Chang Liu(chang_liu@student.uml.edu)
Computer Graphics I
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Literature Review I

The papers that I choose as the primary paper is that "**Using Global Illumination in Volume Visualization of Rheumatoid Arthritis CT Data**", and the secondary paper that I choose is that "**Fast Global Illumination for Interactive Volume Visualization**".

In this literature review, I will talk about the problem of global illumination. As these two papers shows, global illumination means that texture or object surface's reflection under some specific environment like lights and x-ray. Here the global specifies the overall features that the object shows in a broad view, instead of local view in a small area.

As we all know that high global illumination can enhance the visual perception of depth cue and the local thickness of volumetric data has limited power of representing the images, so it has been a focus of doing research in this area. In the second paper "**Fast Global Illumination for Interactive Volume Visualization**", the author presents a novel grid-based illumination technique which is specially designed and optimized for volume visualization purpose. The methods models light propagation, including both absorption and scatting, in a volume using a convection-diffusion equation that can be solved numerically. The advance of this method is that it could be separated for the light modeling and simulation, so that it is possible to use a unified partial-differential equation to model various illumination effect and adopt highly-parallelized grid-based numerical schemes to solve it. Unlike before, the complicated evaluation of the inner-affected factors are all changing, by using this method, it is more precise and approachable to conduct numerical study of the light illumination.

When using the method, it is rather convenient to solve sub-problems at the same time. As the reasons above, we are allowed to choose different numerical schemes for solving the model equation. For an overview of the equation, we could divide it into five parts: light propagation, absorption, scattering, distant lights and point lights. All these five parts contribute to the light

illumination model, and they could be calculated by different equations by different schemes of their own characters and variables. In previous situation, some factors are inner-affected and cannot be calculated separately, but now it is disconnected and we can calculate them using different factors at the same time. When we calculate each of the five parts, it is necessary to use some metrology. First, split the equation into a convention step and a diffusion step. In convention step we solve the problem by using a first-order upwind schemes for each light source. The results are accumulated into a single energy volume and then in the diffusion step, we solve the problem using this result for scattering effects.

In the convection step, the author use a finite difference method to solve the model equation. For mathematical reason to minimize the computational cost, split the equation for each light source and calculate the entire effect. After the splitting schemes, they then use an upwind scheme for convection. This scheme use stencil points along the inverse wave direction in order to achieve stable results. After this step, we then composite the solution for all light sources and combine all the energy density fields together with corresponding light color into a single light color field. At last, simulate the the scattering effect by changing the model equation into its vector form. Then the solution could be got when the time $t = 1$ is used as the final illumination volume.

In the final part of the second paper, the author gives some test on different light sources, and it achieves a good result in all the situations. we could know that illumination model could be efficiently solved using classical numerical methods and it also produces high quality realistic rendering result. This result improves the visual perception on the volume data and shows that the model has an advantage over other ones in the global illumination area.

According to the description in the above part, we could know what we did in the global illumination and its numerical evaluation. Then back to the primary paper "**Using Global Illumination in Volume Visualization of Rheumatoid Arthritis CT Data**", this paper gives a specific application scenarios that could apply the global illumination in volume visualization. In this primary paper, the author has referred to the second paper because the later one gives a detailed and numerical evaluation. But in the primary paper, we could see how to apply this kind of technique in the area of CT Data analysis.

In this paper, the author shows how they use global illumination in volume visualizations of x-ray computed tomography(CT) wrist data for evaluating response to treatment of rheumatoid

arthritis(RA). They conduct the study with experts who are familiar with the disease process and medical-image interpretation. Then study tasks for which they believe proper illumination can enhance user performance. After carefully comparison and result analysis, it is possible to conclude that global illumination could give a good result in RA detection.

In the first part, the paper shows that global illumination has a wide potential in medical-image analysis, especially in the RA images. A study with molecular and multimodal imaging about bone resorption and formation will provide a complete information about the disease's progress and optimization of volume visualization technique for examining RA patients' wrist and finger bones could greatly affect clinical imaging. So we could use this method in our CT-Data analysis and explore the potential in this field.

Then the paper gives some detailed information about their methods and settings. First, they created an interactive volume renderer enhanced with GPU-accelerated global-illumination calculations, the calculation is based on highly parallelized, grid-based numerical schemes to solve a light propagation model including both absorption and scattering, which has a clear description in the secondary paper. Then they use multiple light sources because they could have a complex impact on the bone structures' shape, due to effect of shading. And then by changing the position, they use different setting to get more detailed surface information. Then by using different sources and position, all of those give an different view of the X-ray image perception, and it is obvious to find the best setting in all the experiments.

At last, the paper, gives another import description about the evaluation. As it contains: an informal assessment of global illumination, validation with perceptual-quality measures, consideration of light sources and a formal user study. In this part, first local and global illumination are compared in all the same setting, the participant examine the global and local illumination images and conclude that they could better identify the true erosion and their extension. In their study, local illumination yields high sensitivity but resulted in a high false-positive rate. Global illumination resulted in high specificity but might have missed small changes in morphology that might have proved important. The participants therefore unanimously agreed that it was advantageous to have both locally and globally illuminated renditions. In that way, they could better disambiguate the relationship between the features of interest and therefore improve interpretation. And a perceptual-based metric can quantify an image's perceptual quality. Images convey visual information such as shape, surface properties, and real-

ism, which can be described by features such as edges, shading gradients, shadows, highlights, and the light source, so it is quite necessary to use a metric to measure the effectiveness of the volume-rendered images. In the global illumination model, according the reference paper, they use four sub-functions to calculate the features in total, which includes detected edge prominence, luminance variance's distance, mean distance to a target men and luminance histogram's distance from an ideal equalized histogram. Calculate the sum and the smaller it is, the better it has to represent perceptual quality.

Another evaluation is the setting of the light source, they adopted three-point lighting for global illumination, and experimentally determined optimal settings for the visualization tasks. By examining the features and the effect of the image, it can give us some clues about the ability to represent the whole image. From the figures, with the 3D renditions of the data using global illumination and the ability to interactively manipulate lights and the viewpoint, the participants were more confident about differentiating image noise or truncation from real change. With local illumination, the perceived erosion was harder to distinguish from other high-frequency surface structures. With global illumination, erosive changes were more prominent than other features, drawing the participants' attention for further investigation.

At last, compare all the result with formal result and previous experiment, it could give us some numerical comparison for the representation ability. We can learn that it is clearly approachable to use the global illumination for interactive CT-Data analysis for the RA disease.

So all these two papers have a deep survey about the theoretical and application level using global illumination in real-world. I think they appeals well in the topic and selects them to read, it gives much clue about how to represent the whole image and how to use mathematical models to evaluate the target function and explore the important factors that will affect our results. I think they are both good in describing the topic and it's really a good experience to learn from them. More details and future work will be done to explore the details and application-level to better explore this topic and even form my own ideas and innovations.