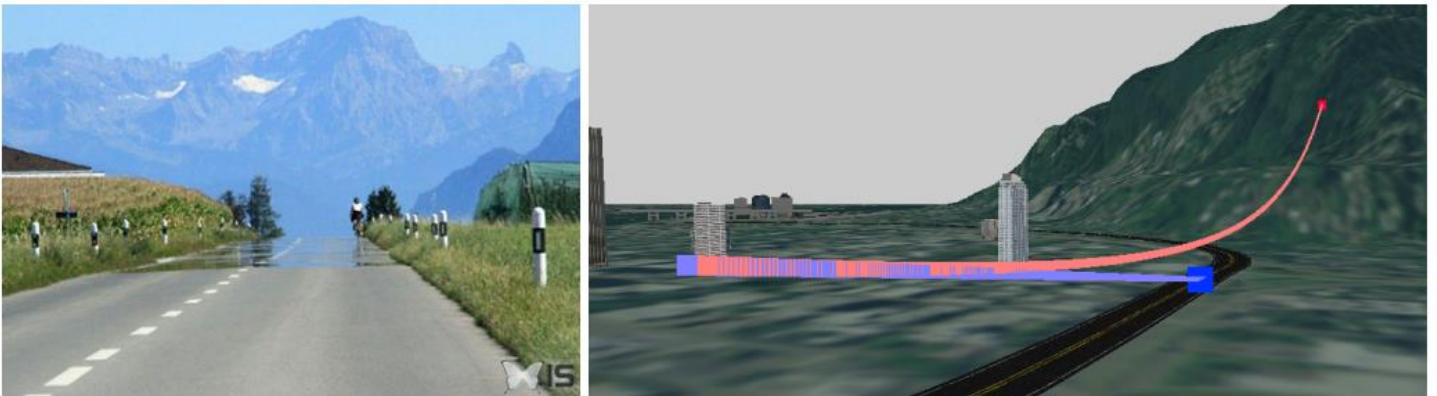# 신기루 영상 제작을 위한 굴절률 분포의 직관적 편집*

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Artistic Editing of Refractive Index Distributions for Mirage Image Generation

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Figure 1: *The left image shows a photography of the mirage captured in the real life. The inferior mirage of the mountain is visible on the road. Image courtesy Intra Science. The right image shows a pair of source and target points to create the mirage effect resembling the one shown in the photography. We want the mirage image of the source point (red) to be in the target point (blue). Our method computes a refractive index distribution to fulfil the user's specification. The light-red curve represents the curved light path under the influence of varying refractive indices, producing the similar mirage effect as shown in the photography. The light-blue line represents the perceived light path from the observer at the specified direction.*

Abstract

We propose a novel user interaction scheme to enable an artistic control on editing a refractive index distribution in the light media. The system mainly targets for the production of a desired mirage effect, that is, the mirage of a particular object appearing in the user-specified spatial position of the scene. The refractive index distribution of the light media can be encoded to a compact, low dimensional model. The distribution is constructed by minimizing our cost function measuring the spatial distance between the user-specified and generated mirages.

1. Introduction

Mirage Image Rendering and its Artistic Editing. Rendering the mirage effect has been studied, since it is frequently observed in our daily lives, e.g., sky reflection on roads in hot and sunny day, and is thus used in visual effects for movies. Nonetheless, there have been only a few attempts providing artistic controls over producing desired mirage effects in rendered images. Rendering such effects is different from other rendering techniques in many ways, especially due to the nonlinear nature of the light propagation involved in the mirage effect. Note that mirage itself is occurred by curved light paths, and these nonlinear light paths are caused by varying refractive indices of the light media. This nonlinearity requires a different artistic control over conventional approaches designed to support visual effects associated with straight light paths. Adjusting the mirage effect boils down to controlling refractive

indices in the light media. As a result, it is critical to have an intuitive control on the spatial distribution of the refractive index, to easily handle the nonlinearity.

2. Our Approach

Task Definition. The *desired result* specified by the artist is defined in the output image with the mirage of a particular object on a specific spatial position of the scene. Our goal is to provide an intuitive artistic control over producing the desired result.

User Interface. To achieve our goal, we propose a novel user interface. The user first picks a source object to be rendered by the mirage effect. Specifically, we let the user to pick a position on the surface of the geometric model of the source object by using a mouse click on the screen with the pre-rendered scene. Then, the user moves that point around to specify the target position by dragging it using the mouse pointer, where the mirage effect will appear. These two chosen points form a point pair. The user may define more point pairs as necessary.

Spatial Refractive Index Distribution Encoding. The spatial distribution of the refractive index in the light media is represented in a low dimension to design an effective parametric regression. Any space representation can be used as an encoding method as far as it provides a spatial gradient, which is required for calculating the curved light path. A simple encoding method is to use a uniform grid, whose each cell maintains a refractive index.

Cost Function and Parametric Regression. We construct the light path starting from the camera facing the mirage position defined in a point pair. The refracted light path traveling through the light media is numerically calculated using Refractive Radiative Transfer Equation (RRTE) [1]. The cost function used for our parametric regression is computed by the difference between the predicted and desired light paths. The parametric regression is then performed on the spatial refractive index distribution to minimize the total cost function. The resulting light media description will let the light to travel in the right way, producing the desired result.

3. Future Works

The artistic control can be further improved by finding an appropriate encoding model. Such models could be based on the real atmosphere model [2].

References

[1] Ament, M., Bergermann, C., and Weiskopf, D. Refractive radiative transfer equation. *ACM Transactions on Graphics (TOG) 33*, 2, 17. 2014.
[2] Gutierrez, D., Seron, F. J., Munoz, A., and Anson, O. Simulation of atmospheric phenomena. *Computers & Graphics 30*, 6, 994–1010. 2006.