Combining Level-of-Details on Terrain Meshes and Texture Images for Landscape Visualization

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Abstract: Terrain representation is one of the most common tasks in visualization of geoinformation. In order to realistically visualize the real landscape, several issues have to be addressed, in particular, how to combine terrain meshes and texture images. In this paper, Level of Detail (LoD) is used to treat both terrain meshes and texture images for producing realistic visualization with better performance but without too much information lost. Several layers of terrain grids and texture images with different levels of details created from original high resolution digital elevation model and satellite image using quad-tree and image pyramid algorithms, respectively, and to be used as base data. Then, new terrain meshes consisting of different LoD patches are generated dynamically according to the viewing position and viewing distance. Similarly, corresponding texture images with regions of different resolutions are also created instantaneously according to viewing condition changes.
Keywords: level of detail, terrain mesh, landscape visualization

1 Introduction

Landscape representation is an essential task in geovisualization and its applications. For instance, air force and airliners commonly use fly simulation systems that generate various terrain conditions to train pilots. A national park may use a similar system to suggest hiking routes to visitors. For these applications to work and reflect real landscapes, terrain meshes and texture images must be constructed effectively in the visualization system. In order to visualize landscapes realistically and efficiently, several problems have to be addressed, such as how to integrate terrain meshes and texture images. These two data have different characters. In addition, terrain meshes and texture images may have different resolutions. The data format of terrain meshes is usually vector, but texture images are raster data. Therefore, a geovisualization system must be capable of dealing with these issues.

Level of Detail (LoD) technique may be an ideal solution to the problems mentioned above. The concept of LoD is to duplicate data in several levels of resolution (detail) and use appropriate level based on various viewing conditions or requirements. The main reason is to make the computation more efficiently. Traditionally, when visualizing a landscape, the entire landscape terrain and texture image data would be loaded into the system regardless the distance and viewing geometry. With LoD, one can supply the most appropriate layer of data to avoid the waste of rendering high resolution terrain meshes and images which are located in the far distance.

In this paper, LoD is used on both terrain meshes and texture images. On terrain meshes, quad-tree algorithm is used to divide digital terrain model (DTM) into different layers of detail. On the texture images, the concept of image pyramid is used to generate images of multiple details. Which level of image to load for presentation is determined from viewing parameters dynamically. When the viewer is far away from the object, the detail of land cover is not necessary, so high resolution texture will waste a lot of computer resources to calculate unnecessary information and degrade the rendering and display efficiency. When the viewer is close to the object, the detail is important, or the frame will be blurred. Consequently, the distance between viewer and object is the most critical point to determine which level of detail should be used.

In some visualization systems, shadings of terrain are commonly represented with auto-color or auto-grayscale. This approach does not produce accurate landscape impressions (look-and-feel) thus limits the reality of the visualization result. In this study, high resolution satellite image is used to map onto the terrain to create more realistic landscape texture.

2 Level of Detail for Terrain and Texture

A few researchers have developed several LoD techniques for visual representation two-dimensional or three-dimensional objects. For example, Chen et al. (1999) developed a LoD-Sprite algorithm to accelerate the efficiency of landscape visualization processing. They used multi-resolution meshes and multi-resolution texture images to construct a terrain. In their approach, the high level texture image is used to build the “key frame”, that is the first frame and also the best frame of an animation sequence. The low level image is used to fill in the gaps when the viewer moves.

Duchaineau et al. [1997] developed a triangular quad-tree algorithm to build the terrain meshes with different resolutions. The original data was set as level 0, the course level, and then each triangle was divided into two equal parts as the next level. Gross et al. (1996) also used initial grid elevation data to construct a multi-resolution terrain using quad-tree algorithm. If the difference between pixels is bigger than a threshold, the mesh separated to four equal parts to construct the next level.

All of these techniques are aimed to provide a mechanism for generating multiple levels of detail from original data. This study also adopts the concept to construct LoDs of terrain meshes.

