EG UK Computer Graphics & Visual Computing (2016)
Cagatay Turkay and Tao R. Wan (Editors)

Improving and Optimising Visualisations of full-waveform LiDAR data

M. Miltiadou[†1,2], N. D. F. Campbell[1] and M. Brown[1] and D. Cosker[1] and M. Grant[2]

[1]Centre for Digital Entertainment, University of Bath, Bath, UK
[2]Remote Sensing Group, Plymouth Marine Laboratory, Plymouth, UK

1. Introduction

Visualisations of Remotely Sensed data has a significant role in forestry. Foresters have a great knowledge about forests (for example they can identify tree diseases) and they can derive a wealth of information directly from visualisations, saving the travelling time and cost of getting into the forests.

In this paper, we use the state-of-art LiDAR data. LiDAR refers to the acquisition of information from laser scanners and they are extremely beneficial in forestry due to the ability of penetrating tree canopies. There are two types of LiDAR data: the discrete and the full-waveform (FW). The discrete LiDAR systems record a few peak laser returns, while the FW LiDAR systems record the entire backscattered signal (Figure 1). Typically FW LiDAR datasets are 5-10 times larger than discrete data, with data sizes in the range of 50-250GB for a single flight. FW LiDAR data suggests new possibilities but also many new problems from the point of view of data processing and visualisation.

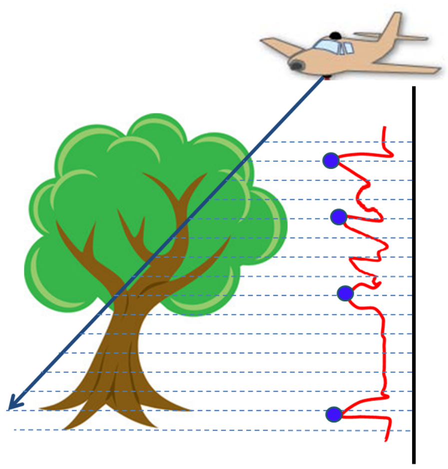

Figure 1: *The discrete LiDAR systems record a few peak laser intensity returns (blue dots), while the FW LiDAR systems digitise and record the entire backscattered signal into equally spaced time intervals (red waveform).*

DOI: 10.2312/cgvc.20161295

The primary output of this research is the open source software DASOS (=forest in Greek), which aims to enhance visualisation and classifications of FW LiDAR data. In this extended abstract, we sum up our previous visualisation research applied using DASOS [MGB*14] [MWGB15], and present a new algorithm for faster surface reconstruction of real volumetric data.

2. Previous work

Previous work in visualising FW LiDAR used transparent voxels [PSTA05], point clouds [BACL13] [Ise12], or spheres [CBD*09]. Voxelising the waveforms and visualising them using different transparencies across the voxels was proposed by [PSTA05]. Voxelisation is an integral part of this research and while previous work is based on small regions (i.e 15mx15m), this research is expanded and supports visualisations of larger areas.

3. Introducing Computer Graphics Approaches to Remote Sensing

The output of our paper [MGB*14] is a polygon representation of the scanned area showing well defined structures that can be directly rendered using commodity 3D-accelerated hardware. At first, a 3D density volume is generated by inserting all the waveforms into a voxelised space. Then a function is defined to represent this space. The function takes as input a point and returns the corresponding intensity of the voxel that that point lies inside. Nevertheless, visualising algebraic objects is not straight forward, since they contain no discrete values. This problem can either be address by ray-tracing or polygonisation. At [MGB*14], the polygonisation direction was taken using the Marching cubes algorithm.

4. Optimising Surface Reconstruction

In this extended abstract, we propose a new algorithm for speeding up the polygonisation process. The computational complexity of the Marching Cubes is linear to the number of voxels and it is therefore expensive considering that an average of 96% of the voxels are empty, due to outliners. In addition, the object is neither close or manifold; trees may be detached from the ground because of missing information. Previous work on optimising surface reconstruction talks about surface tracking [RdAPJ05] [Har98], which can only be applied on manifold objects, SIMD machines [HH92] that benefits from longer instructions and octrees [KKDH07].

