PROCEDURES FOR GEOMETRIC DATA REDUCTION IN SOLID LOG MODELLING

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ABSTRACT

One of the difficulties in solid log modelling is working with huge data sets, such as those that come from computed axial tomographic imaging. Algorithmic procedures are described in this paper that have successfully reduced data without sacrificing modelling integrity.

1. INTRODUCTION

To survive in a highly competitive marketplace, hardwood sawmill operators are faced with important decisions about the operation of their mills. These operational changes are precipitated by expanded markets (both domestic and export), low-quality raw material, increased competition from non-wood products, social pressures to manage public lands for non-timber resources, and the reduced profit margin between log costs and lumber prices. To meet current and future consumer needs for hardwood products, sawmill operators have to produce high quality and consistent products from current growing stocks of low-grade timber and increase the value of each board sold.

To manufacture the highest value products possible from hardwood logs, decisions made during the first stage of processing must be good ones. The hardwood log breakdown practice is both geometric and defect-oriented owing to the nature of hardwood end utilization. For producers of hardwood lumber, the objective is to maximize the volume and grade of lumber that generates the highest dollar value for the mill. Higher lumber grades have larger proportions of clear wood on each face, which requires highly judgmental breakdown decisions in patterns such as grade sawing or around sawing with resaw.

Over the years, the human sawyer has been making saw placement decisions based on limited information provided by the external view of log shape, visible external defects, and whatever internal defects are eventually revealed on already cut log faces. Improved recovery of high-value lumber is hampered by the inability of the sawyer to foresee or “see” the internal defect location, orientation, and distribution inside the log, Non-invasive internal scanning of solids has opened up new avenues in the log breakdown planning problem, Using photon tomography scanning, cross-sectional slice images of the log are obtained. These images can be reconstructed into three-dimensional solid models (Occeña, 1992).

One of the major obstacles in converting tomographic scan images to solid log models is the difficulty of working with huge data sets. These data sets are in the magnitude of 7-10 megabytes per log, consisting of cross-sectional profiles for both the log and its defects (knots, worm holes, shake, pitch, rot, bark, etc.). In a previous study for example, red oak logs measuring 10-12 feet long were scanned every quarter-inch to detect the occurrence of degrading internal defect information (Zhu, et al., 1991). The significant cross-sectional changes in the log profile, however, do not occur minutely in increments of a quarter-inch but rather over a range of several inches. For the log profile representation then, it is possible to cull the significant data and not have to carry the overhead of such a massive data set.

For defect profile representation, it is still necessary to examine at a scale of a quarter-inch because of degrading defects in this range. For log profile representation, however, cross-sections that have neither defect nor significant log profile eccentricities can be dispensed with at no loss of important information. The objective of the project described in this paper was to develop data reduction procedures that would reduce the

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data set to a more manageable size without sacrificing the representational integrity of the eventual solid log model.

Two types of cross-sectional variations occur in hardwood logs: centroidal variations which cause the bowing or sweep of the log, and cross-sectional area variations which are denoted by humps or bumps in the log profile.

The centroidal variation, simplistically represented by Figure 1, can be described as the problem of having cross-sections that maybe similar in size but vary in relative position. The centroids are denoted by the crosshairs which are shown to be non-aligned, resulting in a crooked or perhaps bowed log shape profile.

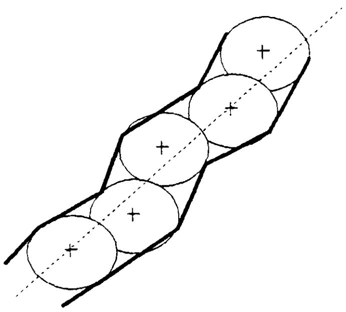

Figure 1. Centroidal Variation.

The cross-sectional area variation, simplistically represented by Figure 2, can be described as the problem of having cross-sections that maybe centroidally aligned, but vary in geometric size. The centroids denoted by the cross-hairs are shown to be aligned, but the cross-sectional slices vary in size, resulting in a lumpy or non-uniform longitudinal shape.

