Ray tracing algorithm rendering

doc.dr.sc. Zvonimir Sabati
Faculty of Organization and Informatics
University of Zagreb
Pavlinska 2, 42000 Varaždin, Croatia
zvonimir.sabati@foi.hr

Andrija Bernik, dipl. inf.
Veleučilište u Varaždinu
J. Križanića 33/6, 42000
42000 Varaždin, Croatia
andrija.bernik@gmail.com

Abstract: Ray tracing is a rendering method based on global illumination for use in 3D applications to obtain a real image models. The application is available in computer games, special effects, medicine, interior and exterior design, and various simulations, advanced engineering and in all kinds of computer graphics. Ray tracing uses mathematical algorithms and physical background of for getting the real picture. Rays of light are calculated from the viewer to the source of light. Its disadvantage is that it is relatively slow and therefore hard to find applications where higher speed is required (eg video games). There are several types of programs for 3D modeling and it is important for the user to know the domain, ie he must know what is expected as the result in manipulation of certain attributes. The aim of this paper is to describe the ray tracing algorithm, explain how it works and define the settings required to achieve a real image scene. For example, the program will use Autodesk Maya 2011 and V-Ray plugin. In addition to practical work in real rendering interiors, will be defined and the various settings that were used, and mathematical functions that are used in the background of the algorithm.

Keywords: Ray tracing algorithm, 3D modeling, rendering, computer graphics

1. Introduction

Ray tracing is an algorithm that runs in the background of 3D computer program and it is used to get a realistic computer graphics. This technology is used in all computer programs that are used for 3D modeling and in industry such as film, video games, medicine etc. It is based on global illumination. It follows the rays of light backwards, from the eye, through the pixels in the image plane and into the scene. Then the rays are re-tested together with all objects in the scene to determine whether there is a collision with some of the objects. If rays do not strike in any of the objects, then this pixel is changed into the background color. If the rays collide with some of the objects, then the pixel is changed to a color that is determined for that object. Ray tracing includes shadows, reflections and texture mapping.

2. Global illumination

Primary ray becomes passes through each pixel and it is tested for the impact into objects. If there is a collision, then it creates a few more ray becomes. Shadow rays are sent to two light sources LA and LB. If the surface is reflected, then the generated reflected ray becomes Ri. If the surface is not transparent then it creates transfers and creates Ti. Each of the secondary rays are tested with all the objects in the scene. The reflected beam and / or transmitted beams are continuously generated as long as the rays do not escape from the scene without colliding with any of the objects or until the level of recursion is completed.

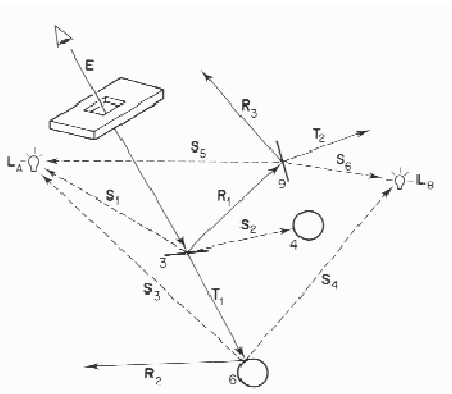

Figure 1. Global illumination

2.1. Shadow Rays

Shadow ray is a ray that starts is in the point of collision ray of light and the object, and finishes is in the source of light. The purposes of these rays are to determine whether the point of collision is in the shadow of one of the sources of light. Each light source has a shadow ray. The source of shadow ray is the point of collision, and the direction vector is normalized vector between the point of collision and the position of light sources. A and B are two balls and 1 and 2 represent two sources of light. Shadow ray travels from eye, where it collides with the object A. In order to determine whether there is a shadow or not, there are new rays that are generated by

each of the sources of light. Shadow ray of light 2 travels from A to the source of light 2 without any obstacles, but the object B lies in the path of rays from the object A. So that creates a shadow in the comparison to that source of light. The intensity of color on a object A depends on the source of light 2 that reaches to the object A.

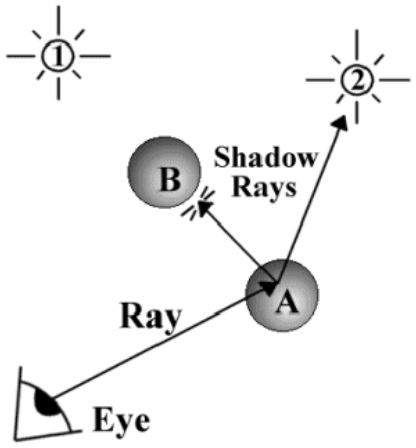

Figure 2. Generating shadows

2.2. V-Ray and sources of light

V-Ray is a plugin that is relatively new and is used as a plugin for ray tracing. V-ray has simplified many things such as different sources of light, ease of metallic colors, adds realistic grass in the scene. V-Ray is one of the few plug-ins that can in a very simple way make the scene realistic. Physics of V-ray is the closest to that what is normal for humans, and how people perceive it. In other modes of ray tracing it is necessary to determine the various paths, and "cheat" Physics of scenes to be realistic. In V-ray the physics it based on certain calculations that are more similar to the real world and real conditions. Below will be described some parts and the possibility of V-ray, and it will be shown the practical part of using V-ray.