The new algorithm is fundamentally different from octrees and its novelty stands to the ability to calculate the sum of any cuboid in constant time using the Integral Volumes, which is an extension of Integral Images [Cro84]. The algorithm repeatedly divides the volume and quickly identifies empty spaces, which are ignored during surface reconstruction. A simplified version is given at Algorithm 1.

Algorithm 1 Integral Volumes Optimisation Algorithm

```
Push the entire Volume as a cuboid inside a Stack
while stack is not empty do
    Cuboid-A ← next cuboid from the Stack
    if Cuboid-A and neighbours are empty then
        discard Cuboid-A
    else if Cuboid-A consists of only one cube then
        polygonise Cuboid-A
    else
        divide Cuboid-A
        push the two new Cuboids into stack
    end if
end while
```

Because this is work in progress the proposed algorithm is compared with the Marching Cubes algorithm and the results are shown on Figure 2. The voxel length is the size of the voxel in meters and smaller it is the finer the quality of voxelised FW LiDAR is. As shown, a speed up of 23.5% was achieved using our novel algorithm.

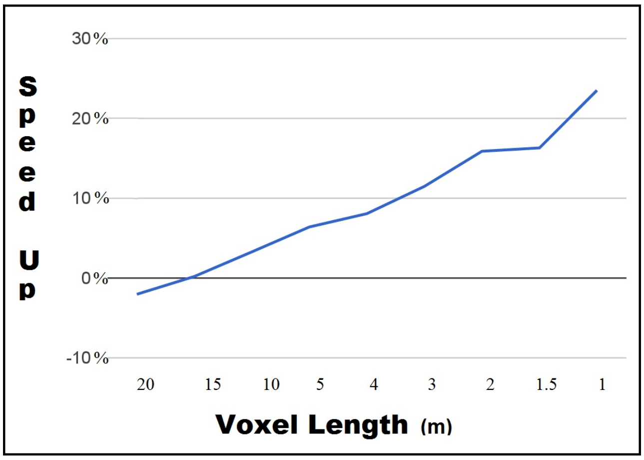

Figure 2: *This image shows the speed up at run time achieved with the new Algorithm proposed at Section 4. While the voxel length decreases, the number of the voxels increases and the performance of our algorithm improves.*

In the future the Integral Volumes algorithm will also be tested against octrees. On the one hand, integral volumes requires more space for storing the empty voxel's values but on the other hand, the voxelised space does not have to be a cube and many memory jumps are avoided by keeping memory allocation consistent. Therefore the performance of this new algorithm is expected to be better.

5. Alignement with Remotely Sensed Imagery

Simultaneous interpretation of FW LiDAR data and images confers better results due to the increased amount of information [MWGB15]. Regarding visualisations, in order to preserve the highest possible quality of the images, non-geocorrected images (their pixels are not equally spaced and each pixel is associated with a geolocation) are used to avoid rastering images twice. DASOS projects them by adjusting the texture coordinates of each vertex according to the geolocation of the nearest pixel. To speed up the process, we first import the pixels into a 2D grid, similar to [WTGS14] to find the nearest pixel to a vertex in constant time. The results are coloured polygons exported into .obj files with increased visual details (Figure 3).

