AN EVALUATION OF IMAGE PROCESSING TECHNIQUES FOR MEASURING CANOPY STRUCTURE IN DECIDUOUS WOODLANDS USING DIGITAL AERIAL PHOTOGRAPHS.

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ABSTRACT

Foresters in many countries have developed manual techniques to collect tree data from aerial photos either for economic or management purposes. The use of these techniques is limited by the experience of the interpreter, the time available and the repeatability/precision. With improvements in the technology of remote sensing instruments and software tools new automatic methods have the potential to replace the traditional techniques. In this study, image texture and convolution, raster contour tracing as well as statistical classifiers have been used for extraction of geometrical features of the woodland upper canopy. Such features include tree crown diameter, tree density and canopy gap characteristics. The field site used in the study was the deciduous woodland of Frame Wood, New Forest. Colour large-scale (1:4000) aerial photos were employed as the main remotely-sensed data source. The techniques applied, the results and a discussion for use in further research involving ecological interpretation are presented in this paper. The main conclusion of this section of the project is that the combination of texture measures together with traditional image segmentation techniques holds great promise in the context of this application.

K e y w o r d s: Image texture, Canopy structure, Tree data

INTRODUCTION

In order to yield models and management scenarios, studies of forests and their subsystems (soil, understorey, energy flow, gradients, succession, forest microclimate, fauna and flora) typically require extensive and expensive fieldwork.. In many studies, foresters have used aerial photo interpretation, as an inventory construction tool, mainly for deriving tree volumes and wood production. Regression analysis has then been used in many cases to predict growth and production in silviculture. Most of the stands in these studies were plantations and managed systems. Many ecological studies exists but manual interpretation of aerial photos is the dominant method, with digital image processing of aerial photos not in operational use in Europe.

The objective in this paper is to evaluate different image processing techniques that can be applied to digital colour aerial photos in order to derive spatial characteristics of trees. With the quantification of these tree crown parameters, it will then be possible in a subsequent stages of the project, to use allometric relationships to derived estimates of DBH, tree height and tree age (Engle and Kulbeth, 1992; Hall et al., 1989; Minor, 1960).

METHODS

The site used for this project is Frame Wood in the New Forest, which contains several types of semi-natural deciduous woodlands. The site has been used by the authors for a number of field-based ecological studies and during several NERC Airborne Remote Sensing campaigns.

A series of multi-temporal aerial photos at various scales were available for this research. As a first step colour aerial photos, at 1:4000 scale, were used, dated July 1995. Two training areas were selected, one with a widely open canopy (beech-oak ancient woodland) and one oak plantation (as a representative of a closed canopy) (see figures 1,2). In order to replace visual interpretation and analysis of the image data with quantitative techniques for automating the identification of the features in a scene, a series of image processing techniques

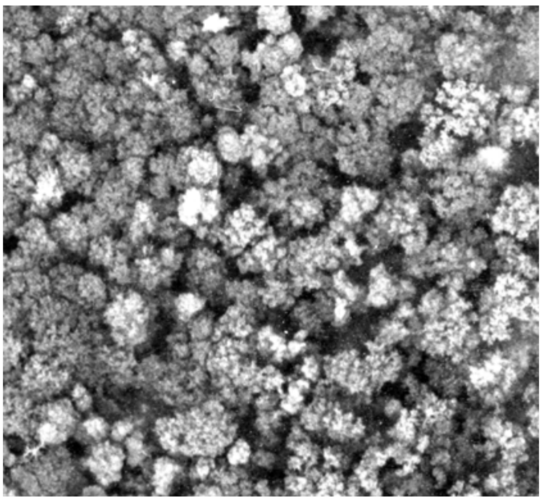

Fig.1*:* Oak plantation [area **a**]

