**Project Plan**

DV1478 Kandidatarbete i datavetenskap

2017-04-10

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| Thesis | Tentative title | Procedural city generation viable in games |
| Classification | Theory of computation, Randomness, geometry and discrete structures, Computational geometry |
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**1 Introduction**

Exploring a huge open world environment is a desirable feature in games. But creating a big open city such as in the *Grand Theft Auto*[1] series and *Batman: Arkham City*[2] involves years of work for a lot of people. Making big open cities in games is simply not feasible for most game companies. These games all have massive success with their big open worlds making a feasible generated city an attractive technique for smaller companies to be able to compete with big open worlds of their own.

To create massive amounts of content without a big workforce algorithmically based solutions exist, *Procedural Content Generation* (PCG). PCG was in the past used to minimize the disk space required for games. *.kkrieger*[3] is an excellent example of this. It has since evolved into a method to minimize workforce required for content. *No man’s sky*[4] is an excellent example of a game using PCG to minimize workforce while maximizing content.

In this work, we want to explore the possibility of procedurally generating a city viable to use in games. When measuring the performance of procedurally generating content, impact on the following resources will be measured:

* Primary and secondary memory (RAM, disk space).
* Video memory (VRAM).
* Loading times.
* Repetition in patterns.

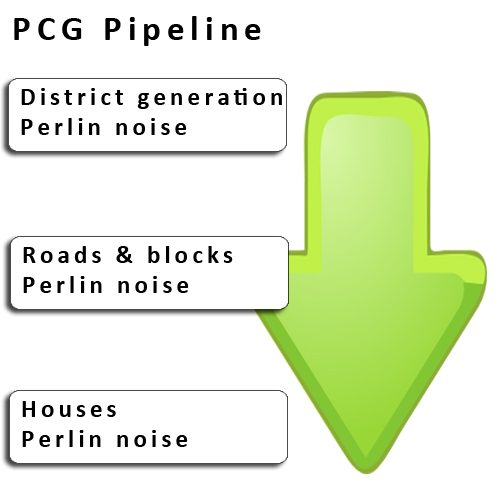
After the initial research into what PCG technique(s) to use, a budget will be specified for each resource. This budget will match system requirements for contemporary games.

## 1.1 Techniques and previous work

There are many techniques to achieve PCG such as ray marching, squarified treemaps[5], Perlin noise [12], fractals, L-systems [9][10], Shape grammar[20] and rule based subdivision[10] among others. Part of this work will be to research previous work on the subject [6][7][8][9][10][11] and evaluate what technique(s) works best for our purpose.

## 1.2 Hierarchical PCG

First we generate the districts with a PCG technique. Later the roads and blocks are generated with a PCG technique, but taking the districts and its parameters into consideration. Like this the houses are generated and using information from the roads, blocks and districts for its generation. This is what we refer to as Hierarchical PCG. The individual PCG techniques does not matter but the latter stages use data from the previous procedural content in some way.

  
*Figure 1: Hierarchical PCG through the pipeline planned to use in implementation*

**2 Aim and objectives**

* Research and explore what techniques to use when procedurally generating a city.
* Find a way to generate a city viable to use in games.
* Explore what constraints a city must have to be viable in games.
* Research what parameters and steps to use in the procedural generation of cities.
* Collect relevant data for analysis to answer the research question.

## 2.1 Qualities

The city generation should be viable to use in an online setting such as a game. This means that the user is waiting for the results of the city generation in a loading screen. For us to consider the generation viable in an online setting we have a time limit of 20 seconds loading time. The city should be playable on a mid-range gaming pc. We will measure computer resources used by the city and compare them to the limits of a specified mid-range gaming pc. Frames per second will not be measured as this is highly depending on the culling capabilities of the rendering pipeline [7][11]. Repeating patterns will be measured since the city should have variation for it to be viable in games.

**3 Research question**

* Can PCG techniques be combined in a hierarchical manner to procedurally generate a city that is viable in games according to set constraints a real-time application such as games have?

**4 Method**

The method used to answer these questions will be studying and researching of PCG techniques along with an implementation of said techniques to generate a city viable in games. This implementation will be able to generate cities according to a set of variables. The performance of the implementation will be measured with different input resulting in generation of different cities. The result of these measurements will be compared against the specified resource constraints. If a result is within limits, it is considered viable.