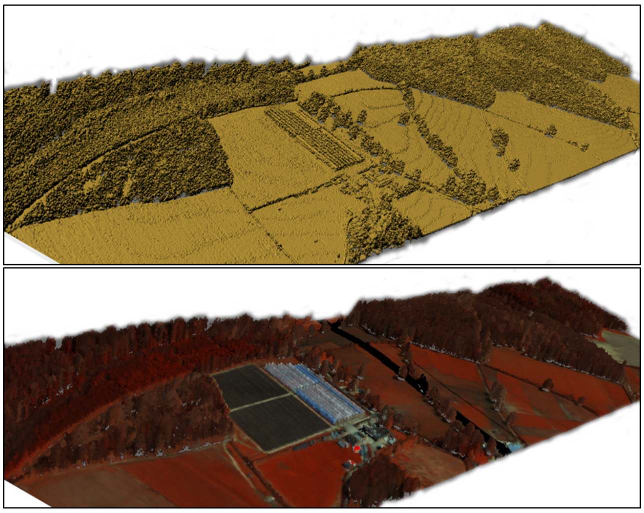

Figure 3: *This is a scanned area from New Forest, UK. The first top image shows a polygon representation generated using the approach discussed in Section 3. The bottom one is the same area after the Remotely Sensed images are projected into the mesh (Section 5).*

6. Results and Conclusions

To sum up, at this extended abstract we present the state-of-art work of visualising FW LiDAR data. This includes:

1. Generating 3D polygon from FW LiDAR data using functional representation of objects, which is new in Remote sensing
2. Optimising surface reconstruction of real volumetric data using Integral Volumes; an up to 23.52% speed up was achieved
3. Alignment of Remotely Sensed Images which confers increased visual quality and the ability of interpreting both datasets simultaneously.

6.1. Acknowledgements

Credits are given to NERC ARSF for providing the full-waveform LiDAR data.

References

[BACL13] BUNTING P., ARMSTON J., CLEWLEY D., LUCAS R. M.: Sorted pulse data (spd) libraryâĂŤpart ii: A processing framework for lidar data from pulsed laser systems in terrestrial environments. *Computers & Geosciences 56* (2013), 207–215. 1

[CBD*09] CHAUVE A., BRETAR F., DURRIEU S., PIERROT-DESEILLIGNY M., PUECH W.: Fullanalyze: A research tool for handling, processing and analysing full-waveform lidar data. *IEEE International Geoscience and Remote Sensing Symposium* (2009). 1

[Cro84] CROW F. C.: Summed-area tables for texture mapping. *ACM Computer Graphics 18*, 3 (1984), 207–212. 2

[Har98] HARTMANN E.: A marching method for the triangulation of surfaces. *The Visual computer 14, no 14*, 3 (1998), 95–108. 2

[HH92] HANSEN C. D., HINKER P.: Massively parallel isosurface extraction. *Proceedings of the 3rd conference on Visualization '92* (1992), 77–83. 2

[Ise12] ISENBURG M.: Pulsewaves: An open, vendor-neutral, stand-alone, las-compatible full waveform lidar standard. 1

[KKDH07] KAZHDAN M., KLEIN A., DALAL K., HOPPE H.: Unconstrained isosurface extraction on arbitrary octrees. *Symposium on Geometry Processing 7* (2007). 2

[MGB*14] MILTIADOU M., GRANT M., BROWN M., WARREN M., CAROLAN E.: Reconstruction of a 3d polygon representation from full-wavefrom lidar data. *RSPSoc Annual Conference 2014, New Sensors for a Changing World* (2014). 1

[MWGB15] MILTIADOU M., WARREN M. A., GRANT M., BROWN M.: Alignment of hyperspectral imagery and full-waveform lidar data for visualisation and classification purposes. *The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences 40*, 7 (2015), 1257. 1, 2

[PSTA05] PERSSON A., SODERMAN U., TOPEL J., AHLBERG S.: *Visualisation and Analysis of full-waveform airborne laser scanner data.* V/3 Workshop, Laser scanning 2005, 2005. 1

[RdAPJ05] RODRIGUES DE ARAUJO B., PIRES JORGE J. A.: *Adaptive polygonization of implicit surfaces*, vol. 29. Science Direct, Computer and Graphics, 2005. 2

[WTGS14] WARREN M., TAYLOR B., GRANT M., SHUTLER J. D.: Data processing of remorely sensed airborne hyperspectral data using the airborne processing library (apl). *ScienceDirect, Computers and Geosciences 64* (2014). 2