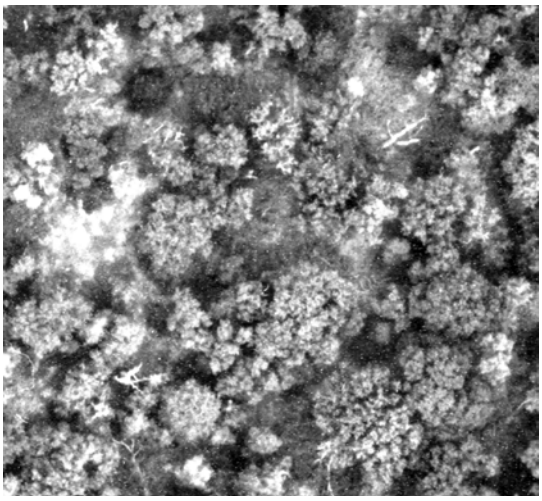

Fig. 2: Ancient woodland (beech-oak) [area **b**]

have been applied and evaluated. Generally, the analysis of multispectral image data can be approached through the application of statistical decision rules based on either the spectral radiance (referred to as *spectral pattern recognition*) or geometrical shapes, size and patterns (*spatial pattern recognition*) (Lillesand & Kiefer, 1987). In this study both types of approaches were investigated and ERDAS-Imagine served as the principle image processing package.

In our study area, a parameter that can be measured directly on the aerial photos (without having to use allometric equations) is tree crown perimeter/area. This is in fact distance measurement and the main thrust of the work was focussed on developing image processing methodologies for deriving accurate estimates of this parameter. The main problems associated with such measurements are the complex shape of deciduous tree crowns, the highly variable size of such features, distortion from topographical effects, and partial cover or shade from the neighbour trees. Tree height is another parameter that can be measured using the shade length, but in this case this was not possible as the test sites selected were imaged from near-nadir and furthermore the overlapping of tree crowns prevented the identification of distinct shadows from specific trees. Space limitations mean that only a summary of the most interesting results can be presented below. At this stage in the project a detailed statistical evaluation of the accuracy of the various approaches was not attempted. Instead it felt to be more appropriate to assess the results of each technique by comparison to visual analysis of the original aerial photographs by human interpretation of the complex scenes.

RESULTS AND DISCUSSION

Among the least successful techniques, for deriving spatial features, was principal components analysis, as it could not distinguish the understorey vegetation from the tree canopy. As a part of a multiband image created including the original bands of the visual spectrum, the principle components had a smoothing or generalisation effect. However, a combination of blue, green and the first principle component seems to be very helpful in species recognition, as it acts as an enhancement of the spectral differences. Also of limited utility was grey-level thresholding, which was used to segment the image in to two classes, dominant canopy and understorey. Those pixels with values below a defined grey level represented canopy gaps and those above this value represented tree canopy. The problem with this technique was that the resultant binary image could not represent the complex scene presented by the deciduous woodland. This technique was undermined by the fact that some areas of the understorey vegetation had a similar level of visible reflectance to the tree canopy and some of the canopy, which was shadowed, was classified as gap area. In dense areas such as plantations the results for this technique were more promising. The technique was least successful in the ancient woodland site, which was much more spatially diverse.

Among the most productive techniques were the raster contour tracing, clustering and filtering, image texture analysis, and combinations of these procedures:

Raster contour tracing

The raster contour tracing technique is based in the logic used in topographic maps where points with the same height define a contour and many of these lines, given a contour interval, define the topography of an area. In this case pixels having the same digital value, representing a radiance value, form contours and their visual interpretation can be used to identify distinct areas in the vegetation cover.

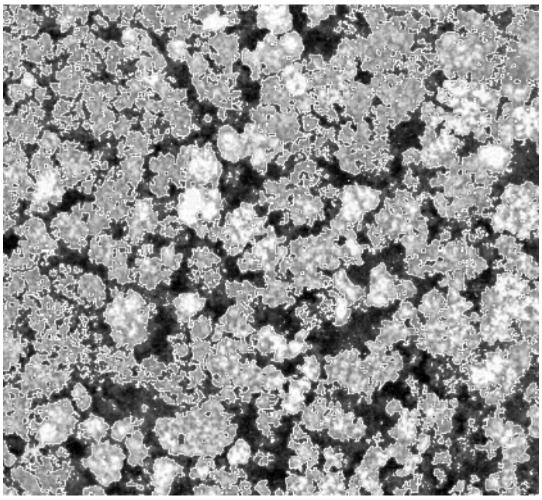

Fig. 3: Contour tracing of area **a**
(contour interval = 45)