**Limitation:** To find a set of suitable parameters that can be used in generating a city viable in games through PCG is a big difficulty. Generating content that is viable requires computational power and the ability to judge that content to check if it is indeed viable. The generation must also satisfy all the constraints imposed by all parameters we choose to use.[13][14] This may cause a complexity out of the scope of this thesis, culling, changing or adding of parameters may be needed.

**Parameters:**

* Seed, this will be used to keep all generation deterministic, this may also be used to create a pseudo infinite number of cities with all the same parameters except the seed.
* Distance between district, this will be used as a guide for the procedural generation how close two districts may be placed.
* District spread, approximately how big will the district be.
* Density, how closely packed are the houses within the blocks in a district.
* House size, how big or small should the houses be in this district.
* House part to district connection, some house parts may only be used in certain districts.
* District amount, how many districts of this type will there be.

## 4.1 Constraints

The focus of this thesis will be on the PCG techniques and if they produce viable results for games, with this in mind we have the following constraints.

* Do not create our own models for any property in the implementation.
* Do not implement optimizing techniques for the rendering pipeline.
* Limit content generation to the city (i.e. no terrain generation etc.).
* Do not implement property generation (i.e. no cars or street signs etc.)

## 4.2 Early implementation plan

To generate a city viable to use in games, three different generation stages have been recognized. The city will contain houses that will be arranged in blocks connected with roads.

### 4.2.1 District generation

For more variety and logical placement of the houses in the city districts will be generated. A city may have several district areas covering the whole city. Districts may have different kinds of houses in them. For example, there may not be big skyscrapers in a poor district. Every district will be generated through a seed position and will grow outwards from that position conforming with the districts spread variable. Several districts may overlap; these positions will have weighted values of the different districts overlapping.

### 4.2.2 Block generation

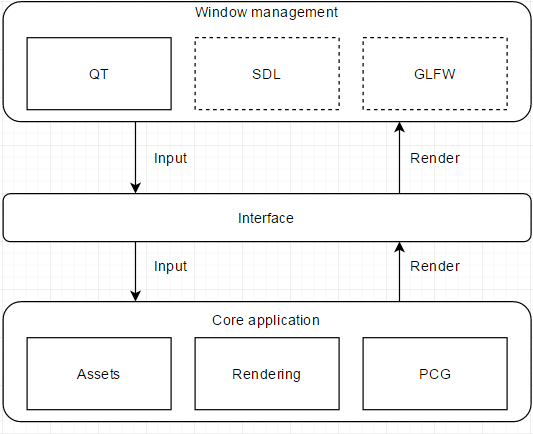
Blocks and roads needs to cover the entire city. The roads need to connect the whole city and the blocks may not have anomalies such as the block is in no way connected to any road. The blocks may have some constraints in their form and size.

### 4.2.3 House generation

The houses will be generated to avoid repeating houses all over the city. This generation system will add different house-parts together creating a seemingly new house. This system will decrease the repeatability of the city creating a more organic city that hopefully is viable in games.

### 4.2.4 Rendering pipeline and libraries

OpenGL will be used to render the city and GLM [16] for 3D math. QT [15] will be used for the user interface. The user interface is connected to the core PCG and rendering application through an interface. The user interface will modify all the previous mentioned parameters and control what the core application is generating.

  
*Figure 2: Rendering pipeline and input from user interface*

Through the interface any kind of window management and user interface could be used, we use QT but it is possible to create a user interface with GLFW and SDL too as can be seen in *Figure 2*.

