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View-dependent progressive transmission and rendering for lunar model based on bicubic subdivision-surface wavelet

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Abstract

Given the fact that the back of the digital lunar model is invisible from any viewpoint, a view-dependent progressive transmission and rendering method for lunar model is proposed and a client-server browsing system is implemented. On the server side, the semi-regular lunar surface is partitioned into dozens of segments, and each segment is compressed independently using bicubic subdivision-surface wavelet and SPIHT. For any viewpoint, only the data of the visible segments are transmitted to the client side progressively, then decoded and locally reconstructed there. This approach not only improves the efficiency of transmission, but also reduces the reconstruction time greatly. We can browse the lunar model on the client almost in realtime.

Keywords: Lunar model; Progressive transmission; Local reconstruction; View-dependent; Subdivision-surface wavelet

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1. Introduction

China launched her own unmanned, lunar-orbiting spacecraft, Chang'E-1 (CE-1), in October 2007. In this exploration, the Laser Altimeter (LAM) on CE-1 collected about 8.6 million elevation values on lunar surface. Yankui Sun et al. have used these LAM data to construct a lunar model and enable us to browse it interactively on an ordinary personal computer (Sun et al., 2011). Nowadays, more and more people have interest in lunar knowledge. In order to make more people know about the moon through Internet, this paper is devoted to develop new 3D geometry compression and transmission schemes to browse the lunar model interactively through remote network.

There are some researches about 3D geometry compression (Hoppe, 1996; Khodakovsky, 2003; Pajarola and Rossignac, 2000).The progressive mesh compression and transmission scheme is a popular solution because it can transmit detailed 3D meshes to end users with acceptable quality. It represents the mesh with multiple Levels of Detail (LOD). A coarse mesh can give the end user with a quick look and subsequent refinements can progressively improve the quality. This scalable representation is commonly obtained with a wavelet transform, because it produces a good decorrelation of the data. The best compression rates on 3D meshes are currently obtained with a wavelet decomposition, also called Multi-Resolution Analysis (MRA) on Semi-Regular (SR) structures (Jessl et al., 2005; Khodakovsky et al., 2000; Khodakovsky, 2003; Lavu et al., 2003; Payan and Antonini, 2005). The basic idea of such approach is to remesh complex model to acquire a series of meshes with subdivision connectivity. Then a wavelet model, which is convenient for compression and transmission, can be obtained by decomposing the remeshing models. The advantage of this approach is that the client can construct the topological structures for different resolutions with only a base mesh, greatly reducing the transmission of topology data. In addition, subdivision wavelets make it easy to adopt efficient encoding scheme for progressive transmission.

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Previous transmission schemes of 3D model using subdivision wavelet are based on whole-model. Although they are suitable for small-scale model, they do not take account of the viewpoint which leads to unnecessary transmission of invisible data. For large-scale model, they give rise to a sharp decline of performance on network transmission. Moreover, the client needs to spend more time to reconstruct the whole model which lowers the efficiency of visualization. Consequently view-dependent compression, transmission and rendering methods emerged, to accelerate the huge amount of computations involved in the context (Céline, 2010; Hoppe, 1997; Sim et al., 2004; Payan et al., 2009; Yang et al., 2004; Guan et al., 2008). Hoppe (1997) was one of the first to introduce the concept of view-dependent simplification and refinement, for fast and efficient rendering of 3D irregular meshes. Initially, the coarsest mesh is rendered. Then the algorithm iteratively checks whether each vertex need to be further refined, according to the user's viewing frustum. Recently, several view-dependent compression and transmission schemes have been proposed for SR meshes (Céline, 2010; Sim et al., 2004; Payan et al., 2009; Yang et al., 2004).

Clustering according to normal vectors was used to partition the mesh in Guan et al. (2008), while degrees of roughness reflected by the wavelet coefficient amplitude were utilized to create regions on the mesh surface in Céline (2010). But it is difficult to cluster spherical surface according to normal vectors and wavelet coefficient amplitudes. These methods are not good at spherical lunar mesh. In this paper, a segmentation method based on topology is proposed to partition the SR lunar mesh which is got from LAM data by denoising, subdivision and resampling. Each segment getting from segmentation satisfies subdivision connectivity and is encoded during preprocessing on the server. Given a viewpoint on the client, only the data of the visible segments are transmitted progressively and decoded, reconstructed, rendered locally. This novel view-dependent progressive transmission and rendering framework possesses better transmission efficiency, and local reconstruction and rendering can make it take much less time than a whole-moon reconstruction and rendering. Our main contributions in this paper are:

- a particular partition method for lunar surface based on topology;
- local progressive transmission and reconstruction to reduce the waiting time on the client;
- other improved techniques like improved method of occlusion culling and breakpoint-resuming scheme based on our framework.

The next section illustrates the main stages of the proposed framework. The schemes are described in detail in Section 3. Section 4 shows the implementation and experimental results. Conclusions are given in Section 5.

2. Overview of the proposed algorithm

Figs. 1 and 2 illustrate the main stages of the proposed framework. On the server, an input lunar LAM data is first denoised and triangulated to get an irregular mesh S_{origin}. S_{origin} is then resampled into a SR mesh S_{approx} (Fig. 1a). SR mesh S_{approx} is partitioned into dozens of segments. Each segment is decomposed by subdivision wavelet transform independently, and then encoded to get a segment-independent compressed bitstream. Meanwhile the coarse mesh S_{coarse} which has lowest resolution can be got (Fig.1b). Our partition and segment-independent encoding stages can be seen as a pre-processing step on the server side and is not dependent on the user's viewing position. The lunar mesh is progressively transmitted by Client-Server (CS) mode (Fig. 2).

On the client, a connection should be established with the server and the coarse mesh data should be transmitted firstly. At the same time, the connectivity data is constructed by subdividing the base mesh which consists of dozens of faces, and some information such as normal vector and bounding sphere for each segment can be obtained on the client. After the whole coarse mesh data is received, the lunar model can be rendered quickly with a rough view. Given a viewpoint, visible segments are judged and these view-dependent segments' compressed bitstreams are transmitted progressively, decoded, reconstructed and rendered on the client.

3. Algorithm description

3.1. Constructing SR lunar mesh

For our LAM data, there are 8,610,511 data points in all. SR lunar surface model is constructed by a method similar to the one proposed in Sun et al. (2011). It consists of two stages:

(1) Denoising.
Identification and rejection of the noise caused by instrumental error and incomplete calibration is realized utilizing the data correlation of 2B level LAM data. After that, we construct an original moon surface model S_{origin} using the Delaunay triangulation method.

(2) Surface subdivision and resampling.
First, a base mesh is constructed. Then based on S_{origin} and the base mesh, a hierarchical representation of the lunar surface with subdivision connectivity is generated using surface subdivision and resampling. After several iteratively subdividing and resampling, a SR mesh S_{approx} which has similar resolution with S_{origin} can be obtained.

During the above construction of SR lunar mesh, Catmull–Clark subdivision (Bertram et al., 2000) are used. In Catmull–Clark subdivision scheme, one N-sided polygon