# Development and Evaluation of a Close-range View Representation Method of Natural Elements in a Real-time Simulation for Environmental Design

## *Shadow, Grass, and Water Surface*

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*In this research, a close-range view expression method used in real-time simulation based on virtual reality technology is developed for environmental design evaluation. After describing the purpose and accuracy of representation, the problem of natural element representation in a close-range view, which has not been developed yet, is clarified. Next, the close-range view expression method of shadows, grass, and water surface is developed. Furthermore, the developed method is applied to a number of actual environmental design projects and frame rate measurement and user evaluation are performed.*

***Keywords:*** *Environmental Design; Real-time Simulation; Virtual Reality; Consensus-building; Representation of natural elements.*

### Introduction

In recent years, the real-time simulation method based on Virtual Reality (VR) technology has been used in the environmental design field, which is a field in which a landscape is created as a tool for study and communication among stakeholders (Fukuda, 2003). Stakeholders include specialists such as architects, and non-specialists such as local residents. Using the real-time simulation method, stakeholders can understand a design proposal more intuitively. In addition, this method provides interactivity, which enables stakeholders to move and study a viewpoint and a design plan in real time. Its validity as a landscape evaluation tool is accepted (Yeo, 2004).

In the real-time simulation method, a rendering speed of more than 10fps (frames per second) is needed (Shibano, 1994) and it is necessary to work on content to keep the amount of data small for high-speed rendering. If attention is paid to the representation method in a real-time simulation, realistic representation of the same quality as still pictures and animations created with 3-Dimensional Computer Graphics (3DCG) is possible for artificial elements. Although detailed rendering is needed in close-range view representation, it is inadequate for natural elements. This research aims at clarifying the subject of close-range view representation of natural elements in a real-time simulation, and also develops the representation method of shadows, grass, and water. The developed representation method is applied in actual environmental design projects, and is evaluated.

## Representational purpose, accuracy and problems

An environmental design process needs to envisage the landscape to be created (Sasada, 1999). Therefore, it is important to build a consensus of stakeholders' opinions about the completion image of a design at various levels, from the whole to details. Generally, the process of consensus-building is carried out by a series of communications which repeat the design proposal by the specialists and state the stakeholders' reactions to it. For smooth communication, it is necessary for specialists to express their ideas intelligibly, even to non-specialists. To put this another way, intelligibility combined with ease of understanding is needed. That is, gaps in understanding of stakeholders must be kept to a minimum. If there is a gap in understanding, even if consensus-building is achieved at a design study meeting, the landscape that is finally created is not what the stakeholders desire. Therefore a real-time simulation method is being developed, featuring interactivity and equipped with real-time nature representation (which is a feature that still pictures and 3DCG animations do not have) as the visual expression method, which should reduce gaps in understanding more effectively.

Next, the content and accuracy which should be represented, and present still picture and animation by 3DCG and a present real-time simulation consider a possible expression. The objects for representation in an environmental design are roughly classified into artificial elements and natural elements. Moreover, the contents which should be expressed differ according to the distance from the viewpoint, i.e., a close-range view, a middle-range view, and a distant view. In a close-range view (from viewpoint up to 360m away), a degree of accuracy which can enable viewers to recognize details, such as form, color, and textures of the object composition element is sought. In a middle-range view (from 360m to 4.4km), although detail is not recognized as in a close-range view, a level of accuracy which enables the viewer to discern individual object outlines and an object's position is sought. In a distant view (beyond 4.4km), although the outlines visible in the middle-range view cannot be recognized, the accuracy as which those groups grasp the skyline formed with the sky is sought.

