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VOLUME RENDERING BY RAY CASTING

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***Abstract*-Volume rendering is a method of extracting meaningful information from the volumetric data using Interactive graphics and Imaging.It is concerned with volume data representation,modeling,manipulation and rendering.Volume data are 3D entities that may have information inside them ,might not consist of tangible surfaces and edges,or might be too voluminous to be represented geometrically.They are obtained by sampling, simulation, or modeling techniques.This set of samples in three dimensions can be transformed in to a meaningful image viewed in two dimensions on the computer screen.Various techniques are in practice in extracting volume data.Here in this paper we are going address it by RAY CASTING method. In the rendering process volume rendering uses lighting function from the study of computer graphics and it uses point processing from image processing to classify its data.in its compositing function,it emulates an alpha blend from computer graphics.alpha blending is also in the family of frame in image processing.the idea behind volume rendering is to create a two dimensional image that is composed of numerous three-dimensional values.**

KeyWords:Ray Casting , Volume rendering,Volume Data

I. INTRODUCTION

Volume rendering is a method of displaying volumatric data as a two dimensional image.the volume data may be the result of sampling an object in three dimensions one example of this would be a magnetic resonance image scan of a person's head.though strikingly scenes can be achieved with computer graphics,if you want to look beyond the object surfaces into the object you will find nothing.these scenes lack the internal matter that you would find in objects in the real world.it is very hard to combine the computer graphics primitives mentioned above to truthfully represent the inside of an object as well like the inside of a human body.this is where volume rendering comes in to play.

The basic steps in any volume rendering algorithm consist of assigning a color and an opacity to each sample in a 3D input array , projecting the samples onto an image plane, andthen blending the projected samples. The foundation of this visualization technique is aphysically-based model for the propagation of light in a colored, semi-transparent material.we develop the model by writing an energy balance equation and reducingit to the volume rendering equation. In Section we show how to simplify the volumerendering equation to a form known as the volumetric compositing approximation. This approximation is the starting point for the algorithms in this thesis.The Volume Rendering Equation.The input to a volume rendering algorithm is a 3D array of scalars (as opposed to vectors which have a directional component). The array is called a volume and each element of the array is called a voxel. Although some volume rendering algorithms assume that each voxel represents a small cube in space with a constant scalar value, we will assume a voxelrepresents a point sample of a continuous scalar function.V olume rendering is an approximate simulation of the propagation of light through a participating medium represented by the volume The medium can be thought of as a block of colored, semi-transparent gel in which the color and opacity are functions of the scalar values in the input array . As light flows through the volume it interacts with

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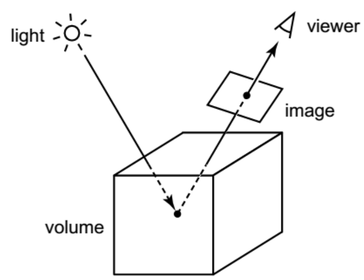
the gel via several processes: light can be absorbed, scattered or emitted by the volume. Many other types of interactions are also possible, such as phosphorescence (absorption and re-emission of energy after a short time delay) and fluorescence (absorption and re-emission of energy at a different frequency). However since the goal of volume rendering is data visualization, not accurate simulation of the physics, we will omit many parts of the fulloptical model that are not necessary for the visualization.

II. VOLUME RENDERING

Given a simplified optical model,a volume rendering algorithm produces an image by computing how much light reaches each point on an image plane.Light transport is governed by a special case of the Boltzmann equation from transport theory, which is the study of how a statistical distribution of particles (such as photons) flows



A physical model for volume rendering: A light ray propagates through a cube of semi transparent gel and scatters onto the image plane through an environment contain introductions to transport theory and its application to computer graphics, and contains a more detailed treatment of the underlying physics. Here we summarize the major results.The flow of photons in a fixed environment rapidly reaches equilibrium, so the numberof photons flowing through a given region of space in a particular range of directions must be constant over time. Thus if we consider the photons in a differential volume about a point **r** traveling in a differential range of angles about a direction $\vec{\boldsymbol{\omega}}$ and we sum the change in the number of photons due to each possible type of interaction with the volume then the netchange must be zero.Instead of counting photons we will write an energy balance equation in terms of radiance, designated by $L(\mathbf{r},\vec{\boldsymbol{\omega}})$.Radiance describes the density of power transmitted by the photons at a particular point in a given direction. More precisely it is the power per unit area(projected onto the direction of flow) per unit solid angle, and it has units of W/m^2-sr . The energy balance equation states that the directional derivative of the radiance along a particular ray equals the sum of three terms representing losses and gains due to interactions with the volume:

$$\vec{\boldsymbol{\omega}}\bullet\nabla L(\mathbf{r},\vec{\boldsymbol{\omega}})=$$
$$-\emptyset(\mathbf{r})\boldsymbol{L}(\mathbf{r},\vec{\boldsymbol{\omega}})+\epsilon(\mathbf{r},\vec{\boldsymbol{\omega}})+\int_{s^2}k(\mathbf{r},\vec{\boldsymbol{\omega}}')L(\mathbf{r},\vec{\boldsymbol{\omega}}')\mathrm{d}\vec{\boldsymbol{\omega}}'$$