Light sources are one of the most important items on the scene. As in the practical work of this paper uses a plugin for ray tracing, V-Ray, will be described as a light source. Depending on the size of scene is required a certain strength of the sources the light. Most often it's not just one source, but there are more, while only one source is visible. These "hidden" sources are used only to enhance the lighting scene and it softens or eliminates unwanted shadow rays. Because of the way of the light source in the V-ray it is necessary to have a scene in the real size, since here the light sources operate in such a way that they can increase the intensity of using watts or lumens. Therefore, the power source of the light is predetermined in the real world and as such provides valid light. If there would be no light source on the scene, there would be no rays or light, and hence, ray tracing would have no purpose.

2.3. Reflection and transparency

If the surface, with which a ray of light collisions, is reflective, or a mirror, ray tracer has to find the color, but in this case not only the color of the surface, but also the color of objects that are visible in this area.

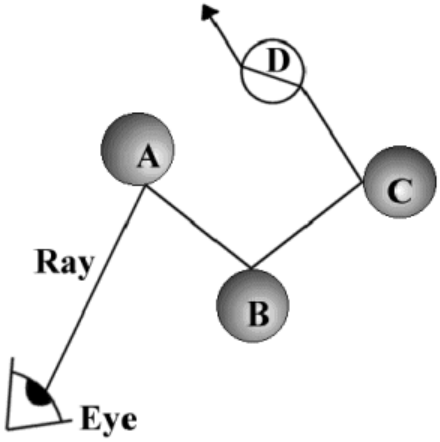

Figure 3. Generating reflections

Balls A, B and C are reflective. As rays that travels from the eye it collides with A, it is automatically reflected on to B, and then on to C. For this to be possible in ray tracing, you need to calculate the angle at which the rays are rejected, and it then creates a second beam that travels from the point of collisions in calculated way. Shadow ray concludes the color by calculating all objects collisions and it finds the closest. Color information is transmitted back to in pixel through which the original rays were emitted.

Transparency mode is similar to reflection, but rather that the new rays reflected from the surface, it leaks through the surface and creates refraction. Refraction is an optical phenomenon that occurs when light bends as it passes through the material. If in the item is inserted a glass of water, then, depending on the viewing angle, that object changes shape, thickness, length, etc.
Light is deducted differently through different materials. The same logic applies in the ray tracing algorithm.

2.4. Anti aliasing

Anti-aliasing is a method that is used to improve realism of the images so that eliminates sharp (toothed) edges with it. These sharp edges occur because a computer monitor has a pixel in a square, and those pixels are not adequate to show the lines or curves that are not parallel with them.

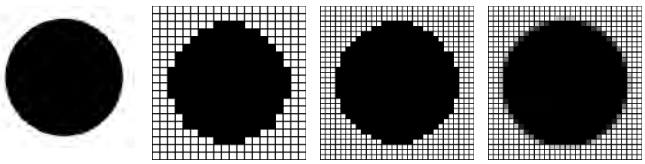

Figure 4. Anti aliasing

If you put a circle over the network and select only the squares that are filled with color, we get the first picture. Interference is called aliasing and it is an example of what happens when the circuit is shown on the computer screen. This problem can be minimized by using the "finer", i.e., better networks, i.e. networks on to higher quality resolution. In ray tracing each pixel is treated as infinite square area. Rays are emitted on to scene through the center of each pixel and its neighboring rays intensities are compared. If they differ for some predetermined amount, then is emits more rays into the pixel area. The intensity of all rays emitted in the given pixel is the average time taken to find the pixel color. Anti-aliasing then helps to eliminate jagged edges and it makes the image more realistic.

2.5. Cameras

Camera controls the manner in which the scene is projected onto on to image. In V-ray, there are several types of cameras. These are:
- **Standard** - This is a standard camera that is used in various parts of the ray tracing (called pin-hole camera)
- Spherical - circular camera, i.e. the camera lens are round (spherical) shape.
- **Cylindrical** (point) - for these types of cameras all rays are emitted from the center of the cylinder. In vertical direction the camera acts like a standard camera and in the horizontal direction as a spherical camera
- **Cylindrical** (ortho) - in the vertical direction has the orthographic view and in the horizontal direction acts as a spherical camera.
- **Box** - for these types of cameras, there are six standard cameras, and each is placed on to edge of the cube.
- **Fish Eye** - fish eye camera has a small focal length and for it you can control exactly which part of scene will be displayed. The shape is orbicular and it distorts the picture.
The biggest difference, except that there are several types of cameras, is that you can fully customize the aperture, exposure, focal length and it viewing angle, and is therefore much easier to get the kind of scene the user wants. Because of these features it is possible to regulate the depth of field, and can be used for motion blur (motion blur). For each camera there are also settings on quality, rotation, simulation forms of cameras, etc.