On the other hand, because the texture image is in raster format, quad-tree or mesh subdivision may not suitable for image LoD process. Instead, image pyramid scheme will be used to provide multiple resolutions of landscape texture.

3 Methods and Material

The test area of this study is located at Daken, Taichung, Taiwan. A digital terrain model (DTM) in grid format generate from original Lidar point-cloud data is used as the base terrain data (Fig. 1). A QuickBird high resolution satellite image (Fig. 2) covering the study site is used as the source of landscape texture.

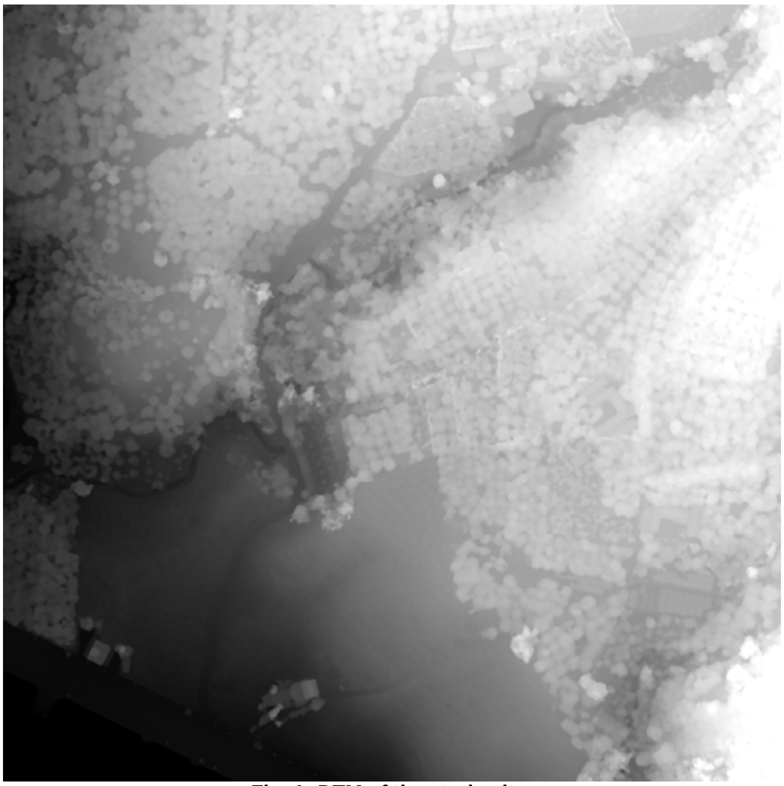

Fig. 1: DTM of the study site.

Fig. 2: Original (QuickBird) texture image.

Six layers of terrain meshes with six levels of resolution are created from the base terrain data using quad-tree algorithm. If the elevation difference between two pixels is bigger than a threshold, the mesh is separated to the next level. When all the elevation differences in the same segment are smaller than the threshold, the separation stopped, and a new level of terrain mesh is completed. To construct a landscape visualization scene, the terrain mesh is partitioned into sixty four (eight by eight) equal-area rectangular patches, and uses the distance between viewing point to the center of an individual patch to determine which level should be assigned in that region. This will generate a complex terrain mesh with each patch has its own level of detail according viewing geometry.

The texture images are arranged in five levels to build up the image pyramid. Each image is also classified into several land use types to be used for integrating with multi-LoD terrain. Similar to the dynamic generation of terrain mesh, a composite texture image is created. The image also consists of 64 patches with each patch's resolution determined by the same criteria when constructing the terrain mesh. Then, the composite texture is mapped on the terrain mesh and send to the visualization system for rendering. When the viewer moves, if the viewing position change is within a threshold, the terrain mesh and texture image does not need to be modified, since the constructed scene will not differ from previous view too much. Only if the cumulative viewing geometry change is substantial, a new multi-resolution terrain mesh and composite texture image will be generated dynamically.

4. Results

Fig. 3 shows the generated multi-resolution terrain mesh when the viewer is located at the upper left corner (50, 50). As can be seen in the figure, the terrain mesh in the upper left part is more dense (high resolution, greater level of detail) than other regions. Similarly, the texture image (Fig. 4) of the same viewing position also comprise of multi-resolution patches and with the highest resolution around the viewing position.