$\emptyset_t$(r) is the extinction coefficient (with units of m^{-1}) which equals the probability per unit distance that a photon traveling along the ray will be either absorbed or scattered into a different direction by the volume of W/m^3-sr that accounts for photons emitted within the volume.$\boldsymbol{k}(\mathbf{r},\overrightarrow{\boldsymbol{\omega}'}\rightarrow\vec{\boldsymbol{\omega}})$is the scattering kernel (with units of sr^{-1} m^{-1}) which is the probability per unit solid angle per unit distance that a photon moving in direction $\vec{\boldsymbol{\omega}}'$will scatter into direction $\overrightarrow{\boldsymbol{\omega}'}$.We integrate this function against the incoming radiance from all directions (denoted by $\boldsymbol{s}^2$) to account for the photons scattered to account for the photons scattered into the ray . Equation 1.1 is a first order differential equation known as the differential form of the equation of transfer. It can be written in an equivalent integral form as follows $L(\mathbf{r},\vec{\boldsymbol{\omega}})=$ $e^{-\Gamma(r,r_B)}L_B(\mathbf{r}_{B,}\vec{\omega})+\int_{\Gamma(\mathbf{r},\mathbf{r_B})}e^{-\Gamma(\mathbf{r},\mathbf{r_B})}\mathrm{Q}(\mathbf{r}',\vec{\omega})\,\boldsymbol{dr}'$

$\boldsymbol{\tau}(\mathbf{r},\mathbf{s})$ is the integral of the extinction coefficient along the straight-line path between points **r** and **s**

$$\tau(\mathbf{r},\mathbf{s})\equiv\int_{\Gamma(\mathbf{r},\mathbf{s})}\phi_t(\mathbf{r}')\,dr'$$

The path between the two points is denoted by $\Gamma(\mathbf{r},\mathbf{s})$. We note that $e^{-\tau(r,s)}$ the integrating factor used to convert Equation 1.1 into Equation 1.2. is the integrating factor used to convert Equation 1.1 into Equation 1.2.$\boldsymbol{L_B}(\mathbf{r},\vec{\boldsymbol{\omega}})$is a function specifying boundary conditions over a closed surface surrounding the volume. The point $\boldsymbol{r}_B$ is the intersection between the closed surface and the ray from direction $\vec{\boldsymbol{\omega}}$.Q$(\mathbf{r},\vec{\boldsymbol{\omega}})$ is short-hand for the sum of the emission and scattering terms:

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$Q(\mathbf{r},\vec{\omega}) \equiv$

$$\epsilon(\mathbf{r}, \vec{\omega}) + \int_{s^2} k(\mathbf{r}, \vec{\omega}' \rightarrow) L(\mathbf{r}, \vec{\omega}') d\vec{\omega}' \qquad \mathbf{1.2}$$

This function can be thought of as a generalized source function that accounts for all of the gains in the energy balance equation.The integral form of the equation of transfer states that the radiance at any point along a rayequals a contribution from the radiance entering at the boundary of the volume plus a sum ofcontributions from the source terms along the ray . All of these contributions are multiplied by an exponential attenuation function that depends on the distance between the source and the measurement point (located at $\boldsymbol{r}$) Equation 1.2 is a generalization of many equations used in rendering. Kajiya's rendering equation is equivalent to the equation of transfer specialized for environments consisting of surfaces (represented by boundary conditions) separated by empty space, in which case volume absorption, emission and scattering drop out of the equation.Zonal radiosity is a method for solving the equation of transfer assuming that the scattering and emission functions are isotropic, i.e. independent of $\vec{\boldsymbol{\omega}}$.Finally , with a different set of assumptions we arrive at the volume rendering equation.First, we only model single scattering, i.e. all of the photons reaching the image are assumed to have scattered only once after leaving a light source. Second, we ignore absorption between the light source and the scattering event (but not between the scattering event and the image plane). Third, we assume isotropic absorption. Fourth and finally , we choose a simple boundary condition: we assume that the only energy entering the volume comes from a finite set of point light sources.The first two assumptions allow us to drop the scattering integral from the equation of transfer since we can use the emission term to model the single scattering event. In this model the light sources deposit energy at each voxel and the voxels then re-emit the energy .The emission function describes the amount of re-emitted energy as a function of the viewing angle. Typical volume rendering algorithms compute the value of the emission functionat a voxel using a local illumination model that is a function of the voxel' s scalar value and the positions of the light sources. Since we have ignored absorption between the light source

