Route-Friendly Navigation With 3D Curved City Visualization

YING Shen, YANG Haoran, HE Ruiyang

School of Resource and Environmental Sciences, Wuhan University, 129 Luoyu Road, Wuhan 430079, China.

Abstract. 3D city navigation can provide spatial information services in the rapidly changing geographical context and is widely used in commercial systems and scientific research. Traditional 3D navigation has an occlusion effects because of 3D buildings that impedes the transmission, acquisition, and perception of geographic information. This paper introduces 3D curved city visualization with visualization of unobstructed paths, customized visualization of landmarks, and multiple navigation modes into 3D city navigation. The results indicate that the proposed technique can effectively decrease the occlusion effects in 3D visual scenes, enhance users' spatial information acquisition and perception ability in 3D city navigation scenes with dynamic changes which improves users' wayfinding ability and enhances the user-friendliness of navigation.

Keywords. navigation friendly, 3D city visualization, occlusion effect, spatial cognition, wayfinding, landmark

1. Introduction

Navigation map is a comprehensive product that integrates mapping, positioning and information services, and plays an important role in path planning, space resource allocation and other fields. Based on the navigation map, 3D city navigation combines 3D urban spatial information to provide spatial information services for the rapidly changing geographical context, meeting users' requirements for 3D visualization and spatial wayfinding of navigation maps. Traditional 3D visualization methods, such as perspective projection, can cause geographical entities near the view point to block geographical entities far away from the view point, affecting the transmission, acquisition, and perception of urban environment. Many researches are developed to improve 3D city navigation from the first-person perspective

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and the third-person perspective. The use of non-standard perspective projection (Moser et al. 2008, Degener & Klein 2009, Deng et al. 2011) required a high level of expertise, which was not convenient for technical implementation; at the same time, this method lacks flexibility. Static visualization (Grabler et al. 2008) was used to simulate spatiotemporal dynamic navigation tasks. Only one kind of person perspective navigation visualization is studied (Deng et al. 2016), but it is not applicable to systems requiring multi-person perspective navigation, which is short of the user's interactivity and can't satisfy the initiative of spatial cognitive process in navigation. Visual effects (Vaaraniemi et al. 2013) were defined by designers, but it cannot meet the multiple needs of users caused by cognitive difference in multiple navigation processes. In the way-finding process, the user's movement behaviors are spatiotemporal dynamic, and the geographic location and context changes continuously and dynamically. Therefore, the navigation process is a process of dynamic cognition of geographical space. How to reduce the occlusion effect, improve the navigation effect and enhance the friendliness of navigation visualization in the dynamic and real-time changing geographical environment is the key and become the difficulty of 3D city navigation visualization research. To solve the above problems, this paper introduces the visualization of 3D curved deformation with urban environment, with the visualization of unobstructed paths, the visualization of customized landmarks, and multi-navigation modes into 3D city navigation, to improve the way-finding effects.

2. 3D Curved Visualization of Terrain Deformation

Non-standard perspective projection visualization involves changing projection mode and image fusion technology, which is not suitable for dynamic and autonomous navigation tasks. Considering that the characteristics of the electronic map itself and the representation method are very important factors (Schäfers et al. 2008), this paper introduces terrain deformation visualization into 3D urban navigation. Terrain deformation refers to the use of spatial surface function to simulate the city topography. The spatial surface function is user-defined, so the deformation can also be customized according to user needs and urban layout characteristics, as shown in *Figure 1*. In the process of navigation, the user's spatial position changes dynamically in real time, and the user's position in 3D scene also changes dynamically in real time. Therefore, this paper designs dynamic adaptive deformation with the change of user's position that has a better viewshed. As shown in *Figure 1*(b), terrain deformation of 3D city will change adaptively with the movement of user's spatial position, so that the Angle characteristics of the user's spatial perspective will remain unchanged no matter where the user drives on the route.

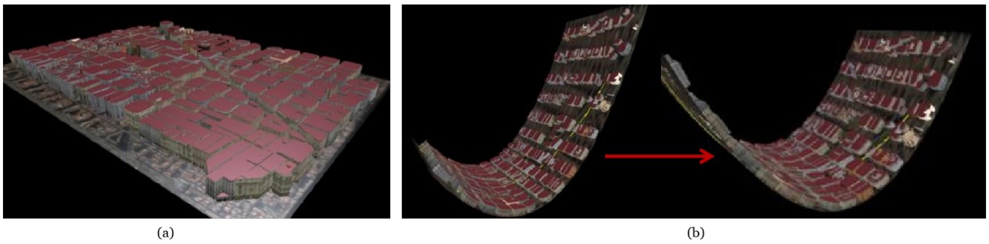


Figure 1. Visualization of terrain deformation.(a) No deformation.(b) Terrain deformation.

