# 3D ANALYSIS AND EVALUATION FOR LANDSCAPE IN NATIONAL PARK

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**ABSTRACT:**

The walking direction image sequences in Oze national park are taken by camcorder, and 2 kinds of analysis were performed by using the image sequences in this paper. One of the analyses is landscape evaluation was performed in the nature park by using fractal theory. This paper adopted 2 kinds of fractal analysis which were performed for each frame of the image sequences, and complexity of the landscape for each object or overall could be expressed respectively. Therefore, quantitative analysis for sequential landscape in the national park was realized. On the other hand, 3D measurement was performed for landscape materials in the national park which are herbaceous, tree, footpath, and so on. Generally, in order to perform 3D measurement by using digital images, stereo or triplet images by objects need to be taken. However, the taking images in national park can be performed at only limited positions on footpaths. Therefore, 3D measurement method by using walking direction images was developed. With these results, this paper propose a method of landscape preservation in the national park by landscape simulation which constructed by the 3D measurement data and the fractal dimension.

## 1. INTRODUCTION

In Japan, There are some nature parks in the mountain area around the country. These parks are valuable as walking and hiking place for many people who are not only keeping health but also enjoying the own view and landscape. In addition, some nature parks which have such landscape were designed as natural heritage; e.g. national monument or park, and the environments are preserved. The district of “Oze” which is located about 50km from Tokyo to the north is one of the popular nature parks in Japan. The Oze has many kinds of landscape which was constituted by forest, wild, marsh, lake and other unique natural materials. With such various and natural landscapes, the Oze was designed as the special natural monument of Japan (1960), the Ramsar Convention (2005) and national park of Japan (2007) respectively, therefore such natural landscapes are preserved more positively. In addition, almost footpaths in the Oze are set with boardwalks as a view point of environmental protection. Therefore, the landscapes for walking direction on the boardwalks are obtained mainly by visitors, and it seems that the features of the Oze are generated by the landscapes on the boardwalks. Furthermore, the landscapes are obtained with walking, and the changes of the landscapes can be seen as the sequence landscapes by the visitors.

In order to record such sequence landscapes easily, the walking direction images are taken by any cameras. Particularly, the camcorders can take the landscapes as image sequences, and the sequence landscapes can be recorded. Generally, such image sequences are used for subjective evaluation of the landscapes, however the landscape evaluation should be performed objectively.

With these circumstances, fractal analysis which can be calculated index of complexity for an image was performed for each frame of the image sequences. The fractal analysis was applied for some landscape evaluation fields, and it seems that also applies to the nature landscape. This paper adopted 2 kinds of fractal analysis methods, and the sequence landscape was evaluated quantitatively by each methods.

On the other hand, 3D measurement for landscape materials was performed by using the image sequences. Generally, stereo or triplet images are needed for 3D measurement, nevertheless only the walking direction images were used for the measurement in this method. Furthermore, the measurement method can also perform interior and exterior orientation simultaneously; therefore non-calibrated camera can be used. Moreover, the 3D measurement data from this method were applied to landscape simulation by 3D modelling.

This paper investigates objective evaluation of nature landscape by using fractal dimension and 3D models.

## 2. OBSERVATION FIELD IN OZE NATIONAL PARK

In order to obtain the image sequences of walking direction, the observation with the camcorder was performed at 4 routes from A to D of these boardwalks. Figure 1 shows the observation routes. The walking route from “Yamanohana” is visited many number of people more than other gates of Oze national park. Table 1 shows outline of this observation.