With regard to representation of still pictures and by 3DCG animations, representation which is realistic for natural elements such as water and trees, and artificial elements such as roads and buildings, is realized by a plant 3D form generation algorithm, advanced optical simulation technology, etc. On the other hand, if representation of a real-time simulation is considered, realistic representation of artificial elements is possible by using texture mapping as with still pictures and by 3DCG animation. However, in the close-range view that requires detailed rendering, representation of natural elements is inadequate. For example, in representation of a shadow, representation of the exact form of a shadow and the darkness projected by the sun is needed. In order to express a shadow in the present real-time simulation system, it is necessary to carry out operation processing, using the CPU, of the process of judging the portion by which sunrays are intercepted, rendering a shadow on the intercepted portion and being crowded into it,. Consequently, since the rendering load is large, it is common to omit this. Moreover, in a plant representation, representation which can show even the form and textures of the leaves and branches used as the composition elements of trees, grass, or a flower is needed. In the present real-time simulation system, since the grass, which has fine composition, is expressed by texture mapping, it does not serve as a three-dimensional representation, but remains in a superficial representation. Next, in the representation of water, representation including reflection or refraction is needed, including elements such as brightness, fluctuations of the water surface, and reflected objects at the waterside. In the present real-time simulation system, since expression is done by texture mapping, textures including reflection or refraction of water are not expressed (Figure 1).

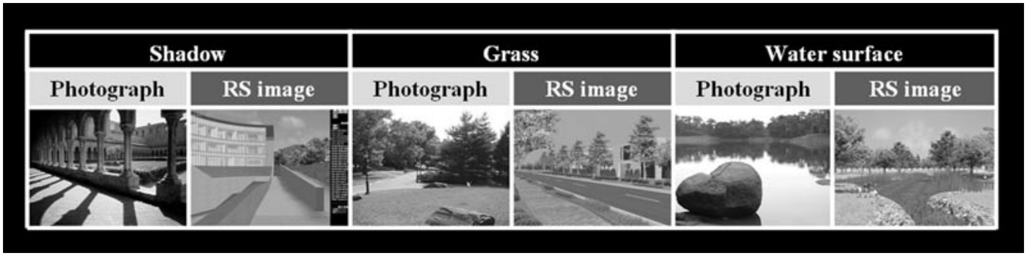



*Figure 1*
*Comparison of the photograph and a real-time simulation representation (shadow, grass, and water surface).*

## Development of a close-range view representation method of natural elements

This research develops an expression method of shadows, grass and water surfaces, which are important elements in an environmental design. In order to utilize a real-time simulation system in an environmental design process, in addition to realization of real-time rendering of more than 10fps, all stakeholders should be able to operate the system easily, and a graphical user interface in which interactive operation is possible is required. Furthermore, in order to use real-time simulation content in a design study meeting, after determining the design proposal shown at the meeting, it is necessary to make the content. Therefore, development conditions are sought that the contents creator who is the shortest possible development period (even if long about several weeks), and does not have advanced systems development capability can also make. In order to fulfill such conditions, the following hardware and software were adopted in this research. The hardware was a note PC (Pentium Processor 2.1GHz, 1GB RAM, 64MB VRAM). Software was VirtoolsDev3.0 of VirtoolsTM whose API is DirectX9.

### Shadow

For shadow representation, two functions are required; the movement of the light source in the same way as the solar orbit and the rendering of shadows. The movement of the light source draws an orbital equation from a solar position function and moves the light source using this equation. There are two methods of carrying out the rendering of shadow in real-time; the shadow volume method and the shadow mapping method. Since the shadow mapping method performs cover judging for each pixel, it can respond to an object which has been subject to texture mapping with the alpha channel, such as tree data. However, the shadow mapping method has the fault that calculation speed is slower than the shadow volume method. Therefore, we considered using the shadow volume method for almost 3D data, and the shadow mapping method for tree or human data. The real-time simulation flow of a shadow is shown in Figure 2.

### Grass

The shader programming function of GPU using HLSL (Microsoft Corporation, 2006) is applied. In the shader program used for representation of grass, some special processing routines are added to the

