3D Computer Animated Walkthroughs for Architecture, Engineering, and Construction Applications

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Abstract

The purpose of this paper is to discuss the basic issues involved and to suggest methods for the planning and creation of 3D computer animation walkthroughs and flythroughs for architectural, engineering, and construction applications. The intended audience for this paper is international educators seeking to incorporate useful methods and techniques into their curriculum when 3D walkthroughs are needed.

Keywords: *3D computer animation, walkthrough, flythrough, architectural animation*

1. INTRODUCTION

Walkthroughs, as they are commonly called, are not only valuable for conveying information about a building, structure, or large scale environment, they are also relatively easy for almost anyone to produce at a simplistic or amateur level. Typically in walkthrough animations, structural and environmental objects such as walls, columns, doorways, buildings, and trees remain stationary while the camera moves through the scene. Walkthroughs and flythroughs differ in technique. A walkthrough is used to show the actual point of view of a person walking through a scene and is generally shot at or slightly below eye level. Flythroughs are not as narrowly structured as walkthroughs and can be made from any point of view desired and at any speed and camera angle. (Weishar). For descriptive purposes in this paper, the term 'walkthrough' will be synonymous for all architectural, engineering, and construction walkthrough and flythrough animations.

Another reason that 3D animation walkthroughs have come into popular use in business and industry is that they are fairly inexpensive to produce, as well as an excellent way to 'pre-visualize' what a building or environment will 'look like' before it is built. The purpose of this paper is to identify critical strategies and issues which must be considered when either teaching students or directing employees in the creation of a 'professionally' produced 3D computer graphic architectural walkthrough.

2. MOTION PLANNING & CAMERAS

Planning an AEC walkthrough should always start with deciding on the optimum path to be followed. A popular technique for initially planning a walkthrough is to sketch the proposed travel or motion path of the camera on the floor plan of the building or site plan. The direction and line of travel for a walkthrough is almost always based on showing the most important views or vistas either inside or outside a building or environment.

The assumption in most walkthroughs is that the animation will be a fairly accurate approximation of the finished building or site from the point of view of an observer. The height of the camera for a walkthrough gives the viewer a visual cue as to his or her relationship to the scale of the model. Most film directors position the camera about a foot below eye level. (Weishar).

Just as in filming home movies, a camera is used to establish the point of view and the path of the observer moving in a walkthrough. For this reason it is important to be knowledgeable of the basic mechanics of field of view and movement with cameras. Understanding camera movement is also highly important when applied to typical foot speed and head turn rates created in a walkthrough Further study to understand the role of motion blur and depth of field is also valuable for adding realism to motion in walkthrough scenes.

2.1 Field of View

The *field of view* for a camera is the angle described by an imaginary cone, the vertex of which is at the camera's origin. This also corresponds to the station point of the observer in the scene. The field of view angle with a camera is determined by the focal length of its lens. Camera lenses may be simplified into three broad categories; wide angle, normal, and telephoto. Wide angle lenses typically start at focal lengths of 30 mm or less and have wide field of view angles greater than 75 degrees. The 'normal' lens, typically found on most still cameras, has a focal length of 50 mm with a field of view of approximately 48.5 degrees. Telephoto lenses start at focal lengths of 135 mm or greater and have narrow field of view angles of less than 20 degrees. It is vital to understand that varying the type of lens and the corresponding field of view in a walkthrough tends to distort perspective in a scene. For that reason, in order to avoid distortion in a walkthrough, it is recommended to have minimum change of field of view in a walkthrough; typically approximately 50 degrees, plus or minus 5 degrees. Rapidly changing the field of view in a scene also creates dynamic distortion and a false sense of motion that is referred to a zooming.

2.2 Camera Moves

Due largely to exposure to the predictable camera movements in movies and television, audiences have learned to expect and anticipate the familiar movements of cameras. Unfortunately, the terminology of camera movement is frequently misunderstood and applied improperly. Therefore, understanding the terminology and application of camera movement is important to establish a correct basis for creating a walkthrough.

Basic camera moves are classified into two groups. The first group of camera moves are based on the rotation or change of camera orientation of the camera and are called *pan* (also yaw), *roll*, and *tilt* (also pitch). The second group of camera moves are based on the position and physical movement of the camera through a scene and are called *dolly* (forward and backward), *track* (side to side), and *boom* (up and down movement). (Maestri).

