Designer Worlds: Analysing various noise algorithms in realistic terrain generation

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Abstract

Generating realistic terrain is a crucial aspect of creating immersive and believable environments in game development and simulations. This task, however, poses significant challenges due to the complexity and variability of natural landscapes. Procedural generation techniques, particularly those involving noise algorithms, offer a promising solution by enabling the creation of diverse and intricate terrains. This research aims to evaluate the impact of different noise algorithms on the realism of procedurally generated terrains, leveraging human evaluation and statistical analysis to determine which algorithms produce the most convincing results. By systematically analyzing the effectiveness of various noise algorithms, this study seeks to enhance the tools available to game developers, enabling them to create more authentic and visually appealing virtual worlds.

1 Introduction

1.1 Goal

This research aims to explore the effectiveness of various noise algorithms in generating realistic terrains for game development and simulations. By leveraging human evaluation and statistical analysis, we seek to determine which noise algorithms produce the most convincing results. This study will benefit game developers and simulation designers by enhancing their ability to create immersive virtual environments.

1.2 Previous Work

The standard approach to procedurally generating random terrain, as detailed in Parberry's 2014 work [1], involves using a fast noise generator such as Perlin noise. This method, while efficient, often produces terrain that is uniform and lacks interesting features, necessitating significant post-processing. Parberry's research emphasizes the application of Perlin noise to generate terrain and the importance of tuning the post-processing to achieve specific types of terrain, a process that requires a good grasp of mathematics. In contrast to Parberry's focus on Perlin noise, our research aims to explore the effectiveness of various noise algorithms, including Perlin, Simplex, Voronoi, and White noise, for terrain generation. By expanding the scope beyond just Perlin noise, we aim to identify which noise types can generate the most realistic and visually appealing terrains when applied to original geographic data.

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2 Methodology

2.1 Data Collection

We obtained a Digital Elevation Model (DEM) file of Christmas Island. This file served as the basis for applying different noise algorithms to generate varied terrains.

2.2 Processing the Data

The processing was done using a Python script that applies various noise algorithms to the DEM data. The following is an outline of the script's functionality:

The Python script processes a Digital Elevation Model (DEM) file of Christmas Island by applying various noise algorithms to generate modified terrain data. Initially, it reads the DEM data and its metadata, handling "No Data" values by setting them to the lowest elevation found in the dataset. The script then calculates the pixel coordinates for the DEM, which are used as input for generating noise. The noise algorithms applied include Perlin, Simplex, Voronoi, and White noise. For Perlin and Simplex noise, the script uses functions from the noise library, while White noise is generated using a normal distribution. Voronoi noise is generated by creating random points and building a KD-Tree for efficient nearest neighbor queries, processing the image in tiles to save memory. The script then applies the noise to the DEM data, either additively or multiplicatively, and saves the noisy data as new GeoTIFF files.

In addition to generating and applying noise, the script collects statistical information for each noise type, such as time taken, frequency, scale, and statistical properties (min, max, mean, and standard deviation). The results are then visualized through plotting functions, which create bar charts and box plots to display the time taken, frequency, scale, and statistical properties of the noise data. These visualizations help in comparing the different noise algorithms and understanding their impact on the terrain generation process. The final output includes the modified DEM files and the visual representations of the statistical analysis, providing a comprehensive overview of the noise effects on the terrain.

2.3 Rendering and Evaluation

After running the Python script, we obtained TIFF files of the DEM data with added noise. These files were rendered in Terragen 4 to obtain visual images of the terrains. The rendered images were compared to the original, and statistical analyses of the noise generation were conducted.

2.4 Evaluation

Human evaluators visually inspected the generated terrains to assess their realism. Statistical analysis of the noise data included measurements of time taken, frequency, scale, minimum, maximum, mean, and standard deviation values for each noise type.

3 Experiment and Results

3.1 How Success Was Measured

Success was measured by evaluating the realism of the generated terrains using human evaluation and statistical analysis. We analyzed the statistical properties of the noise algorithms and their visual impact on the terrain.

3.2 Experiments Conducted

The experiments involved applying Perlin, Simplex, Voronoi, and White noise to geographic data, generating terrains, and comparing the results. We measured the time taken for each noise generation, collected statistical data, and visually inspected the terrain images.

