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Interactive panoramic map-like views for 3D mountain navigation

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ABSTRACT

In 3D terrain navigation applications, the views based on general perspective projection often find features of interest (FOIs) being occluded. As an alternative, panorama-like views preserve the similarity between 3D scenes before and after the deformations while ensuring the visibility of interested features. In this paper, an automatic method for generating panoramic map-like views is proposed in mountainous areas. The created panorama-like views by moving up the view position as well as the terrain deformation can successfully avoid occlusions of the FOIs. The final views also ensure the resemblance in appearance for the FOIs and landscapes, and thus satisfy the demand for interactive occlusion-free navigation in 3D complex terrain environments.

1. Introduction

Virtual spatial environments based on 3D terrain models have wide applications in real-world applications as well as research laboratories. 3D navigation platforms have a major advantage over those based on 2D maps, for human eyes interpret 3D environments such as current locations, surroundings, and features of interest (FOIs) much easier than map interpretation in 2D space.

The current systems usually use perspective projection for rendering 3D spatial objects. In virtual spatial environments; however, perspective projection generally suffers from occlusions by near objects (Fig. 1a). This problem becomes particularly common in rugged mountainous areas and cities with myriads of buildings. One solution is to recognize the occluded objects by embedding 2D maps into 3D systems, but it requires users' frequent interpretation of 2D maps and occupies more screen space. Accordingly, for 3D navigation systems, using the panorama views instead of standard projection views is an appropriate alternative.

This paper concentrates on real-time generation of panorama-map-like views (Fig. 1b) for terrain navigation across mountainous areas. This serves the demand for interactive visualization in navigation applications, under the support of multiresolution 3D terrains.

2. Related work

2.1. Nonstandard projections

Nonstandard projections, an alternative to the standard perspectives, can generate a closed effect of the deformation. Existing methods can be generalized by single camera projections, composite projections, and deformation of the models and space.

Using a single camera to create nonstandard projections is achieved by deforming the ray of sight or the projection plane. The former was introduced by Gröller (1995) as nonlinear ray tracing, in which numeric methods are used to propagate the ray. Mei et al. (2005) designed a camera, which bends the ray of sight in the vicinity of a silhouette to reveal occlusion parts of the models in image-based rendering. Brosz et al. (2007) redefined view volume to produce the effect of light bending. For the latter, Levene (1998) extended the work of Inakage (1991) by using the projections onto nonplanar surfaces. Yang et al. (2005) furthered their approaches to 3D lenses. The general linear camera (GLC) model (Yu and Mcmillan, 2004), which is defined by three rays originating from the image plane, can provide a single model that unifies most of previous perspective and multiperspective cameras.

The composite projection is to combine and blend multiple views created by standard projections into a single view. The first work along this line was done by Agrawala et al. (2000), in which different parts of the scene are seen by different standard cameras, and the final view is composed by comparing the depth values of the objects. In Singh's method (2002), the camera and viewport parameters are interpolated to combine multiprojection

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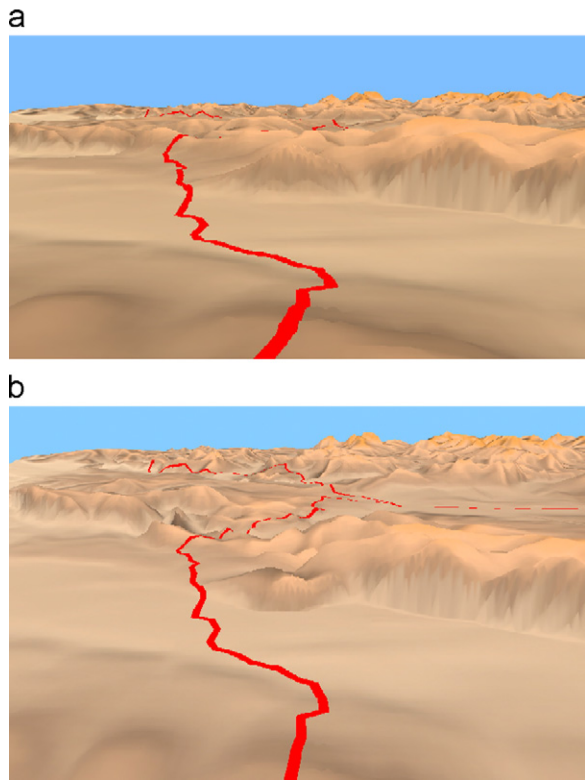

Fig. 1. Two terrain rendering views. (a) Terrain in ordinary perspective view and (b) Panorama-like perspective view generated by our method.

to ensure smooth deformation. Coleman and Singh (2004), Coleman et al. (2005), and Sudarsanam et al. (2005) have developed their frameworks and tried to control the deformation.

