Using Point Clouds to Capture Growth and Change in Experimental Urban Planting Trials

Michael G. White[1], M. Hank Haeusler[2], Joshua Zeunert[2]

[1]University of New South Wales/Australia · m.g.white@unsw.edu.au
[2]University of New South Wales/Australia

Abstract: A time series of detailed point clouds of an experimental planting trial were captured at regular intervals using photogrammetry techniques. Each point cloud was segmented into individual plant specimens, which were analysed to determine growth parameters. These parameters describe the approximate growth and seasonal characteristics of the subject species and can be used to inform future designs. The outcomes of these design experiments support the use of spatial data capture tools to make decisions about species selection and design in the future practice of landscape architecture.

Keywords: Landscape architecture, point clouds, planting design

1 Introduction

There is growing awareness of the importance of structurally complex planting within our public spaces to increase biodiversity (THRELFALL 2017, SMITH 2006, MEYER-GRANDBASTIEN 2020, GUNNARSON 2016, SCHEBELLA 2019, DEARBORN 2010). Successful urban plantings require an awareness of the dynamic growth patterns and maintenance requirements of plant species (DUNNETT & HITCHMOUGH 2004). Designed experiments and physical planting trials are an essential step in creating new evidence-based knowledge and understanding (RAYNER 2016, AHERN 2013, FELSON & PICKETT, 2005). As the call grows for the further development of evidence-based practices and knowledge in the profession of landscape architecture (Brown 2011, CHEN 2013), developments in botanical and ecological research may offer new methods for the incorporation of evidence and data in the design process. In this study, spatial data was captured in the form of point clouds to describe experimental in-situ planting trials at multiple points in time throughout the trial period. This data describes the spatial and colour changes that occur in the urban landscape over the first years of growth of understorey vegetation. Growth and form characteristics extracted from these trials can be used to explore possible outcomes of future urban plantings.

Point Clouds in Landscape Practice

Spatial data represented as an arrangement of discrete points in coordinate space are referred to as point clouds (LEVOY & WHITTED 1985). Recent advances in graphics technology allow the capture and display of much larger and more detailed cloud geometry on consumer hardware. These point clouds have found successful application in landscape architecture teaching, research and practice as a tool for measuring and communicating complex geometry (GIROT 2018, MELSOM 2022, SPIELHOFER et al. 2017, URECH 2019, LIN & GIROT 2014). Point clouds are also frequently used in the scientific study of plant structures both at a wide landscape scale in ecology and at the individual level in botanical and agricultural sciences (SAHA et al. 2022, FIAVOLA et al. 2022, CAMMARETTA et al. 2021). While there has been some previous application of point clouds to studying urban vegetation in the context of landscape architecture, there has been little discussion of their use and application in capturing

Journal of Digital Landscape Architecture, 9-2024, pp. 614-620. ISBN 978-3-87907-752-6, ISSN 2367-4253, e-ISSN 2511-624X, doi:10.14627/537752056.

the characteristics of individual species in situ, for application in a process of designing urban plantings.

2 Methods

An experimental planting trial was installed in September 2022 and monitored for 12 months. This paper focuses on the point cloud data capture used for monitoring of the trials. Further information on the methodology, objectives and outcomes of the horticultural study are available in the [Withheld] trials report and urban planting guide. The subject site is a heavily disturbed area of urban development, with all plantings on site in an imported soil profile, consisting of a 300mm depth layer of mineral based green roof material introduced for the trials. The trial site was subdivided into 32 plots with typical measurements of 2.7m x 2.7m. These plots each contain 56-75 plants of varying species organised into mixes or typologies. The plants were installed as a mix of tubestock and 150mm pots in a randomised configuration. Of the 32 plots tracked for the planting trials, 2 were selected for detailed spatial data capture that is the subject of this paper.

Base Layer	**Qty**	**Mid Layer**	**Qty**	**Emergent Layer**	**Qty**
Arthropodium milleflorum	14	*Lomandra 'Lime Tuff'*	8	*Austrostipa flavescens*	8
Brachyscome multifida	26	*Pelargonium australe*	8	*Geranium homeanum*	8
Chrysocephalum apiculatum	19	*Pimelea spicata*	12	*Chrysocephalum semipapposum*	10
Dampiera diversifolia	10	*Calocephalus citreus*	12	*Patersonia occidentalis*	7
Actinotus minor	8	*Eryngium ovinum*	8	*Poa labillardieri*	16
Bulbine bulbosa	10	*Calocephalus lacteus*	12	*Pycnosorus globosus*	10

Fig. 1: i) Photograph of experimental planting trial plot. A two weeks after installation in October 2022 Species composition, quantities and initial location of plants at Day 0.

