Analyzation of the Efficacy of Early Ray Termination

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1 Introduction

After finishing the minimum requirements for the volume rendering project, I noticed my program was running *very* slow. To help speed my program up, I first restructured my code to go from a two-pass algorithm to a one-pass algorithm, however, the program still wasn't running fast enough for my standards. This is when I decided to implement early ray termination to increase performance. In this analysis, I will compare the run time of my volume rendering program while generating a low and high resolution image using differing termination criteria for early ray termination.

2 Method of Analysis

In order to have a proper analysis, both the low and high resolution images that my program generated needed to be the same size. Thus, they both have the same 1000 x 1000 dimensions (i.e. 1 million pixels total). The difference between the low and high resolution images are the number of samples taken per ray cast and the size of the data sets; the low resolution having 256 samples per ray with a 64 x 64 x 64 rectilinear data set, and the high resolution having 1024 samples per ray with a 512 x 512 x 512 rectilinear data set. From here, the next step was deciding what exactly should be timed in my code.

For an appropriate examination of run times, I wanted to ensure I was timing my volume rendering algorithm alone; nothing more, nothing less. Therefore, the clock starts right before the very beginning of the volume rendering process, in which I find the ray to cast, and ends immediately after the completion of the rendering, where I set the color for every pixel. This was done using the clock function from C's time library and the equation:

Total Time = (End Time - Start Time) / Clocks per Second

Note that the *Total Time* will be in seconds. After setting the clock up, the next task was to set up the independent variable for the experiment.

Evaluating the efficacy of early ray termination would be impossible without establishing some sort of termination criteria. In my program, this termination criteria is a global constant double representing the opaqueness percentage that a ray should stop compositing samples at. For the purpose of this analysis, we will explore three different termination values: 95%, 99%, and 99.9%. These different values impact the run time, as well as the accuracy of the image that the program produces.

The final aspect of this experiment was comparing the generated images utilizing early ray termination against the control images. Here, the control will be the images (low res and high res) generated by running the program without early ray termination, and the associated run times for producing said images. These images were compared via a Differencer program provided to me by Professor Hank Childs.

3 Results

Since the low resolution and high resolution images use two different sized data sets and have a different number of samples per ray, it doesn’t make sense to compare and contrast the run times of these against each other. Instead, we will split the resulting data into two parts and compare results for the low resolution image with other low-resolution-image results, and vice versa for high resolution.

After running the volume rendering program with different termination criteria and comparing the generated images against the control image via the Differencer program, the results for the low resolution image are as follows:

	Run Time (sec)	**Number of Differing Pixels from Control**
No Early Ray Termination (Control)	267.47	—
95% Opaque Termination	211.02	349,202
99% Opaque Termination	218.653	203,089
99.9% Opaque Termination	228.26	0

We see a similar pattern when generating high resolution images, just with longer run times:

	Run Time (sec)	**Number of Differing Pixels from Control**
No Early Ray Termination (Control)	2901.05	—
95% Opaque Termination	1984.08	367,113
99% Opaque Termination	2042.45	257,210
99.9% Opaque Termination	2246.41	0

In both the low and high resolution cases, the termination criteria and the run time have a positive correlation; the higher the percentage of opaqueness to terminate at, the longer the run time will be. Although, even with a high termination percentage of 99.9% the run time will still be significantly faster than if there was no early ray termination at all. Oppositely, the number of differing pixels between the images generated via early ray termination and the control images has a negative correlation; the higher the termination percentage, the lower the number of differing pixels. This leaves us to conclude that if the termination percentage used in early ray termination is high, it is both effective at speeding up our program and accurate in the resulting image it yields.

4 Discussion

Considering the positive impacts of early ray termination, and knowing it takes only one if-statement to implement, it’s almost always the case that we should utilize this method when volume rendering. However, determining what termination percentage should be the standard for early ray termination is a topic for discussion. To the naked eye, it’s not easy to tell the difference between the images generated using 95%, 99%, and 99.9% opaqueness termination. Does this signify that a 95% termination criteria should be acceptable? What if the data we’re trying to volume render happens to come from the medical field? Would the resulting image using just a 95% termination criteria be acceptable then, too? It’s difficult to give a specific answer to these questions since every use case for early ray termination is slightly different. For now, we can simply enjoy the fact that early ray termination exists and can save us painful waiting times when running our programs.