PHOTO-REALISTIC MODELING OF TREE ROOTS

Jing-Yuan Li[1], Dong-Huang Li[1], Kai-Jie Yang[1], and Walter Chen[1*]
[1] Dept. of Civil Engineering, National Taipei University of Technology
1 Sec. 3 Chung-Hsiao E. Rd., Taipei 106 Taiwan
Email: x0930578397@gmail.com, alex03308@gmail.com, kj717057@gmail.com, waltchen@ntut.edu.tw

KEY WORDS: Tree roots, 3D models, photographs

ABSTRACT: Tree roots are a vital part of a tree's anatomy as well as an ecosystem. Increasingly, tree roots are linked to providing anchorage for soils and stability to slopes. Both shallow landslides and surface erosion can be reduced by planting trees and seeding grasses. For the sake of visualizing roots to study their structure, we devised a method of building 3D models of tree roots using digital cameras. Both above-ground and below-ground roots were used to illustrate the procedure. Although compared to other objects (such as buildings), roots are much smaller and much more difficult to capture in pictures, we were able to show that the resulting models are both photo-realistic and accurate in dimensions. These successes point to the new possibilities and challenges of future research.

1. INTRODUCTION

Tree roots are a vital part of a tree's anatomy as well as an ecosystem. Increasingly, tree roots are linked to providing an anchorage for soils and stability to slopes. Both shallow landslides and surface erosion can be reduced by planting trees and seeding grasses. Since any difference in the shape and diameter of roots will perhaps affect their tensile strength and change the effect of soil reinforcement, it is important to be able to characterize individual roots by measuring not only the diameter of the roots, but also the overall shape and bend of the roots. Recent advances in 3D technology have greatly enhanced our ability to do exactly that. There are a number of methods to digitally reconstruct a real object. Laser scanning is the most precise one among the various 3D modeling technologies and has been shown to work in many applications (Chen et al., 2010; Tseng et al., 2013; Tseng and Chen, 2014; Wang et al., 2013). However, it is also the most expensive one. Low-cost alternatives are needed to reduce the cost of 3D modeling. These days, smartphones are cheap and ubiquitous. Therefore, we devised a method of building 3D models of tree roots using digital cameras (such as those found on smartphones) to take snapshot photos. This method not only removes the need for expensive equipment, but also dramatically reduces the training time of novice operators. It is ideal for the sake of visualizing roots to study their structure and replicating roots for laboratory experiments, such as centrifugal model tests. Both above-ground and below-ground roots were used to illustrate the procedure in the following sections.

2. STUDY METHOD

This study explored a method of creating virtual 3D models of tree roots. Miller et al. (2015) uses handheld cameras to estimate heights, diameters and volumes of trees in a nursery, but it did not include tree roots. The following sections describe the procedures we took to create 3D root models.

2.1 Surface Roots (Above-Ground Roots)

Sometimes portions of a few large roots at the base of a tree are exposed above ground. For these roots, we photographed the roots with the tree trunk and the ground around the base of the tree. A series of pictures taken around the tree with a high degree of overlap were necessary in order to build a virtual model.

2.2 Underground Roots (Below-Ground Roots)

Roots that are underground cannot be photographed directly. Therefore, we used roots that were extracted during field pull-out tests to take their pictures. Due to the difficulties of building 3D models of fine roots (detailed below), coarser roots were used and trimmed. The roots were very slim and small, unlike the man-made structures and other objects (Tseng and Chen, 2015; Tseng et al., 2015) that we have photographed before, making it difficult to take good quality photos and build a good model. We found that the scene's background color and the objects in a scene were especially problematic. When other objects were present in a scene, they tricked the camera into focusing incorrectly on those objects rather than on the roots. After a few failed experimentations, a special room with green background was set up to eliminate all unnecessary objects and to photograph the root correctly (as shown in Figure 1) for later model creation. A series of pictures were taken around the root at three different heights (shown with red arrows in Figure 2). The pictures were also taken from 360° to ensure a complete coverage of the root. For images that were too dark, more light sources were later added and additional photos were taken. To achieve the best results, plenty of pictures were needed with sufficient overlaps between adjacent photos (at least 50% was necessary).