3. Preferences of vray engine

Way of getting a real image from the 3D program depends not only on lighting and materials, but also on the settings of the engine that rends. In this case, that is the V-ray. Most of the standard settings for V-ray is in order and it you need to change only some of the settings.

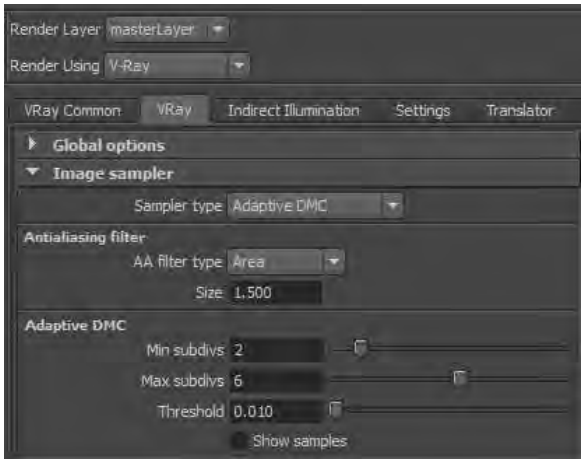

Figure 5. V-ray settings

The V-Ray tab, type sampler was placed on to adaptive DMC. Adaptive DMC is one of the best and the fastest anti-aliasing process. The rate depends on its settings and quality. Min and max subdivisions indicate the range of departments. This means that the gap between these two fields of higher anti-aliasing will take place on to a larger area and render time will be longer. Also, this is a very important part of and threshold, which reduces interference on to rendered picture. Thus, the lower the number of smaller areas is, the more subdivision are processed in the given area range. Therefore, the result is better and sharper picture, but time rendering takes a lot the more. Adaptive DMC is most commonly used in the scene when there are more detailed textures, more detail on to objects and with effects such as blur and gloss.

In the Indirect Illumination tab the control for global illumination, or GI. Global illumination is used in order to get realistic colors from the refusal of certain areas. If the Global Illumination option were excluded, it would reduce the rendering time, but the picture would not be realistic because there would be no rejection of colors. For example: if an entity enters the room, whose walls

are white, It will get the impression that the there is a light in the that room. However, if the room is black, the subject will get the impression that the room is too dark, that there lacks brightness. This is exactly what is global illumination, given certain rejection of colors depending on the material and size. Global illumination is regulated by Primary and Secondary bounces. Primary bounces are primarily a rejection of the light, therefore the refusal of light from the first surface, while the secondary light rejection is rejection of each other. Global illumination uses a different "engine" for the refusal. There are several types of engine, but here are used two: Brute force and irradiance map.

Figure 6. V-ray – Brute force settings

Brute force is one from most accurate method of global illumination. Works so that transmits a lot of light rays and each of these rays collects information about surface color, intensity, and other. Has an extremely slow engine and it has a big flaw that produces noise in the picture. It contains settings for subdivs and depth. Subdivs is the amount of subdivision that are available to brute force (the higher the number, the engine has the more parts of an area to process and thus the image quality is better), and depth uses the depths of a brute-force. The greater the depth of brute force the render shows better picture and gives better results. Brute force engine is not recommended as the primary engine in the global illumination because it gives a lot of interference and noise in the picture but very often is recommended as a secondary engine.