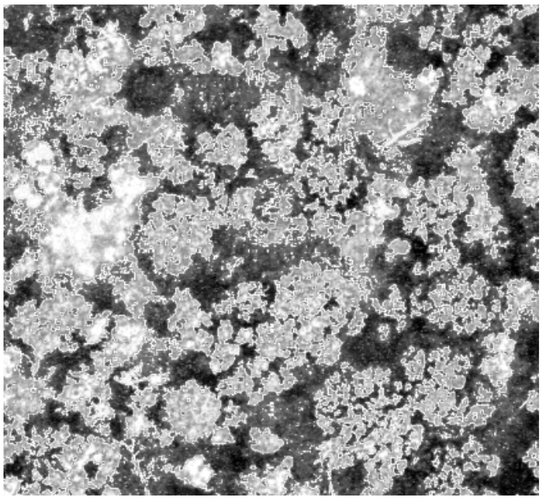

Fig. 4: Contour tracing for area **b**
(contour interval = 45)

In this technique a contrast stretch was first applied to a scanned colour aerial photo. Then, different contour intervals were applied in two parts of the scene; one with very dense upper canopy, representing an oak plantation (marked as area ***a*** in the figures) and the other with a very sparse tree cover representing area of an ancient woodland (marked as area ***b*** in all figures). In figures 3 and 4, the results of a contour segmentation with contour interval of 45 (Digital Values) are shown. Contour lines are distinct, showing tree crown outlines. Trees seem to be well extracted as objects, although a closer inspection reveals problems of mixture between tree upper canopy and understorey grass, at the ancient woodland site where the canopy is relatively open. This is not surprising in view of the basic principle of the algorithm. The algorithm is based on digital values representing radiance and since these two vegetation classes have similar spectral values the results were expectable. In the closed canopy plantation this seems not to be a problem as the understorey is absent from the scene. An important advantage of this technique is that the internal structure of the tree crown is represented in detail. Small gaps within tree crowns are shown as well as canopy openings at the stand level. Both of these characteristics are very important in the modelling of light regimes in the stand which will be the focus of subsequent work in this project.

Clustering and filtering

In clustering, the classifier identifies the distinct spectral classes present in the image data. In this case the Isodata algorithm (Iterative Self-Organising Data Analysis) was employed which uses minimum spectral distance to assign a cluster for each candidate pixel. The routine uses a specified number of arbitrary cluster means or the means of existing signatures, and then it processes repetitively, so that those means will shift to the means of the clusters in the data (ERDAS, 1995). Again, the main problem of this method was that the understorey sometimes has the same spectral signature as the tree canopy and as a result the two classes are not distinct. To overcome this problem, the results of the texture analysis –described below- were used.

Apart from clustering another well-known technique, spatial filtering was applied as one of the earliest steps of this study. Here, the objective was to find the tree crown boundaries and filters such as edge enhancement including Laplacian edge enhancement and Sobel edge detector have been employed. At this stage only these two algorithms used which are the most popular ones and contained in the most image processing software. These methods are very basic, but given the complexity and the variance of the digital values of radiance within a tree crown, it is unlikely that more sophisticated algorithms will provide greater detail or accuracy, except those using variance for the estimation of image texture as analysed below.

Texture Analysis

Although the human eye can identify similar regions based in their texture, it is often difficult to automate this task through digital image processing. In response to the need to extract information based upon the spatial arrangement of digital image data, numerous texture algorithms have been developed. These include methodologies based upon: structural approaches, spatial frequency patterns, first order statistics, second order statistics, texture spectrum and spectral texture pattern matching (Treitz & Howarth, 1996). In remote sensing, textural analysis typically involves quantifying only the spatial variation of tones or intensities in a two-dimensional image (Haralick et al., 1973; Marceau et al., 1990). The majority of the remote sensing texture methodologies employ statistical models, due to the considerable spatial variation of 'objects' in natural scenes, such as for example the varying size, shape, and the spatial arrangement of trees in a forest. It is often the textural differences on aerial photos that allow accurate identification of forest cover types (Swain & Davies 1978). So far, in this project first order statistics, such as variance have been applied as a texture descriptor. Second order statistics (such as the grey level co-occurrence matrix) as well as object specific textural analysis are been considered at present but their implementation was not possible for this paper.