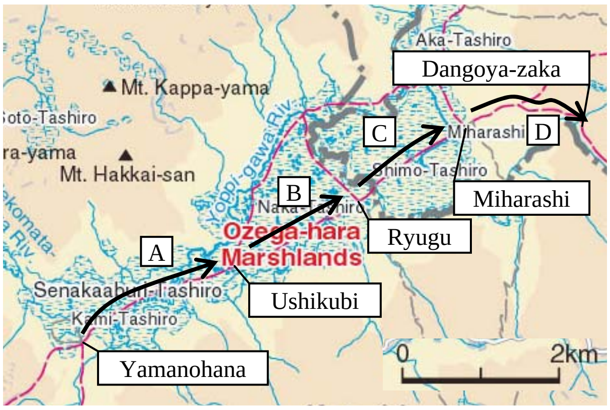



Figure 1. Observation routes in Oze national park

Table 1. Outline of observation

| | | |
|---|---|---|
| Date | Oct. 25, 2007 | |
| Time | 10:00 AM-12:00 PM | |
| Weather | Fine | |
| Route and Distance | A. Yamanohana-Ushikubi | 2.2km |
| | B. Ushikubi-Ryugu | 2.1km |
| | C. Ryugu-Miharashi | 1.5km |
| | D. Miharashi-Dangoyazaka | 1.5km |

## 3. OUTLINE OF THE OBSERVATION

The observations were performed by using the camcorder and GPS, and the routes were walked by an operator. Figure 2 shows the equipment of the observer. The camcorder was set at front of face, and visual angle of the observer and camcorder were adjusted to become almost same. On the other hand, each position for the walking was obtained by using GPS, and the positions and image sequences by the camcorder were synchronized. Table 2 shows major components of the camcorder and GPS.

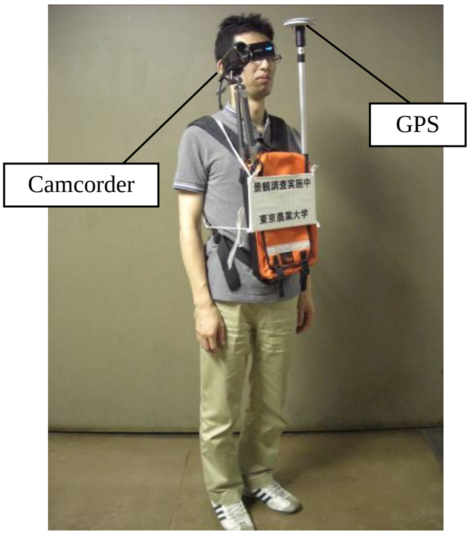



Figure 2. Equipment of observation

Table 2. Major components of equipments

| | | |
|---|---|---|
| Camcorder | Product Name | DZ-GX5300 (HITACHI) |
| | Number of Pixels | 640×480 (0.3MPixel) |
| | Focal Length | 6.1mm |
| GPS | Product Name | GIR1600 (SOKKIA) |
| | Receiving Frequency | L1:1575.42MHz |
| | Positioning Method | DGPS |
| | Accuracy | ±1m |

## 4. FRACTAL ANALYSIS

In order to evaluate the landscapes objectively, fractal analysis for the image sequences was performed. The fractal means a generic term of uncharacteristic figure, architecture, and other objects. The index of complexity for these objects is expressed by fractal dimension, and the dimension is calculated by the fractal analysis (Turner, 2001).

This paper investigates 2 kinds of fractal analysis which are box-counting and gray scale methods. The procedures of each method are as follows.

### 4.1 Box-Counting Method

The processing of box-counting is performed for binary images shown in figure 3. Firstly, a square mask which has only 1 pixel scans in the image, and numbers of religions which include black pixel is counted. Secondly, size of the square mask is increased by one pixel respectively, and repeats to become image size. Finally, a logarithm the mask sizes $r$ and numbers of religions $N(r)$ are calculated. Consequently, the linear approximation is performed like shown in figure 4, and gradient of the line means a fractal dimension. The fractal dimension by the box-counting is indicated by real number from 1 to 2.

The binary images which include feature objects as black pixels are analyzed by the box-counting method, and the feature objects should be extracted. Therefore, green (grass, leaf) and brown (trunk, dried grass) objects were extracted as the features by thresholding respectively. Figure 5 shows example of the feature extraction images.