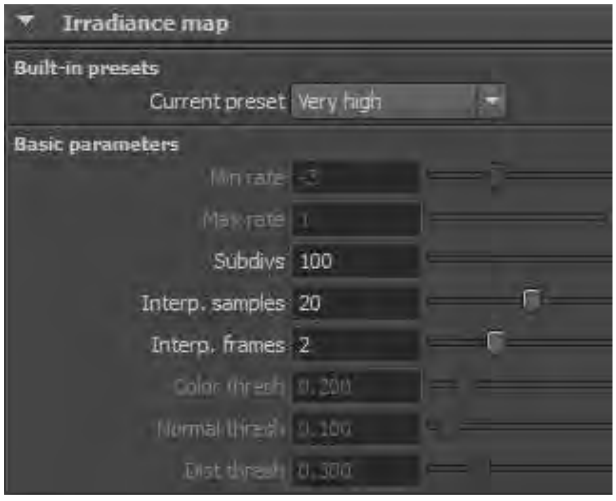

Figure 7. V-ray – Irradiance map settings

Irradiance map method uses a global illuminated camera to find out which parts of the scene are visible or not. On this basis, it creates patterns that are common to more complicated objects, and rarely on flat objects. Depending on these calculations, each of the samples emits a number of light rays that return the value of color, its intensity, distance from the camera, etc. It gives very nice results and is used in the interiors and exteriors because of these patterns. It features speed, accuracy and quality. Preset are certain settings that are set by the quality, so you can regulate the quality of the rend. Also properly concludes where there is more detail on the scene and therefore adjusted samples. Min and max rate, i.e. the difference between these two numbers determines the number of samples, and thus the number of rays that are emitted into the scene. If the difference is 4, the scene will render four times and each pass will do the part. The more of these passages the final product will be better and with more detail. Subdivs determine how rays are of light will be emitted from the sample. Of course, the more rays are emitted, the results will be better and more accurate. Interp. samples is used to remove noise from the image (the value increases), but may lose the sharp edges of objects. If this number is too low, it gives the noise effect in the picture.

4. Result of rendering and conclusion

Ray tracing rendering algorithm is one of the best display modes of virtual reality. Although it can not be used in large quantities in video games, it is widely used in medicine, animated films, simulations of real world, engineering, etc. V-Ray is one of the most advanced parts of a ray-tracing and it is able to make a lot of complicated tasks in a very simple ways. From the setting of the sun, his inclination, and even the possibility of setting the coordinate positions and the date, through a variety of lighting options, settings, shadows, reflections, and the final product that can be achieved in the easiest way ever. Computer technology is progressing strongly and it is possible to use a variety of 3D applications in construction, interior design, modeling a variety of vehicles, running through the virtual space. Everything that once had to be drawn on paper, today we can draw on the computer and make the whole project in one of the 3D programs. Ray tracing has proven to be valuable, and V-Ray plugin allows the user to view a photo realistic virtual environment.

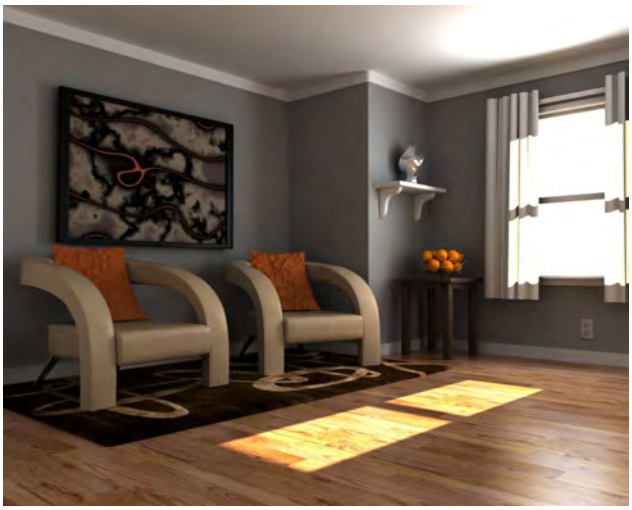

Figure 8. V-ray – Final product of a computer scene

References

[1] Siddhartha Chaudhuri: **FuzzyPhoton**, available at: http://fuzzyphoton.tripod.com/whatisrt.htm

[2] **Aversis**, available at: www.aversis.be/tutorials/vray/essential_gi_methods_01.htm

[3] **Trinity3D**, available at: http://vray.us/vray_documentation/vray_gi_methods.shtml

[4] **Global illumination**, available at: http://en.wikipedia.org/wiki/Global_illumination

[5] Spot3d: **VRayPhysicalCamera**, available at: http://www.spot3d.com/vray/help/150SP1/examples_vrayphysicalcamera.htm

[6] **Global Illumination in a Nutshell**, available at: www.thepolygoners.com/tutorials/GIIntro/GIIntro.htm

[7] G. Scott Owen: **Ray Tracing,** available at: http://siggraph.org/education/materials/HyperGraph/raytrace/rtrace0.htm/

[8] G. Scott Owen: **Ray Tracing,** available at: http://siggraph.org/education/materials/HyperGraph/raytrace/rtillumi.htm

[9] Jamis Buck: **The Recursive Ray Tracing Algorithm**, available at: http://reocities.com/SiliconValley/haven/5114/raytracing.html#AntiAliasing

[10] Jamis Buck: **The Recursive Ray Tracing Algorithm**, available at: http://reocities.com/SiliconValley/haven/5114/raytracing.html

[11] Spot3d: **VRayPhysicalCamera**, available at: www.spot3d.com/vray/help/150SP1/render_params_advancedimap.htm

[12] **Trinity3D**, available at: http://vray.us/vray_tutorials/vray_tutorial_irradiance_map1.shtml

[13] **Ray tracing**, available at: http://en.wikipedia.org/wiki/Ray_tracing_(graphics)