DEVELOPMENT OF SOIL CALCULATION FUNCTION IN A 3-D VR SYSTEM FOR ENVIRONMENTAL DESIGN

TOMOHIRO FUKUDA, ATSUKO KAGA, MASAHIRO KAWAGUCHI
Graduate School of Engineering, Osaka University, Japan
fukuda@see.eng.osaka-u.ac.jp, kaga_atsuko@env.eng.osaka-u.ac.jp, kawaguchimasahiro1980@yahoo.co.jp

AND

WOOKHYUN YEO
Yonsei University, Korea
yeowh@yonsei.ac.kr

Abstract. When performing an architectural design or an environmental design with complicated geographical features, soil calculation is needed to study the soil balance between the amount of cut and the amount of bank. In recent years, construction activities involving small environmental load have been called for. Therefore, it is necessary to stop the discharge of surplus soil. Moreover, the result of soil calculation can show that the landscape after completion may change greatly. A system which can study soil calculation and landscape simultaneously is called for. Furthermore, to correspond to the citizen participation type design process, a system which can allow understanding of a plan by stakeholders who do not have professional knowledge is called for. This research studies landscape and soil calculation with the aim of developing a possible system. A 3D-VR system which studies environmental design is extended and a soil calculation function in which high precision calculation and visual expression are possible is developed.

1. Introduction

A 3D-VR (Virtual Reality) system for an environmental design has been developed and applied in many real projects (Fukuda, 1997; Fukuda, 2003; Kobayashi, 2004; Yeo, 2005; Matsushita Electric Works, 2006; shown in Figure 1). In the simulation by 3D-VR, it is called for not only expressing a landscape on real time, but calculating and expressing technical fields, such as structure, and equipment, environmental assessment, on real time. For example, when performing an architectural design, a civil engineering design or a regional design with complicated geographical features in an environmental design process, soil calculation is needed to study the soil balance between the amount of cut and the amount of bank. In recent years, construction activities involving small environmental load have been called for (Zero Emissions Forum, 2006). Therefore, stopping the discharge of surplus soil is necessary. Moreover, the result of soil calculation can show that the landscape after completion may change greatly. A system which can study soil calculation and landscape simultaneously is called for. This research studies landscape and soil calculation with the aim of developing a possible system. A 3D-VR system which studies environmental design is extended and the soil calculation simulation is developed.

Figure 1. Examples of 3D-VR System (1: architectural design, 2: road design, 3: regional design, 4: study with notebook type VR, 5: study with large dome screen type VR).

2. System Requirement

The system requirements for studying both landscape and soil balance are as follows:

1) Soil calculation should be carried out seamlessly with a 3D-CAD (Computer Aided Design) model for landscape simulation. When utilization of a designer is supposed, without making up the new model for soil calculation, it is necessary to make the model for soil calculation with seamless operation of the 3D-CAD model which is used for landscape simulation.
2) Although it depends also on design stage, higher accuracy can be simulated. Soil calculation is usually performed using a 20m mesh size. In order to lessen discharge of surplus soil, in this research, a system calculable above 20m mesh size was developed. As well as simulation of physical appearance, other simulations such as measurement of interval or gradient, and representation of section are needed.
3) As well as professionals, non-professionals such as clients or citizens can evaluate the result of the simulation intuitively. Visual output representation of the simulation result is useful, although a designer understands the result and evaluates the contents of a design. Moreover, in various study meetings between a primary contractor and a designer, or between a primary contractor and a citizen, the system is effective in enabling stake-holders to share the contents of a design and in making communication smooth.

3. System Implementation

In this paper, some functions of soil calculation, interval calculation, and section representation are developed using Virtools™, which is commercial 3D-VR software. Figure 2 shows the system flow to create 3D-VR contents.

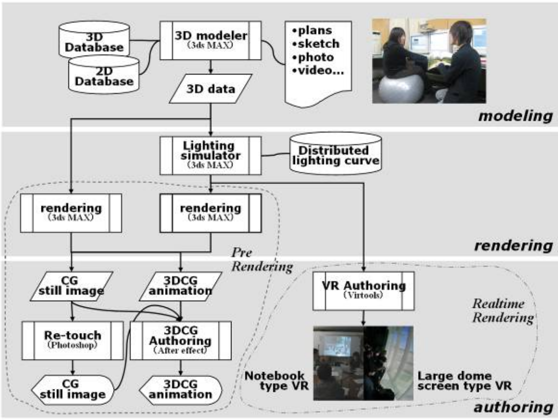

Figure 2. System Flow to create 3D-VR contents.