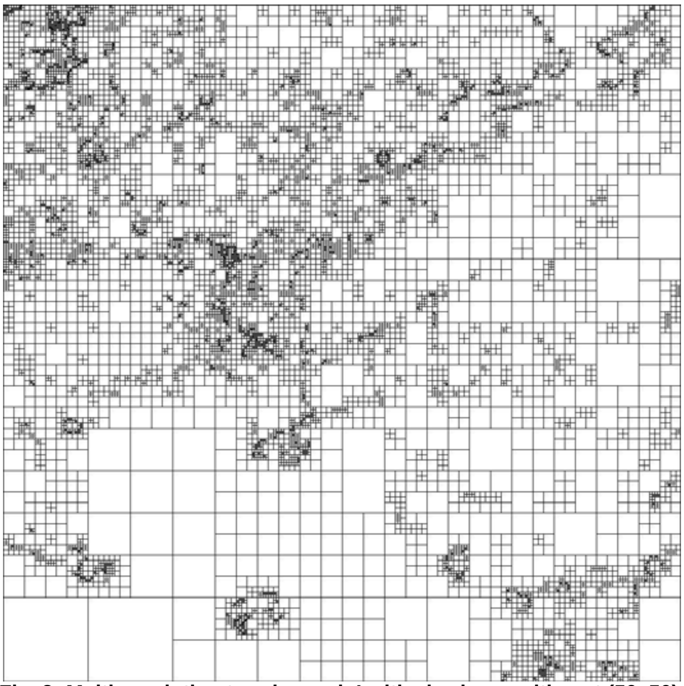

Fig. 3: Multi-resolution terrain mesh I with viewing position at (50, 50).

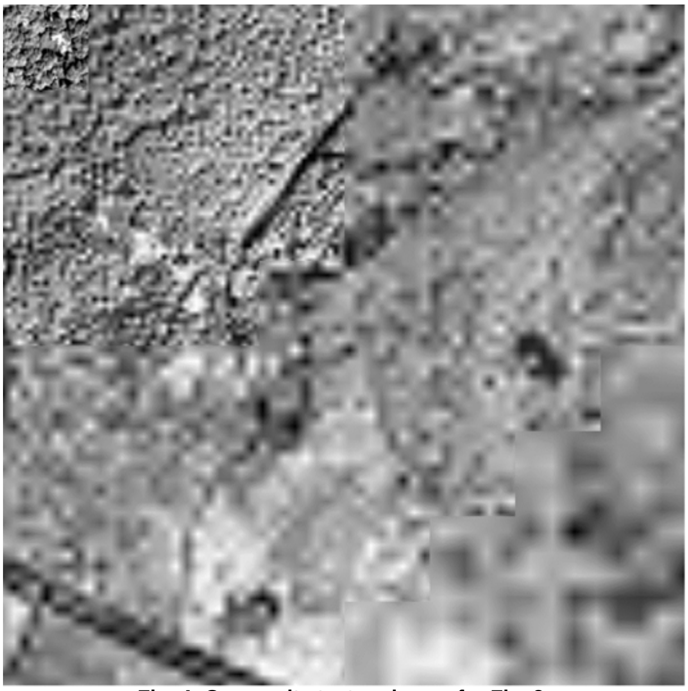

Fig. 4: Composite texture image for Fig. 3.

Fig. 5 shows another generated multi-resolution terrain mesh with the viewing position located at the middle of the right (540, 1000). As expected, patches in the right side have higher resolution. The texture image of this viewing condition is displayed in Fig. 6.

