The tree identification and delineation algorithm

Environment, Plants

The sustainable management of forests for multiple uses requires fine-scale resource information for a range of attributes. Remotely sensed imagery, if appropriately interpreted, can provide detailed, quantitative data for deriving forest information. This paper describes the tree identification and delineation algorithm (TIDA), an image analysis tool designed to delineate tree crowns automatically in high spatial resolution digital imagery. The (local) radiometric maxima and minima are the primary image features used for the crown delineation process, being indicative of crown centroids and boundaries, respectively. TIDA was developed for application to imagery of native Eucalypt forests in Australia, and uses a ‘ top–down’ spatial clustering approach involving key steps designed to reduce the effects of crown segmentation. The assumptions and fundamental processes of the algorithm are described, examples of the output and performance considerations are given, and possible limitations are discussed.

Forest management is a discipline increasingly dependent on detailed resource information. The growing demand on forest resources, together with an imperative to manage sustainably, is promoting a trend toward management at finer scales. Information about the resource must therefore be available at a compatible resolution, both spatially, in the form of detailed resource maps, and temporally, as components of monitoring and change-detection programs. Remotely sensed data, if appropriately interpreted, is capable of meeting both the spatial and temporal information requirements of forest managers. Historically, aerial photography has been the most popular application of remote sensing in forestry (Skidmore et al., 1987). Most practical forest management decisions are made at the stand scale, where a stand typically represents a discrete area of forest with similar species and structural composition. Aerial photography is often used for the delineation of forest stand boundaries (Leckie et al., 1998), a task that is often performed manually.

According to Kadmon and Harari-Kremer (1999), there are two main problems with manual stand delineation. Firstly, the delineation of homogeneous vegetation units is not based on explicit measurement procedures, and as such, the information is not objective and therefore not necessarily repeatable. Inconsistencies between- and within-interpreters makes it difficult to evaluate changes in forest condition over time, and to reconcile multiple maps of the same area (Edwards and Lowell, 1996). Secondly, although it is possible to use large-scale photography or enlargements to extract information at the individual tree level, to perform this task over an entire photograph would be prohibitively time-consuming. There is little doubt that the need for accurate and efficient forest information is growing (Leckie, 1990).

Further development of modern remote sensing systems as components of forest inventory is seen by some as a major task for the future (Preto, 1992). The potential for major advancements in remote sensing has been largely brought about by digital technology. In particular, the availability of powerful, low cost computers, coupled with the growing demand for detailed forest resource information, has provided incentive for computer-assisted or automated approaches to image interpretation. A relatively new approach involves the automated delineation of tree crowns in high spatial resolution digital imagery. By delineating crown boundaries using an automated process, it is possible to generate a range of spectral and spatial statistics for each crown which may be combined with field-measured values and environmental datasets for modelling and mapping tree attributes across the whole landscape. Whereas forest management agencies do not make management decisions at the individual tree scale, collecting information on all trees in a forest, i. e. performing a total inventory, and then collating this data at the stand scale has obvious benefits over the subjective delineation of stand boundaries. The development of automated tree crown delineation algorithms is a growing area of interest to researchers and forest organisations alike. A forum held in 1998 at the Pacific Forestry Centre in Victoria, Canada, brought together over 100 researchers, developers and potential users of automated image interpretation techniques for forestry (see Hill and Leckie, 1998).

The first of its kind, the forum emphasises this young but rapidy expanding field of research. All tree delineation algorithms are developed for use with high spatial resolution imagery. Whereas the optimum spatial resolution will vary between forest types and individual algorithms, they typically require that the ground resolution cell of the sensor be considerably smaller than the size of the tree crown objects in the scene. Perhaps, the most fundamental assumption of crown delineation algorithms is that the centre of a crown appears radiometrically brighter than the edge of the crown.

Although algorithm assumptions are inherently similar, there are a number of different conceptual approaches to the problem of automated tree crown delineation. For example, Gougeon (1995) developed a valley-following algorithm for the isolation of individual crowns in Canadian Boreal forests. The method finds crown boundaries by first following the shaded areas (radiometric valleys) between trees, and then refining the boundaries using a rule-based program. Pollock (1996) and Larsen (1998) developed algorithms that delineate crowns based on the optimal match of predefined geometric shapes with local radiometric values. Walsworth and King (1999), in a multi-temporal study of forest canopy condition from scanned aerial photographs, developed and compared two tree delineation techniques. One involved the calculation of radiometric surface aspects, and the other was based on a high-pass filter. Brantberg and Walter (1998) perform tree delineation in high-resolution imagery using convexshaped edge segments, local maxima and region growing.

An algorithm developed by Warner et al. (1998) uses the direction of minimum local texture as a means of isolating crowns, where the direction of minimum local texture is often aligned with the shaded gaps between crowns. This paper outlines a new approach, the tree identification and delineation algorithm (TIDA), an algorithm developed for the delineation of tree crowns in native Eucalypt forests of Australia. The assumptions and fundamental processes of the algorithm are described, examples of the output and performance considerations are given, and possible limitations are discussed.