GPU Accelerated Method for Constructing and Rendering Trees

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Project Notebook

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Introduction

This notebook will serve as a reference for all activites related to the completion of my project. I will separate each entry by week, listing and describing everything I did that week and how it will help my project progress.

Week 1 Sem 1, 28th Sept - 4th Oct

This week I was introduced to the expectations for the project. I have started by scheduling a meeting with Stephen Laycock, my supervisor, and starting off my project proposal by doing some market research of similar software and reading some papers covering the subject of constructing trees using algorithms.

I have not yet decided any approach for the project due to being unsure what kind of aims I should be making, after my meeting with Stephen on the 5th I will hopefully know what route to be going down for the project.

Week 2 Sem 1, 5th Oct - 11th Oct

After my meeting with Stephen on the 5th I am more aware of what direction I will be taking the project. I will be creating an OpenGL module that can be added into a project to allow for the construction of trees in whatever environment the user has created. There are many avenues of complexity I can go down but at the moment I have decided that my focus will be to have the branch creation be as realistic as possible and hopefully include some sort of obstacle avoidance system wherever the tree grows. I have scheduled another meeting with Stephen for the same time next week on the 12th where we have agreed I should have completed the project proposal for review.

Nearing the end of the week I have completed my project proposal and sent it to Stephen for him to review and discuss in our meeting on the 12th. I have fleshed out more of my thoughts towards how I should approach the project.

Week 3 Sem 1, 12th Oct - 18th Oct

During this weeks meeting with Stephen he provided me with feedback on my project proposal and we discussed moving on to the literature review. His comments about the proposal were very useful and his advice for the literature review has helped me understand the structure that I should use

when writing it. I will be focusing on bringing together and comparing the content of multiple papers with respect to specific parts of my project such as tree branch construction or leaf placement etc.

The end of the week was used to start the introduction to my literature review where I described the project and discussed the required knowledge for completion of the project.

Week 4 Sem 1, 19th Oct - 25th Oct

This weeks meeting with Stephen was used to discuss the introduction I sent him for the literature review and how to improve it, along with how I should proceed with the rest of the document. I have a better understanding of how I will be approaching the rest of the literature review now. I have also downloaded several papers related to the project that I will use for my comparisons in the rest of the document, I hope to have it finished by my next meeting with Stephen on the 26th.

Progress on the document did not proceed as quickly as I would have hoped. After evaluating the papers I downloaded I found that a few were not strictly relevant to the project and so had to remove them, leaving me with less content to use. Other obstacles prevented much work being done on the literature review but it is not expected until the end of next week so I am still on target.

Week 5 Sem 1, 26th Oct - 1st Nov

This weeks meeting with Stephen wasn't as productive as I would've hoped due to me not making as much progress on the literature review as I wanted to. We discussed some of the upcoming sections in the review giving me a better understanding of what I should consider for content.

The second half of this week proved quite productive where I managed to write a lot of content relating to branch structure, leaf placement and wind affect with respect to various papers. This process has greatly improved my understanding of many of the key areas of knowledge that will be required in the design and implementation stage.

Week 6 Sem 1, 2nd Nov - 8th Nov

This weeks meeting was used to discuss the content I had written in the latter half of Week 5. Unfortunately the review was not finished for the end

of Week 5 but good progress has been made and I will be able to finish it in the next couple of days.

I have now completed the literature review and sent off my final draft to Stephen, the last content added was a comparison of work related to detail management with tree models, such as different approaches to LOD dropoff, and then a simple conclusion.

Week 7 Sem 1, 2nd Nov - 8th Nov

During this weeks meeting Stephen and I discussed how I should proceed into the design and planning stage of the project and that including beginning to experiment with opengl 3D programming.

I have been making progress understanding some basics with opengl 3D programming gathering together the fundamentals for creating an application such as opening a window and setting clear colour.

I will continue working to understand the general requirements for producing an opengl application during this week.

Week 8 Sem 1, 9th Nov - 15th Nov

This week I have continued with more basic progress with the opengl application being able to load in objects and apply textures. I have also continued general research on various tree related 3D rendering methods to further my understanding. I have mostly been focussing on the work of Przemysław Prusinkiewicz as his various work covers most facets of this subject.

Week 9 Sem 1, 16th Nov - 22nd Nov

This week has been slower than previous as I have started working on producing generated shapes in my opengl application. I will need some sort of struct to generate lines for my branch structure that can be loaded in from certain points.

I will continue to work on this and make as much progress as possible while beginning to write up the progress report for the project.

Week 10 Sem 1, 23rd Nov - 29th Nov

This week I have been working on getting more general facets of the opengl application working such as a basic lighting setup and gaining a more thorough view of the opengl rendering pipeline which has helped me with understanding how the application should be written.

I have made decent progress on the progress report having added the introduction and the explanation for the problems of branch structure and leaf placement.

Week 11 Sem 1, 30th Nov - 6th Dec

In this weeks meeting I received feedback from Stephen about the report and opengl program helping me understand how I should progress from here.

I will be continuing to work on the progress report more having started on the design and planning stage of the report where I will discuss the method of L-systems.

Week 12 Sem 1, 7th Dec - 13th Dec

In this weeks meeting with Stephen we discussed the design and planning section I had started about L-systems. After some discussion we decided that I should rewrite this section with more detail for the L-system description.

I have done further research into L-systems while looking to write the design and planning stage and learned more about how I could possibly approach the implementation stage. I will likely change my design from using lines as a skeleton and then applying thickness afterwards. To producing an L-system that accounts for thickness of branches by using cylinders instead of lines.