Figure 1 Experimental set-up of the “green” room (for taking pictures of roots)

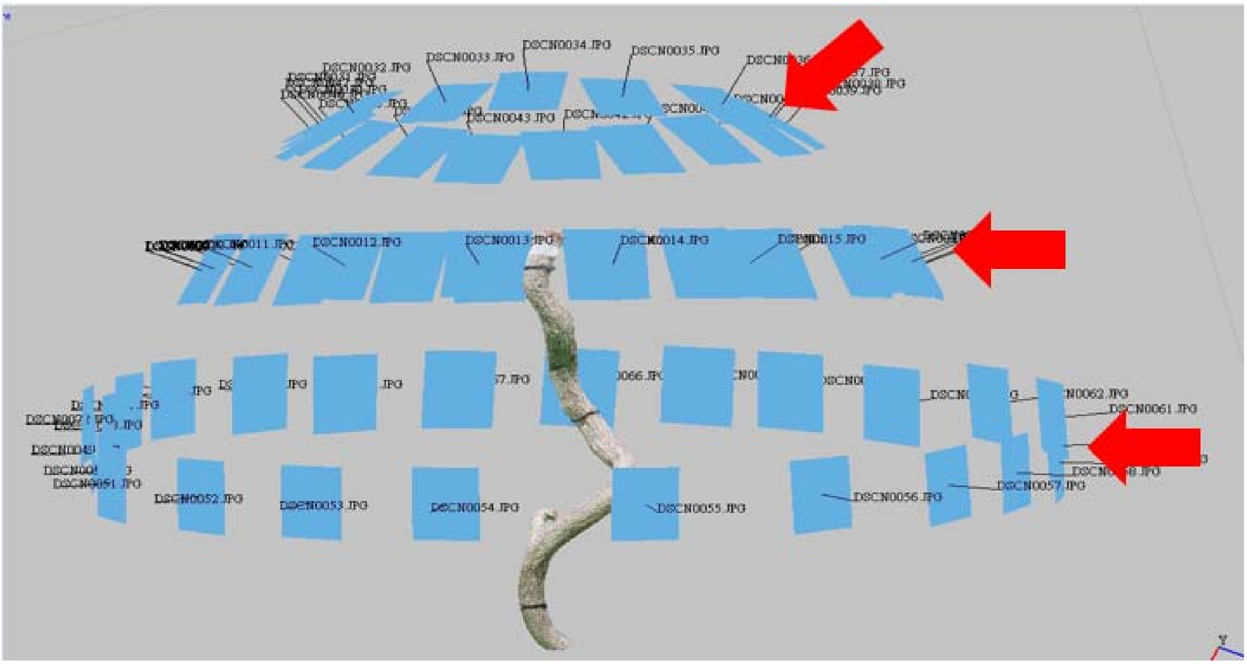

Figure 2 Photos were taken around the root at three different heights

3. ROOT MODELING

After taking many good quality photos, focused correctly on roots (both surface roots and underground roots), the images were imported into the PhotoScan software (by Agisoft) for image synthesis and model creation. To achieve a correct and precise matching of point clouds in the photos, sufficient overlaps between adjacent photos (at least 50%) were necessary. The following sections show the results of root modeling for 1) surface roots and 2) underground roots.

3.1 Surface Roots

To make the virtual models of surface roots, we photographed several trees in the Daan Forest Park (or Da-An Park) located near downtown Taipei. The tree roots were photographed with the bottom of the tree trunk and the surrounding ground. Many photos were taken to ensure at least a 50% overlap. The photos were imported into the PhotoScan software to match point clouds and model creation. The schematic diagram of the process of photo taking is shown in Figure 3. Figure 4 shows a final virtual model of one of the trees. As can be seen from Figure 4, because of the size of the tree, matching point clouds and generating a virtual model for surface roots was straightforward and successful. The model looks realistic. Mismatches and imperfections in the model were very few.