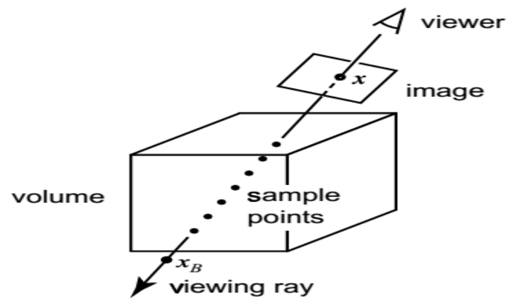

Figure 1.3: A simplified model for volume rendering: Each voxel in the volume emits light (computed using a local illumination model) and absorbs a fraction of the light passing through it, butscattering is ignored. The value of a pixel is computed by sampling the voxel values along a viewing ray from a point x on the image to a point $\boldsymbol{x_B}$on the opposite boundary of the volume and then numerically evaluating the volume rendering integral,and the voxel this model cannot be used to produce shadows. We discuss volume rendering algorithms that correctly render shadows**.**

With all four assumptions Equation 1.2 reduces to the volume r endering equation:

$$L(x)=\int_{x}^{x_B} e^{-\int_{x}^{x'} \emptyset_t(x")dx"} \epsilon(x')dx' \qquad 1.3$$

. In this equation we have reparametrized the radiance in terms of a one-dimensional positionvariable $\boldsymbol{x}$ representing distance along a viewing ray . The upper limit of integration is $\boldsymbol{x_B}$,the point at which the ray exits the volume.A simple ray casting algorithm based on the volume rendering equation operates by tracing rays into the volume parallel to the viewing direction as shown in Figure 1.3. The rendering algorithm then numerically evaluates the integral in Equation 1.3 along each ray . The user of the volume renderer specifies a mapping from the scalar value associated with eachvoxel to the parameters in the physical model, such as the absorption coefficient and the parameters of the illumination model for computing the emission function. In the next sectionwe will describe a common method for evaluating the integral, called

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volumetric compositing, and we will refine the ray casting algorithm.

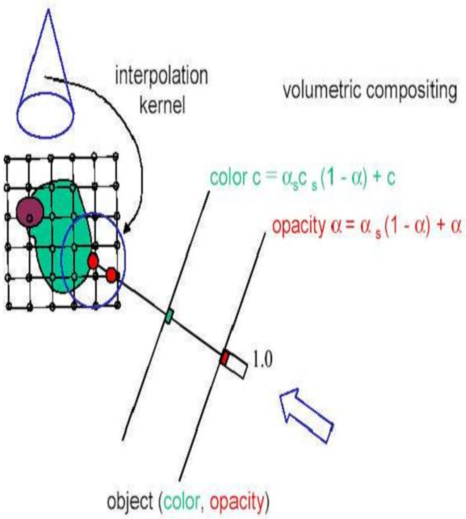
The volume rendering equation derived in this section is equivalent to the volume rendering models proposed by Blinn ,Levoy and Sabella .Other volume rendering models based on the more general equation of transfer , which includes multiple scattering, have also been proposed: Kajiya & V on Herzen derive an approximation for the case of a volume containing high-albedo (highly-reflective) particles, Kr ¨ uger evaluates the full equation using Monte Carlo integration techniques, and Sobierajski & Kaufman perform volumetric ray tracing including ideal specular reflections at isosurfaces in the volume. A key advantage of volume rendering is that the volume data need not be thresholded, in contrast to surface rendering techniques. Surface rendering techniques for volume data operate by fitting polygons to an isosurface in the volume (using, for instance, the marching cubes algorithm and then rendering the polygonal model with traditional polygon rendering techniques. The surface-fitting process requires making binary decisions, i.e. the volume must be thresholded to produce regions that are either insideor outside the isosurface. If the volume contains fuzzy or cloud-like objects then a polygonal surface will be a poor approximation. In contrast, volume rendering algorithms neverexplicitly detect surfaces so they naturally handle fuzzy data as well as sharply-defined surfaces.

