Article has been reported and discussed at 17th International Conference on Advanced Laser Technologies, ALT09,
26 September – 01 October 2009, Antalya/Turkey

TREE MAPPING USING A TIME-OF-FLIGHT 3D CAMERA

ARTTU V.H. OLLIKKALA, ANSSI J. MÄKYNEN
Measurement and Sensor Laboratory, University of Oulu
Technology Park 127, 87400 Kajaani, Finland

The purpose of this work was to study the use of a time-of-flight (TOF) 3D camera for tree mapping. The main idea was to measure a panoramic range image of the surrounding environment and use suitable segmenting algorithm to find standing sticks that were modeling trees in laboratory environment. Also real trees were measured in outdoor environment. The possible affect of different weather conditions to distance values measured by the 3D camera were also tested.

1. INTRODUCTION

The need to map trees is to make an inventory of the biomass of the forest and also to plan the tree harvesting. The conventional way to plan the tree harvesting is done with a human eye. To make the harvest planning more accurate, tree measurement system is needed. Previous researches have used 2D or 3D laser range finder (LRF) based measurement systems [1]-[2]. 3D LRF systems scan the desired area in a few minutes. However, they are expensive. TOF 3D cameras such as those manufactured by PMDTech, Canesta and Mesa Imaging, for example, are low-cost non-scanning (staring) range imagers based on CMOS imager chips that are capable of providing range images at full video speed. TOF offers a direct depth data acquisition, whereas LRF involves a great amount of computational power for the same 3D image. Because of the progress in TOF-vision systems, current 3D matrix cameras can be manufactured and be used for many applications such as robotic, automotive, industrial, navigation, safety, medical and multimedia applications. For all application areas new accurate and fast algorithms for 3D measuring and surface recognition are needed. In this paper a tree measurement, particularly the measurement of location using a TOF 3D camera in forest environment, is explored.

Fig. 1. PMD [vision]® 3k-S 3D video range camera

2. MEASURING SYSTEM

2.1 Equipment

The 3D camera (PMD [vision]® 3k-S) produces a two-dimensional range image by measuring 3072 distances simultaneously using a 64*48 pixel array [3]-[4]. The 3D camera has a field-of-view of 22.5°. The range image is generated by illuminating the entire field-of-view with sine modulated light produced by LEDs and measuring the phase delay of reflected light concurrently in each pixel. It attains a measurement speed of 10 to 25 frames per second and allows averaging and suitable filtering. Unambiguous measuring range is depended on the modulation frequency. For example using 20 MHz modulation frequency unambiguous measuring range is 7.5 m. More specific information on the characterization of the 3D camera has been done and published before [5].

The 3D camera was set on a pan-tilt unit, which main specifications are:

- Tilt range: -47˚ to +31˚ from level
- Pan range: ±159˚ (±180˚ with extended range mode enabled)
- Tilt resolution: 0,003˚
- Pan resolution: 0,013˚

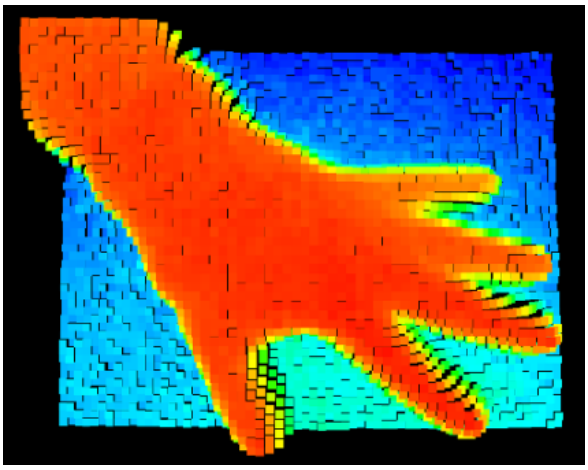

Fig. 2. Range image taken with the 3D camera.

2.2 Panoramic range image

To attain a panoramic range image, the 3D camera has to be panned around to 16 different angles to reach 360 degrees. The 3D camera was set on a pan-tilt unit to make possible accurate movement of the camera. Range images are stored to data files and later on processed. All the data handling is performed as offline computing on MATLAB.

A room was measured in ten different angles to test the panoramic range image construction. The point clouds, shown in Fig. 3, are represented from above and are measured using a field of view of 225 degrees. The point clouds formed from the single range images are fitting correctly to the geometry of the room.

