Abstract - The success of camera tracking in 3D studio max is hinged on world measurement of tracked objects where footage is shot. Although, the other packages can project objects’ positions automatically and some can generate a file that could be imported into 3D max, but where the footage site is unknown or proves unreachable, a manual operation within the 3D studio max package can reconstruct 3D scene from the 2D footage.

Keywords: Architectural visualization, camera tracking, 3D studio max, computer graphics, 3D scene, 2D footage.

1 Introduction

In most media arts including architectural visualization, a Computer Graphics (CG) camera that would match the motion of a live camera is obtained through camera tracking. It provides the only route to rotoscoping and aid site investigation where the original site is lost or proves unreachable. Voodoo, boujou, maya, and 3D max are some CG packages with the camera tracking utilities. In any case, a fundamental operation in camera tracking is to reconstruct objects’ positions in 3D scene as they are in world space. 3D max among other packages provides very accurate tracking operation but does not reconstruct objects’ positions automatically rather it relies on track markers, manually reconstructed 3D scene and taking world measurement where footage is shot. This is a huge problem because the CG artist scarcely knows where his desired footage is shot. Even if he does, circumstances could prevent access and where tracked objects are far apart, taking measurements is discouraging. The big question therefore is how can objects’ positions in 3D scene be derived where the only available information is a photo or video footage?

Although, the other packages can project objects’ positions automatically and some can generate a file that could be imported into 3D max but the accuracy and reliability for architectural visualization are often not satisfactory. Besides, these packages only project the positions of some selected points but do not really reconstruct the 3D scene as might be required for site investigation. Again, they are licensed packages that make affordability very remote especially for low income earners as often obtained in African continents.

This paper therefore uses diagrams to demonstrate in clear steps how a 3D scene can be reconstructed from a 2D footage to adequately serve the purpose of camera tracking and site investigation in a completely affordable way using only 3D max. Meanwhile, in my paper “Overcoming Premature Terminated Rendering Operation In Disadvantaged Working Environment” for Worldcomp 2009 proceeding, I mentioned that every student of architecture must have had cause to project a 3 dimensional view of an architectural design from the plan and elevations. As it is possible to project 3D view from a point of view by tracing rays of light, it follows that a point of view can be identified by tracing back rays of light from a 3D view. This paper demonstrates that the same principle makes it possible to project scene objects’ positions in 3D and further reconstruct objects’ forms.

2. Understanding how 3d view of an architectural design is projected from plan and elevations

In order to understand how scene objects, an architectural design for example, can be reconstructed from a footage it would be necessary to understand how such footage is projected by tracing rays of light. Below are the floor plan, front and left side elevation of a simple two bedroom bungalow.

![Fig. 1. Floor plan](image)
2.1 Procedure

2.1.1. Position the floor plan and draw your Direct Line (DL) as shown in fig 4. Choose your View Point (VP) and draw lines PLA and PLB so that they are parallel to the sides of the plan and also pass through VP.
2.1.2. Draw the horizontal line to represent the Paper Plane (PP) and draw lines that would represent light rays from VP to PP, each line passing through a feature in the floor plan like windows, doors and wall corners as shown in fig 5.

2.1.3. Draw the Eye Level (EL) line and vertical lines from the intersections of PLA and PLB with PP to meet EL at VP1 and VP2. VP1 and VP2 would form the two varnishing points. Draw the other vertical lines from where the light rays meet PP as shown in fig 6.

Fig. 6

Fig. 7
2.1.4. Create the Ground Line (GL) about 2.5 meter below the eye level EL as shown in fig 7 and project the length of a wall to meet PP at PPHL1. The vertical projection would form the building Height Line (HL) from which most height measurements would be taken.

Tips: For convenience, a number of height lines could be made for different wall planes as shown in fig 7 and the height line could further be calibrated. The figure also shows that Pe’ plane is projected by drawing lines from the varnishing point P2 through the height HL to the verticals representing the corners of that plane.

2.1.5. Project the other planes from VP2 if the plane is parallel to PLB but if parallel to PLA, project it from VP1 as shown in fig 8 and project the details as in fig 9.
2.1.6. Clean up.

Fig. 10

At this stage, any other desirable details could be projected to make the 3D view more realistic.