III . IMPLEMENTATION BY RAY-CASTING

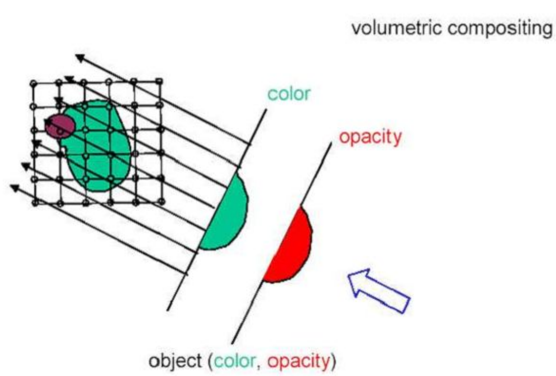
Ray Casting is similar to ray tracing in surface-based computer graphics.In volume Rendering we only deal with primary rays, i.e. no secondary rays for shadows,reflection or refraction are considered. Ray Casting is a natural image order technique.Since we have no surfaces in DVR we have to carefully step through the volume.A ray is cast into the volume, sampling the volume at certain intervals.The sampling intervals are usually equidistant,but they don't have to be(e.g. importance sampling). At each sampling location , a sample is interpolated/reconstructed from the voxel grid. Popular filter are nearest neighbor (box), trilinear, or more sophisticated (Gaussian, cubic spline).

i)Volumetric ray Integration:

The rays are casted through the volume.Color and opacity are accumulated along each ray(compositing). How is color and opacity determined at each integration step.Opacity and (emissive)color in each cell according to classification.Additional color due to external lighting: according to volumetric shading(e.g. BlinnPhong).How can the compositing of semi-transparent voxels be done?.Physical model emissive gas with absorption.Approximation,density-emitter-model(no scattering)**.**Over-operator was introduced by Porter.



Ray Casting



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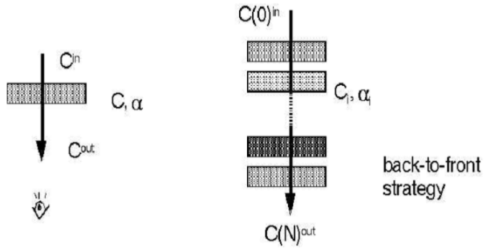
$$C^{out}=(1-\alpha)\, C^{in}+\alpha C$$

$$C(i)^{in}=C(i-1)^{out}$$

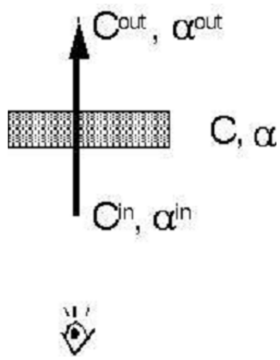


a) Over operator

The picture illustrates the back-to-front-strategy.The color value is computed from.A front-to-back-strategy is also possible:

$$C^{out}=C^{in}+(1-\alpha^{in})\alpha C \quad , \quad \alpha^{out}=\alpha^{in}+(1-\alpha^{in})$$

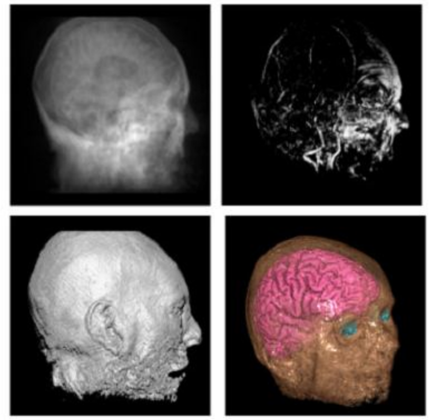
This approach causes the need to maintain α .



b) Front-to-back-strategy

The illustration shows the front-to-back-strategy.The color value is computed from the old color/opacity and the values of the sample.There are several traversal strategies.Front-to-back(most often used in raycasting) Back-to-front(e.g. in texture-based volume rendering) Discrete(Bresenham)or continuous(DDA) traversal of cells.

IV. RESULT ANALYSIS



The above pictures illustrate the technique of ray casting.In the case above rays(like X-Rays) are passed through the volume data.When these rays come of the volume they store the values of the data sample with them.These data is specifically volume data or 3D data.We process this volume 3D sample to produce 2D values to be projected on the computer screen.

V.CONCLUSION

Non-photorealistic volume rendering(NPVR) is a relatively recent branch rendering. It employs local image processing during the rendering to produce artistic and illustrative effects, such as feature halos, tone shading,distance color blending,stylized motion blur, boundary enhancements ,fading, silhouettes, sketch lines,stipple patterns, and pen+ink drawings.The overall goal of(NPVR) is to go beyond the means of photo-realistic volume rendering and produce images that emphasize critical features in the data, such as edges,boundaries,depth,and detail, to provide the user a better appreciation of the structures in the data. This is similar to the goals of medical and other illustrators,as well as related efforts in general computer graphics. Since the set of parameters that can be tuned in NPVR is even larger than for traditinal volume rendering,interactive rendering of the NPVR effects is crucial,and indeed a number or researchers have proposed interactive implementations that exploit the latest generations of commodity programmable graphics hardware.

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