2.3 Spatial resolution

The number of the pixels in the array of the 3D camera is relatively small when compared to common camera technology (usually 1000×1000 or even more). In tree map measurement low spatial resolution can make the determination of the tree location difficult when the trees are far away. It can also have an effect on the accuracy of the tree location. Especially low spatial resolution affects on the accuracy of the tree width estimation. However spatial resolution can be increased by overlapping two or more range images. In measuring situation this means that the angle of the 3D camera is changed horizontally less (half, one-fourth etc.) than the angle formed by single pixel. The disadvantage of the overlapping method is that it also increases the measuring time.

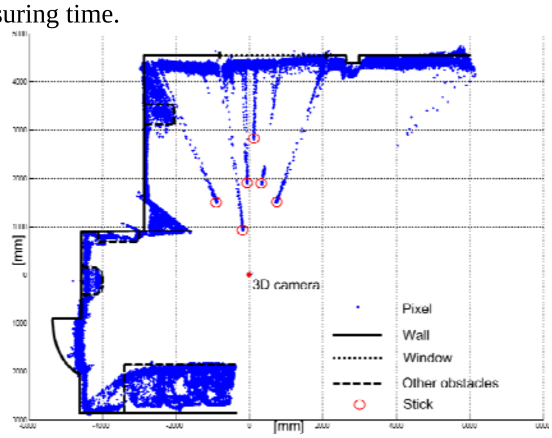

Fig. 3. A room measured with the 3D camera.

2.4 Segmenting algorithm

To detect right objects from the measured data, segmenting algorithm has to be used. The algorithm uses different kind of thresholds. The thresholds have to be set manually to fit to different measuring targets. The following threshold criteria were used:

- The distance difference of the adjacent points
- The maximum distance of a point to origin
- The distance of a point to another point
- The maximum width of a group of points.

3. EXPERIMENTS

In outdoor environment, measuring conditions are not ideal. Measurements done outside can be interfered by the weather (rain, snowfall, mist, sun etc.) and cause error to the measuring results. On the other hand the forest environment is its own problem. Well managed pine tree forests would be the easiest measuring target, but in the worst case the underbrush and branches make the tree measurement more difficult or even impossible.

3.1 Weather

The effects of the weather to measurements were tested in cloudy and sunny daylight, rain, snowfall and dark night time. Rain and snowfall effects were measured only in daylight. The 3D camera was pointed outside through a window. The target was placed outside to about 6 m from the 3D camera. The 3D camera and the target were kept ready for the measurements whenever the weather was right.

Measurements showed that distance results were a few centimeters longer on a rainy day than in clear weather conditions. This is due to reflections and refractions of light in drops of water. This kind of behavior can be compared to the effect of the multipath propagation of light. Snowfall didn't have any effect on the distance results. Although the 3D camera suppresses the background illumination, there was a slight, but almost insignificant, difference between the measurements made in the daylight and in dark conditions. In these measuring situations the sun was shining behind the target towards the camera. The worst case was realized when the target was enlightened by the sun. Error of tens of centimeters was induced to the distance values making the distance values longer.

3.2 Indoor

In the indoor setup 25 mm wide sticks were used to model trees. The sticks were placed approximately to the distances of 1 - 3 m from the 3D camera. This setup corresponds to 25 cm wide tree trunks on distances of 10 - 30 m.

The point clouds, shown in Fig. 4, are measured using field of view of 67.5 degrees. In Fig. 4.a), two range images have been overlapped, which means double amount of measuring points horizontally compared to Fig. 4.b). Corresponding segmented data is shown in Fig. 5. Measurements were done using six sticks in the field of view of the 3D camera. All of the sticks were found when better resolution was used. However, the segmenting algorithm does not detect the stick farthest away (3 m distance) when the resolution is lower (Fig. 5.b)). This happens because the pixel size is about the same as the width of the stick. In this case the segmenting algorithm using the distance difference of the adjacent pixels can't reliable distinguish the sticks from other possible objects. The stick in 3 m distance can be detected, when increasing the threshold, but can also cause false detections. Fig. 5 shows that with better resolution, the segmenting algorithm detects more right data points also in vertical direction which improves the reliability of the detection.