3. Reconstructing 3d scene from 2d footage.

The illustrations above show how a camera uses the interaction between light rays and scene objects to projects an image on a screen which we get as photo or video footage. In order to reconstruct a 3D scene from footage, the whole process would be a reverse operation. Meanwhile, it is important to remember that some photos present only one-point perspective and some present three-point perspective once the camera pitches. In any case, the principle basically remains but just a little more issues need to be considered. Below is a good example of a photo footage which the building can be reconstructed in a 3D scene.

3.1 Procedure

3.1.1. Trace out the horizontal line to identify the varnishing points VP1 and VP2 and direct line DL that must pass the center of the photo as shown in fig 12.

3.1.2 Draw a paper plane PP line and project vertical lines from the building features to meet PP as shown in fig 13.

3.1.3. Draw a semi circle (C) of diameter PPVP1 and PPVP2. Label the intersection of DL and C the view point (VP) being the camera position and draw lines from PPVP1 and PPVP2 to VP. Notice that the angle at VP is a right angle because the angle subtended at the center of circle is mathematically a right angle.

3.1.4 Project lines from the vertical lines to VP as shown in fig 15. These lines represent the light rays from the camera. The basic corners of the building can be identified on plan by offsetting lines PPVP1-VP and PPVP2-VP to meet the light rays.

3.1.5 Project the wall plane ‘Pa’ to meet PP and a vertical HL from the point of intersection to form the height line. Notice that the relative height of the windows can now be measured from the height line and their values should be transferred to the Z values where the light rays cut the building plan in 3D scene.
3.2 How to derive the Z values of the building features

It might be necessary to mention that all the above figures and illustrations were viewed directly from top. At this stage, an isometric view is required to appreciate the Z values.

3.2.1 Draw the line ‘E’ on HL that represent the height of each edge of the building as shown in fig 17.

3.2.2 Rotate it so that it stands upright in 3D scene and place it at it’s corresponding positions on plan as represented be E1, E2 and E3 in fig 17.

Fig.17

Fig.18
3.2.3 Use the same procedure to locate other features like windows as shown in fig 18, doors, roof etc as shown below.

Fig. 19

4 How to scale the scene to match world measurement.

You may have realized the relative positions, scale and proportion of objects were derived without world measurement but the scene often provides a clue that can enable us make a good calculation that would match our scene measurement with the world measurement. For instance, the distance between a building floor to the next floor is often 3 meters. It follows that the distance between a window and the one on the next floor should be 3 meters. Let ‘x’ represent scene measurement and ‘y’ represent world measurement. The formula \( \frac{x}{100} \) is the scale factor with which the scene would be scaled to match world measurement.

5 Tips

5.1 If objects are scattered in the scene yet they are the best objects to track, create a box around them in such a way that the box relates very well with the perspective. The corresponding positions, scale and proportion of the object can easily be derived in relation to the box.

5.2 While you must use the footage as your scene background in 3D studio Max, set the background image to 'render output'. In the render dialog box, set the output dimension exactly the dimension of the background footage. This operation would prevent distortion which would in-turn falsify certain measurements.

5.3 If the footage provides a noticeable third varnishing point, trace a number of height lines to locate the point. This would provide slanting height lines and height measurements should be made according to their position irrespective of the slanting position.

5.4 Once reconstruction of a footage scene is satisfactorily concluded, it is important to test your accuracy with camera match operation. The position of the automatically generated CG camera in relation with your assumed camera position at ‘C’ would determine you level of accuracy.
6 Sources of error

6.1 A cropped footage would cause error because the identification of camera position is based on the footage frame.
6.2 An edited footage would cause the projection of embedded elements and after effects can result in a falsified scene.
6.3 Avoid projecting objects that are far from the camera because grid lines appear to close up and make precise projection very difficult.
6.4 Use the distance between far objects to calculate your scale as short distance would multiply its percentage error.

7 Limitations of this method

7.1 A footage without identifiable vanishing point cannot be reconstructed using this method.
7.2 The method also imposes the objects that would be used for camera tracking since projectable object and point may not be the best object to track.

8 Conclusion

The success of camera tracking in 3D studio max is obviously hinged on world measurement of tracked objects from where footage is shot. The importance of this is not really made in help manuals and online helps but where the footage site is unknown or proves unreachable, a manual operation within the 3D studio max package as explained in this paper can reconstruct 3D scene from the 2D footage without revisiting footage site as claimed compulsory. Although, this paper only offer a manual reconstruction of 3D scene but has tactfully avoided the cost of third party package, rekindled the hope of tracking a footage of a lost site and in addition to accomplishing camera tracking, the investigation of a lost site is also made possible using this method.