2.3 Applying Cameras to Walkthrough Movement

Camera animation is a very active process where the camera is continuously moving or changing its orientation in the scene. (Duff & Ross). In applying cameras to a walkthrough, there are three types of decisions to be made. First, an appropriate field of view needs to be established. A typical camera setup for a walkthrough starts with a field of view of approximately 50 degrees. The second issue is to establish the 'walking pace' or rate of travel of the camera through the scene. This will typically vary from a casual stroll at approximately 3 feet per second to a brisk walk at approximately 6 feet per second. The best way to establish this requirement is to analyze the floor plan or site plan and determine the amount of travel time required in seconds. In most 3D computer animation programs, the animation is generated at 30 frames per seconds. It is therefore important to use 'frames per second' time wisely and not waste time getting from one point to another in a scene unless the visual information is essential or useful. The third decision to be made in a scene is to determine whether to use pan or 'head turning' with the camera in a walkthrough. As an example, an average pan or 'head turn' of 45 degrees should take approximately 1 second at 30 frames per second. (Maestri).

3. LIGHTING & RENDERING

Being successful with architectural rendering often means that the user is not only careful with the mechanics of lighting and materials (surfaces), but also with the nuances of the human eye's perception of color and intensity (brightness). A high-quality rendering can evoke a predictable mood and perception of the structure from the viewer based on its subtle use of color, light direction, shadow, and composition.

Color of light, or more appropriately, color temperature, is the perceived hue of light based on the color of a black body radiator being heated from a black to a white-hot state. The heat is measured in the Kelvin scale of temperature (Smith & Bertolone). Warm colors such as red, yellow, or orange have a low temperature, and cool colors such as green and blue have a high temperature. To put it into perspective, a rising sun will cast a low temperature in the range of 2900 to 3200 K, while a noon sun in a clear sky has a temperature around 6000 K.

3.1 Exterior Lighting

Time of day can be one of the most important decisions made when approaching a rendering. A dramatic sunrise on a building facing east will envelope the façade and environment with a warm, vibrant, and inviting low light that casts long cool shadows across the image. Composing the structure in a three-quarter view that emphasizes the bright rising sun on the front and also reveals the detail of a side with less intensity can capture the viewer and make him/her not only visualize the structure, but also put it in context with its environment.

Unfortunately, most modeling and animation applications cannot achieve this look without a user that has taken these subtle details into account. The software will create lights with an artificial gray or perfectly white color, the lights will not decay over distance like "real" sources, and the lights will not even cast shadows by default. When lighting exteriors, the process of setting up the "sun", and shadows is relatively strait-forward. It requires a source that produces parallel light rays to simulate the sun, shadows that are relatively sharp when the sky is clear, and one other source that fills in the shadows with some illumination and color. The sun must be placed in the sky at the appropriate height and direction for the time of day and year, and it must be colored based on that height and direction. A few applications actually have a sunlight type of light that allows the user to simply supply the time of day and year, as well as indicate the North direction. Illuminating, or filling the shadows cast by the sun generally requires another light. This fill light should be a cool color, should not cast shadows, and should be aligned with the camera so it can fill all of the shadows that the camera "sees".

3.2 Interior Lighting

Lighting interiors is much more involved. Unless the user has access to software that employs global illumination, he/she must simulate the bouncing of light off of diffuse surfaces such as walls, ceiling, floors, and tabletops. Unfortunately, global illumination solutions take an enormous amount of time and processing power to render, so other, more conventional methods must be used. It is easiest to tackle an interior lighting project by first adding a light source such as a spot light or omni-directional light for each fixture in the design. These lights should also all cast shadows and decay over distance naturally (with inverse-squared decay). Next, add illumination through material adjustments by increasing the amount of self-illumination (luminosity) of each material. This will begin to fill the shadows and take away any absolute black areas. The last step is to add fill lights that simulate bounce light. These lights should cast a very diffuse, and weak shadow, be a fairly low intensity, and if possible, add their energy only to the diffuse and ambient properties of the surface (this will keep them from adding unnatural highlights to the objects).

4. 3D MODELING STRATEGIES

Although the 3D computer graphics model should be one of the last things considered, it is usually the first item dealt with in in the creation of a 3D walkthrough and occupies a great deal of project time. As a consequence, many architectural walkthroughs end up with 'over modeled' buildings and structures which must be simplified before they can be effectively 'animated'. Conversely this takes valuable time away from lighting, camera, materials, textures, and environmental issues. As a result, many walkthroughs have great looking models with poorly developed lighting systems and weak camera work.