First Order Statistics: Variance

One of the simplest methods to describe texture is to use moments of the grey level histogram of an image or region.

The n^{th} moment of a random variable z (z denotes discrete image intensity) about the mean is described as:

$$\mu_n(z) = \sum_{i=1}^{L} (z_i - m)^n \, p(z_i)$$

where

z : a random variable denoting discrete image intensity

$p(z_i)$: the corresponding histogram

i = 1,2, ..L

L : the number of distinct intensity levels

m is the average image intensity : $m = \sum_{i=1}^{L} z_i \, p(z_i)$

(from Golzalez & Wintz, 1986)

The second moment is the variance $\sigma^2(z)$, and it is important texture descriptor. It is a measure of grey-level contrast that it can be used to establish descriptor of relative smoothness. In this particular project the variance descriptor has been applied and their results are shown in figure 5 below.

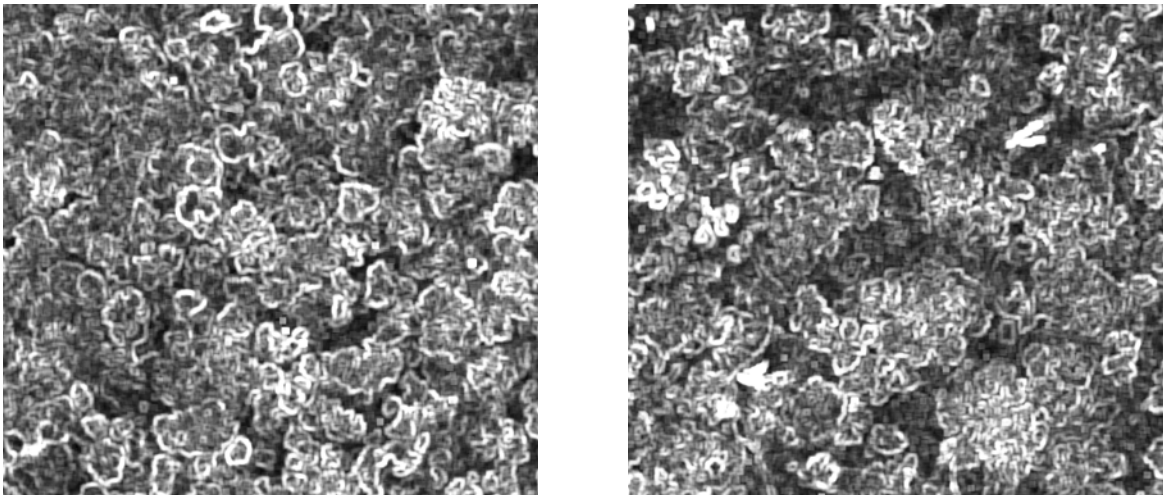

Fig. 5: Variance descriptor of Image Texture in areas **a** and **b.**

Object specific texture analysis: TPN Method

A new structural image-texture technique, termed the triangulated primitive neighbourhood method (TPN), has been introduced by Hay *et al.,* 1994. Based on current psychophysical texture theory, this technique incorporates location-specific primitives and a variable-sized and shaped moving kernel to provide automatically object- and area-specific regularised images. Tis technique has been applied by Hay *et al.* (1996) in H-resolution forest imagery (CASI) and specifically to a coniferous forest.

An attempt to employ this method in this research has been made, but initial results with aerial photos and CASI (Compact Airborne Spectrographic Imager) imagery showed that it was difficult to identify tree crown peaks automatically. We attribute this problem to the large degree of grey-tone variability within the crowns of deciduous trees which is not the case with coniferous tree crowns where a distinct peak can be more readily identified. Further attempts to use the TPN method are currently being undertaken, using a modified procedure for locating the centres of deciduous tree crowns.

Combinations of spatial and spectral context analysis : Contour tracing applied to texture descriptors

In the images below (fig.6) the results of contour tracing applied on variance texture descriptors are presented. It is clear that now the understorey vegetation is distinguished from the upper canopy. However, this method of image segmentation has the disadvantage of discontinuous contours around the tree canopies. Traditional techniques of image processing such as mode and majority filtering, together with vector based analysis within a GIS (Geographical Information System) environment have not improved the quality of the outcome. Using cluster (Isodata) analysis with the texture descriptor image as input, helped to distinguish tree canopy from the understorey but the result is not tree-object specific (fig 7).