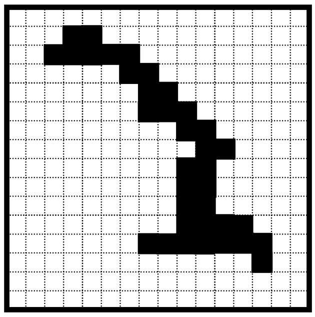


Figure 3. Example of binary image

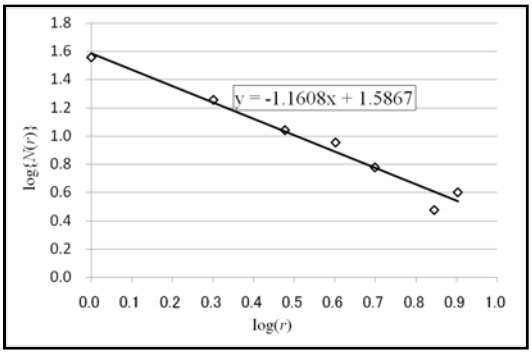
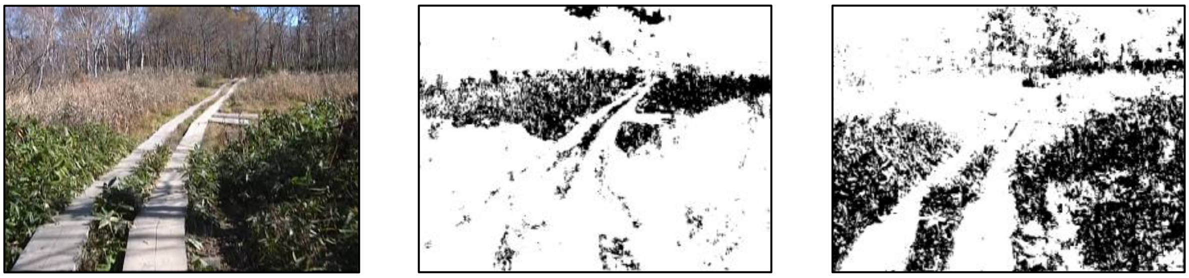



Figure 4. Linear approximation of box-counting



(a) Original (b) Brown extraction (F=1.565) (c) Green extraction (F=1.764)

Figure 5. Feature extraction images (F: Fractal dimension)

### 4.2 Gray Scale Method

The processing of gray scale method which uses gray scale images is also processed by using square mask which is increased by one pixel. Firstly, the gray levels of the four corners in the square mask are extracted, and subtraction value of max and minimum for the four gray levels *Id* is calculated. Secondly, number of pixels for a mask $n(r)$ is calculated expediently by using equation 1.

$$n(r) = \mathrm{floor}\left(\frac{Id}{r}\right) + 1 \quad (1)$$

The above processing was performed for all masks in the image, and average value of $n(r)$ is calculated as $n_a(r)$. Finally, the number of regions $N(r)$ is calculated by using equation 2.

$$N(r) = n_a(r)\left(\frac{S}{r^2}\right) \quad (2)$$

whrere $S$ = Number of pixels in image

Therefore, the linear approximation for $r$ and $N(r)$ is also performed, and fractal dimension can be obtained by above method. The fractal dimension by the gray scale method is indicated by real number from 1 to 3.
Figure 6 shows example of the images and its fractal dimension by gray scale method.

(a) Image at Ushikubi (F=2.320)

(b) Image at Dangoya-zaka (F=2.648)

Figure 6. Observation routes in Oze national park

## 5. 3D MEASUREMENT

The 3D measurement for each landscape material is performed by conjugated points for each frame of the image sequences. The image sequences are divided by fixed time span respectively, and processing of the measurement is performed for each time span. Following example shows each 8 seconds (240 frames) from the image sequences were divided and 5 frames from the 240 frames were extracted equally. Furthermore, image matching by Least Squares Matching (Gruen, 1985) and manual correction was performed for each neighbouring frames of the 240 frames consecutively (Kunii and Chikatsu, 2005), therefore 500 conjugated points were acquired. Figure 7 shows the extracted 5 images and conjugated points. The procedures of the 3D measurement are as follows.

