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Case study

An improved texture-related vertex clustering algorithm for model simplification

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ABSTRACT

As an important data source in 3D GIS, 3D landmark models are built to simulate the real-world scenario. However, due to the enormous volume and complexity of 3D models, the data transmission under limited bandwidth and the real-time rendering have always been an open problem. In order to improve the visualization and the efficiency, this paper proposes a novel model simplification algorithm in consideration of texture after the analysis of the existing model simplification approaches. Differing from the previous research, our approach defines a new error metric related to the model texture, which extends the vertex clustering scheme in 3D geometry space and 2D texture space independently. Since the uneven distribution of vertices is taken into account, the clustering unit is divided adaptively in consideration of both geometry and texture information. In view of reducing the memory overhead and improving the algorithm efficiency, we don't create new vertices by iterative calculations, but use the inherent vertices in the initial meshes as the characteristic vertices. To demonstrate the feasibility and effectiveness of our strategy, a series of simplification experiments have been carried out on the platform of DirectX 3D, a widely used 3D application programming interface. The results show that the simplified models in consideration of texture preserve more texture details than those traditional ones. It apparently makes a good balance between the reduction rate and visual effects.

1. Introduction

With the rapid development of computer, network and virtual reality technology, the current Geographic Information Systems and Services demand a unified visual platform for rendering the remote sensing image, regular grid DEM and 3D models together, as the integrated expression of the multi-source spatial geographic information. Especially, 3D building models have the advantage to show the realistic city landscape vividly, owing to their abundant information, intuitive expression, excellent visual effects and suitability for human spatial cognition. Nevertheless, the intricate topology and additional attributes such as material, texture, skeletal animation and so on bring about enormous data redundancy, which creates impediments to providing online services about global three-dimensional spatial information visualization. Therefore, the fast data interpretation and real-time rendering within limited CPU resources have been a critical challenge in 3D GIS, and model simplification is no doubt an effective solution to this problem.

More significantly, however, it is important to balance the contradictions between high simplification rate and satisfactory visual quality. Without appropriate error metrics, oversimplified models will lose material particulars. Motivated by the above, our main contributions are as follows: A novel vertex clustering simplification algorithm is put forward, which takes the texture details into account as well as the geometry information. It introduces appropriate thresholds in texture error metrics, which aims to preserve essential texture pattern details in different levels. Moreover, in order to achieve the partitioned organization of the vertices, we use adaptive subdivision based on Oct-tree to control the scope of vertex clustering dynamically according to the local vertex distribution and error metrics. The optimized algorithm shows stricter error control, higher operation efficiency, lower memory usage and better visual effects, which is conducive to simplifying the massive amount of complicated models.

In this paper, the remainder is organized as follows. Section 2 reviews the previous research on simplification of urban building models, which provides new insights into our approach. Section 3 describes the detailed algorithm process of vertex clustering simplification in consideration of texture, which makes specific explanation of the feasibility of this algorithm. Section 4 demonstrates our approach by rendering a series of complicated building