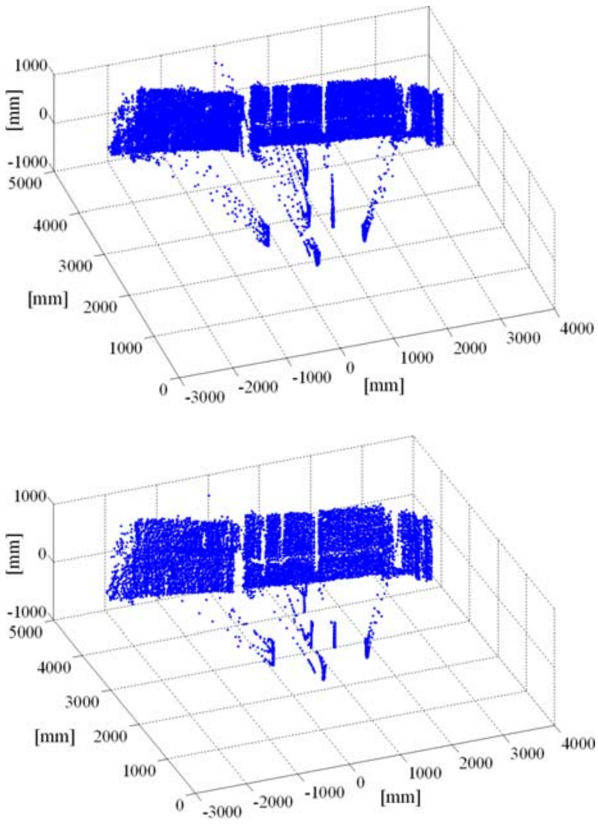

Fig.4. Point clouds using a) better resolution b) lower resolution.

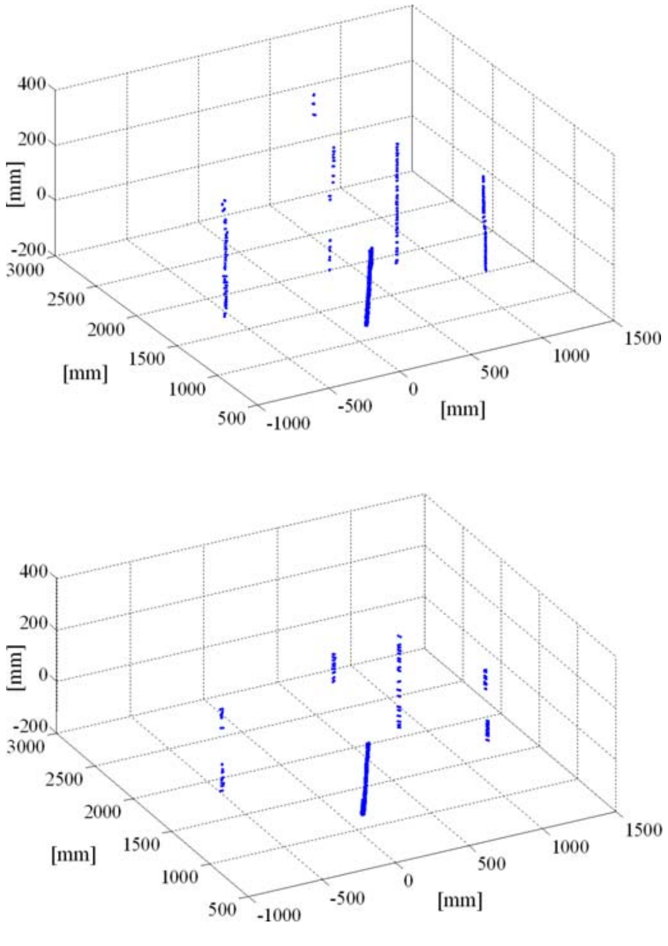

Fig.5. Segmented point clouds using a) better resolution b) lower resolution.

3.3 Outdoor

Outdoor experiments were done in a well-kept grass area (Fig. 6). Because the distances outside were much longer, the modulation frequency of the 3D camera was changed to 5 MHz, which extends the unambiguous measuring range to 30 m. Fig. 7 shows the results of the measurements done outside. The individual measuring points, shown in Fig. 7.b), are branches which the segmenting algorithm didn't cut away. The segmenting algorithm detects just the trees seen in front in Fig. 6. This maybe results from the function of the 3D camera, which didn't work as expected. The main reason was that the sun was shining to trees while the measurements were done.