3.3 Results Indication

The results indicate that while White noise is the least time-consuming to generate, Voronoi noise, despite being the most time-consuming, produces the best and most consistent results in terms of realism. This suggests that Voronoi noise may be more suitable for applications requiring high-quality terrain generation.

3.4 Image Results

The results for different noise types are displayed below.

Figure 1: Original GeoTIFF

Figure 2: Perlin Noise

Figure 3: Simplex Noise

Figure 4: Voronoi Noise

Figure 5: White Noise

Figure 6: Image Results of Different Noise Types

3.5 Statistics Results

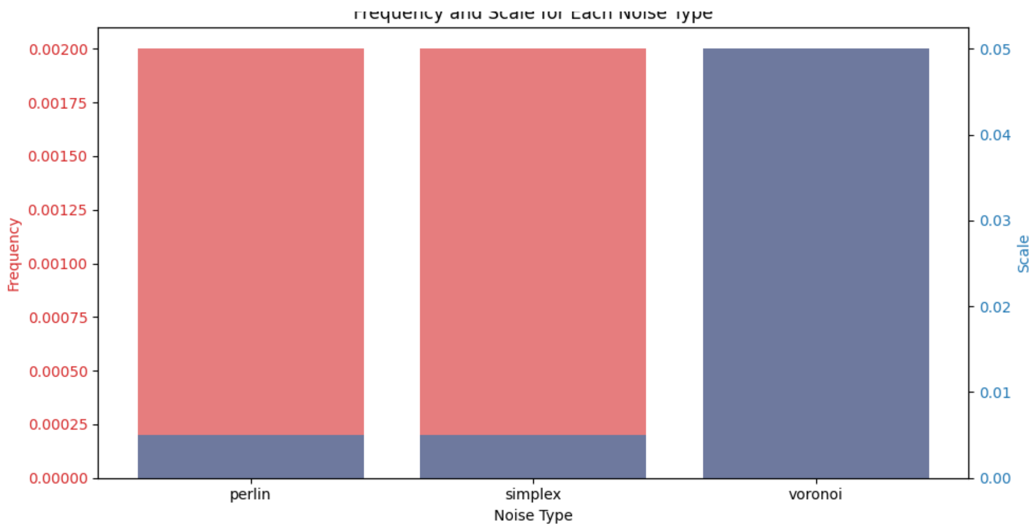
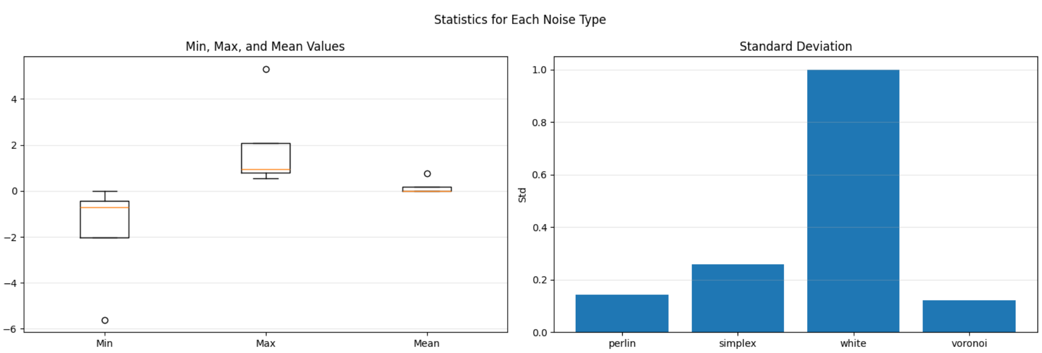


Figure 7: Frequency and Scale for Each Noise Type

Analysis: The frequency for both Perlin and Simplex noise is 0.002, while Voronoi noise does not have a directly comparable frequency value displayed. The scale for Perlin and Simplex noise is set to 0.005, whereas Voronoi noise has a significantly higher scale at 0.05. This higher scale suggests that Voronoi noise introduces more significant variations in the terrain compared to Perlin and Simplex noise. The low frequency of Perlin and Simplex noise means the noise pattern will be broad and less detailed, indicating that increasing the frequency can introduce more intricate patterns.