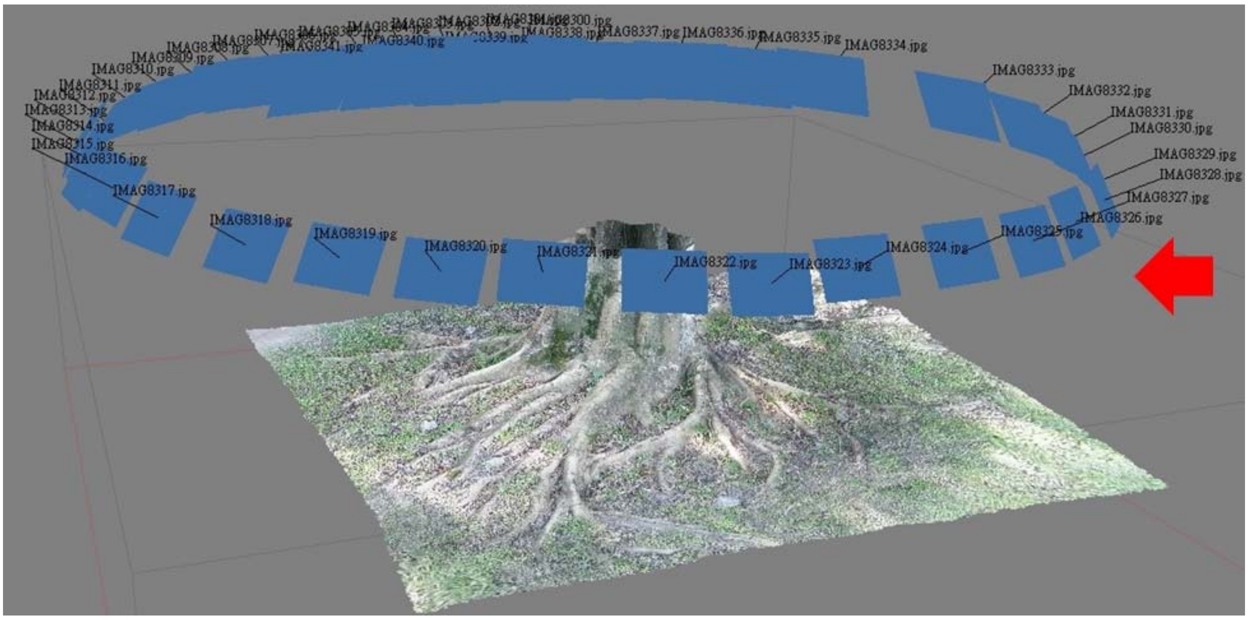

Figure 3 Schematic diagram of locations where photos were taken

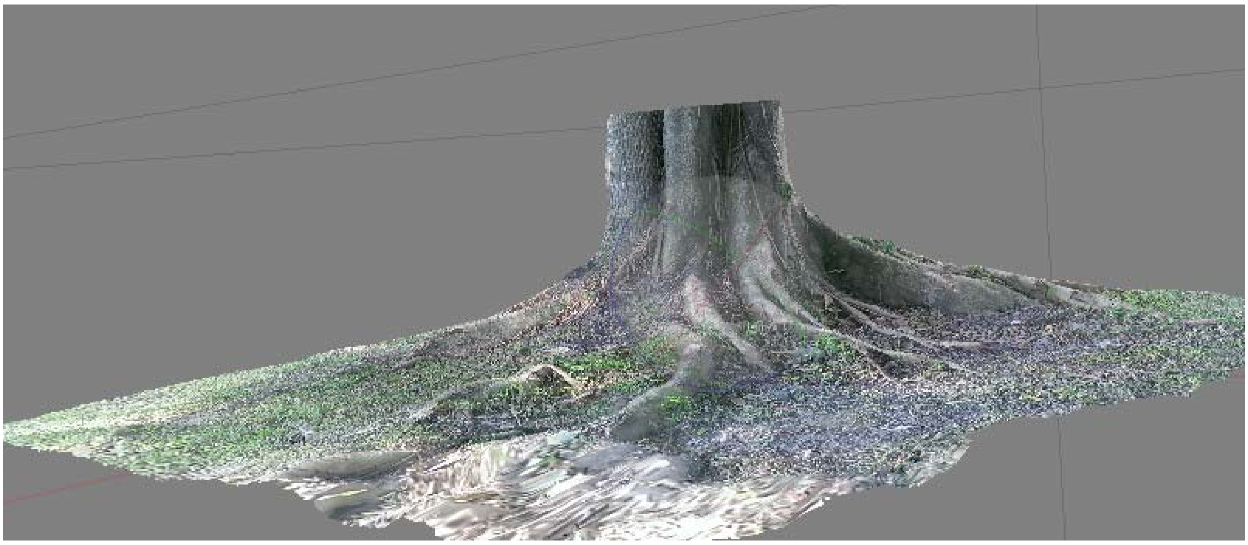

Figure 4 Virtual model of surface roots of a tree in the Daan Forest Park (or Da-An Park) located near downtown Taipei

3.2 Underground Roots

Here underground roots refer to the roots that were extracted during field pull-out tests. Because the object (a root) was very small in comparison to the room, we took pictures in an especially set-up “green” room (as described earlier) and we improved the success rate by cropping out and removing the backgrounds from each of the images. Figure 5 shows the detailed workflow of the model creation of a root. First, images of the root were taken in the “green” room. Then, the background was removed digitally before being imported into PhotoScan. The software analyzed the characteristic feature points of each photo and matched them to those of other photos to form a 3D virtual object. The model consisted of a dense point cloud as shown in Figure 5. Then, meshes were created, and texture was pasted onto the root model.