Combinations of these eccentric shapes are responsible for the departure from what would otherwise have been a perfectly cylindrical or conical shape. Interspersed between such eccentric cross-sections are uniformly shaped cross-sections which can be removed to reduce the number of slices without distorting the overall profile of the log. The following sections describe procedures for doing this data reduction and also for validating the result. Note that this reduction is performed only on the log representation, although it can be applied as well to defect data or other axially enumerated data that may need reduction.

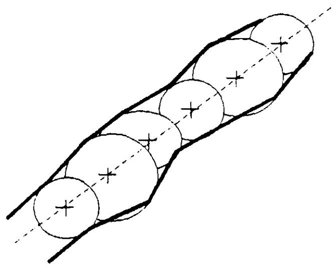

Figure 2. Cross-sectional Area Variation.

2. DATA REDUCTION PROCEDURES

2.1. Polygon Decomposition into Triangles

Each cross-sectional slice consists of a closed-loop enumeration of data points describing the "circumference" at a particular location along the length of the log. Each slice can actually be viewed as a simple polygon. Non-adjacent sides have no common interior or end points. The simple polygon can be decomposed into multiple triangles. The centroid and area of each triangle can be easily calculated using geometry.

2.2. Calculation of Cross-sectional Slice Centroid and Area

Suppose that after decomposition the cross-sectional slice now consists of N triangles. Let (x^c_i, y^c_i) be the centroid, and s_i be the area, of the ith triangle. Then the centroid (CX, cy) and the area (s) of the cross-sectional slice can be calculated as

$$cx = \frac{\sum_{i=1}^{N} x_i^c s_i}{\sum_{i=1}^{N} s_i} \qquad cy = \frac{\sum_{i=1}^{N} y_i^c s_i}{\sum_{i=1}^{N} s_i}$$

$$s = \sum_{i=1}^{N} s_i$$

2.3. Reduction from Centroidal Variation

We represent reduction from centroidal variation as a recursive procedure which retains only those cross-sectional slices which exhibit significant centroidal variation. A slice has a significant centroidal variation when it exhibits a maximum relative displacement from a reference line in each iteration and also exceeds a specified threshold value. We subdivide the log at each retained slice, resulting in two log sections which are recursively evaluated with the same procedure to find other cross-sectional slices with significant centroidal variation.

Suppose a log consists of M cross-sectional slices. Let $p_j(cx_j, cy_j, cz_j)$ describe the centroid of the jth slice, for j= 1,...,M. cx_j and cy_j come from the previous step, and cz_j is the location of this slice along the length of the log relative to the small end of the log, i.e., cz_1=0. Ideally, if the log was perfectly shaped (which is impossible), all cross-sectional centroids will lie on the line segment connecting p_1 and p_M, the first and last slice, respectively.

Let $p'_j(cx'_j, cy'_j, cz_j)$ be an ideal centroid on line segment p_1p_M at location cz_j. $p'_j(cx'_j, cy'_j, cz_j)$ is calculated in a linear relationship from (cx_1, cy_1, cz_1) and $p_M(cx_M, cy_M, cz_M)$. We can define the deviation d_j of the actual centroid from the ideal centroid at cz_j as

$$d_j = \sqrt{(cx_j - cx_j')^2 + (cy_j - cy_j')^2}$$

Find the maximum deviation d^m_j in the interval [1,M]. If d^m_j > T (where T is a specified threshold value), then let k=j. Mark and retain this kth slice as having significant centroidal variation. Then subdivide the log at the kth slice into two sections with slices, 1 $\rightarrow$ k and k $\rightarrow$ M, respectively. Recursively repeat the above procedure for each log section in search of other slices with significant centroidal variation. We run this procedure for varying threshold values T.

2.4. Reduction from Cross-sectional Area Variation

In order to capture the effects of cross-sectional area, we run the same M slices through an evaluation for significant cross-sectional area variation. From the previous procedures, we have the cross-sectional area s_j of the jth slice, for j=1,...,M, and the longitudinal location cz_j of the jth slice relative to the small end of the log.