The above figure details the species composition and quantities introduced at the start of the planting trial in July 2022 in each of the subject plots. An orthophoto was constructed with manually labelled species distribution. This initial tracking of species location was used to aid in the segmentation and classification of the captured point clouds in later steps.

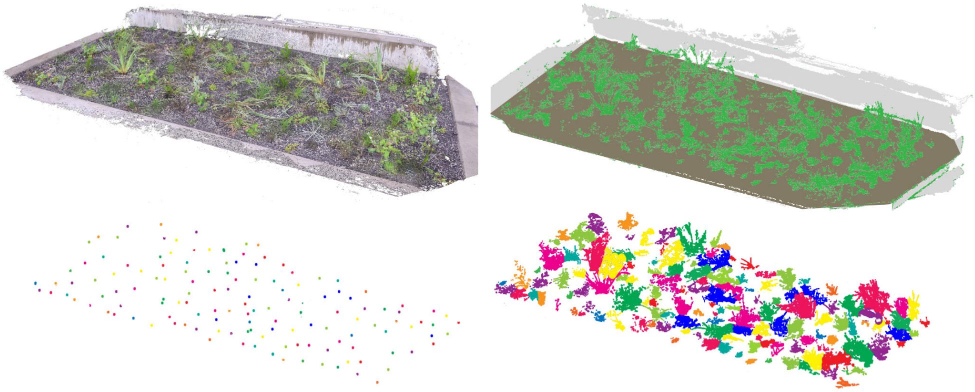

Fig. 2: Diagrammatic Overview of methodology showing i) raw point cloud including colour data produced in RealityCapture from images taken on site; ii) point cloud segmented in CloudCompare into concrete, soil and vegetation classes; iii) seed locations identified from orthophoto to define start points for plants; iv) point cloud segmented into individual plants.

The following methodology outlines the steps involved in the data capture process:

i) **Photo Capture:** Photographs were captured from multiple angles with consistent lighting following general principles of photogrammetry. A handheld digital camera was used to capture site photographs. The camera was placed at predetermined positions within and around the planting trial area. Photography was conducted periodically throughout the experimental period, creating a time series of point clouds. Scans were typically taken on a 3-monthly basis, depending on the growth rate of the vegetation, and the interruption of the scan schedule due to poor weather. Detailed records of the equipment setup, scan locations, and environmental conditions were maintained throughout the study.

ii) **Point Cloud Construction:** After each scan session, photographs were used to construct coloured 3D point cloud using Reality Capture software. Point cloud data was registered and aligned to create a single, coherent dataset. This point cloud captures the spatial structure of the planting, while also including an RGB colour value at each point in space. To ensure accuracy, the captured point clouds are compared with ground-truth measurements, such as manual measurements of fixed concrete structures on site.

iii) **Time Series Alignment:** The time series of point clouds were aligned to the master cloud containing manually tagged origin points of species, and prepared for cloud processing using CloudCompare software.

iv) **Cloud Processing:** For each cloud, points were removed that captured the ground layer and any non-vegetation structures. Overall vegetation height, percentage of vegetation vertical cover and volume were recorded from the remaining points. The remaining points are segmented into individual plant-clouds, by detecting local maxima and generating a contoured top surface, then using a watershed algorithm to define boundaries. Growth parameters were extracted from each individual plant-cloud and compiled to provide a tracking of individual plant specimens across the duration of the planting trials.

v) **Aggregate Species Data:** Following segmentation, the point clouds can be used to accurately describe the following characteristics: a) height, width and volume of species at time intervals; b) rate of growth computed from (a); c) seasonal flowering and structural changes in vegetation.

vi) **Design Exploration:** Following the extraction of individual plant clouds aligned over the time series, new alternative planting arrangements were reconstructed from the segmented clouds for conceptual design exploration and testing.

This methodology is proposed as a system of learning from in-situ urban plantings and passing data on to the design phase, creating a tool that enables greater possibilities in the planting design process.