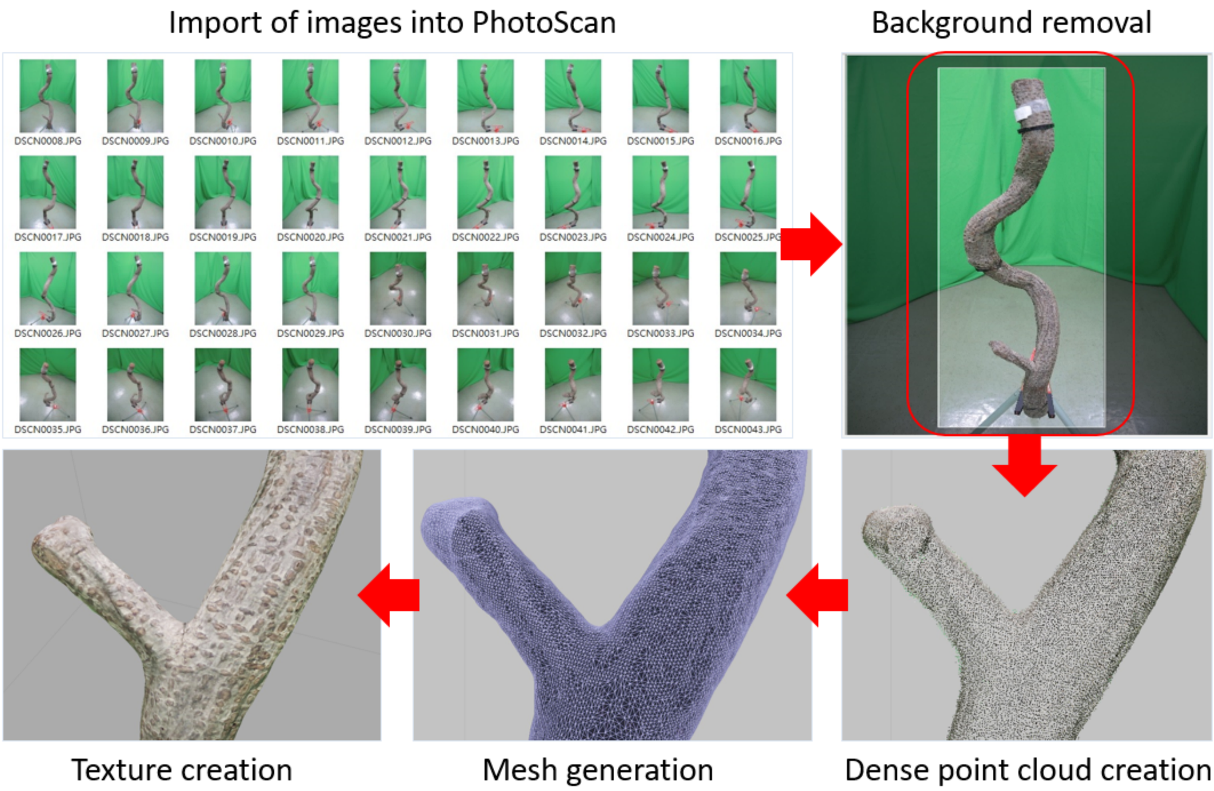

Figure 5 Workflow of a root model creation

4. RESULTS AND DISCUSSION

A lot has been learned from building root models. The following discusses the successes and failures of this experiment.

4.1 Successes

Figure 6 shows the comparison between a real root and a virtual model of the root (left half of Figure 6). The result was very satisfactory. Even after a portion of the root was enlarged (right half of Figure 6), the texture of the model still looked very realistic. There were no noticeable mismatches and imperfections in the model.


Figure 6 Real root vs. virtual root model (realistic texture even after enlargement)

In addition to a realistic model, a dimensionally accurate model is also desired. In order to check the dimensions of different parts of the root model, we affixed a tape scale to the root (Figure 7) before taking the pictures. The resulting model was then outputted to a PDF file, in which the root model could be rotated 360^0, viewed, and measured. As can be seen from the results, although roots are much finer than trees (as the study done by Miller et al., 2015) and much more difficult to photograph correctly, we were able to build a good model that is very accurate in terms of dimensions and textures.