3.1. FUNCTION OF SOIL CALCULATION

The function of soil calculation is developed by the mesh method. In particular, the points of both the present terrain model and planned terrain model intersected by the ray are calculated. To get these points, Ray Intersection BB (Behavior Building Blocks) of Virtools™ is used (shown in Figure 3). The amount of cut/bank is calculated by the difference between these two points. Then, the volume of each mesh is given by multiplying an evenness projected area of each mesh by the average value of landfill height of each mesh point. The result of soil calculation is displayed with a graphic image (shown in Figure 4).

The GUI (Graphical User Interface) for this function includes a “Soil Calculation” button, a “Calculation” button, and a “Display” button (shown in Figure 3). When the “Soil Calculation” button is clicked, functions such as camera operation are stopped and the “Calculation” button appears. When the “Calculation” button is clicked, soil calculation is started. The calculated mesh size can be input by meter unit. After calculation, the amount of soil balance, the amount of cut, the amount of bank, and mesh size are displayed. When the “Display” button is clicked, distribution of the amount of cut/bank is displayed graphically.

3.2. FUNCTION OF INTERVAL AND SECTION CALCULATION

The function of interval calculation which includes distance, slope, and height difference is developed by acquiring the specified Y coordinates value of two points. The function of section calculation acquires the Y value of the geographical feature data on a straight line connecting two points in a certain pitch. And each point is arranged on a 2D image and a line segment is expressed as a set of a points (shown in Figure 5).

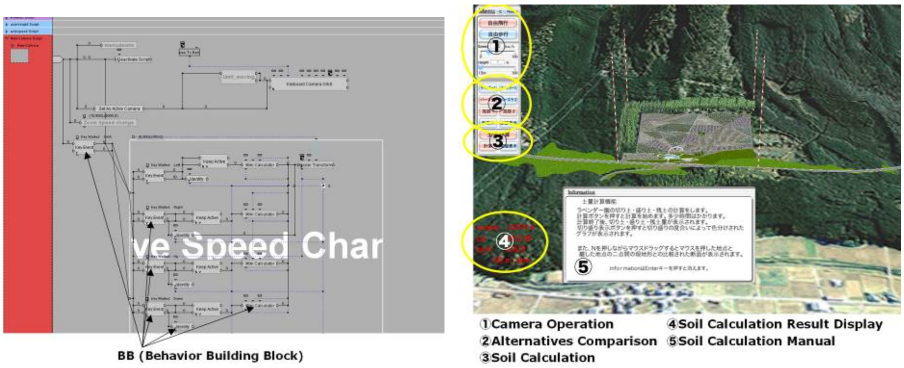

Figure 3. Function of soil calculation (left: visual Programming on Virtools™, right: GUI).

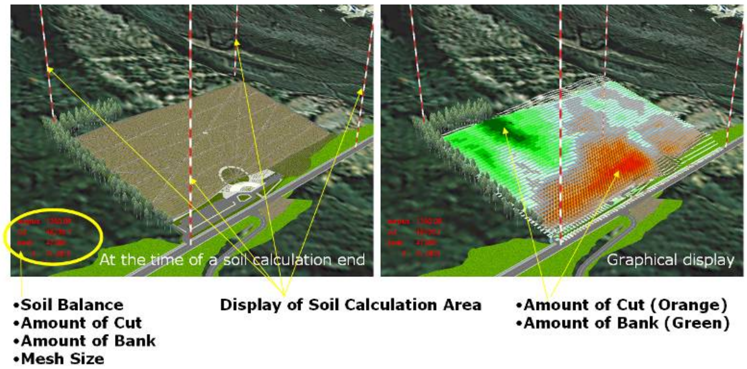

Figure 4. Execution of the function of soil calculation.

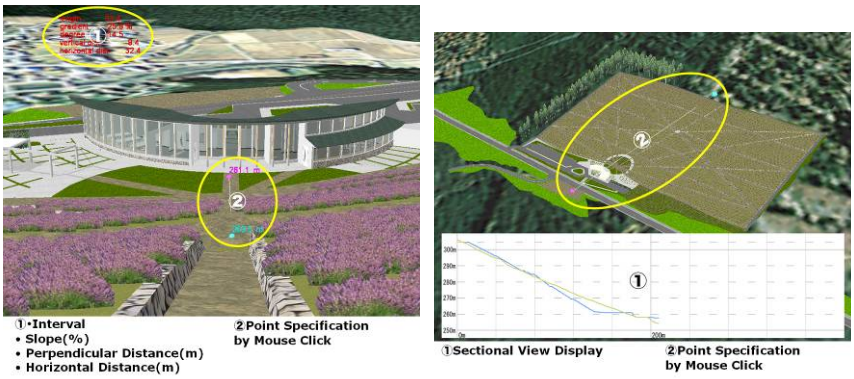

Figure 5. Function of interval and section calculation.