Different from the above image-based approaches, the other classes of geometric deformation-based approaches are object based, directly altering the models and surrounding spaces. In this class, the pioneering work was done by Barr (1984) and Sederberg and Parry (1986). Related works includes those of Rademacher (1999) and Martin et al. (2000) that automatically deform the model according to the viewpoint. The former is view-dependent geometry that changes the shape based on the direction from which it is viewed. The latter uses a group of observer-dependent controlling functions to indirectly control the result.

2.2. Panorama generation

Panorama maps can provide a good overview and reduce occlusions of the FOIs. The techniques of occlusion reduction have been studied for many years. A taxanomy by Elemqvist and Tsigas (2008) has provided an overview and classification of the existing methods. Premoze (2002) developed a system for interactively producing panorama maps. The system allows users to execute vertical scaling and rotation on the terrain. Takahashi et al. (2002) presented an approach for generating panorama guide maps from digital elevation models, which can semiautomatically calculate the displacement and rotation effect of the landscape. All these approaches, however, need to manually produce the deformation of the occluded areas.

To our best knowledge, there are only a few automatic methods reported. Takahashi et al. (2006) presented a method used in the occlusion-free animation of route navigation. Their method first extracts landmarks, and the occlusion is avoided by computing the arrangement on the 2D screen. An alternative approach has been explored by Degener and Klein (2009) to generate panorama, where two factors, resemblance and visibility, are taken to restrict the possible deformation. But these approaches to find optimal surface deformations, which cannot meet the requirements for roaming the deformed terrain interactively, are time-consuming. Recently Möser et al. (2008) and Lorenz et al. (2008) have reported that their systems can support interactive panorama-like views of terrains and city models by only simply rotating the spatial objects in the scene to enhance the visibility. For terrain navigation, this rotation can introduce some exaggerated distortions to the terrain surface.

3. Preprocessing

3.1. Terrain partition

Generally, occluders that block the line of sight (LOS) are convex parts of the terrain, e.g., peaks and hills. These occluders must be found first before any treatment can be done. For instance, for an occluded road as shown in Fig. 2, to eliminate occlusions, we first extract the occluder, i.e., the hill in Fig. 2a. Then we can guide the camera up vertically and scale down the hill to clear the lines of sight to the road according to their relations to the hill (Fig. 2b). Starting with this scenario, we extract the convex parts, which are considered as the set of potential occluders. The convex parts are extracted according to geomorphic features of the terrain. We achieve this goal by finding the Morse–Smale complex in the Morse theory (Comic et al., 2005).

A region covered by ridge lines emanating from a maximum to saddles form a region called *unstable cell* in the Morse–Smale complex. This means that this cell has its center at the maximum

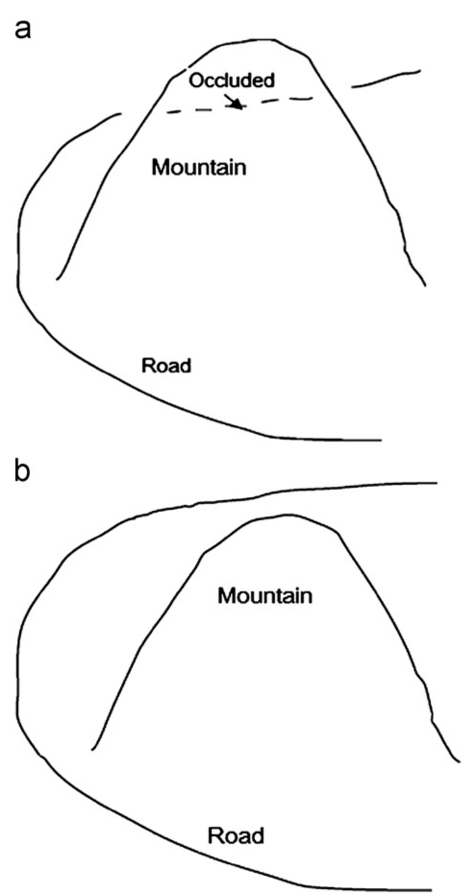

Fig. 2. Example of occlusion elimination. (a) A road segment occluded by the massif and (b) The visible road after the occlusion culling.