(a) Min, Max, and Mean Values and Standard Deviation

Analysis: The box plot shows that Perlin and Simplex noise have a similar range of values with some outliers indicating extreme values. The maximum values for Perlin, Simplex, and Voronoi noise are relatively close. The mean values for Perlin and Simplex noise are close to zero, indicating a balanced distribution of positive and negative variations. Voronoi noise shows less variation in the mean values, suggesting a more consistent pattern. White noise has the highest standard deviation, indicating the most significant variation in values. Perlin and Simplex noise have lower standard deviations, producing smoother variations. Voronoi noise strikes a balance, providing structured variations with moderate deviation.

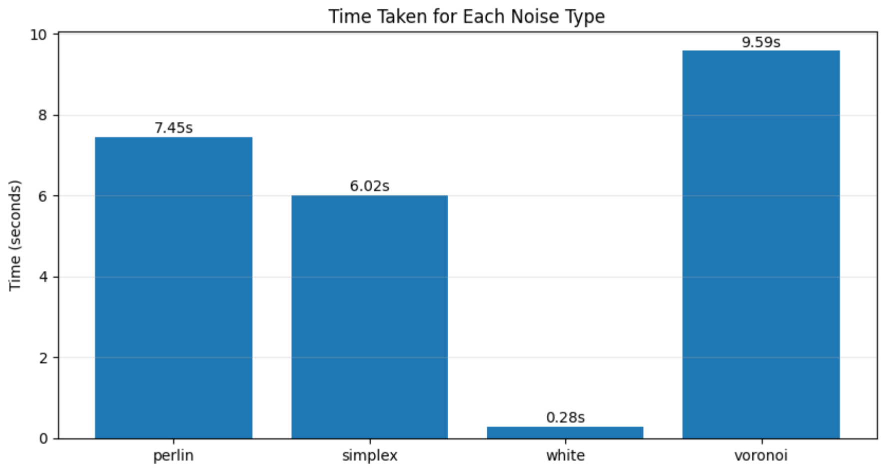
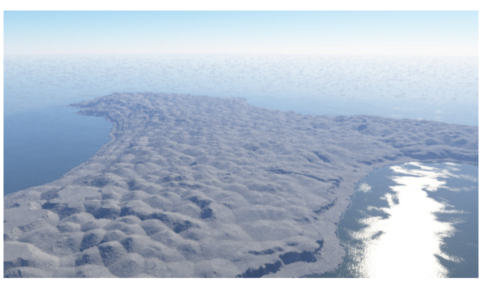


Figure 9: Time Taken for Each Noise Type

Analysis: The time taken to generate Perlin noise is approximately 7.45 seconds, while Simplex noise takes about 6.02 seconds. White noise is the fastest to generate at 0.28 seconds. Voronoi noise is the slowest, taking 9.59 seconds. This indicates that while White noise is quick to generate due to its simplicity, Voronoi noise is the most time-consuming, likely due to the computational complexity involved in calculating distances and building KD-trees. Perlin and Simplex noise have comparable generation times, with Perlin being slightly slower.

4 Discussion and Conclusion

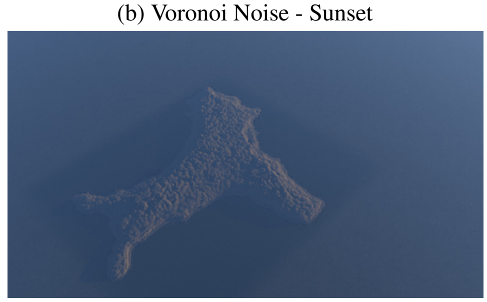
The results indicate that while White noise is the least time-consuming to generate, Voronoi noise, despite being the most time-consuming, produces the best and most consistent results in terms of realism. This suggests that Voronoi noise may be more suitable for applications requiring high-quality terrain generation.



(a) Voronoi Noise - Afternoon

(b) Voronoi Noise - Sunset

(c) Voronoi Noise - Morning



(d) Voronoi Noise - Island Top View

Figure 10: Image Results of Voronoi Noise at Different Angles and Lighting

5 Future Work

Future work could explore the development of an AI classifier to better evaluate the realism of procedurally generated terrains. Additionally, experimenting with varying or smoothing noise parameters could potentially yield even more realistic results.

References

[1] Ian Parberry. Designer worlds: Procedural generation of infinite terrain from real-world elevation data. *Journal of Computer Graphics Techniques (JCGT)*, 3(1):74–85, 2014.