According to Matthews, "It's a short jump-not a leap of faith-from two dimensions to three dimensions". Modeling for animations can be accomplished quickly and easily using several software products, or if other software products are not availablethe animation software can be an alternative product to accomplish the modeling. The modeling of the structure should be the first concern when considering a walkthrough or fly over. Unfortunately, it is probably the last item on the mind of the animator. With the location of the camera, position of the lights, and textures to be applied to the components- the model is usually rushed through to begin the animation process.

A building can be modeled in any software capable of creating solid or surface models. Some packages are better than others due to the way the software creates the models. Ethier and Ethier state, "It is essential for 3D users to understand the concepts of extrusion, wireframe, surface models, and solid models." This holds true for the animators as well they need to understand how the models are created and what the consequences are later. Hubbell and Boardman state " Efficient modeling is not just the ability to create a model quickly but to do so while setting the scene up for flexible editing and optimizing models with a minimum number of vertices and faces." The software packages capable of creating a model are AutoCAD, ArchiCAD, Vertex, Revit, CADSoft, and 3Dviz are just a few capable of model creation. Each has its own way of creating the model and along with the creation type comes benefits and drawbacks.

Solid modeling software packages usually create the best type of model to import into an animation package. Although the solid model generates 6 polygons, it allows the user to apply materials onto the object with minimum difficulty. Almost all solid modeling packages place the viewer's line of sight for the materials, or normal, toward the outside of the object allowing a totally viewable plane. Surface modelers on the other hand are great because they have fewer faces, but the user might get walls that allow the user to view right through portions.

Models created in each software package contain more information than the animation needs. Jones refers to excess information, as "Taking out the Trash" The walkthrough requires realism with the fewest possible polygons. It is not necessary to include complete models of windows or doors if they are passed by within one second or viewed from a distance of 75 feet. A bitmap image of the window or door, with a corresponding bump map, applied to a single plane accomplishes realism with the fewest number of polygons- one. Animations of Architectural, Engineering and Construction (AEC) walkthroughs can be extremely long- on the verge of several thousand frames. The animator must understand the relationship between rendering time, textures and polygon count.

5. ENVIRONMENTAL DETAIL & TEXTURE

Interior and exterior environments and details are another source of intricacy in the AEC animation process. Interior details can be anything from doors and windows to formal place settings on a dining room table. Exterior details are everything except the main structure like foreground trees, background trees, bushes, fences, vehicles and even lawn furniture. Interior and exterior details can create a substantial increase in vertices and faces. There are certain procedures or tricks in the animation process that will allow animator to render the scene quickly. First is the use of single polygons to replace entire entities like trees, shrubs, or tree lines. This procedure works extremely well for items that are distant from the the observer and camera. Placing a bitmap, (or a picture of the designated object, such as a tree or shrub) onto a single plane accomplishes the illusion that the object is there in all its complexity. There are important issues in using this method. The first is the addition of extra channels on the bitmap like opacity and bump maps and procedure does not work in all cases. Secondly, for realism, the colors in the image and direction of light and shadow should be carefully matched with the 3D lighting environment in the animation.

5.1 Geometric Detail

In situations where the object is close to the camera position or observer in a scene, a reduction or simplification of the model's number of vertices and faces unrealistic and unattractive appearances in the walkthrough. Therefore, it is common practice to utilize the complete and complex models. For objects farther away from the viewer's station point, a simplified model is usually adequate for realism. For interior objects that are at extreme distances from the station point, a single plane is all that is necessary for realism. Interior details have ever-changing needs or requirements during the animation due to the ever-changing camera or station point. These details can be turned on and off once they come into an out of the field of view of the camera. The turning off and on of interior and exterior detail items will greatly save in production rendering time, but can be rather overwhelming for the beginning animator to keep track of during the animation. Usually, for the beginning animator working on an architectural, engineering, or construction walkthrough, complete models may be required for all objects in the scene of interior animations and considered necessary for spatial visualization for the audience.

Exterior details can take advantage of the single plane models and maps more easily than interior objects due to the fact that the camera is typically farther away from the object. The greater camera distances allow the use of the single photograph of the object on a single rectangular plane. This also incorporates problems into the exterior scene. As the camera is moving, it will frequently come into closer proximity to the given single-plane object and the line of sight will change its angle with the given plane. A common practice is to rotate the plane containing the image to always stay 90 degrees to the line of sight of the camera. The largest complication with using a single plane to render entire objects is the shadow for the given plane requires the scene to be rendered using raytraced shadows, which take into account the planes opacity channel, instead of shadow-mapped.