Let s_1 and s_M be the cross-sectional areas of the first and the last slice, respectively. We can define a line segment connecting (s_1, cz_1) and (s_M, cz_M). Let s'_j be an ideal cross-sectional area at cz_j. We can define the deviation between the actual cross-sectional area and the ideal cross-sectional area at cz_j to be $sd_j = | s_j - s'_j|$.

As in the previous procedure, find the maximum deviation sd^m_j in the interval [1,M]. Then if sd^m_j > T (where T is the specified threshold value), then let k=j Mark and retain this kth slice as having significant cross-sectional area variation. Then subdivide the log at the kth slice into two sections with slices, 1 $\rightarrow$ k and k $\rightarrow$ M, respectively. Recursively repeat the above procedure for each log section in search of other slices with significant cross-sectional area variation. We run this procedure for varying threshold values T. In the end, we have a set of slices that are significant in either centroidal variation, cross-sectional area variation, or both. These are the slices we want to retain as descriptors for the log profile. Slices that are not significant in either criteria are discarded.

3. PROCEDURE VALIDATION

Varying the threshold values in both centroidal and cross-sectional area tests will result in different degrees of data reduction. The higher the threshold, the greater the data reduction. Because our objective was to reduce the data set without sacrificing the representation integrity of the resultant log solid model, we chose the threshold values for centroid and area which rejected the most number of slices with the least variation in solid volume. We used a ratio to represent this criterion. The volume of the solid was determined by a summation of the approximate volume subscribed between each consecutive pair of retained slices. Let the volume V for the L remaining slices be described by

$$V = \sum_{i=1}^{L-1} \frac{s_i + s_{i+1}}{2} l_i$$

and the reduction ratio by $r = \Delta V / n_r$ where

s_i, s_{i+1} are the cross-sectional areas of adjacent remaining slices
l_i is the distance between adjacent remaining slices
ΔV is the difference between the original volume and the reduced volume
n_r is the number of slices discarded.

The above procedures were implemented in a C program and integrated with a microcomputer-based interactive graphics simulator for hardwood log sawing (Occeña and Schmoldt, 1993). Figures 3 and 4 below show a comparison of an original log representation and the reduced representation after performing the above procedures. The reduction ratio for this example was 0.142 which was equivalent to a 59% reduction in number of slices for only a .03% reduction in solid volume.

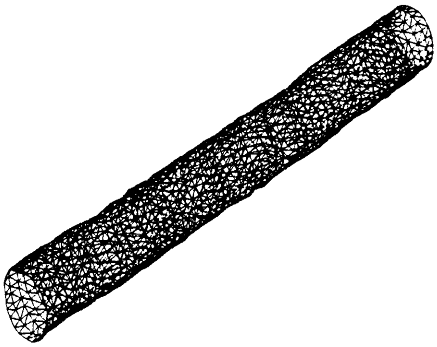

Figure 3. Original Log Representation.

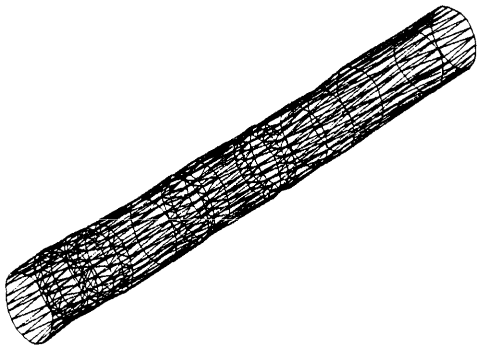

Figure 4. Reduced log representation.

4. CONCLUSION

This paper describes the result of research work that sought to develop procedures for reducing the size of the data set in solid log modelling without sacrificing integrity of the solid model representation, The motivation in this reduction stems from the massive data sets in which the raw data from photon tomography are originally described, However, significant characteristics can be represented from a smaller data set. The problem of selecting the cross-sectional slices to retain was solved by recursive procedures which geometrically evaluated each slice, from whole log to log sections, in terms of its centroidal and cross-sectional area variations from ideal values with respect to a specified threshold. Selection of the best solution was determined using a reduction ratio. The paper presented the procedures with illustrative examples.

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