Chapter 1
Tropical Tree Species 3D Modelling and Classification Based on LiDAR Technology

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ABSTRACT

Over the last decade or so, laser scanning technology has become an increasingly popular and important tool for forestry inventory, enabling accurate capture of 3D information in a fast and environmentally friendly manner. To this end, the authors propose here a system for tropical tree species classification based on 3D scans of LiDAR sensing technology. In order to exploit the interrelated patterns of trees, skeleton representations of tree point clouds are extracted, and their structures are divided into overlapping equal-sized 3D segments. Subsequently, they represent them as third-order sparse structure tensors setting the value of skeleton coordinates equal to one. Based on the higher-order tensor decomposition of each sparse segment, they 1) estimate the mode-n singular values extracting intra-correlations of tree branches and 2) model tropical trees as linear dynamical systems extracting appearance information and dynamics. The proposed methodology was evaluated in tropical tree species and specifically in a dataset consisting of 26 point clouds of common Caatinga dry-forest trees.

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INTRODUCTION

The many different types of tropical forest are distinguished by differences in the amount and distribution of rainfall throughout the year, as well as by elevation and by soil type. Often categorized on the basis of leaf habit and/or climate (for example "evergreen moist forest" vs. "seasonally dry tropical forest"), although the many different types of tropical forests may have many structural dissimilarities (Torello-Raventos et al., 2013), one common feature is their high diversity and richness of tree species (Banda et al., 2016; Cardoso et al., 2017). However, in sharp contrast to the tropical rain forests and savannas, seasonally dry tropical forests (SDFTs) remain barely studied and under-represented in conservation programs (Banda et al., 2016). As example, the Caatinga SDTF of north-east Brazil not recognized by the scientific community as distinct until a few years ago (Da Silva, et al., 2018).

Caatinga constitutes the largest SDTF region in South America (approximately equal in area to the United Kingdom and Germany combined), also being one of the most diverse and rich species SDTF areas within South America. This area is home for more than 28 million people (Martinelly & Moraes, 2013, Da Silva, et al., 2018) and recent studies have found increased land conversion rates during the past two decades, with over 89.000 km^2.of natural SDTF vegetation lost since 1990 (Santos, et al., 2011, Beuchle, et al., 2015). It is remarkable that more than 250 plant species are currently identified as highly threatened in the Red List of the Brazilian Flora (Martinelly & Moraes, 2013), but only less than 1% of Caatinga is included within the National Protected Area Network (Leal, et al., 2005, Pennington & Ratter, 2006). Although Caatinga has been characterized as a socio-ecological system, mismanagement of SDTFs can lead to biodiversity loss and to reduction in the flows of the ecosystem services required to sustain the livelihoods of millions of low-income people (Da Silva, et al., 2018). For example, a large number of Caatinga species are used by indigenous and rural communities in north-eastern Brazil for medicinal purposes (De Albuquerque, et al., 2007). To this end, the classification of Caatinga tropical tree species is an essential step that plays a crucial role in forestry investigation, forestry planning and environmental protection for maintenance of ecosystem services that underlie human wellbeing.

As described by Szenjner and Emanuelli (2016), there are many requirements for the identification of tree species in tropical forests. This is because structure of tropical tree species is complex with a large diversity of species and with the procedure of species recognition requiring a specimens' collection and taking pictures of each part of the plant (flowers and fruits). The next important step for recognition is the drying of specimens using specific instructions. For the identification process the use of a stereo microscope and the help of literature is suggested. Finally, for the purposes of robust identification, it is often necessary for a local expert to join in the field and/or herbarium. As deduced from the above, in order to have the confidence to identify species at a glance, the identification of tree species in tropical zones requires many years of experience in the field.

Based on the recent advances in the area of three-dimensional analysis, computer vision and pattern recognition, researchers have used 3D laser scanning technology in order to extract accurate information about the structure of large objects as buildings and trees. Light Detection And Ranging (LiDAR) sensors have been proven to be a powerful tool with a variety of capabilities for the analysis of woody vegetation structure and properties (Bournez, et al., 2017). Such LiDAR technologies generally are integrated into three categories: a) airborne laser scanning (ALS) systems, b) terrestrial laser scanning (TLS) systems and c) mobile laser scanning (MLS) systems. ALS systems are able to scan large areas and their use is ideal for modelling of tree crown while the TLS measurements extract more dense point clouds but are restricted by limited areas of surveillance. MLS systems combine components of both

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