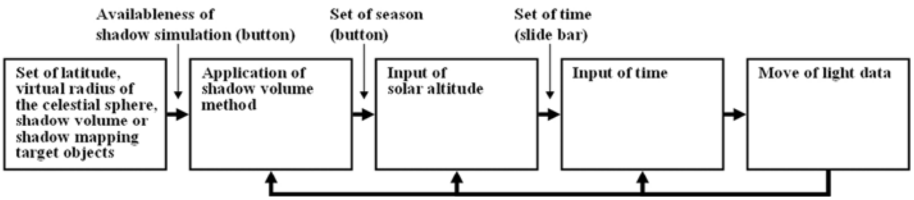
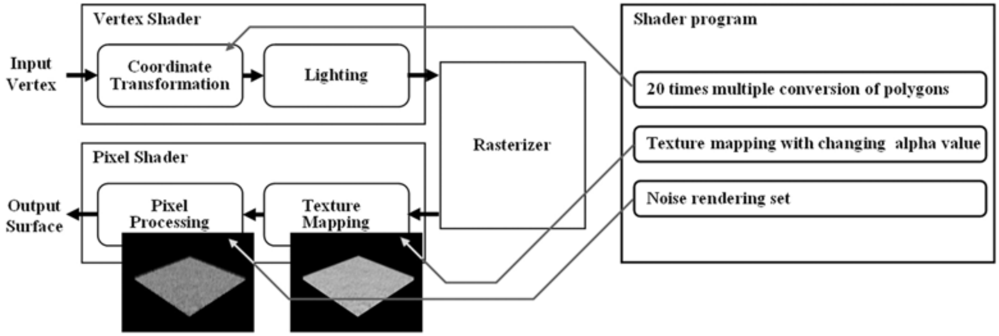



*Figure 2.*
*Real-time simulation flow of a shadow.*

Figure 3
Real-time simulation flow of a grass.




real-time rendering algorithm. The output before adding processing is the representation of a superficial polygon. First, in the process of vertex shader coordinate conversion, processing is performed that draws the original polygon up to a screen in piles 20 times in the normal direction of a polygon. Next, in texture mapping of the pixel shader, a texture is mapped to each polygon, raising the alpha value. By this processing, although it was a surface object without the thickness of one sheet in the stage of vertex input, it is thick and the upper part can be displayed as a solid with small density. The interval of the polygons at the time of rendering in piles 20 times is changed. Then, in the process of pixel processing, the portion to be rendered can be specified in the shape of a spot by mapping the noise texture. Thereby, an object with the textures of the shape of hair, such as grass, can be rendered. By this technique, plural thin polygons can be expressed as a thick object. The real-time simulation flow of a grass is shown in Figure 3.

## Water surface

In representation of the water surface realistically, it is necessary to reproduce two elements, reflection and refraction. However, if exact optional calculation of refraction or reflection is performed, a real-time simulation will become impossible. Therefore, using the GPU rendering method, refraction and reflection are performed with pseudo-representation and an attempt to produce realistic water surface representation is made. First, rendering is performed to ob-

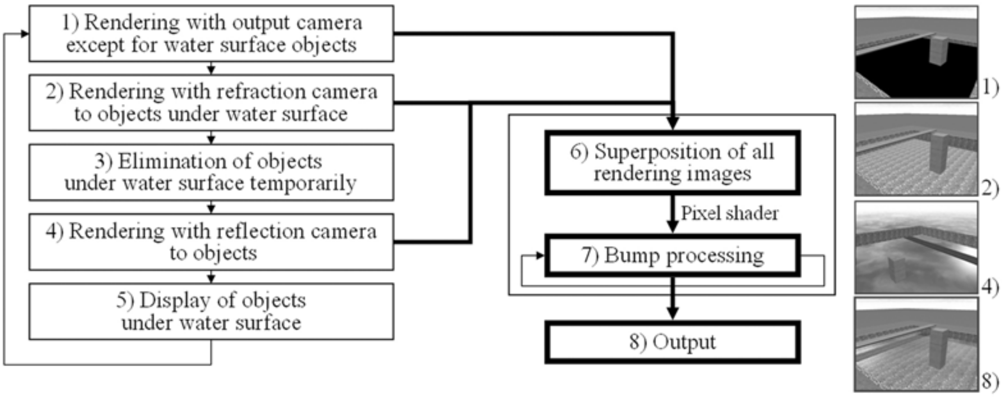



Figure 4
Real-time simulation flow of a water surface.

jects other than the water surface. Next, the texture picture for reflection is created. A virtual camera is set as the position which becomes symmetrical as an axis about the water surface to a rendering camera, and the objects above the water surface is rendered. The obtained picture is compounded with the picture under the water surface which is rendered by the rendering camera. Bump mapping processing is carried out to the picture, and a final rendering picture is outputted. The real-time simulation flow of a water surface is shown in Figure 4.