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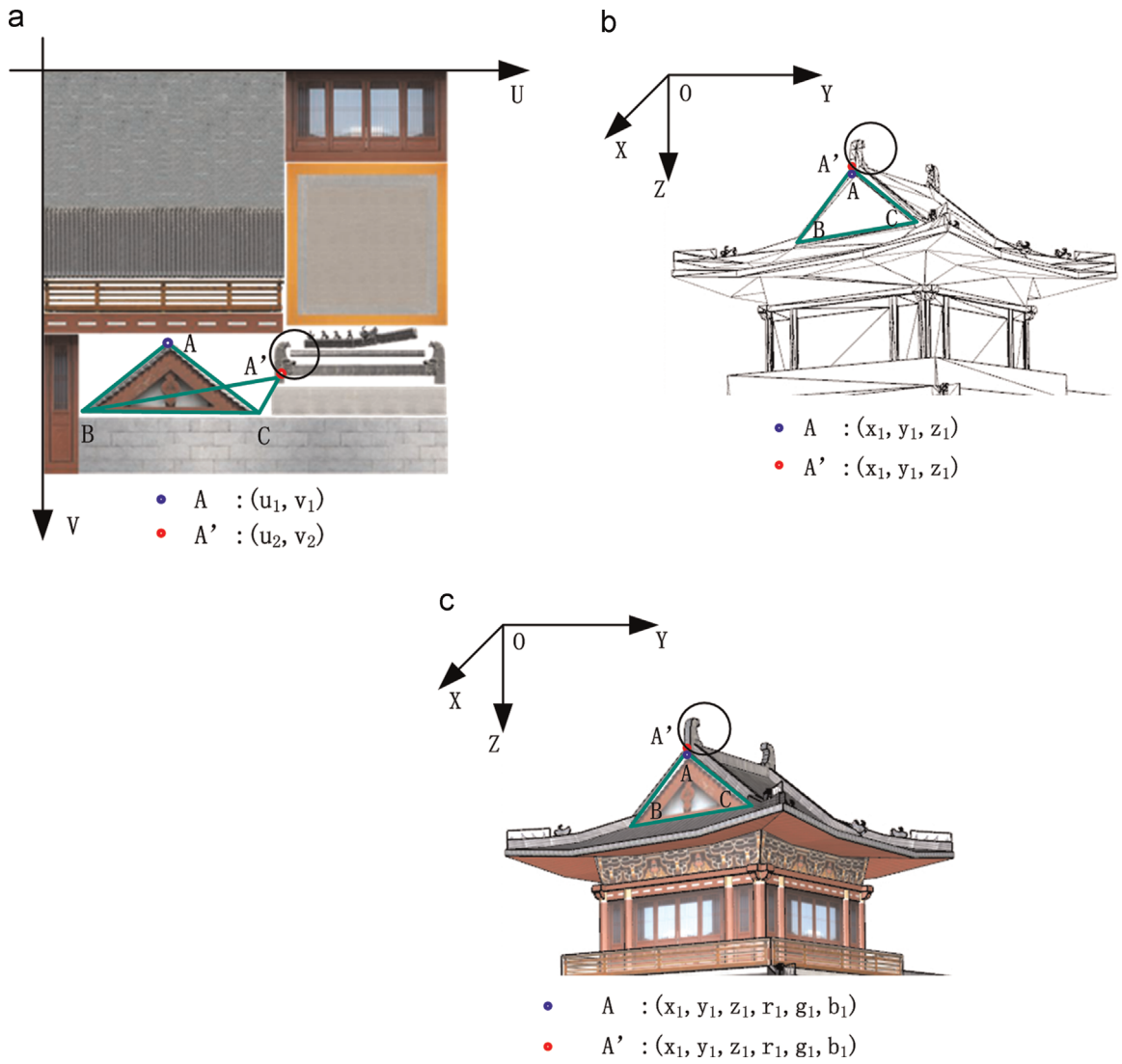

Fig. 1. Vertex mapping relationships in different rendering spaces. (a) Texture space. (b) Geometry space. (c) Geometry-color space.

models in DirectX 3D. The performances are compared with those using the traditional strategies. Section 5 concludes and discusses the future work.

2. Related work

The most notable available simplification algorithms include vertex clustering algorithm (Chan and Kok, 2001; Li et al., 2008; Tsuchie et al., 2014), wavelet decomposition algorithm (Esteve et al., 2000; Wang and Zhang, 2010), vertex decimation algorithm (Kobbelt et al., 1998; Franc and Skala, 2002), iterative edge contraction algorithm (Heckbert and Garland, 1999; Ungvichian and Kanongchaiyos, 2011) and so on. These ordinary model simplifications are more likely to aim at streamlined models, that consist of smooth and regular surfaces without sharp edges and corners. However, unlike the 3D game environments, as for 3D GIS, we are more interested in geographical landmark models that are built in accordance with the reality and keep more complex geometric structure. In order to achieve the hierarchical visualization in 3D GIS, various methods have been proposed for model simplification, generalization, aggregation and merger in 3D virtual scenes. Thiemann and Sester (2006) proposed a generic set of adaptive templates to replace the original urban landmarks. Characteristics can be highlighted or enhanced easily since the semantic information is known, but the templates adaptation is limited. Royan et al. (2007) developed a merging algorithm based on Delaunay triangularization and PB-Tree structure used for hierarchical rendering, but too complex hierarchy would affect the rendering efficiency. Another scale-space approach worked for generalization by shifting parallel facets to erase cracks and adaptive squaring non-orthogonal structures (Forberg, 2007). Mao et al. (2011) put forward a multiple representation data structure named CityTree for dynamic visualization of generalized 3D city models. It works well for simple building blocks, but not for those with complex roofs. Xie et al. (2012) presented a view-dependent scheme consisting of simplification of individual buildings and aggregation of building groups. The former includes footprint correction, special structure removal, roof simplification, oblique rectification and facade shifting, while the latter includes hierarchical clustering, footprints generation and hierarchical tree establishment. Although the above algorithms cover a wide variety of situations, the texture information still has no role in model simplification.

After taking texture constraint into account, Chang et al. (2008) introduced a hierarchical texture rebuilding approach, which combined the textures into texture atlases according to geographical adjacency. However, this approach is designed rather for urban legibility, not for improvement of visual quality in its