Flexible Terrain Representation using Runtime Surface Reconstruction

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ABSTRACT

Terrain has a great potential as a reference for visual navigation, which can be utilized to access and manage information. From this standpoint the geometry of the terrain is a unique defining surface for all geographic applications as well as for any geo-related information. However, a data representation of terrain in three-dimensions provides numerous challenges for visualization as well as for analytical purposes. Solutions that satisfy visualization criterions often appear to be less optimal for maintenance or scalability required by analytical applications and vice versa. This work proposes a geometric data representation of the terrain that respects both visualization and analytical applications. The solution can be used for an entire planet, which allows avoiding needs for performing conversions between cartographic projections and transformations between geodetic datums. The data representation provides good local geometric flexibility like TIN but also supports multiple levels of detail. Amounts of data can grow large gradually---it is possible to alter local areas only while leaving distant parts of the terrain unchanged, which is convenient for maintenance. Introduced approach is based on runtime construction of triangulated irregular network using Delaunay triangulation. The mass points used for the surface reconstruction are structured in order to support multiple levels-of-detail. The proposed representation allows managing terrain data in numerous detached repositories, which can be used for distributed solution.

Keywords
Terrain representation, Runtime surface reconstruction, Delaunay triangulation, Global terrain, TIN, LOD.

1. INTRODUCTION

Visualization of terrain datasets with LOD capabilities is an active area of research. Two main kinds of approaches can be identified within these works. The first are based on construction of bin-tree of similar triangles that represent the surface. The second kind of approaches is based on irregular triangulated networks (TIN).

Since all these works assume terrain data as an offset from plane, global solution addresses additional problem. Existing solutions utilize projections of the sphere (or its part) onto a plane. Methods with projection onto one [Aas02] four [Cig03] and six [Pen04] planes have been introduced in order to provide global terrain solutions.

2. METHOD

Spatial Division Scheme

For purpose of indexing terrain globally a global grid system called geoindex has been developed [Kol04]. This approach takes advantage of the height field property of the terrain, meaning the terrain is a displacement from a simpler mathematically defined surface, such as the sphere. Geoindex tessellates the sphere into a set of cells of similar size forming a

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Voronoi diagram on the sphere [Luk87]. Using tessellations with different number of cells around the sphere, geoindex can provide multiple levels of tessellation. Advantages of geoindex with respect to indexing of global terrain data are avoidance of projections onto a plane and use of a single uniform division scheme. In contrast spatial indices based on plane cannot avoid projections and usually employ a set of projected planes.

LOD Construction

A decimation technique similar to greedy insertion algorithm introduced by [Gar95] has been used for construction of discrete LOD. This approach involves an iterative process of inserting DTM points of the highest importance to a triangulation that provides an approximation of the surface. The importance of DTM point is defined as a vertical offset of the point from the decimated version of the surface at particular iteration (i.e. the importance changes over iterations). On each pass one or more DTM points are inserted to the triangulation. Insertions of DTM points are irrevocable; meaning that the resulting list of mass points is sorted according to their importance to the original DTM. This property of the result facilitates the construction of LOD.

Terrain Data Structure

Mass points are kept in a simple data structure. There is one record per mass point, which can be modeled as a six-tuple *(l, gl, gc, x, y, z)*; where *l* denotes LOD, *gl* is the geoindex level (density) used for tessellation of the sphere, *gc* stands for the code of the tessellation unit [Kol04] at the corresponding level *gl* and *x, y, z* are the Cartesian coordinates of the mass point. Data are structured according to the spatial tessellation associated with particular LOD, i.e., according to *l* and *g* properties of the six-tuple.

An extent of a spatial unit in which LOD is stored also reflects the range that is feasible for the particular LOD. This means that data from different LOD are stored in spatial units of different size, e.g., mass points that constitute lower LOD are in larger tiles than tiles used for more detailed LOD. This is a valid reasoning mainly for visualization applications in which near geometries are required to be in higher detail while still be visualized in a coarser but broader context of the surrounding terrain.

This data structure allows reuse of mass points meaning that the data from all coarser LOD are required in order to obtain complete geometry at given location.

Runtime Surface Reconstruction

At any point when navigating through the scene, the appropriate LOD is used for visualization of the terrain geometry. An effective approach to achieve this behavior is to use pieces of the scene in different LOD and combine them into a seamless surface. This is a traditional major problem for terrain geometry because there is no topological correlation between the data from different LOD. Using proposed data structure in combination with runtime surface reconstruction, however, avoids this "stitching" problem, because there is no topology stored for mass points.

Delaunay triangulation has been proven to be the optimal triangulation in 2D, fast enough to reconstruct surface from several thousands of points at runtime. However, because the global terrain solution is represented as an offset from the sphere, the plane against which the triangulation is performed changes with the viewpoint. As a solution a tangent plane at the centre of the nearest tessellation unit from the coarsest LOD is used.

3. ACKNOWLEGMENTS

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