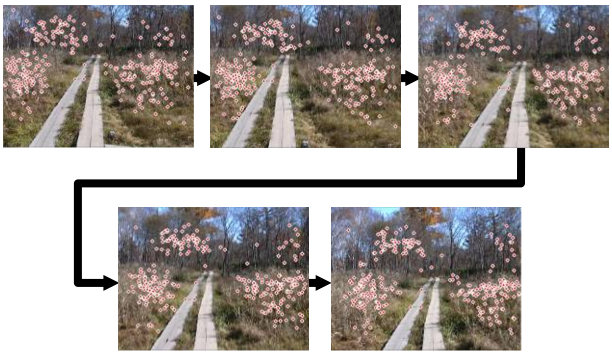


Figure 7. Extracted images and conjugated points

### 5.1 Relative Orientation

The 5 images were taken from column position like shown in figure 8, therefore the relative orientation in this method should be acquired relative parameters for all images (Atkinson, 2001). Figure 9 shows extraction and expansion of 1st and 5th images from figure 8, and details of the orientation are as follows;
Firstly, coplanarity condition for 1st and 5th images is derived as equation 3.

$$\begin{vmatrix} B_x & B_y & B_z \\ X_5 & Y_5 & Z_5 \\ X_1 & Y_1 & Z_1 \end{vmatrix} = 0 \qquad (3)$$

where $X_5, Y_5, Z_5 = $ 3D coordinate of $p_5$
$(X_5 = x_5,\quad Y_5 = y_5,\quad Z_5 = -f)$
$X_1, Y_1, Z_1 = $ 3D coordinate of $p_1$
(include rotation angle $\omega, \varphi, \kappa$)