4. CONCLUSION

In this paper, the use of a time-of-flight (TOF) 3D camera for tree measurement was explored. The paper also discussed the problems in tree measurement. The research shows that it is possible to use 3D camera technology in this kind of application. More work has to be done to get the system to work properly. In future larger forest area is wanted to be mapped. Covering larger area needs measuring trees in several locations and therefore needs map matching. Also the calculation of the width of the tree will be added.

Fig. 6. Outdoor measurement area with trees.

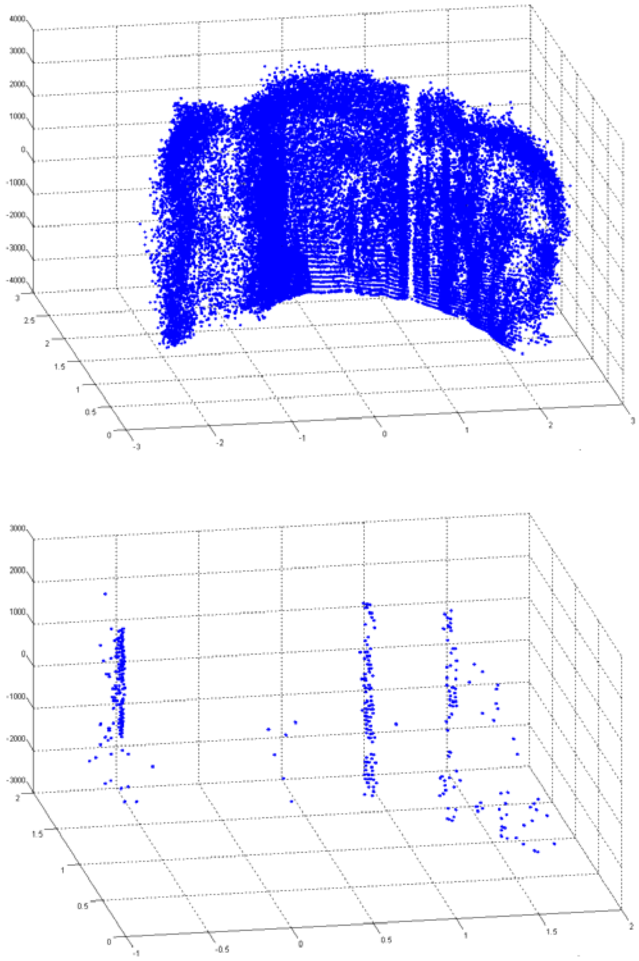

Fig.7. Point clouds from forest environment a) raw data b) segmented data.

5. ACKNOWLEDGEMENT

The authors would like to thank Finnish Funding Agency for Technology and Innovation (TEKES) and European Regional Development Fund (ERDF) for funding this research.

[1]. *J. Jutila, K. Kannas, and A. Visala*, "Tree Measurement in Forest by 2D Laser Scanning", in: Proceedings of the 2007 IEEE International Symposium on Computational Intelligence in Robotics and Automation, Jacksonville, FL, USA, June 20-23, 2007, pp. 491-496.

[2]. *P. Forsman, and A. Halme*, "3-D Mapping of Natural Environments with Trees by Means of Mobile Perception", in: IEEE Transactions on Robotics, vol. 21, no. 3, June 2005, pp. 482-490.

[3]. *T. Möller, H. Kraft, J. Frey, M. Albrecht, and R. Lange*, "Robust 3D Measurement with PMD Sensors", Proceedings of the First Range Imaging Research Day at ETH Zurich, ISBN 3-906467-57-0, 2005.

[4]. *Z. Xu, R. Schwarte, H. Heinol, B. Buxbaum, and T. Ringbeck*, "Smart pixel - photonic mixer device (pmd) New system concept of a 3d-imaging camera-on-a-chip", Tech. rep., PMDTec (2005).

[5]. *A. Ollikkala, and A. Mäkynen*, "Range Imaging Using a Time-of-Flight 3D Camera and a Cooperative Object", in: Proceedings of 12MTC 2009 - International Instrumentation and Measurement Technology Conference, Singapore, 5-7 May 2009, pp. 817-821.