INTRODUCTION
Choosing the right terrain generation tool for a game can be a difficult but important decision. The environment affects not only the aesthetics, but also the mechanics. For example, the designs and types of vehicles varies based on the type of ground they need to traverse. If a game is intended to utilise discovery as a type of fun (Hunicke et al. 2004), terrain diversity is desired as discovery requires unpredictability. Diversity is particularly important if the game features near-infinitely sized maps that expand upon exploration; the experience of discovery only lasts while terrain that appears new presents itself to the player. Existing evaluation algorithms tend to be designer driven (Smelik et al. 2011) or employ genetic algorithms to generate a single terrain feature (Frade et al. 2008). In this paper we present the diversity scale, an evaluation algorithm that objectively compares the diversity of terrains at varying scales.

THE ALGORITHM
The diversity scale algorithm (see below) requires a predefined set of quantifiable terrain features (e.g. temperature, material compositions, relief smoothness, vegetation, buildings and roads, precipitation). It returns a value $[0, 1]$ that represents the diversity of terrain feature combinations at a particular scale. This is measured by taking the average value of features in given areas and then computing the Shannon entropy (Shannon 2001) over these averages. Note that if multiple terrains are compared, only features occurring on all terrains should be measured.

```
var scales = array
for each feature F do
  var values = array
  for each area A of size Q in terrain T do
    compute the average value of F in A
    insert the average W in values
  var diversityScale = 0
  for each value W in values, step precision P do
    diversityScale += $\log(\sum W in values closest to I) / \log(length(values) / P)$
  insert diversityScale in scales
return the normalised sum of all values in scales
```
We start by taking the average of each feature value for each area in order to account for locality bias. The average feature value of each area is uniform across multiple areas, given that features are uniformly random occurring across the terrain. We then compute the Shannon entropy over all these area averages, which gives us an indication of the diversity of the feature distribution. Higher entropy indicates a more diverse terrain. Finally, the sum of the entropies is weighed per feature, where weights should be adjusted according to the relative importance of features in the game.

RESULTS

The figure above shows the diversity scale plotted for different area sizes \((Q)\) of four distinct generated terrains, where the average height of an area is the only feature measured. The four maps consist of 2000x2000 height points ranging \([0, 1]\) coloured by the shader (below 0.5 blue, green below 0.85, above 0.85 grey and over 0.95 white). The slight drops around \(Q = 500\) and \(Q = 1000\) occur because the algorithm jumps from measuring 5x5 areas to 4x4 areas, and 3x3 to 2x2, respectively. Note that the results become more accurate for larger terrains.

CONCLUSION

The diversity scale can be used by game developers to select a terrain generator based on feature diversity. It can also be used to make an informed decision on the size of a terrain, by choosing a lower bound for the diversity scale that still leads to acceptably diverse terrains.

BIBLIOGRAPHY