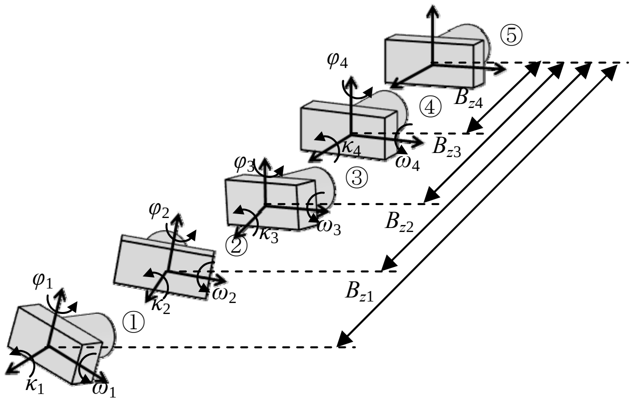



Figure 8. Relative parameters for column images

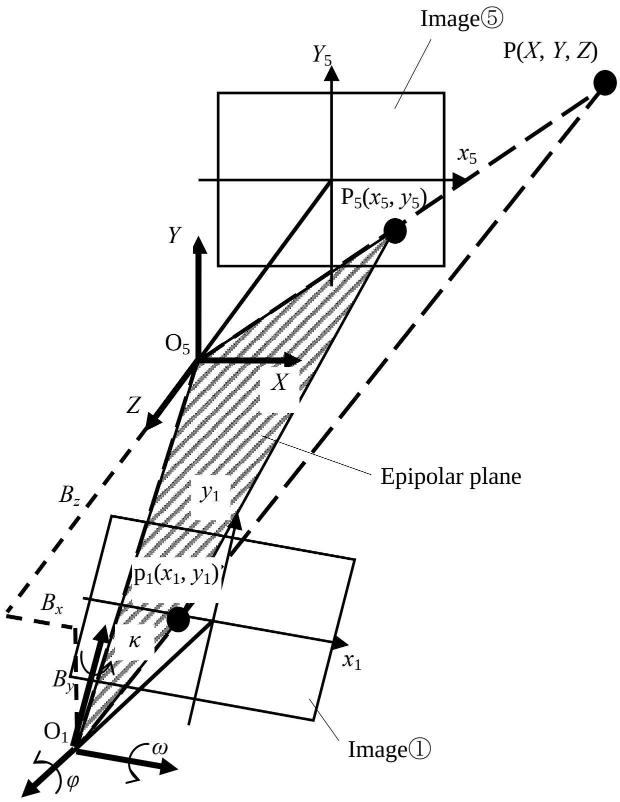



Figure 9. Coplanarity condition for column images

The unknown parameters of equation 3 are 6 parameters which are $B_x$, $B_y$, $B_z$, $\omega$, $\varphi$ and $\kappa$. Nevertheless, $B_z$ is calculated by using width of boardwalk (400mm), and other 5 parameters are unknown. The coplanarity condition is also derived by each pairing of images which fix 5th image consecutively; e.g. 2nd and 5th, 3rd and 5th, and so on. Furthermore, the interior parameters of the camcorder are also decided as unknown parameters, and these all unknowns are calculated simultaneously. Table 3 shows unknown parameters of the relative orientation.

Table 3. Unknown parameters of relative orientation

| Interior parameters (10) | | Relative parameters (20) | |
|---|---|---|---|
| Focal length(mm) | $f$ | Rotation angle | $\omega_2$, $\omega_3$, $\omega_4$, $\omega_5$ |
| Principal point(pixel) | $x_p$, $y_p$ | | $\varphi_2$, $\varphi_3$, $\varphi_4$, $\varphi_5$ |
| Scale factor | $a_1$, $a_2$ | | $\kappa_2$, $\kappa_3$, $\kappa_4$, $\kappa_5$ |
| Radial distortion coefficient | $k_1$, $k_2$, $k_3$ | Projection center | $B_{x2}$, $B_{x3}$, $B_{x4}$, $B_{x5}$ |
| Tangential distortion coefficient | $p_1$, $p_2$ | | $B_{y2}$, $B_{y3}$, $B_{y4}$, $B_{y5}$ |

