論文の内容の要旨

論文題目　　3D Graphics User Interface for Natural Phenomena
(自然現象デザインのための3次元グラフィックスユーザインタフェースの研究)

氏　　名　　岡部　誠

Designing natural phenomena with computer is one of the most important and challenging topics in computer graphics. While recent progress in computer graphics technologies has made it possible to render a three dimensional (3D) natural phenomena realistically and beautifully, design and control of 3D natural phenomena are still difficult tasks, because of a lack of efficient user interfaces. Existing tools typically impose two different processes on the users. One is parameter tweaking for designing appearance and behavior of natural phenomena, and the other is to render the scene and to make sure that the result is what the designer wants. These two processes cause numbers of iterations of trials and errors, where the user has to switch alternately between two processes through out the whole design process. To address these issues, we propose three basic principles for designing efficient and productive user interfaces for authoring natural phenomena in computer graphics: 1) user interface should be appearance-based, that is, the user directly works on rendering result and the system automatically adjusts internal parameters. 2) Separate user interfaces should be provided for low and high frequency components. Low frequency component should allow directly control by the user while high frequency component should be synthesized by the system under user's guidance. 3) User interface should support iterative design process allowing fast exploration of various scenarios.

After a short introduction, motivation and list of contributions, we review the current standard user interfaces for computer graphics design process. We built describe four experiments of systems to verify the effectiveness of the proposed principles.

Our first experiment is interactive design technique of 3D botanical trees that allows the user to quickly and easily design 3D models of botanical trees using freehand sketches and additional example-based editing operations. The user of existing methods, like L-systems or the other rule-based systems, has to specify production rules and adjust their parameters to design a 3D tree. In contrast, our system generates a 3D geometry from a two-dimensional (2D)

sketch using the assumption that a botanical tree spreads their branches so that the distances between the branches are as large as possible. User experience demonstrates that our interface lets novices design a variety of reasonably natural-looking trees interactively and quickly.

Our second experiment is single-view relighting system that allows the user to change the illumination in a photograph, especially the direction of the illumination. This requires to the user must reconstruct the 3D geometrical information. Instead of modeling the geometry using existing 3D software, we propose pen-based interactive method, by which the user can quickly draw an approximate normal map directly over a photograph using tilt-sensitive tablet. The photo and the approximately painted normal map are then given as input to a novel algorithm that estimates the original illumination condition, refines the normal map, and assigns reflectance information to every pixel. We present relighting results for a variety of scenes, and use our technique to match the illumination of multiple photographs.

Our third experiment is interactive design system of all-frequency lighting that provides an appearance based user interface for artists to efficiently design customized image-based lighting environments. Our approach avoids typical iterations of painting an environment map, rendering, and confirmation processes by providing a set of intuitive user interfaces for directly specifying the desired appearance of the model in the scene. Then the system automatically creates the lighting environment by solving the inverse shading problem. To obtain a realistic image interactively, all-frequency lighting is used with a spherical radial basis function (SRBF) representation. Rendering is performed using pre-computed radiance transfer (PRT) to achieve a responsive speed. User experiments demonstrated the effectiveness of the proposed system compared to a previous approach with paint softwares.

Our final and fourth experiment is example-based fluid video synthesizer, where we propose a novel method for designing a fluid animation from single still like photograph or picture and example videos. Using our system, the user can make still fluids in the image move. Our system can synthesize fluid behaviors extracted from example videos on the still fluids. Our system allows the user to control the animation by three factors: 1) the user can control the appearance of the fluid by changing the still, 2) the user can control the visual behavior of the fluid by selecting appropriate fluid animation videos as examples, and 3) the user can also sketch fluid flows on the still to control flow directions of the fluid. Given all the user inputs, the system semi-automatically synthesizes each video frame on the still. The system decomposes an example video into low frequency and high frequency components: motion information and dynamic textures. Motion information is used to synthesize motion vector field, low frequency information of the target fluid. Dynamic textures are used for synthesizing high-frequency behaviors of the target fluid. The motion information can also be controlled by the user-specified flow directions. We demonstrate that our system is useful to design photorealistic and non-photorealistic animations of various types of fluids like river rapids, waterfall, firework, flame, explosion, smoke, etc.

In closing, we discuss our proposed solutions, present open questions related to this dissertation and user interface design in general, outline possible improvements, and propose areas for future research.