ABSTRACT: Terrains are of great interest in flight simulators, geographic information systems and computer games. In computer graphics, terrain rendering is a special case because of their bulk. They cannot be handled as a single entity like other object models like teapots, cars and crates. Triangulated irregular networks of terrains are typically created by simplifying a dense representation. Such representations are popular in GIS and computational geometry. The recent trend in graphics is to use regular grid representations since they go well with today's graphics hardware. We explore different representation techniques to render terrains in this thesis. We look into real-time rendering, editing, and physical interaction with external objects on terrains. We also present a representation for efficient rendering of spherical terrains. Apart from rendering terrains realistically, we develop a method to render terrains artistically with painterly abstraction as well.

We create a system that exploits the power and flexibility of the modern GPUs to store, render, and manipulate terrains with minimal CPU involvement. The central idea is to use a regular-grid representation, hierarchically divided in fixed size blocks/tiles that change in resolution.

The potentially visible portion of the terrain is cached at the highest necessary resolution and is rendered from the GPU. The cache is updated with the viewerpoint. Lower resolutions used for farther areas of the terrain can be constructed from the cache on the GPU. Todays GPUs have a limited capability to generate geometry within itself. Thus, the CPU can send a light geometry template which is expanded to the triangles by GPU. The CPU performs a coarse culling of the tiles with the GPU performing fine culling. Our system enables the terrain to be modified procedurally or edited interactively on the GPU with no CPU involvement. The terrain can also interact with a large number of external objects in real-time with all the physics calculations done on the GPU.

Terrains can also be mapped over a sphere for a planetary structure. However, terrains on sphere require a different representation due to the pole singularity of latitude-longitude representation. A 2D grid of height cannot be mapped directly on a sphere with uniform triangle count. Spheres can be rendered uniformly using Hierarchical Triangular Mesh (HTM) but the representation does not fit with 2D grid of heightmaps. We present a unified representation of HTM and clipmapping (flat terrain rendering technique) to render spherical terrains. Our representation works at any distance from the planet/sphere without any scripted work arounds.

The regular nature of terrain data also enables us to render the samples in a required order with no overhead of sorting. This introduces the possibility of applications which require sorted rendered triangles. We explore non photo realisitic rendering of terrains. Artistic painterly appearance and the impression of terrains is created by effectively rendering several translucent brush strokes in a back to front order. The strokes are located in 3D space for frame-to-frame coherence during animation. The strokes are oriented along the slope of terrain analogous to the way artists paint on canvas. We use shaders to render strokes in real-time. A level of detail scheme is used to maintain a uniform stroke density in screen space. Various styles can be achieved with different stroke variations. We achieve real-time painterly rendering with a combination of object space positioning and image space rendering of strokes