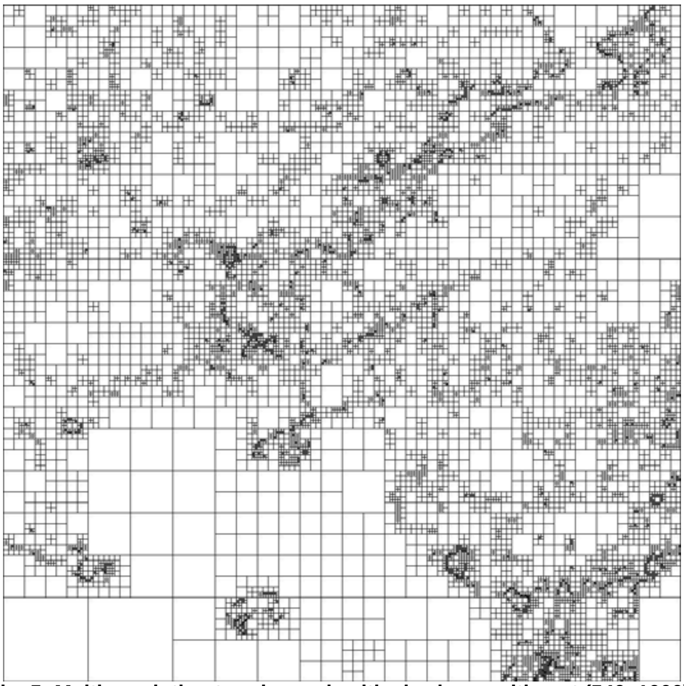

Fig. 5: Multi-resolution terrain mesh with viewing position at (540, 1000).

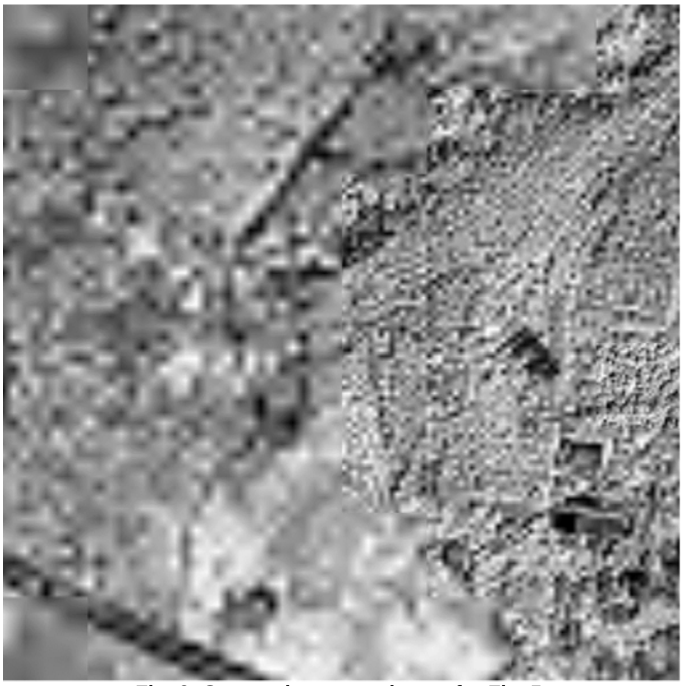

Fig. 6: Composite texture image for Fig. 5.

The tests demonstrate that using the method described in the previous section, the developed system can dynamically generate multi-resolution terrain meshes and composite texture images according to viewing geometry. The rendering of the multi-resolution terrain and texture should be faster than using original DTM and high-resolution image, but the required details of constructed scenes are still preserved based on viewing distance. This should increase the efficiency of the landscape visualization.

5. Conclusion and Future Work

The research developed a LoD approach to dynamically generate multi-resolution terrain meshes and texture images for efficient landscape visualization. The levels of detail of mesh and image patches are determined from viewing distances in real-time. The generated terrain mesh and texture are fast to render and maintain the reality of constructed scenes. The test results demonstrated in this paper indicate that this is an appropriate approach to improve the performance of landscape visualization.

As a work in progress, the developed algorithm will be further improved with more sophisticated multi-resolution terrain mesh and composite texture generation. For example, in addition to the viewing distance, viewing direction will also be taken into account when creating the terrain mesh and texture image. In addition, the mapping of texture to the terrain data will also be addressed with environmental mapping or other texture algorithm.

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