4. System Evaluation

The authors applied the developed system to the Lavender garden project. This is a project accompanying the development project of the Hyogo prefectural road "the Hikami Kami line." The road development project involved planning of the supervision needed to improve traffic access to the whole neighborhood, the lavender garden, and resting-place. It was also necessary to raise a seedling facility that utilized the hilly ground along the route for the purpose of attaining activation of the area accompanying the increase in visitor numbers. The design team to which the authors belong performed a study of the site preparation (about 5ha, vertical interval: 45m) of a lavender garden, and a landscape study of the whole plan including buildings and roads, etc. using the real-time simulation system (shown in Figure 6).

In the design condition, a reduction of amount of bank, amount of cut, and exhaust surplus soil are needed when the land is cleared. The authors can study about five alternatives a day including both landscape study and soil calculation simulated by 4m mesh size on the same 3D-VR system. The system is used in meetings with the architect and the civil engineering consultant responsible for budget and construction.

In order to perform a detailed design study, the accuracy of a present condition model was created in 1m mesh size. Plan proposals were created to a high degree of detail, including features such as walkways, stone walls, and lateral grooves. The accuracy of the plan model was about 10cm (shown in Figure 7).

The soil calculation time for mesh sizes of 20m, 10m, and 4m, respectively was 20 seconds, 105 seconds, and 690 seconds. (CPU: Intel Pentium4 3.40GHz, RAM: 2Gbyte, OS: Microsoft Windows XP Service Pack2). Mesh size, the number of meshes, soil calculation time, and the calculation time per mesh are shown in Table 1. It was found that the calculation time per mesh increased, so that the mesh became highly precise. Therefore, in the design process, a rough study was performed in 20m mesh size at the beginning. Mesh size was reduced as design conditions were narrowed down, and finally, the 4m mesh size was considered as the highest. After the Lavender garden project, the authors applied the system in other road design projects (shown in Figure 8).

TABLE 1. Calculation time in Lavender garden project contents.

Mesh size (m)	20	10	4
Number of meshes	150	600	3,600
Soil calculation time (s)	20	105	690
Calculation time per mesh (s)	0.13	0.175	0.192

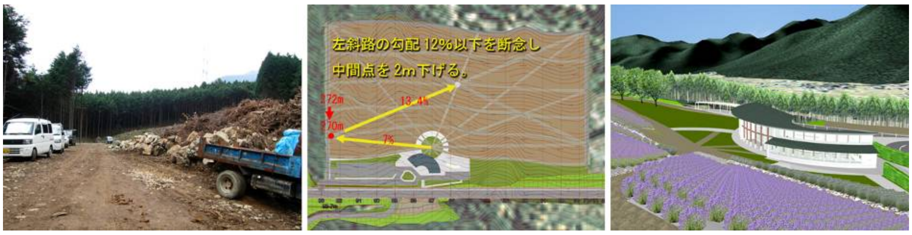

Figure 6. Lavender garden project.

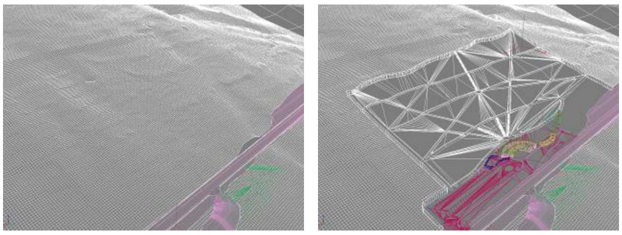

Figure 7. 3D model of lavender garden project (left: present condition, right: plan).

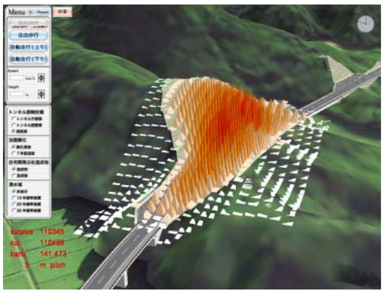

Figure 8. Application to other road design projects.

5. Conclusion and future work

In this paper, the 3D-VR system is extended and a soil calculation function in which high precision calculation and visual expression are possible is developed. The system was applied to actual design projects and it was found that the method of gradually reducing mesh size according to the contents of study was effective in the design process.

In future work, it will be necessary to consider the problem of who makes 3D data. In this research, the authors' designer group created all the 3D data of the present condition and the plan proposal. At present, the designer group which uses 3D data in the design process is still restricted. If role assignment is organized in which the government, which is the primary contractor, offers the present data, and a designer group creates only the plan proposal, the time and effort of data work of the designer group can be reduced, which will enable more designer groups to create 3D data than is possible at present. For that, it is necessary to consider the role assignment of data work etc.

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