CONCLUSIONS

In reviewing the processes which have been applied, we are able to conclude that attention must be given to the combination of texture measures and traditional image segmentation techniques. A further analysis in a vector-GIS framework is recommended in order to extract

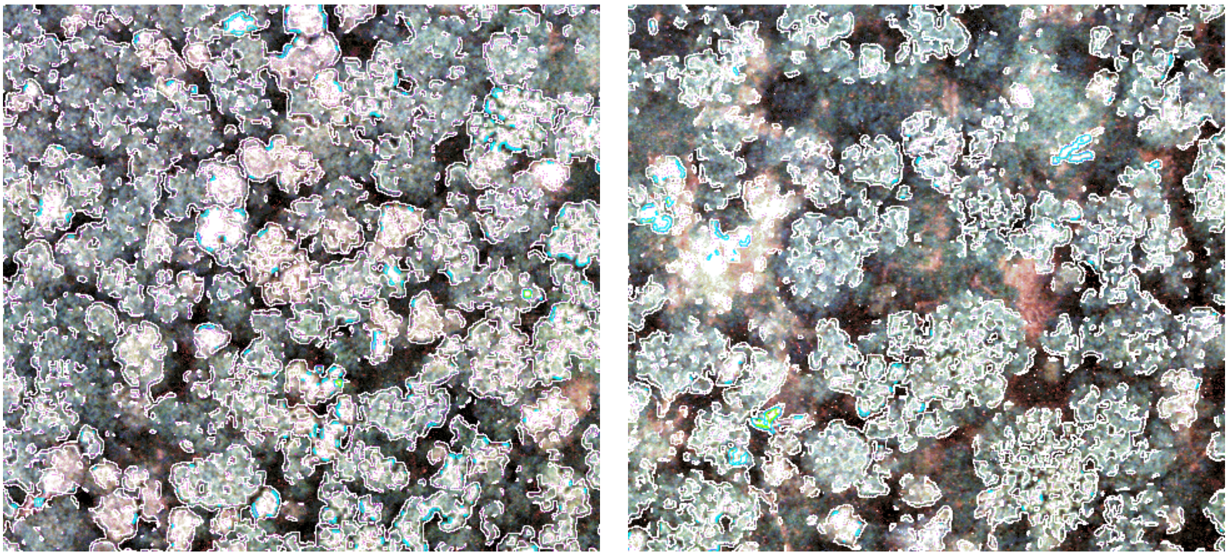

Fig. 6: Contour tracing applied to variance texture descriptor in areas **a** and **b**.

tree crowns as polygons and quantify the spatial characteritsics of these features. Texture measures alone may provide adequate descriptions of the patterns in a woodland environment but these measures do not lead to complete quantification of tree-objects and their spatial characteristics. The variance texture descriptor that has been used for the purposes of this paper may not represent the best texture measure. However, this descriptor was very useful to demonstrate the initial idea of combining spatial and spectral context based techniques and their suitability for identification of objects in deciduous woodlands. Ongoing work is now focusing in the use of second order statistical descriptors, such as the grey level co-occurrence matrix and its indices proposed by Haralick et al. (1973), and the use of the TPN method.

Further work will involve a systematic statistical analysis of the accuracy of the most promising image processing techniques. This will be achieved by comparing the output of automated techniques to manually digitised woodland scenes and ground-based data on tree crown dimensions.