## Evaluation of the developed method by application in real environmental design projects

### Lavender garden project in Taka-cho, Hyogo

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 facilities. 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) of a lavender garden, and a landscape study of the whole plan including buildings and roads, etc. using the real-time simulation system (see Figure 5). Regarding the design proposal for rest facilities, in order to carry out a detailed study, exact 3D modeling was performed based on drawings. Furthermore, texture mapping of the finishing material was carried out, and a highly realistic representation was made. It was difficult not to obtain reality sufficient in representation by mapping which is the conventional method when a study by grass greening is performed about the facility circumference, but to, carry out the image share of the contrast nature of grass, and a building and a concrete pavement side on the other hand. The essence of an environmental design is to take the landscape-harmony with the surrounding environment into consideration, and representation of the circumference environment was called for with a level of reality comparable to the rest facility, which was an artificial element. With regard to the representation of grass, an improvement in the reality of the close-range view representation was aimed at using the representation method developed by this research.

The new representation method containing a parking lot and the slope of a road about study range 1ha was applied, and representation conducive to study was secured (see Figure 6). When the change of a frame rate was measured, the fps before application of the developed representation method was found to be 30.8, and after application it was 30.1. The influence on frame rate was about 2 %.

| application before(1) | application after(2) | variation (2)-(1) | decreasing rate((2)-(1))/(1) |
|---|---|---|---|
| 30.8fps | 30.1fps | -0.7fps | 2.3% |

*Table 1*
*Change of the frame rate by application of the developed grass representation method*

### Tosa road project in Kochi

This is a roadside development project accompanying the Route 56 Tosa national-road project. The project is advancing with collaboration between local residents and the Ministry of Land, Infrastruc-

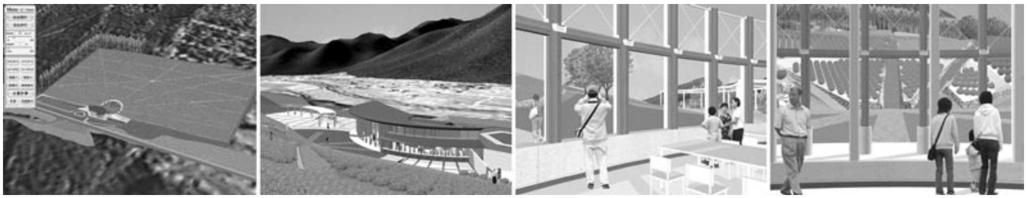


*Figure 5*
*Lavender garden project (Real-time simulation screenshot image).*

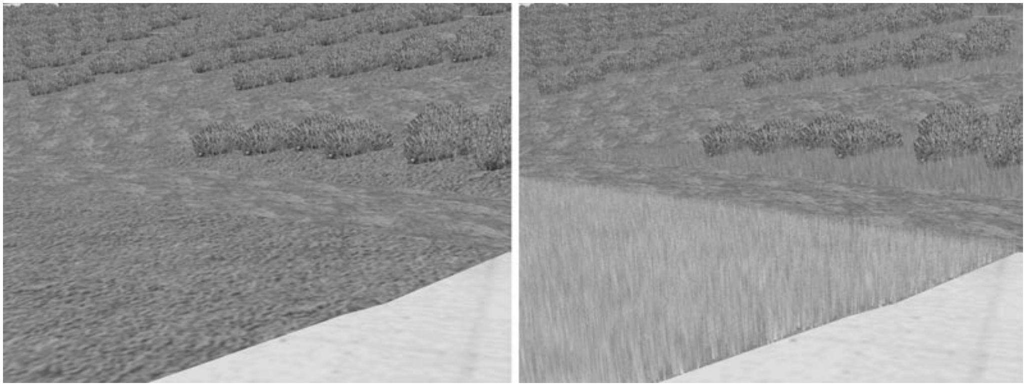


Figure 6.
Representational comparison (left: before application of the developed grass representation method, right: after application).

