Terrestrial Laser Scanning for Forest Biodiversity Assessment - LASERBIO

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Introduction

The Convention on Biological Diversity defines biodiversity as the variability among living organisms from all sources including that of terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species, between species and of ecosystems.

Forest biodiversity is influenced by structural complexity in the forest. Procedures for forest biodiversity assessment are known to be expensive due to their reliance on labour intensive field visits. Precise repeatable measures are difficult to achieve using traditional methods.

Terrestrial Laser Scanners (Figure 1) are electronic devices used on the surface of the earth, that use laser to digitise the geometry of real environments (Figure 2) with high precision by capturing large point clouds (millions of single points) of structural data in a very short time. Machine Learning is a scientific discipline whereby provision of examples to its constituent algorithms, allows computers to evolve behaviours.

The aim of the research presented here is to apply laser scanning technology to the assessment of forest structure and deadwood, and to use Machine Learning techniques to relate these data to the diversity of plants, invertebrates and birds in a range of forest types.

Methods

The utility of Terrestrial Laser Scanning (TLS) as a basis for biodiversity prediction in a variety of forest settings was evaluated. TLS was conducted at the locations shown on Figure 3.

Sites selected were:

- Four native woodland sites which were scanned during summer and winter (leaf-on and leaf-off condition).
- Six conifer plantation forest sites which were scanned during summer (3 mid-rotation and 3 mature). One of the mature conifer plantation sites was as also scanned during winter.

The specific biodiversity measures selected for prediction using machine learning techniques were population abundance and species richness of:

- Birds
- Beetles
- Spiders

Figure 1: Scanner atop surveyor tripod.

Figure 2: Some example photographs and 2-dimensional projections of 3-dimensional laser scans of the forest types considered in this study.

Figure 3: Study sites: those marked in yellow are mid-rotation Sitka spruce sites, in blue are mature Sitka spruce sites, and in red are Oak dominated native woodland sites.

Figure 4: Plot layout: Black dots represent 4 locations at which scans were carried out at within each plots.

Results

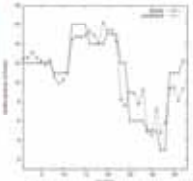
The correlation coeficients achieved between true biodiversity measure and the predictions one gets from the concepts generated by each technique are presented in Table 1. We used 10-fold cross validation. We conducted measurements for 37 different forest locations, so correlation coeficients in excess of 0.325 (0.418) are statistically significant at the 95% (99%) level; this was determined using R, the statistical computing system.

An example of the predictor we obtained for the specific case of beetle species richness (BSR) using the concept generated by pace regression is shown in Figure 5. The concept generated in this case was as follows, where the age of the forests in the data-sets is either mature or mid-rotation, which were numerically interpreted as 0 and 1, respectively:

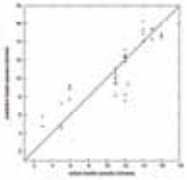
BSR = 34.8974 - 13.0242 x Age - 0.062 x Average Stem Diameter

Technique	Birds		Beetles		Spiders	
	species	pop	species	pop	species	pop
Least Med. Sq.	0.41	0.04	0.57	–	0.41	0.47
Linear Reg.	0.43	0.57	0.78	0.71	0.66	0.76
MLP	0.46	0.55	0.66	0.68	0.67	0.73
Pace Reg.	0.23	0.68	0.86	0.73	0.70	0.68
RepTree	0.10	0.51	0.69	0.70	0.42	0.21

Table 1: correlation coeficients achieved between true biodiversity and predicted biodiversity.



Comparison by Forest Location



Actual versus Prediction

Figure 5: An example biodiversity predictor for beetle species richness obtained using pace regression.

Conclusions

We have shown how several standard machine learning / data mining techniques can accurately predict 6 biodiversity measures, the species richness and abundance of birds, spiders and beetles.

Research in this area has the potential to automate the development of a world inventory of forests rich with biological diversity.

This solution could be used to measure the environmental impact of harvesting trees in a particular forests.

Future Work

To expand the set of features that we extract from the laser scans and to factor in measurements of standing deadwood.

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