Decision tree classification of spatial data patterns from videokeratography using Zernike polynomials *

Michael Twa[†] Srinivasan Parthasarathy[‡] Tom Raasch[§] Mark Bullimore[¶]

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Abstract

Topological spatial data can be useful for the classification and analysis of biomedical data. Neural networks have previously been used to make diagnostic classifications of corneal disease using summary statistics as network inputs. In this study we propose the use of Zernike polynomials to model the global shape of the cornea and use polynomial coefficients as attributes for decision tree classification of a sample of normal patients and patients with corneal distortion caused by keratoconus using C4.5. We then optimize model performance by adding boosting and bagging as enhancements to model generation. Finally, we compare these methods of model optimization with feature selection using principal component analysis. The advantages of this approach are a classification model based upon surface features that consider global shape information as well as more interpretable model output.

1 Problem Specification.

Aberrations of corneal shape that are only a few microns in size can cause severe visual distortions and defocus [?]. Since the shape of the cornea is known to have a great affect on vision, it would be useful to discover clinically relevant aberrations of corneal shape that are predictive of disease or visual dysfunction. Clinicians rely on videokeratography, a procedure that provides a topographic map of the outer surface of the eye for diagnosis and management of diseases affecting the shape of the cornea [?]. Descriptive statistical summaries were the earliest attempt to quantify videokeratography data [?]. More recently, Smolek et al. have used these statistical indices as features for a neural network classification of corneal shape [?]. However,this approach ignores global features that is difficult to interpret clinically.

Corneal surface features measured by clinical videokeratography have previously been modeled with good accuracy using Zernike polynomials [?]. We hypothesized that the resulting polynomial coefficients would be useful attributes for a decision tree classification model of normal and abnormal corneal shape. We further hypothesized that this approach would be accurate, and that this method could provide a clinically meaningful description of corneal shape.

Keratoconus is a progressive non-inflammatory corneal disease know to distort corneal shape, often leading to corneal transplantation [?]. Since one of the earliest signs of keratoconus is a distortion of corneal shape we selected eyes previously diagnosed with this disease and a control sample of non-diseased eyes to test our hypotheses.

2 Experimental Design

Videokeratography data is often provided as an elevation or curvature map of the surface of the cornea representing nearly 7000 individual data points.

Several good ordering algorithms (nested dissection and minimum degree) are available for computing P [3], [7]. Since our interest here does not focus directly on the ordering, we assume for convenience that $P = I$, or that A has been preordered to reflect an appropriate choice of P.

Our purpose here is to examine the nonnumerical complexity of the sparse elimination algorithm given in [1]. As was shown there, a general sparse elimination scheme based on the bordering algorithm requires less storage for pointers and row/column indices than more traditional implementations of general sparse elimination. This is accomplished by exploiting the m-tree, a particular spanning tree for the graph of the filled-in matrix.

Theorem 2.1. *The method was extended to three dimensions. For the standard multigrid coarsening (in which, for a given grid, the next coarser grid has* $1/8$ *as many points), anisotropic problems require plane relaxation to obtain a good smoothing factor.*

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[†]The Ohio State Universtiy, College of Optometry.
[‡]The Ohio State University, Department of Computer Sciences
[§]The Ohio State Universtiy, College of Optometry
[¶]The Ohio State Universtiy, College of Optometry