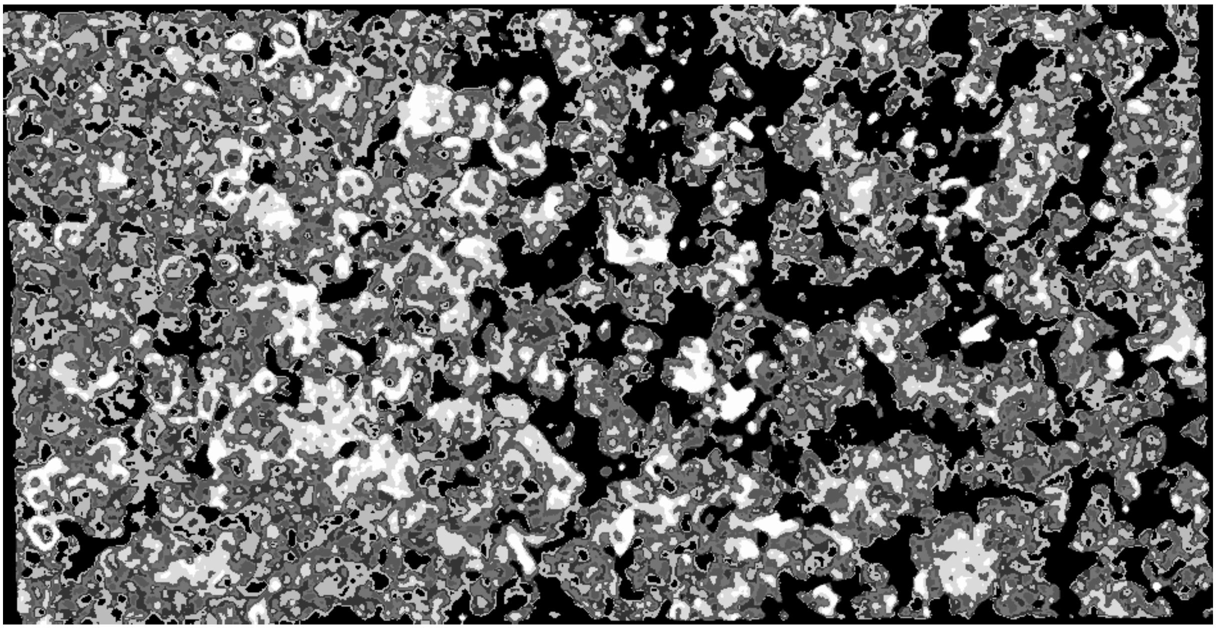

Fig. 7: Top left: Plantation, Right: Ancient Woodland, Grey scale : Vegetation , Black : canopy opening (gaps)

REFERENCES

1. Engle D. M. and J.D. Kulbeth, 1992, Growth dynamics of crowns of eastern red-cedar at 3 locations in Oklahoma, Journal of Range Management 45(3), pp. 301-305.
2. ERDAS, 1995, Erdas Imagine Manual, Field Guide, ERDAS Inc.
3. Gonzalez, R.C. & P. Wintz, 1987, **Digital Image Processing**, 2nd Edition, Adison – Wesley Publishing Co.
4. Hall R. J., R.T. Morton and R. N., Nesby, 1989, A Comparison of Existing Models for DBH Estimation from Large-scale Photos, The Forestry Chronicle, April, pp.114-120.
5. Haralick R.M., Shanmugam K., and Dinstein I.,1973, Textural features for image classification, IEEE Trans. Syst. Man. Cybern. SMC-3 (Nov.):610-621.
6. Hay G., J., K.O. Niemann, McLean G.F, 1996, **An Object-Specific Image-Texture Analysis of H-Resolution Forest Imagery**, Remote Sensing of Environment, 55:108-122.
7. Hay G.J and K.O Niemann, 1994, **Visualizing 3-D Texture: A three-dimensional Structural Approach to Model Forest Texture**, Canadian Journal of Remote Sensing, Vol. 20, No. 2, pp.90-101.
8. Marceau D.J., Howarth P.J., Dubois J.M., Gratton D.J.,1990, Evaluation of the grey-level co-occurrence matrix method for land-cover classification using SPOT imagery. IEEE Transactions on Geoscience and Remote Sensing 28(4):513-519.
9. Minor C.O., 1960, Estimating tree diameters of Arizona ponderosa pine from aerial photographs, Research notes, No. 46, Forest Service – U. S. Department of Agriculture, Colorado.
10. Swain P.H and Davis S. (eds), 1978, Remote Sensing: The quantitative approach (Mcgraw-Hill).
11. Treitz P. and Howarth P., 1996, Remote sensing for forest ecosystems characterisation: A review. Natural Resources Can.ada, Canadian Forest Service-Sault Ste. Marie, ON NODA/NFP Technical Report, TR-12,51p.