Week 1 Sem 2, 1st Feb - 7th Feb

Over the Christmas break I have been making some progress in the early stages of the implementation and testing how I should approach the tree construction problem.

My plan is to use some kind of L-system for the branch construction but at the moment I am testing the best way to represent the branches. So far I have tested the use of gluCylinders which produce a decent result with

simple input. However, I will most likely choose to make my own cylinder loading class so I have more control over the construction process.

Week 2 Sem 2, 8th Feb - 14th Feb

After discussing the choice of using gluCylinders or my own models with Stephen, we have come to the conclusion that making my own models would be more useful because I would be able to fully understand the generation process, and fix any problems that may appear while testing.

Having decided to use my own models rather than gluCylinders I spent some of this week putting together the relevant methodsm for constructing my own cylinder models such as the vertex buffer objects required. Time was spent making sure that I properly understood the underlying concepts required to produce this class.

Week 3 Sem 2, 15th Feb - 21st Feb

This week I finished up the basic cylinder construction methods but have decided to just use line construction for now. This is due to the cylinder geometry being very complicated to work with, and also because at the moment in the early stages of testing it will be easier to diagnose problems in construction when looking at simple lines.

Week 4 Sem 2, 22nd Feb - 28th Feb

To test the use of my line construction and to develop my understanding of L-systems, I have decided to reproduce some example L-systems found online. These L-systems are the binary tree and barnsley fern. The binary tree will be useful for testing rotations to make sure that I can manage the regular rotations required, and due to the binary tree being a very simple shape it will be easy to diagnose any problems. The barnsley fern will be a useful test to see if this line construction method will be appropriate for creating natural patterns.

Week 5 Sem 2, 1st Mar - 7th Mar

This week I finalised the basic binary tree and barnsley fern L-system generation which produce the expected results after some bug fixing. It seems

that the most likely issue when translating these systems to OpenGL is how to properly manage rotations to produce the expected results.

Having shared my results with Stephen I am now happy to move on to try and develop a more advanced L-system that will be able to generate 3D tree structures.

Week 6 Sem 2, 8th Mar - 14th Mar

I have decided that for the advanced L-system I will adapt a parametric L-system from an essential paper I found during the literature review stage. This paper by Przemysław Prusinkiewicz, Mark Hammel, Jim Hanan and Radomír Měch describes many essentials for advancing L-systems that will be useful in developing my understanding.

Week 7 Sem 2, 15th Mar - 21st Mar

This week I spent some more time reading through the paper by Prusinkiewicz et al. and have learned more about L-systems as well as the example that I am going to adapt. This example from the paper is also well documented with some results from chosen inputs so this will assist in the testing process of my adaptation because I will be able to benchmark my results to that of the paper.

I have started to implement the logic required for this L-system and will try and produce it the same way I did with the binary tree and barnsley fern examples.

Week 8 Sem 2, 22nd Mar - 28th Mar

This week I have still been working on adapting the advanced L-system. However, I have decided to stray from the classical approach of L-system string generation to instead use an object oriented approach. L-systems are commonly used to generate strings and then the resulting string is iterated through to perform the related task, in this case however the string is extremely complicated and would be very difficult to translate to generating the structure in OpenGL. The paper uses turtle graphics for it's representation, which removes the issues of cumulative rotations at following bifurcations due to the turtle having a "heading" that can be easily added to or subtracted from. Whereas, with OpenGL the rotations cannot be simply

additive when traversing the string due to parent branch rotations possibly not cooinciding directly with their child branches.

I have therefore decided to use an object called Apex (taken from how Prusinkiewicz et al. refer to the branch segments in the paper) to represent the branch segments with appropriate attributes that can be referenced such as rotations. Another benefit from using objects is that I can use parent child relationships between Apex objects to edity child attributes with relation to the parent Apex.

Week 9 Sem 2, 26th Apr - 2nd May

Over the Easter break I have made good progress in creating Apex objects for tree constuction. I have been using examples from the Prusinkiewicz paper for reference and decided to try and create their version of the simple binary tree first.

This proved relatively simple due to the even rotations and linear length degredation and I was able to get a result equivalent to that shown in the paper. Rotations have been the largest blocker when dealing with bugs due to visualising the problem being quite hard and issues not always being completely obvious.

For the latter half of the Easter break my focus then shifted to producing the other examples from the paper to prove that my structure generation was correct. It seems that trees only using alpha rotations work fine but once the phi rotations are introduced the structure completely breaks down. I have been discussing various approaches with Stephen and at the moment progress has been slowed significantly. Small improvements are being made throughout the program however, while trying to diagnose the rotation issue I have identified various other issues that have now been fixed.

Week 10 Sem 2, 3rd May - 9th May

This week I have continued to try and fix the phi rotation issue with various methods. As with last weeks summary there hasn't been an improvement in the phi rotations but other issues have been fixed and I have added some usability changes such as being able to choose the posistion of the tree in world space, and a better camera for viewing the trees that will be useful for demonstrating the project results.

The phi rotation issue has now been fixed after switching to a matrix rotation method the issue was revealed to be that the rotations meant to be

about the y axis were not acting as expected. Now all examples from the paper have been successfully benchmarked and some acceptable tree branch structures can be produced using the system.

With recommendation from Stephen I have decided to end development and move onto writing the project report at this time. Unfortunately I was unable to add thickness and leaves to the trees, however I have laid the groundwork for branch thickness to be implemented and I know a likely method for how I would add leaves so I will discuss this in the evaluation section of the report.

Week 11 Sem 2, 10th May - 16th May

This week I have been working on the report and am currently on schedule to finish the required content on time for wednesday the 19th.

Week 11 Sem 2, 17th May - 19th May, Deadline