Summary: The Synthesis and Rendering of Eroded Fractal Terrains

Bruce Alcock

Supervisors: Kevin Glass and Shaun Bangay

The paper poses a method of creating intial heightfields for terrain representation using a sampled form of Perlin Noise: Fractional Brownian Motion, and then 2 forms of erosion: hydraulic and thermal to weather the terrain and make it look more realistic, as well as a ray tracer for heightfields.

A method is presented using Fractional Brownian Motion (fBm) to create an initial heightfield for the terrain. The fBm is generated by sampling Perlin Noise at multiple frequencies and applying translation and scaling onto the values. Because the basis (Perlin) function is seeded, the entire fBm generation process is entirely reproducible. The base frequency is calculated by $a_0 = (N(p_0) + c_t)\, c_s + c_0$ and then successive frequencies are calculated by $a_i = a_{i-1} + a_{i-1}(N(p_i) + c_t)\, c_s w^i$, where a is the heightfield point, N is the noise generating function, p is the initial grid point, c_t is a constant translation transformation, c_s is a constant scaling transformation and w^i is a frequency increment constant. The reason that this is not sufficient for terrain is that they do not include mountains and rivers as such, because an upside-down version of an fBm would still look like the same kind of terrain.

To give the raw heightfield a more natural looking appearance with proper mountains and riverbeds, two additional methods are suggested for physically eroding the terrain:

The first method of hydraulic erosion involves dripping water onto the heightfield and distributing the water and sediment accumulated to neighbouring vertices. The erosive power at the current position is calculated based on the volume of water at that point as well as the sediment already in the water. This works by assigning each vertex v at time t an altitude a_t^v, a volume of water w_t^v and an amount of sediment s_t^v. Iterating through time each vertex v passes excess water and sediment to each neighbouring vertex u where the amount of water passed is defined as $\triangle w = min\left(w_t^v, (w_t^v + a_t^v) - (w_t^u + a_t^u)\right)$. If $\triangle w \leq 0$ then $a_{t+1}^v = a_t^v + K_d s_t^v$ and $s_{t+1}^v = (1 - K_d)\, s_t^v$, else $w_{t+1}^v = w_t^v - \triangle w$ and $w_{t+1}^u = w_t^u - \triangle w$ and the sediment capacity $c_s = K_c \triangle w$. Then sediment movement is calculated: if $s_t^v \geq c_s$ then $s_{t+1}^u = s_t^u + c_s$ and $a_{t+1}^v = a_t^v + K_d(s_t^v - c_s)$ and $s_{t+1}^v = (1 - K_d)(s_t^v - c_s)$, else $s_{t+1}^u = s_t^u + s_t^v + K_s(c_s - s_t^v)$ and $a_{t+1}^v = a_t^v - K_s(c_s - s_t^v)$ and $s_{t+1}^v = 0$. K_c is the sediment capacity which specifies the max sediment that may be suspended in a unit of water, K_d is the deposition constant which specifies the rate at which sediment settles out of a unit of water and is added to a vertex, and K_s is the soil softness constant, which specifies the softness of the soil and is used to control the rate at which soil is converted to sediment. What this does is to erode the terrain to an approximation of what happens in reality when rain falls on ground and redistributes soil: it gives it a more natural appearance due to the emergence of more realistic looking river beds and mountains.

The second method of thermal erosion encompasses any natural process that knocks material off ridges and deposits them at the feet of the mountain. If the slope of a vertex exceeds a talus angle T, material is simply distributed to the neighbours, which softens ridges and valleys alike. So if the difference in slope exceeds the talus angle: $a_t^v - a_t^u > T$ then $a_{t+1}^u = a_t^u + c_t \left(a_t^v - a_t^u - T\right)$ where c_t is a constant percentage of the difference to move.

Another method for ray-tracing heightfields is presented, but is of no relevance to the current project.

In summation the techniques described here are a good start for terrain approximation, but as mentioned fBm heighfields are insufficient for terrain. The erosion is a good step to try to fix the problems of fBm heightfields, but it does take a long time to process, taking a good minute for 200 steps on a 100x100 terrain on current lab machines. Heightfields are also insufficient on their own for terrain because they make caves and overhangs impossible. It would be nice if there were a method to combine the generation of fBm height, hydraulic and thermal erosion all into one step so as to do one pass for the terrain, a time-based approach is good in that it simulates real natural processes, but takes too long to be viable.