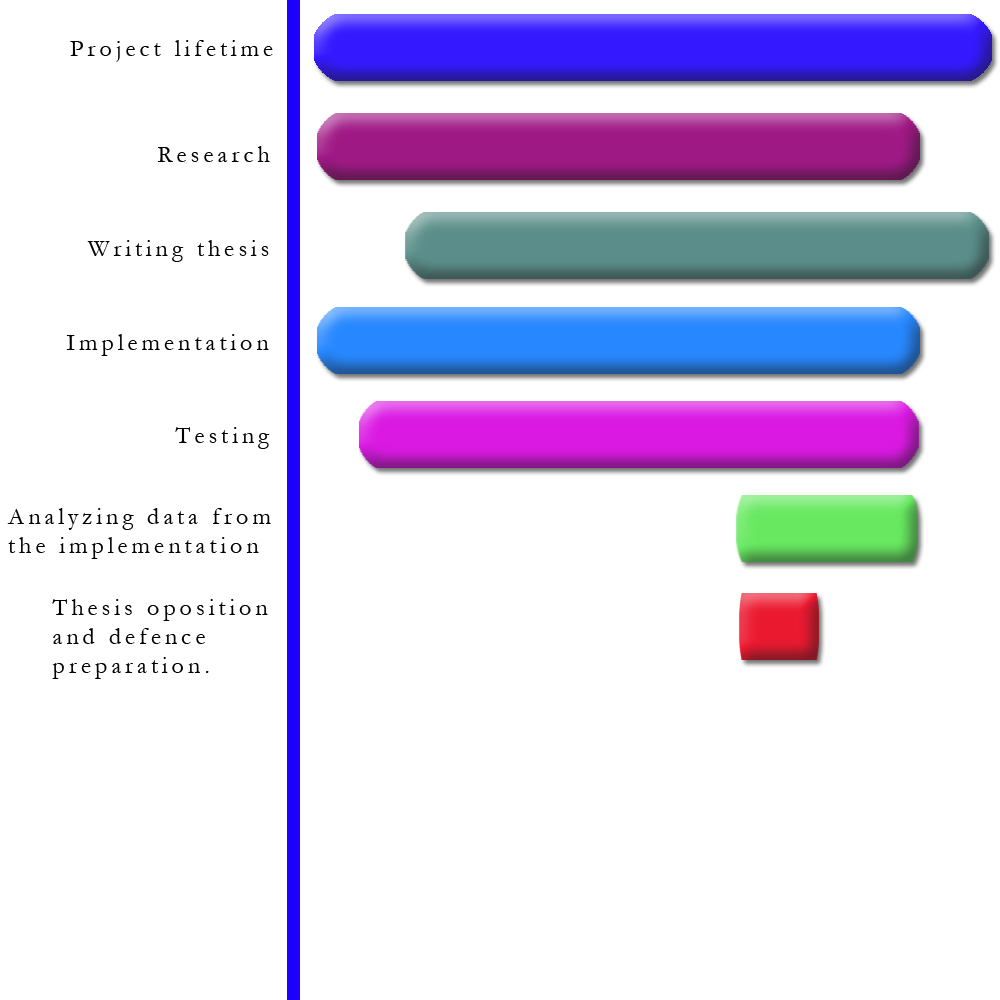
### 4.2.5 Complexity

Many city generators are using L-systems to generate the roads in their urban environment and with the road generation city blocks emerge automatically [9][10][14][17][18][19]. For house generation it is common to use shape grammars with CGA [9][10][14][19][20]. We have identified both methods as too complicated and often used for realism, our city generator does not have the requirement to generate realistic content. These two techniques will consequently not be used. By discarding unnecessarily complex techniques we think the implementation will be feasible for this thesis.

**5: Expected outcomes**

From the implementation, we will gather data to analyze and answer the research question. The implementation will show that it is feasible to use PCG as a method to create a model of a city viable to use in games. Future work will be to find ways to have more control over the generation with parameters or other means.

**6: Time and activity plan**

  
*Figure 3: Visual representation of activity plan*

The implementation and research will be the first things to be done and they will be done simultaneously. Some parts of the implementation require research before we have the knowledge to implement it, but all the parts of the implementation, such as the rendering pipeline, that do not require any research, will be done in conjunction with the research.

The writing of the thesis will begin shortly after we have some basic research and base implementation done. The thesis will be worked on every week until completion. When the implementation has enough features, data gathering and analysis of this data will begin. This data is crucial to answer the research question and conclude the thesis.

* Project lifetime 2017-03-27 – 2017-06-11
* Research 2017-03-27 – 2017-06-01
* Writing thesis 2017-04-17 – 2017-06-11
* Implementation 2017-03-27 – 2017-06-01
* Testing 2017-04-10 – 2017-06-01
* Analyzing data 2017-05-22 – 2017-06-01
* Thesis opposition and defense 2017-05-22 – 2017-05-28
* **7: Risk management**

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| **Risk** | **Probability (1-5)** | **Severity (1-5)** | **Mitigation** |
| Procedurally generating a city is difficult and consumes too much time. | 3 | 5 | Only implement the most crucial features to answer the research question. |
| Failing to communicate with thesis partner. | 2 | 4 | Have daily meetings and work together when possible. |
| Technical issues | 2 | 5 | Make sure all work is on several hard drives. Use git as source control. |
| Collect data from the implementation wrong, twisting the results. | 3 | 4 | Carefully decide what parameters in the implementation to collect data from and in what form to collect this data. |
| Defective construction of the implementation. | 2 | 4 | Before coding the implementation make sure there is a good plan to follow. |

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