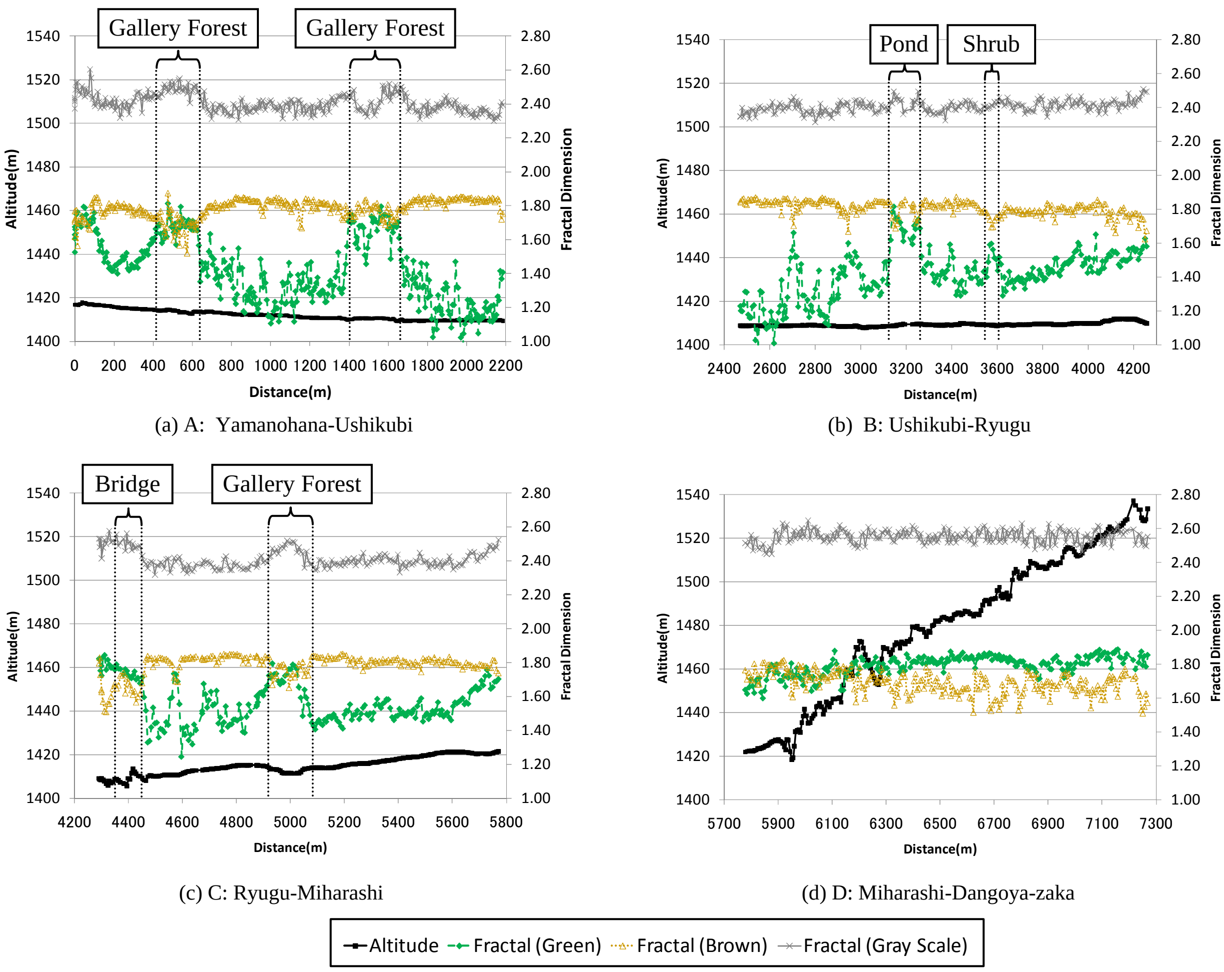
### 5.2 Calculation of 3D Coordinates

In order to acquire the 3D coordinates of each point, relative coordinates are calculated by colinearity condition using the relative and interior parameters. The 2 equations of colinearity condition can be obtained by one measurement point, and 10 equations are obtained by 5 images (2×5=10). Therefore, 3 unknown parameters of the relative coordinate can be calculated, and the relative coordinates for all measurement points can be acquired respectively. Furthermore, these relative coordinates are converted to actual 3D coordinates by using width of boardwalk, therefore 3D coordinates for all measurement points are acquired.

### 5.3 Final Orientation for All Unknown Parameters

As a final step of the 3D measurement, all interior and exterior parameters and actual 3D coordinates for all measurement points are calculated simultaneously as unknown parameters. Similarity with above orientation, 10 equations by colinearity condition can be obtained by one measurement point from 5 images, however 3D coordinates of the measurement points are also increased as unknown parameters. Therefore, number of measurement points should be obtained more than 6 points due to number of equations increase more than number of unknowns.

In order to evaluate the accuracy of the measurement method, 3D coordinate for 56 points on a test target were measured by total station, and image sequences for the target was taken during forward movement from 13m to 3m altitude. R.M.S.E. for *XY* and *Z* coordinate for 56 points were ±1.91mm and ±9.53mm. These accuracies only don't reach the results of bundle adjustment by using GCPs. Nevertheless, it can be said from the view point of easy operation that the 3D measurement is convenient method for the nature park by using only camcorder.




(a) A: Yamanohana-Ushikubi

(b) B: Ushikubi-Ryugu

(c) C: Ryugu-Miharashi

(d) D: Miharashi-Dangoya-zaka

Figure 10. Relation of distance, altitude and fractal dimension for each route

## 6. RESULTS OF ANALYSIS

The results of the fractal analysis and the 3D measurement for each observation route are as follows;

Figure 10 shows relation of distance, altitude and fractal dimension for each route. The fractal dimensions of route A to C were varied frequently at several points. The camcorder at such points could capture unique landscape materials which are pond, bridge, gallery forest and so on are shown in table 4. In addition, the changes in altitude for route A to C were about ±10m, and the undulations of the routes were confirmed almost flat boardwalk. Therefore, it is expected that the visitors can be enjoyed by various landscapes, and these are the safe routes for almost visitors due to flat boardwalk.