5.2 Image Detail & Texture

"Even a perfect model might not make a beautiful rendered image. It all boils down to the materials and lights you add to the scene to draw the desired emotional response from the viewer." (Hubbel & Boardman) Successful architectural walkthroughs can require several thousand frames in order to accomplish complete spatial visualization of the space. Rendering time, textural realism or materials, and details are the keys to successful animations. Textures applied to surfaces can add realism, but can be the source of delayed rendering. "It is possible, and probable, the you will create materials that look great in the material editor, but terrible in the scene." (Hubbell & Boardman) Test renderings during the animation will ensure the material applied to the given surface will produce desirable rendered results. Those test renderings can give user an idea of total rendering time needed in final animation. When animating walkthroughs, the simplest material and models used will allow the quickest rendering time, but will not always ensure realism of the material, clarity of animation, or visualization of space for clientele. It is unfortunately not always possible to apply the simplest texture to the surfaces. Materials that require reflections, bump, or opacity mapping channels usually require longer rendering times. Textures can be very complex or as simple as a single color. A goal to keep in mind is that simple is the key to success. If the animator can keep things simple and while maintaining a realistic look, then the animation will accomplish the end goal.

6. REALISM

The amount of realism in a rendering image is determined by the intended use of the image. In strict visualization of the space it may be necessary to merely show the structure accurately with properly colored surfaces and general light. This type of rendering is usually used for proof-of-concept and not necessarily needed for marketing or even client approval. In other cases, a client may ask for photo-realism and ask that the structure be placed in a photograph or video footage of its future environment so that it is indistinguishable from reality. This type of rendering will need a lot more time because of the camera matching and the process of deleting the parts of the footage that will not be seen after the new structure is erected. The last type of image is more related to traditional rendering in that it is designed to give the viewer an impression of the structure and not necessarily a photograph. Post-processing is usually involved in this type of rendering. After the 3D software has produced an image, the user can load it into a photo processing or compositing application to apply filters to give the image a more “painterly” or “loose” look.

7. COMMERCIAL APPLICATIONS

Commercial 3D walkthrough animations for buildings and building complexes fall into three categories; Residential, Commercial, and Industrial-Plant Layout. Additionally, walkthroughs may also be created for any type of large-scale need, such as ships, aircraft, bridges, damns, and many other large-scale engineering projects.

7.1 Residential Walkthroughs

Residential computer animation walkthroughs are commonly used for designing and marketing large residential apartment or assisted living complex projects. However, the use of 3D computer animation walkthroughs for residential design and marketing is growing rapidly as the cost of producing walkthrough content decreases. Figures 1 and 2 illustrate both exterior and interior sample renderings of a residential model.

Figure 1. Residential Exterior

Figure 2. Residential Interior

7.2 Commercial Walkthroughs

Another popular use of walkthroughs is to visualize, design, and market light commercial buildings, such as small office and institutional buildings. In addition to the creation of the animation itself, a growing trend in walkthroughs is to incorporate the animation as part of a larger interactive multimedia product. Figures 2 and 3 illustrate the use of an interactive multimedia interface as a method of accessing and selectively viewing different rooms in a commercial building.

Figure 3. Multimedia Interface for Multiple Walkthroughs

Figure 4. Walkthrough Seen Through Interface

7.3 Industrial Walkthroughs – Plant Layout

A third application of walkthroughs is for visualizing plant layout for large industrial buildings and complexes. Figures 5 and 6 illustrate two examples of visual content from 3D industrial animations. Because of the large scale of most industrial complexes, flythrough animations are commonly used to save time and to focus on critical processes.

Figure 5. Interior Industrial Animation Scene

Figure 6. Exterior Industrial Flythrough Scene

8. SUMMARY & CONCLUSIONS

In summary, there are a logical set of steps and issues to take into account when planning a professional AEC walkthrough. The first step is to carefully define the purpose of the walkthrough and to develop a camera motion plan. Second, is to thoroughly plan and develop a lighting system which takes color, texture, shade, and shadow into account as realistically as possible without requiring extreme rendering times. Third is to keep the model simple, but realistic; the fewer the number of vertices and faces, the quicker the rendering time. Details included in the scene will be needed for realism, and will increase the number of vertices and faces. Fourth, try to keep the materials and raster image maps simplified. An important 'rule of thumb' is to make use of image detail, instead of geometric detail whenever possible. Along with careful planning and good project management, all these items, along with gaining experience, play an important role in creating a successful 3D computer animation walkthrough.

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