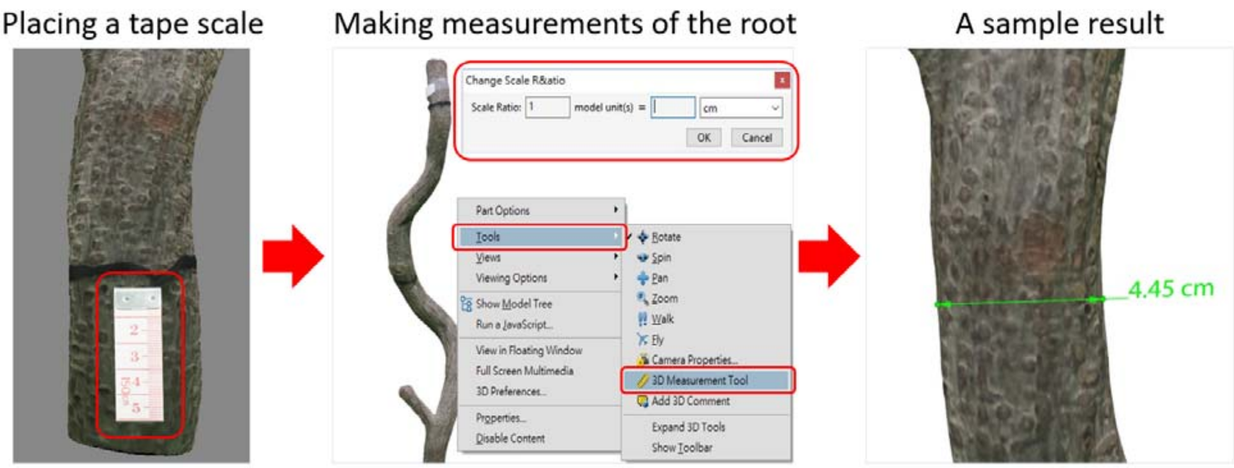

Figure 7 Root dimensions were measured from the model and found to be accurate

4.2 Failures

Before finally making realistic and accurate models of roots, we experienced quite a number of setbacks. Figure 8 is an example of one such setback. For this model, the initial impression of the model was good. However, after carefully examining the model, we noticed a hole in the model near the branching point of the root. We went back to check the original photographs, and were quite confident that we had taken every precaution to ensure that good photos were taken. Hence, we can only speculate that the problem came from the branching point itself. The software might have had problems matching point clouds of a complex surface with two facing surfaces similar to a “saddle point.” Another example of modeling failure can be seen in Figure 9. In this case, the root was incorrectly matched to the green background, and the root was broken in half. Nevertheless, this type of failure can easily be fixed by taking more close-up photos using a camera with a higher number of pixels. Finally, Figure 10 shows an example of a root with a greater complex root structure. This was hard on the software because the algorithm could not match the different parts of the root correctly. The resulting model had branches missing and an incomplete shape. This was also in part due to the shadowing effect of other branches, with the view being obscured by other branches when taking the photos.

Figure 8 A hole in the virtual root model near the branching point

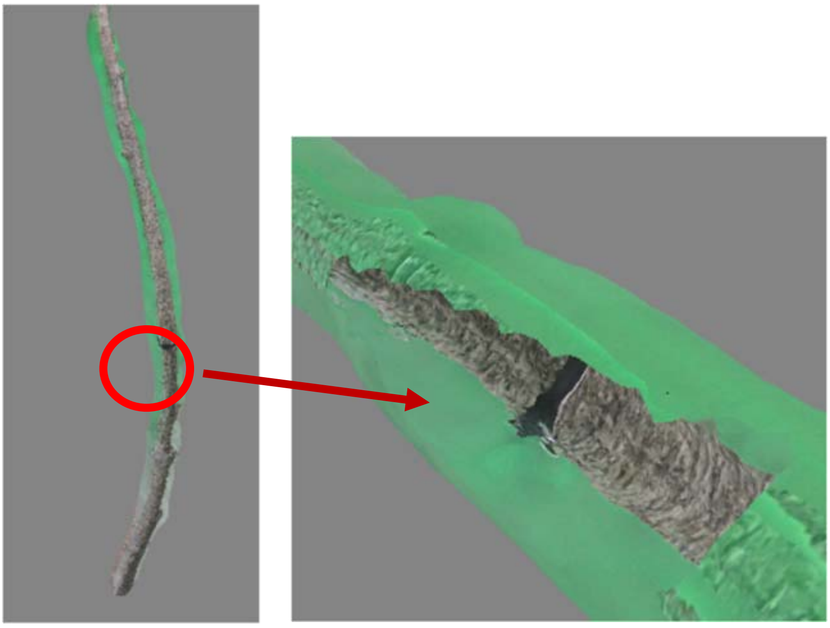

Figure 9 Failure of model creation with the root broken and mixed-up with the background