ture and Transport and the municipal corporation, which are the primary contractors. The design team to which the authors belong studied the roadside development plan through a workshop with the primary contractor, NPO, and the local residents. The workshop considered about 1.1km of sections of this project. In the workshop, a promotion method that considered residents' opinions positively was tried by a designer who created a design proposal in real time based on the opinions of residents, and then expressed this on a real-time simulation system. With regard to the climate characteristics of the project site, it is a place where sunlight is very strong. The assessment of average daily traffic density of the newly planned road is 13,000 vehicles or more. Furthermore, there are also many elderly people among the roadside residents. For these reasons, the provision of rest spaces for crossings and sidewalks was demanded by residents in the workshop. The designer team considered these requests and studied the design proposal of roadside trees. One request was that when presenting a design proposal using the real-time simulation system, the residents should be visually shown what the shadows thrown by the trees would actually look like. Then, changes in season and time were expressed by changes of the shadows of the roadside trees using the representation method developed by this research.

As a result of measuring the frame rate it was found that the rate after the shadow display was 13.1fps while before the shadow display it was 33.1fps. As described in Chapter 3, the shadow mapping method is used for shadow generation of tree data. It has checked that big influence came out of this method to a frame rate as a result of measurement.

Table 2
Change of the frame rate by application of the developed shadow representation method (shadow mapping method)

| application before(1) | application after(2) | variation(2)-(1) | decreasing rate((2)-(1))/(1) |
|---|---|---|---|
| 33.1fps | 13.1fps | -20fps | 60.4% |

Since improvement in the frame rate is aimed at, it is possible to reduce the resolution of shadow mapping. The result of measurements is shown in Table 3. When reducing shadow map size to 256 pixels from 512 pixels, improvement in the clear frame rate through load reduction of shadow map creation is found. However, when reducing picture size from 256 pixels, the frame rate falls. Although the shadow map creation load is reduced by the decrease in the number of pixels, if the size of a shadow map is smaller than a certain fixed value, since many pixels which cannot perform a cover judging on a screen will occur, it is believed that a processing time which complements these pixels is needed.

Table 3
Change of the frame rate by shadow map size

| shadow map size (pixels) | 512 | 256 | 128 | 64 |
|---|---|---|---|---|
| frame rate (fps) | 1.6 | 13.1 | 11.8 | 4.0 |

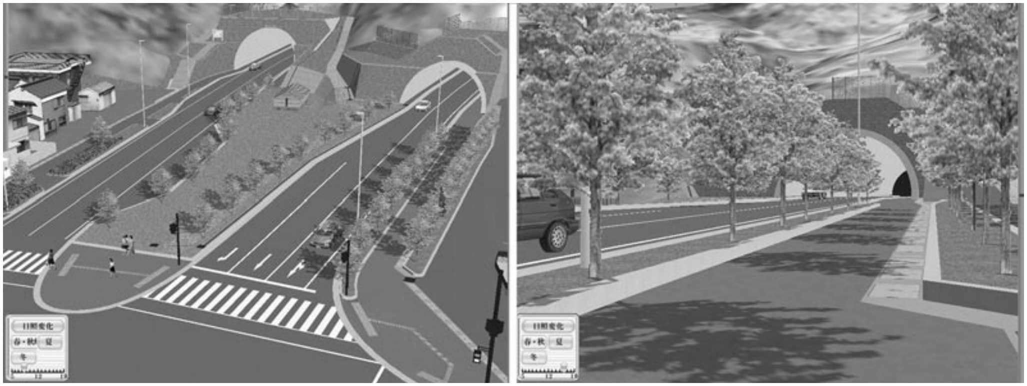


*Figure 7*
*Shadow representation of buildings, signals, and roadside trees (Real-time simulation screenshot image).*

