 40). Three props were added as separate layers

to the scene. Each of the props was individually mapped onto a separate piece of

geometry, so that the parallax perspective would be maintained as the camera moved

Figure 37. Case Study 5. Original Photograph.

Figure 38. Case Study 5. Color Adjusted.

Figure 39. Case Study 5. Final Paint.

Figure 40. Case Study 5. Base Painting.

Figure 41. Case Study 5. Frame From Final Animation.

Breakdown of Stages of Projection Setup: Background, Foreground.

forward into the scene (Figure 41). A volume light was added into Maya to create the dusty

light rays streaming through the windows.

Although the piece was close to being finished, one more detail was needed to tie

the whole thing together. Using the actual location as inspiration, a broken window was

created. This would be the portal by which the camera would enter the room, much as a

voyeur might slowly enter, eyes adjusting to the lower light, taking in the surroundings. A

simple plane was created, and using the split polygon tool, cut and extruded outwards

along the broken planes of glass. A second layer was created for reflections from the

outside, and as the camera moved towards the window the reflection layer was animated

(Figures 42 and 43). The window was created as a projected painting instead as a semi-

transparent reflective shader, which would normally be the method that would be used.

This artist-researcher chose to use this technique in keeping with the purpose of this

research: an exploration of the limits of how camera projection can be used in an animated

shot with a foreground element.

Figure 42. Case Study 5. Window Layer.

Figure 43. Case Study 5. Reflections.

The final look that was achieved is consistent throughout, and the noticeable distortions are minimal, so this piece can be considered a success. The only area that was slightly problematic was the wood projection, which begins to break at the beginning of the piece. This is due to the fact that at this point the viewing angle differs most dramatically from the perspective of the projection camera. However, the window was the perfect cover. As with professional productions, the decision to include the window served multiple purposes. Not only did it help the camera tell a story, it also hid imperfections from the viewer. And in the end, in movies, looking good from the vantage point of the camera is all that really matters anyway!

CHAPTER VI

SUMMARY OF RESULTS

Matte painting has long been an accepted shortcut for creating complex background scenes in film. In the past, its use has generally been limited to shots with little or no camera movement. The technique of projecting textures from the perspective of a locked camera onto simple 3D geometry has opened the door to new possibilities. Specifically, mid and background elements, and shots with a limited range of animation camera motion are ideal candidates for this approach.

Through various case studies, this artist-researcher has developed general solutions for a variety of scenarios, and discovered the flexibilities and limitations of how camera-based projections can be applied. This work builds on the original work done by Nathan Bowden by applying this technique in scenes that integrate camera animation with foreground elements, one of the limitations that he did not address in his work. When used appropriately, this method produces high quality results with less time and fewer resources than creating fully modeled and rendered 3D elements. The trick for success lies in understanding the demands of a particular shot. Is the shot a good candidate, and for which specific implementation of the method: 2d matte paintings, multi-plane paintings used to create parallax perspective, textures projected onto simple 3D geometry, some combination of these methods, or none of the above.

Perhaps it is important to mention again that by testing fully during the preproduction process, much time can be saved later on. Cheap stand-in paintings can be utilized, which is especially important if the animation camera is not yet locked. Ultimately, the success of the methods chosen will depend on their appropriateness for the scope of the shot and their intended use. It has been demonstrated in this work, that shots with foreground elements and significant camera motion can be wonderfully rendered with limited resources, such as with the sand dunes case study. The multi-camera test demonstrated that the tighter the linear perspective, and the closer the range, the more stretching and distortions will appear. Depth of field can allow for more flexibility, such as with the abandoned room, where slight shifts were not overly noticeable. This artist researcher would guess that if the camera was moving quickly enough to create motion blur, that also would allow for a larger margin of error while maintaining believability.

In conclusion, the illusion of a three-dimension scene created from flat textures is entirely possible. The scope of camera animation can be maximized, and foreground geometry integrated successfully with the rest of the scene depending on the specific movements of the camera, and the desired look of the elements that will receive the textures. A painterly style was shown to be more forgiving than photorealism, and natural landscapes more flexible than architecture.

The cohesive integration of flat paintings, projected textures, and practical models with camera motion is dependant, in the end, on two factors. All elements must visually

belong together in style, lighting, and color, and must work within the perspective range visible from the animation camera. A wisely chosen approach is one half of the equation, but the skill of the artist or artists who must achieve this illusion, is truly the key. With the right combination of talent and technique, an artist can find a visual solution to even the most seemingly impossible problem.

CHAPTER VII

FUTURE WORK

Areas of future research might include developing techniques for procedurally approximating solutions to problems that can arise when using camera-based texture mapping. In this work, estimation and adjustment has been the chosen approach. Implicitly defined guidelines may facilitate the efficiency of this process. For example, it may be possible to procedurally generate the ideal location of the projection camera to minimize distortions, as well as the number of textures that need to be created. The use of texture synthesis to procedurally fill small "holes" in projected textures may be another possible area of research. These are some examples, but this artist-researcher expects much future work can be done to continue to push the limits of how quickly and efficiently artists can create complicated digital environments using camera-based projected textures.

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