3 Results

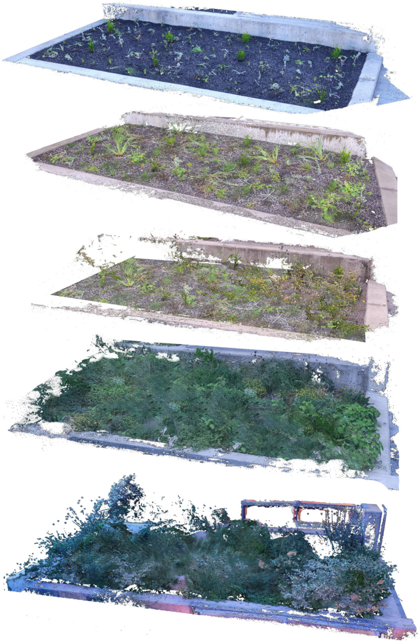

Fig. 3:
Raw point clouds captured over the trial period showing progression of plant growth and seasonal change over time

Characteristics of Individual Plant Species

Following the methods outlined above, data was captured from the physical planting trials and processed to provide descriptive measurements of individual plant specimens over the trial period. The measurements indicated in the above table are the mean of all specimens of that species captured.

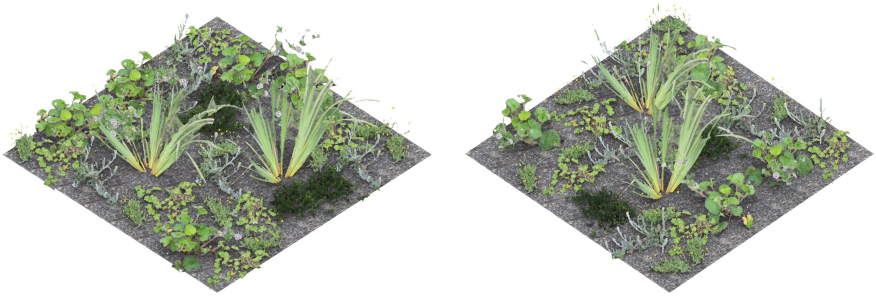

Fig. 4: Alternative planting arrangements generated by recombination of extracted clouds to test and imagine new design possibilities

4 Discussion and Conclusion

There are a number of challenges associated with the point cloud capture process for vegetation with high structural complexity. The methodology used for capturing point clouds of urban vegetation in an experimental planting trial offers several noteworthy benefits and presents a set of associated challenges. The methodology tested provides an acceptable resolution of spatial data, enabling non-invasive monitoring of urban vegetation. Planning camera paths and conducting scans at regular intervals demands careful attention and may necessitate significant time investment. Environmental conditions, such as poor lighting, rain or strong winds, can prevent the capture of sufficient quality images to produce point clouds. This may require adjustments in the data collection schedule. Resolution and accuracy may be improved with the use of specialised terrestrial laser scanning or LIDAR equipment, however this equipment is expensive and requires training. In the initial capture series point clouds were also recorded using LiDAR with a Zeb Revo RT handheld scanning device. The captured clouds were found to be of insufficient quality and resolution to provide the necessary data at this object scale. For this reason LiDAR scanning was discontinued after the initial series. Handling, registering, and processing large point cloud datasets can be computationally intensive and time-consuming, requiring software licensing and expertise. The time series aspect of the methodology offers unique advantages. It permits the tracking of vegetation growth in space over time, aiding in the assessment of growth patterns, plant health, and responses to environmental variables. These time-captures may provide a significant aid in the teaching and understanding of plant growth to young designers. In conclusion, while the methodology proposed for capturing point clouds of urban vegetation in experimental planting trials offers valuable insights into the dynamics of urban greenery, it comes with several challenges that include costs, data complexity, and the need for careful planning. Nevertheless, the benefits in terms of high-quality, time-series data and detailed analysis make it a powerful tool for landscape architects and researchers studying urban vegetation dynamics.

References

AHERN, J. (2013), Urban landscape sustainability and resilience: the promise and challenges of integrating ecology with urban planning and design. Landscape Ecology, 28 (6).

BELESKY, P. (2015), A field in flux: Exploring the application of computational design techniques to landscape architectural design problems. ACADIA 2015 – Computational Ecologies: Design in the Anthropocene.