3. Visualization of Unobstructed Paths

As one of the spatial knowledge of spatial cognition, the cognition of route knowledge is very important. Users need to obtain the full visibility of the navigation path and the spatial relationship between the road and the urban spatial layout. In order to enhance the user's perception of route knowledge, the navigation map design should emphasize the way-finding information for user cognition, and weaken or delete the irrelevant information to user cognition that influence the access the route infomation. In this paper, the unobstructed path visualization with 3D curved city is introduced into 3D city navigation to avoid buildings from blocking the path. The principle of unobstructed visualization is to use the line of sights between the viewpoint and the sampling points on the navigation path to calculate and find 3D models that need not to be visualized. As shown in *Figure 2*(a), the path is blocked by buildings, making it difficult to acquire route knowledge. On this computation, this paper designs real-time dynamic unobstructed visualization of navigation path, that is, users can observe the navigation route at any location. As shown in *Figure 2*(b) and *Figure 2*(c), the approach keeps the enable adaptive real-time dynamic hiding or transparent occlusion. No matter how the view angle is switched, the object blocking the route is always hidden or transparent, making the path visible online.

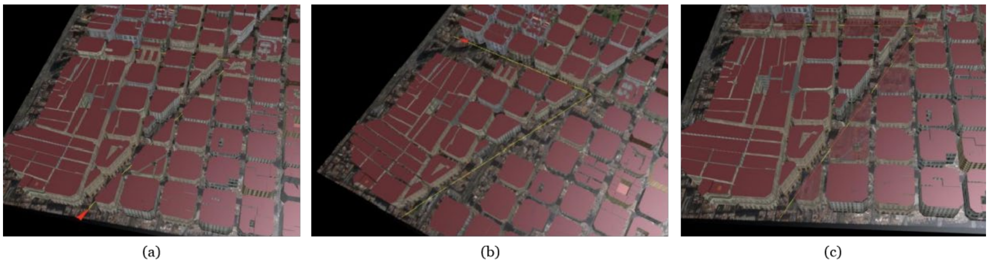


Figure 2. Route unobstructed visualization.(a) No processing.(b) Hidden visualization.(c) Transparent visualization.

4. Visualization of Customized Landmarks

Landmark, as the most basic knowledge in spatial cognition, is very important to determine the position and direction in the process of navigation wayfinding. When entering an unfamiliar environment, the users tend to use landmarks as AIDS to locate (Schafhitzel et al. 2011). Each user needs differentiation in the way they visualize landmarks of interest and landmarks of disinterest. Therefore, this paper designs the user-defined landmark labeling and landmark visualization.

Landmark selection indicates the users can select landmarks of interest according to his preferenc degree through the mouse or other input devices. Landmark custom visualization means that users can use the visualization function to highligt the selected landmark. For the more clear and familiar landmarks in the user's mental map, the landmark can be highlighted or its height or size can be raised or enlarged (*Figure 3)*. To enhance the users' spatial cognition, and users can use this as a reference to identify and determine their position and direction in the route wayfinding.

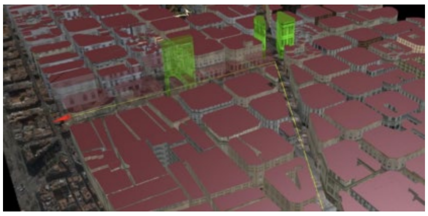


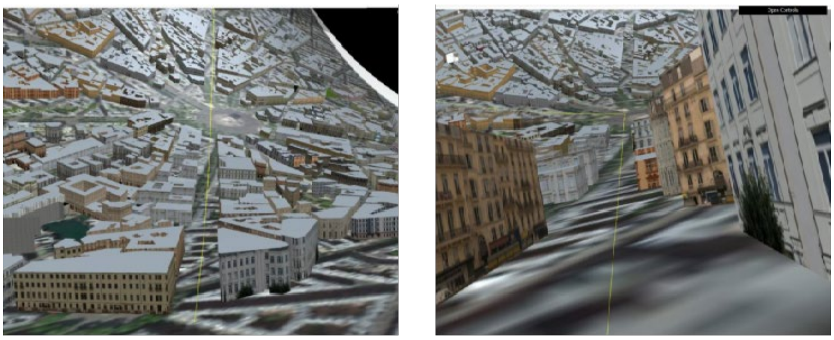
Figure 3. Landmark green visualization

5. Multiple navigation mode

First-person perspective navigation has advantages in route tracing and simulating user perspective in reality, which can bring immersive navigation experience. The third person perspective will provide the global direction of the path and the bird-view of the urban layout, which is suitable for panoramic navigation. This paper designs a variety of personal navigation modes including first-person/ third-person perspectives, as shown in *Figure 4*, which can be seamlessly switched and connected to meet users' requirements for various navigation tasks and give the system a more perfect navigation experience. 3D curved urban visualization can enlarge the view range of the ahead route with urban context that accelerate user cognition to obtain the direction and distance in wayfinding process.

6. Conclusion

In this paper, 3D curved urban deformation visualizations with path unobstructed visualization, landmark-enhanced visualization, and the comprehensive applications of multiple navigation modes are introduced in urban navigation. In future, we aim to quantitatively study the comprehensive cognitive effects of these techniques on user wayfinding and navigation in different visual environments and with the help of eye-tracking techniques.



(a) (b)

Figure 4. Multiple navigation mode with 3D curved visualization: (a) Third person view.(b) First person view.

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