Moreover, the fractal dimensions of route D were varied smaller than the A to C. Therefore, the landscapes of route D are expected monotonously. Nevertheless, the altitude was continued to increase to the last point, and it seems that the hard route for unconfident visitors.

On the other hand, 3D data for each landscape material at some positions were measured, and 3D modelling was performed. The mainly landscape materials which are boardwalk, herbage, tree and so on were developed, and these materials were set at measurement position respectively. Figure 11 and 12 shows example of 3D model for landscape of Oze national park. For these 3D models, situations or conditions of the actual place can be understood easily.

Table 4. Images at feature points and results of analysis

| | A: Yamanohana-Ushikubi | B: Ushikubi-Ryugu |
|---|---|---|
| Image |  |  |
| Distance(m) | 1,619 | 3,159 |
| Altitude(m) | 1,410 | 1,409 |
| Main material | Galley forest | Pond |
| F.D.(Green) | 1.677 | 1.748 |
| F.D.(Brown) | 1.734 | 1.716 |
| F.D.(Gray Scale) | 2.466 | 2.469 |
| | C: Ryugu-Miharashi | D: Miharashi-Dangoya-zaka |
| Image |  |  |
| Distance(m) | 4,416 | 6.255 |
| Altitude(m) | 1,413 | 1,456 |
| Main material | Bridge | Forest |
| F.D.(Green) | 1.726 | 1.813 |
| F.D.(Brown) | 1.612 | 1.732 |
| F.D.(Gray Scale) | 2.502 | 2.588 |

(a) Image Sequences

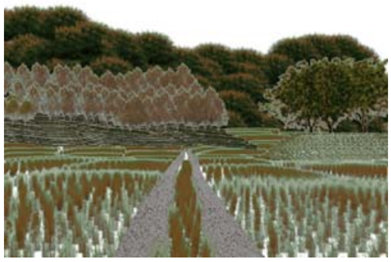
(b) 3D model

| Root | A |
|---|---|
| Distance(m) | 19–25 |
| Altitude(m) | 1,416–1,417 |
| F.D.(Green) | 1.700–1.693 |
| F.D.(Brown) | 1.707–1.696 |
| F.D.(Gray Scale) | 2.481–2.473 |

(c) Components

Figure 11. 3D modelling by image sequences and component for landscapes (A: Yamanohana-Ushikubi)

(a) Image Sequences



(b) 3D model

| Root | B |
|---|---|
| Distance(m) | 3,518–3,524 |
| Altitude(m) | 1,409–1,410 |
| F.D.(Green) | 1.359–1.375 |
| F.D.(Brown) | 1.807–1.790 |
| F.D.(Gray Scale) | 2.379–2.389 |

(c) Components

Figure 12. 3D modelling by image sequences and component for landscapes (B: Ushikubi-Ryugu)

Consequently, it seems that the information which is fractal dimension and 3D model will be provided for visitors, and these results will be become new objective index for understanding of condition, route selection and so on.

## 7. CONCLUSION REMARKS

This paper investigates the fractal analysis was performed for each frame of the image sequences, and 3D measurement for landscape materials was performed. As the results, fractal analysis can be calculated complexly of the landscape, and it seems fractal dimension will become index of landscape evaluation by objectively and quantitatively. Furthermore, 3D measurement by using only camcorder was realized, and 3D modelling for the landscape materials was become possible. Therefore, it is expected that the landscape simulation by using the 3D model can be applied. Consequently, it is expected that the fractal analysis and 3D modelling are useful for objective evaluation of the landscape.
As the further works, physical or psychological data during the walking will be also acquired, and the landscape in nature park will be evaluated more collectively.

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