BELESKY, P. (2018), Plants. http://groundhog.la/documentation/plants/ (24.02.2024).

BRAAE, E. & STEINER, H. (2018). The role of landscape architecture research. In Routledge Research Companion to Landscape Architecture: Vol. I, 1-11. Routledge.

CAMARRETTA, N., HARRISON, P. A., LUCIEER, A., POTTS, B. M., DAVIDSON, N. & HUNT, M. (2021), Handheld Laser Scanning Detects Spatiotemporal Differences in the Development of Structural Traits among Species in Restoration Plantings.

ELKIN, R. S. (2017), Live matter: Towards a theory of plant life. Journal of Landscape Architecture, 12 (2), 60-73.

ERVIN, S. (2001), Digital landscape modeling and visualization: A research agenda Landscape and Urban Planning 54 (1-4), 49-62.

FELSON, A. J. & PICKETT, S. T. (2005). Designed experiments: new approaches to studying urban ecosystems. Front. Ecol. Environ 3, 549-556.

FIALOVÁ, Z., KLEPÁRNÍK, R. & SEDLÁČEK, J. (2022), Visualization of Woody Vegetation Changes in 3D Point Clouds. 301-309. https://doi.org/10.14627/537724029.

GIROT, C. (2018), Cloudism – Towards a new culture of making landscapes, 113-123.

HU, S., LI, Z., ZHANG, Z., HE, D. & WIMMER, M. (2017), Efficient tree modeling from airborne LiDAR point clouds, Computers & Graphics, 67, 1-13.

KULLMANN, K. (2014), Hyper-Realism And Loose-Reality: The Limitations Of Digital Realism And Alternative Principles In Landscape Design Visualization. Journal of Landscape Architecture, 9 (3), 20-31.

LEVOY, M. & WHITTED, T. (1985), The Use of Points as a Display Primitive. Technical Report 85-022, University of North Carolina.

LIN, E. & GIROT, C. (2014), Point Cloud Components Tools for the Representation of Large Scale Landscape Architectural Projects. In: BUHMANN, E. et al. (Eds.), Peer-Reviewed Proceedings of Digital Landscape Architecture 2014 at ETH Zurich. Wichmann, Berlin/Offenbach, 208-218.

MELSOM, J. (2022), Representing Dynamic Landscapes: Temporal Point Cloud Visualisation Applications in Complex Ecologies: The Case Study of the 2020 Rosedale Fires. 282-290.

RAXWORTHY, J. (2018), Overgrown: Practices between Landscape Architecture and Gardening. MIT Press.

RAYNER, J. P. & WILLIAMS, C. C. (2016), Learning from failure: Evaluating plant performance in urban landscapes. Acta Horticulturae, 1108, 221-226.

SAHA, K. K., TSOULIAS, N. & WELTZIEN, C. (2022), Estimation of Vegetative Growth in Strawberry Plants Using Mobile LiDAR Laser Scanner.

SPIELHOFER, R., FABRIKANT, S. I., VOLLMER, M., REBSAMEN, J., GRÊT-REGAMEY, A. & HAYEK, U. W. (2017), 3D Point Clouds for Representing Landscape Change. 206-213.

THERS, H., BØCHER, P. K. & SVENNING, J. (2019), Using lidar to assess the development of structural diversity in forests undergoing passive rewilding in temperate Northern Europe, 1-20.

URECH, P. (2019), Point-Cloud Modeling: Exploring a Site-Specific Approach for Landscape Design. Journal of Digital Landscape Architecture, 4-2019, 290-297.

WEED-AI (2024), A repository of Weed Images in Crops. Precision Weed Control Group and Sydney Informatics Hub, the University of Sydney. https://weed-ai.sydney.edu.au/ (24.02.2024).

WEN, W., GUO, X., WANG, Y., ZHAO, C. & LIAO, W. (2017), Constructing A Three-Dimensional Resource Database Of Plants Using Measured In Situ Morphological Data. Applied Engineering in Agriculture, 33 (6), 747-756.

ZIMMERMAN, A. & MARTIN, M. (2001), Post-occupancy evaluation: benefits and barriers. Building Research & Information, 29 (2), 168-174. doi: 10.1080/09613210010016857.