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Forestry White Paper: Potential Needs in Forest Mensuration

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Abstract- This paper suggests possible advances in forest mensuration that could be achieved through the application of stochastic geometry.

Index Terms- Forest mensuration, forestry, stochastic geometry

The purpose of this white paper is to point out some possible research needs. These needs are in two areas but both are related to geometric measurement problems encountered in forest mensuration. The first concerns geometric measure theory itself and is here designated as Part I. The second concerns anecdotal evidence of a need for a specific field measurement of the internal quality of trees sold for lumber or vaneers.

Part I

Forest mensuration and stereology are two distinct fields. Yet, each could possibly benefit from the other's knowledge. For example, the variable plot method is an example of a class of stereology problem. In fact, in the 1990s the term "local stereology" was created to describe problems where a point is randomly selected and a parameter is statistically estimated from measurements made of what can be seen from that point. The literature of stereology, the science of estimating geometric parameters by statistical sampling, shows no reference to the variable plot method, its discover, Bitterlich, or the instrument, the relascope, used to perform the variable plot method. Similarly, a review of the forestry literature disclosed no reference to Federer's coarea formula, nor to the concept of the "star" which underly the theory of such measurements from the standpoint of stereology and stochastic geometry. In fact, one has to dig deeply into forest mensuration to find a reference to the Steiner formula (presumably the one for Minkowski addition); there seems to be little conversation between stochastic geometry and forest mensuration. Should there be a dialog between the two fields?

Continuing with the topic of the variable plot method, one finds that this method for estimating the relative fraction of basal area, is based on the radial projection of this area onto a line (circle). Projections of three dimensional objects onto lines for the purpose of measuring volume fraction, the three-dimensional equivalent of area fraction, have been perfomed by microscopists for several decades. Transmission electron microscopists in particular have recognized the need for an overlap correction in such measurements. Stereologists responded to this need, and the 1960s through the 1980s saw considerable advancement in the treatment of overlap in measurements made in projection. No such treatment seems yet exists for the case of the variable plot method although experienced foresters attempt to correct for overlap by estimating a radius from the overlapped object, if they know it's there, and then re-sight the object for measurement purposes from a point at which it is visible [Stout, 2003]. Trees not always being circular in cross section is another possible source of error which could be addressed. Foresters have evolved sophisticated statistical techniques for the estimation of sampling variances a posteriori using re-sampling and analysis of variance techniques. Large scale stereological measurements (e.g. histological) might benefit from from the application of these methods. On the other hand, these methods can neither be strictly applied in advance nor be able to easily distinguish between that part of the variance which is inherent to the method and that which belongs to the sample itself. Stereology, on the other hand, has evolved some good estimators for the contribution to variance which is intrinsic to the method itself. Although variance estimators exist for the variable plot method [Schreuder et al., 1993], they involve restrictive and often unrealistic assumptions. Finding such an improved variance estimator for the variable plot method could be useful to those using it both from experimental design and from the standpoint of understanding the covariance structure of forests. Because, the variable plot method is based on rejecting features subtending less than a specified angle, it does not use all of the information potentially available. This loss of information, means a higher variance per measurement. It is therefore highly likely that a stereological treatment of the variable plot method problem would yield another method capable of giving a more informative estimate of basal area. cf [Jensen, 1998; Hilliard & Lawson 2003]

The potential value of stereology to forestry is not limited to the variable plot method. Line intersect methods have been applied to forestry [Canfield, 1941] and intersect methods in general are the "stock in trade" of stereology. Considerable theory exists in stereology covering both projection and intersection measurements as well as the underlying relation between the two as seen through geometric measure theory. Referring back to the example, early on researchers recognized that a straight line could be substituted for the circle of the variable plot method [Strand, 1957]. Such a method might involve cruising with a relascope held at right angles to the line of travel. Since the relascope is an angle gauge, we might inquire as to what sort of information we would obtain. If our angle gauge measured only the angle subtended by the object directly in front of it, we would obtain angle as a function of distance along the line. Since the true widths of the objects sample would be the widths projected onto the line, we could recover more information, projected width and angle subtended, than we would with a single-point measurement. We would now know both how big the nearest trees are and how far away they are as well. The implications are obvious. Would such an approach be practical? The literature suggests that they are not much used. Such an approach has theoretical appeal, but would be of little value to a forester carrying a conventional relascope. However, were we considering automated forest mensuration based on image analysis, the above discussion contains something practical; it contains the germ of an automated method.

Part II

Certain high-value woods such as Black Cherry (Prunus serotina) are subject to internal decay. The presence of such decay has a significant effect on the value of the tree. For this reason a method of determining the presence of decay in the first 18 feet of height of a particular tree would be of economic importance. Decay creates voids, loss of density and possibly locally-increased concentrations of water. These conditions are precisely the same as those of aircraft corrosion. Low-level gamma and x-ray backscatter have proven valuable to the detection of metallic aircraft corrosion [Lawson, 2002]. Furthermore, wood, being composed of carbon, hydrogen and oxygen, has, at “ordinary energies” a higher ratio of scattering to absorption than do aircraft metals. This makes it a better choice for this type of nondestructive inspection than aircraft.

In the past few years, the realization that voids, delaminations and similar gaps, even of the dimensions of microns, give rise to significant effects in the *secondary* scattering of photons, viz. processes involving double scattering where the photon is not scattered directly toward the detector but rather in some other direction and then rescattered toward the detector. These techniques have been utilized for the detection of landmines because landmines need an air gap to function. At the same time, Monte Carlo Markov Chain simulations of scattering processes have become a common tool for understanding multiple scattering processes. Single-scattering processes tend to be relatively symmetric and the backscattered energies are closely related to the scattering angle. Multiple-scattering processes are often quite asymmetric and involve backscatter energies which are significantly less than would be expected for single scattering. Thus, were an image made of a backscattered photon beam, it should be possible to separate the single from the multiple-scattering contribution. This in turn could allow both a qualitative and a quantitative assessment of the presence of non-uniformities in the density of the wood sampled. This approach has been suggested as a means for the diagnosis of spalling refractories in chemical reactors. [Lawson, 2003]. The size of a gamma-based apparatus to evaluate trees would be on the order of the Northrop-Grumman hand held aircraft inspection gauge. The major difference would be the use of an energy-sensitive imaging detector in place of the non-imaging detector used by Grumman. The software would be different and many of the special features of the Grumman gauge would not be needed.

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