Furthermore, the shadows of signals, telegraph poles, and buildings are displayed by the shadow mapping method, and the shadows of trees are simultaneously displayed by the shadow volume method (see Figure 7). The measurement result of the frame rate change from eye level is shown in Table 4. As compared with Table 2, a result which does not change mostly as compared with the case of only a shadow mapping method was brought so that clearly. A rate of 10fps can be secured in this way and it can be said that by using a shadow mapping method and a shadow volume method together it could be shown that representation and study of detailed shadow in close-range views containing buildings, trees, etc. are possible.

| application before (1) | application after (2) | variation (2)-(1) | decreasing rate ((2)-(1))/(1) |
|---|---|---|---|
| 32.9fps | 12.6fps | -20.3fps | 61.7% |

*Table 4*
*Change of the frame rate by application of the developed shadow representation method (both shadow mapping method and shadow volume method)*

**Park design project**

In order to evaluate the developed representation method in the contents of an actual project, a park containing a water surface of 200 $m^2$ was designed. Reflection and refraction of the water surface developed by this research were applied. Furthermore, in addition to the water surface, representation of the grass and shadows developed by this research was performed simultaneously (see Figure 8), and changes of the frame rate in the rendering from eye level was measured. The result of measurement is shown in Table 5. Although a big change appears to exist in the frame rate in the display of shadow using the shadow mapping method, 10fps, which is needed for interactivity where all representation is applied, is securable.

A questionnaire survey was conducted using these contents. This compared the representation method application after using a group of 20 persons comprising ten specialists in the environmental design field and ten non-specialists. Consequently, all 20 persons answered that the direction after application was a realistic representation. Compared with conventional representation, the representation level was better and the opinion that it was easier to understand the completion image of the environmental design was acquired.

## Conclusions and future work

In this research, firstly, the problem of natural element representation in a close-range view was clarified in a real-time simulation method used for landscape evaluation. Next, the close-range view expression method of shadows, grass, and water surfaces was developed. VirtoolsDev3.0 was adopted as a development platform. Furthermore, the developed

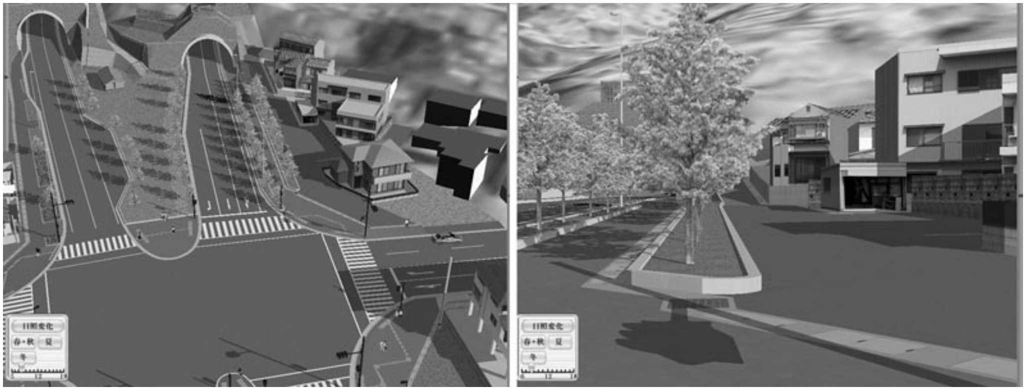


*Figure 8*
*Representational comparison (left: before application of the developed representation method, middle and right: after application).*

*Table 5*
*Change of the frame rate by application of the representation method*

| Representation of each element | un-display of grass, water surface, shadow | display of grass | display of grass and water | display of grass, water, shadow |
|---|---|---|---|---|
| frame rate (fps) | 24.8 | 21.4 | 21.1 | 15.6 |

expression method was applied to actual environmental design projects and frame rate measurement and user evaluation were performed. In frame rate measurement, although a comparatively large decrease in frame rate was seen in shadow expression by the shadow mapping method, it was verified that maintaining 10fps is needed. In user evaluation, all the members supported expression by the developed method. In future work it will be necessary to develop underdeveloped natural element expression methods, for example weather phenomena such as rain and snow, running water, and spray.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