1 Introduction

Landscape visualization has been mainly used for accurately analyzing existing landscape resources and assessing the visual impact of proposed plans. In the computer graphics (CG) of landscape simulation, quality of plants plays an important role. Many researchers have studied realistic plant modeling (HONDA, 1971; AONO AND KUNII, 1984; BLOOMENTHAL, 1985; OPPENHEIMER, 1986; PRUSINKIEWICZ, 1988; DE REFFYE ET AL., 1988; VIENNOT ET AL., 1989). By using techniques of plant modeling, very realistic images have been made for landscape planning and estimation (HONJO ET AL., 1992; SAITO ET AL., 1993, MORIMOTO 1993; HONJO AND TAKEUCHI, 1995). Three-dimensional (3-D) plant modeling techniques have been used to develop landscape visualization systems such as the AMAP system (DE REFFYE ET AL., 1988; PERRIN ET AL., 2001). In the plant modeling in AMAP, 3-D shapes of many species of plants are generated by parametric modeling, which is a technique that a modeler can produce many type of topological and geometrical architecture by using different parameters.

Plant modeling techniques of these systems can be used to render landscapes accurately. While these 3-D visualization systems can make highly realistic images as shown in Fig. 1(b), they have not yet achieved sufficient speed. Animations were made as sequences of the still images by changing the eye points and viewed points. Walk-through simulation or real time rendering of the landscape were difficult.

HONJO AND LIM (2001) developed a system for real-time rendering of landscapes using Virtual Reality Modeling Language (VRML). With the system, which we named “VR-Terrain”, landscape with thousands of plants can be visualized in walk-through in VRML. LIM AND HONJO (2002) also developed advanced version of “VR-Terrain” for forest landscape visualization. In Fig. 1(c), an examples of forest landscape simulations by VRML is shown.

In this study, by using VRML and parametric modeling techniques, we developed landscape visualization systems which enable server side generation of VRML programs by using Common Gateway Interface (CGI) and Perl. We developed several softwares by using parametric modelling. “City-Maker” generates city landscapes made of buildings and trees. “VR-Terrain” converts measured control point data of terrain and plant data to VRML program of landscape. “Forest-Maker” generates VRML program of simple forest landscape. “Greenhouse-Maker” visualizes multi-span greenhouses. In these systems, a user can generate numerous types of buildings, greenhouses and terrain by changing parameters of the modelers.
Fig. 1: Examples of forest landscape simulations by conventional CG with AMAP and VRML. Images in (a) and (b) are from Saito et al. (1993) and (c) and (d) are from Lim and Honjo (2002).
2 Methods

2.1 VRML Systems

VRML is a programming language and library for 3-D computer graphics and has many functions. To make the rendering fast, VRML supports only simple rendering techniques such as shading, setting objects, projection, and texture mapping but does not support complicated rendering such as ray tracing. VRML programs were automatically generated from the parameters by the modelers of the landscape visualization systems developed in this study.

A user can downloads the VRML program from a server and a 3-D image made by VRML is rendered on the local computer of the user. To use VRML, a browser that supports VRML is necessary. In this study, Cosmo Player (Silicon Graphics Inc.) was used as VRML browser with Internet Explorer (Microsoft). For VRML programming, VRML browser and Internet browser are necessary. Cosmo Player and other VRML browsers can be used as freeware and the developing environment can be built very economically.

2.2 Server Side Generation of VRML Programs

In the first version of the softwares, the modelers which produce VRML programs were developed in Visual Basic (Microsoft Inc.). In these cases, the works on visualization were possible on a stand-alone computer. On the other hand, the server side generation of VRML programs were done by the remote servers and the modelers were written in Perl. Parameters were input on web pages and transferred to the modelers through CGI.

While programming in VRML is possible on a stand-alone computer, the server side generation of VRML programs has some advantages. By the server side systems, users don’t need any software on their side. Because the systems are shown in the web pages, many people can access the systems on the Internet. As the server side systems are administrated by the host computer, updating and providing new version of the modeller are always possible.