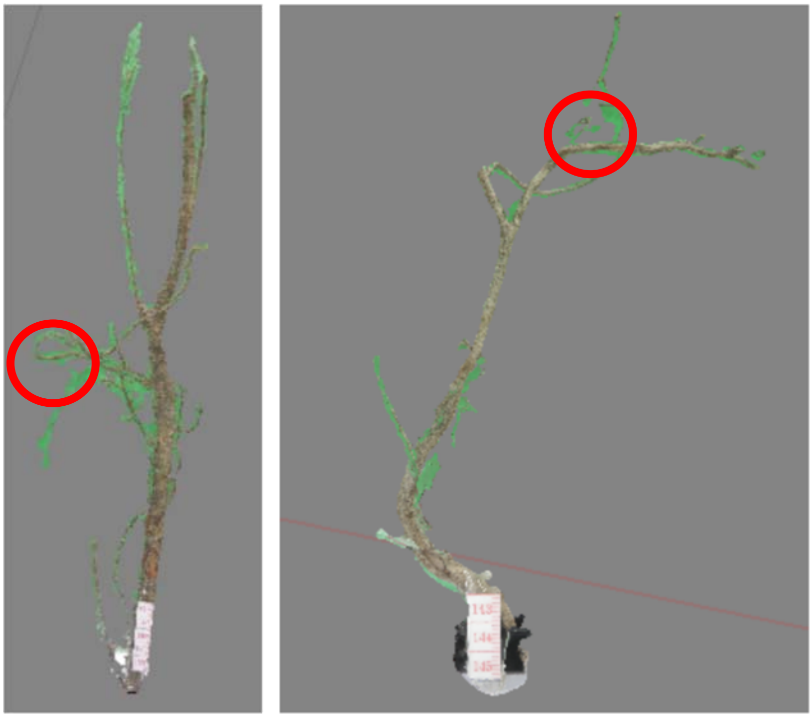

Figure 10 Incomplete shape and missing branches of root model due to the shadowing effect of other branches (view obscured by other branches in original photos)

5. SUMMARY AND CONCLUSION

In this study, we showed how to build virtual models of 1) surface roots, and 2) underground roots. We demonstrated that a realistic looking and dimensionally correct model of a root could be created using a series of photographs. Although compared to other objects (such as buildings), roots are much smaller and much more difficult to capture in pictures, we were able to show that the resulting models were photo-realistic and accurate in terms of dimensions. This success points to new possibilities for future research. The "virtual" root could be viewed and examined in greater detail. More importantly, the overall shape and bend of the root could be measured, and the root could be duplicated physically by 3D printers. If proper material with equivalent mechanical properties of the root can be used in printing, the 3D printed roots can further be used as subjects of laboratory strength testing or in centrifugal model tests. However, plenty of challenges do exist. Perhaps the greatest of these challenges is to overcome problems when there are branching points and many small branches to the root. Taking more close-up photos using a camera with a higher number of pixels is one solution, but it does not completely eliminate the shadowing effect of the other branches. More creative methods must be devised to find a satisfactory solution.

In conclusion, roots are surprisingly similar in their appearance and surface textures. Therefore, matching a root model was much more difficult than matching a building. The small sizes of roots also made it more difficult to build models than other ordinary-sized objects. We have shown in this study that a perfect model (in appearance and dimensions) can be built for a very simple root. However, more complex root structures still require studies of new photography techniques and better point cloud matching software algorithms.

References

Chen, W. W., Chang, C.-H., Chung, M.-K., Huang, P.-S., Chung, W.-T., Chung, Y.-L., and Chen, Y.-W., 2010. Landslide Site Reconstruction with Terrestrial Laser Scanning. In: the 18th International Conference on Geoinformatics (Geoinformatics 2010), June 18-20, Beijing, China.

Miller, J., Morgenroth, J., and Gomez, C., 2015. 3D Modeling of Individual Trees Using a Handheld Camera: Accuracy of Height, Diameter and Volume Estimates. Urban Forestry and Urban Greening, 14, pp. 932-940.

Tseng, Y.-T., Chou, H.-T., Jhan, Y.-K., Wang, J.-A., and Chen, W. W., 2013. Laser Scanning of the Award-Winning NTUT Green Gate. In: the 34th Asian Conference on Remote Sensing (ACRS 2013), October 20-24, Bali, Indonesia.

Tseng, Y.-T. and Chen, W. W., 2014. 3D Virtual Display of Green Gate of Taipei Tech. In: International Symposium on Remote Sensing (ISRS 2014), April 16-18, Busan, Korea.

Tseng, Y.-T., Yang, K.-J., and Chen, W. W., 2015. Virtual Model Creation using UAV Photos. In: the 36th Asian Conference on Remote Sensing (ACRS 2015), October 19-23, Quezon City, Metro Manila, Philippines.

Tseng, Y.-T. and Chen, W. W., 2015. Building Virtual Display Model from Snapshot Photos. In: the International Symposium on Remote Sensing (ISRS 2015), April 22-24, Tainan, Taiwan.

Wang, J.-A., Hsu, C.-K., Jhan, Y.-K., Chen, W. W., and Li, Y.-F., 2013. Scanning of FRP Passenger Bridge in Taijiang National Park. In: the 34th Asian Conference on Remote Sensing (ACRS 2013), October 20-24, Bali, Indonesia.