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Analysing of fine root growth from digital images

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ABSTRACT

In this study, we developed new techniques that analyze continuous scanner image of roots in order to determine characteristic of fine root growth in a forest ecosystem. In our method, the growth of fine root is detected by temporal changes of pixel color information in the root images. Growing speeds and direction of fine root tips was extracted semi-automatically using commercial software.

KEYWORDS: fine root, image analysis , *Quercus serrata* , root growth, tracking

1. INTRODUCTION

Fine roots use significant amounts of photosynthesis products for their growing. Therefore, it is important to clarify the mechanism of fine root growth in order to understand carbon allocation of a tree and the mechanisms of carbon cycling in ecosystems. Recently, analyzing image of fine roots, which is taken by minirhizotron system, for example, has been proposed for studying growth of fine root. However, since the manual analysis of fine root image is normally very laborious and requires a lot of time, our knowledge about fine root growth are still poor. In this study, we aimed to develop an automatic system for analyzing digital images of fine root growth. Here, we report results from two experiments, 1) measurement of growing pattern of fine roots using commercial software, 2) making semiautomatic program for extracting fine root growth using changes in color information.

2. MATERIALS AND METHODS

The root image of oak (*Quercus serrata*) taken by an image scanner (GT-F650, Epson, Japan) was used for the present study (Dannoura et al., 2008). The CCD scanner was inserted horizontally in the soil and the images are acquired every 30 minutes automatically. The size of the image used for the present study is 216 x 297 mm (2448 x 3401 pixel) that corresponds to the A4 size paper. The total of the images are 283 frames, corresponding to nearly 140 hours. In these images, we selected a piece of root and cut out the image around the root, which is the size of 643x481 pixel, to analyze the growth of this with two following procedures.

Experiment 1. Extraction of growing pattern in a fine root
The growing of fine root tip was extracted manually by a commercial software (Move-tr/2D, Library, Japan), which is used for detection of two-dimensional moving object. Position of root tip was extracted and marked frame by frame. The coordinates, growing speed and direction were calculated and recorded. The manually detected data for fine root growth were used for

understanding characteristics of root growth pattern and evaluation of our semiautomatic extraction method shown in Experiment 2.

Experiment 2. Semiautomatic extraction of fine root growth

The detection of fine root tips and their movements from the image data is time-consuming and painful work. We have developed a following new method for measuring root growth semi-automatically and applied it for real measurement data.

(1) We manually marked root points, which were detected in visible fine root tips, in about 40 frames each.

(2) Search area for root was restricted in the rectangle regions, which was constructed by consecutive manually marked points as the diagonal vertex.

(3) In search area, candidates of root were extracted by points, which their colors were differed certain level from the soil color. Difference between soil and root was determined by Euclidean distance in the RGB color domain.

(4) Color changes in the points were caused by various reasons, reflection of light, small creature and so on. Discrete or small amounts of continuous points were considered as noises and removed them.

3. RESULTS AND DISCUSSION

The growth of fine root selected in the images kept almost same direction during the experiment. However, on fifth day, it was found that the direction was affected by a change in soil condition, maybe hardness of the soil. The growing rate (movement speed of the tip) was the fastest on first day, continuing same speed for further 3 days, and then, slowed down on the fifth day, probably because of the same reason with the growth direction. Additional analysis using other fine roots and images will be necessary for making a mathematical model of general fine root growth, which will enable us predicting past and future behavior of fine roots under various environmental conditions.

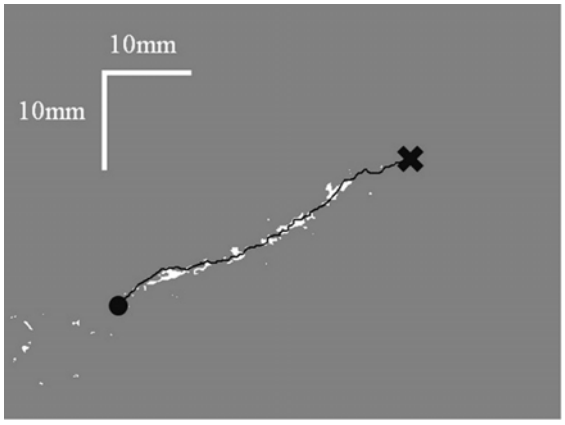

Figure1. Fine root part which we extracted by experiment 2 and the trace of the fine root that we pointed by experiment 1.

The extraction of fine root dynamics was successful and the accuracy of extraction of the fine root has increased by the removal of background noise of the soil. We confirmed that the extracted fine root dynamics in experiment 2 was almost same with the one extracted manually in experiment 1 (Figure 1). In this experiment, however, there are still some noises caused by the changes in soil property, environment condition, soil animals and so on. These unnecessary components make difficult to track the movement of root tip precisely. Additional information such as behavioral pattern of fine roots might be important for tracking fine root behavior individually.

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