2.3 Parametric Modeling

In the parametric modeling, a user gives parameters to a modeler and the modeler produces an object like shape of plants and buildings. A menu of modeler of AMAP is shown in Fig. 2. As shown in Fig. 3 and Fig. 4, the user can change parameters such as species, ages and seasons. These parameters are relatively few considering numerous parameters which the modeler of the plants uses. By limiting the numbers of choosed parameters, a simple user interface is possible.

For a fast rendering of plants in VRML, the texture of plants in a transparent GIF format are mapped on two planes which are crossed each other (Fig. 1(d)). Plant image database made by using AMAP were used in the following systems.
Fig. 2: Example of parameter input in the menu of plant modeler in AMAP.

Fig. 3: Effect of parameter change such as age and season in AMAP.

Fig. 4: Images of some of tree species generated in AMAP. These 2-D images were stored and used in other visualization.
3 Examples of Modelers

3.1 City-Maker

“City-Maker” generates city landscapes made of buildings and trees. In Fig. 5, sample images of buildings used in City-Maker are shown. Numerous types of buildings can be generated by parametric modeling. Mostly, building shape is made of simple object like box. There are also many types of textures and colors mapped on the buildings.

In Fig. 6, a menu of City-Maker and an example image are shown. In the menu, numbers of blocks and stories of buildings and species of trees can be changed. Some example images are shown in Fig. 7. With special glasses (ELSA 3D REVERATOR), walk-through with stereo view are possible as shown in Fig. 8. Techniques used in this system will be easily applied to real city planning and visualization.

![Fig. 5: Images of some of buildings in City-Maker. Numerous type of building shape can be generated by changing shape and texture parameters.](image1)

![Fig. 6: Menu of City-Maker and an example image. Numbers of blocks and stories of buildings and species of trees can be changed.](image2)
**Fig. 7:** Images made by City-Maker.

**Fig. 8:** Stereo view made by City-Maker. Realistic walk-through on 3-D street is possible.
3.2 VR-Terrain

In the investigation of plant data, species, location of plants or density of plants, height, width and diameter of trunk (usually at breast height) were recorded. For topographical data, coordinates of control points were recorded from maps. “VR-Terrain” converts these plant data and control point data of terrain to VRML program of landscape.

Fig. 9: Menu of VR-Terrain on the Web and an image made from the data. The input data on plants and terrain are pasted on the menu page and the images are made.
3.3 Forest-Maker

“Forest-Maker” generates VRML program of simple forest landscape. In Forest-Maker, a user can choose only several parameters on topography, tree species and number of the trees. Then, small forest landscape is shown. This method can be applied to design of parks and administration of forest.

Fig. 10: Menu of Forest-Maker on the Web and an example image. Parameters of topography, tree species and number of the trees are specified on the menu and images are made.
3.4 Greenhouse-Maker

Many types of greenhouses can be made by the parametric modeling. “Greenhouse-Maker” visualizes multi-span greenhouses. In the design of greenhouse, walk-through simulation in a 3-D space is a powerful tool, especially for the understanding of the design and for selection of alternative design. To make architecture of greenhouses simple objects such as boxes and planes are used. There are about twenty parameters that are shown in the menu in Fig. 11.

![Fig. 11: Menu of Greenhouse-Maker on the Web and an example image. About twenty parameters including plant species can be changed.](image)
4 Conclusions

By using VRML and parametric modeling technique, we developed the systems which run on both stand-alone and the server side. The softwares like “City-Maker”, “VR-Terrain”, “Forest-Maker” and “Greenhouse-Maker” were described and images were shown. These systems were primitive but they show the possibility of utilization of the technique in the future. In the advanced systems, complicated objects will be used and number of parameters will be increased to make more realistic images.

5 References