

Abstract

The value of lumber and the grade of each sawn board are determined by the quantity and size of their features, such as sapwood, heartwood and knot. Knowledge of internal features of wood is useful for optimizing log utilization. In this research, computed tomography (CT) images of logs are processed. The main objective of the research is to develop automated methods for CT image segmentation and labeling of selected log features. They will help sawyers to make correct decisions on how to cut logs based upon these internal features as well as external characteristics. Two classes of internal features, i.e., sapwood and heartwood were studied for recognition. Class variables' separability was assessed. Maximum likelihood classifier was established based on using the variables which have good class separability. The results show that the combination of gray level value with textural information produces accurate segmentation for sapwood and heartwood regions.

Introduction

- Sawyers have used external information to cut logs;
- Internal information of logs is also needed.

Benefits of using internal information:

- > For **hardwoods**: potential gains of about 10% in lumber value (Richards 1977).
- > For **softwoods** such as black spruce: lumber grade yield could be increased by >15% if knots are considered in primary log breakdown (Lemieux et al. 2002).



A CT scanner

X-ray based CT Scanner was used to produce cross sectional CT images of logs to acquire the internal information.

Basic parameters of the CT scanner:

- Voltage and current of X-ray tube: 140 kV, 178mA;
- Volume element of the section (voxel) that was scanned 0.78×0.78×5.00mm³.

The general objective

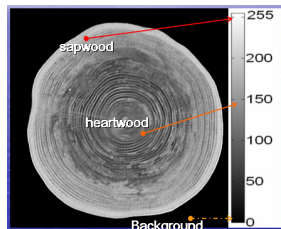
Development of a suitable method for automatic identification of selected internal features of logs using CT images.

The specific goals of this research

- ◆ Class variables' separability assessment;
- ◆ Establishment of maximum likelihood classifier for identifying sapwood and heartwood.

Parameters for establishing the classifier

- ① **Gray level value**, which represents the brightness of each pixel on a CT image. For this research, **mean gray level values** of the raw image was employed;



Each pixel on the CT image has its own gray level value.

CT image of beech cross section with its gray level value scale bar

- ② **Textural information**, which represents the spatial distribution of gray level values for a specific image region. Six variables were used for extraction of the textural information, they were: **Contrast**; **Homogeneity**; **Dissimilarity**; **Mean**; **Standard Deviation** and **Energy**.

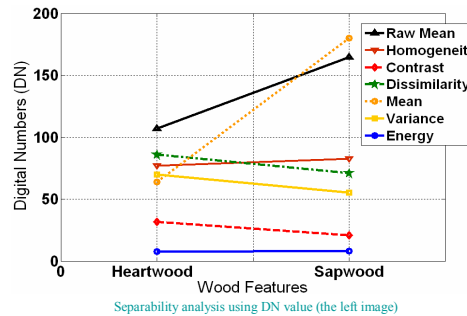
Materials

A beech log was scanned and 20 cross sectional CT images of the log were used for class parameters' separability analysis and the establishment of the classifier.

The classifier

A maximum likelihood classifier was employed in this research based on using seven parameters as the input variables. Maximum likelihood classifier is also called as **optimum statistical classifier** based on Bayes theory.

Results of the two classes (sapwood and heartwood) parameters' separability assessment



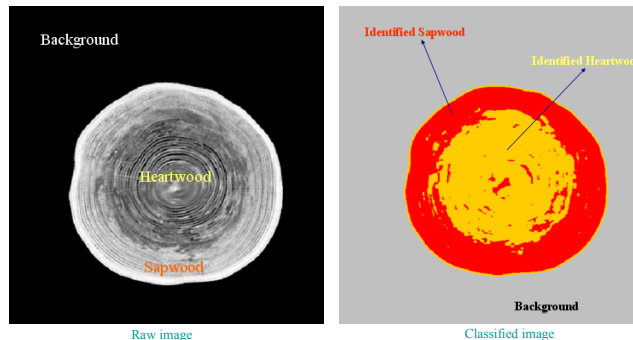
Separability analysis using DN value (the left image)

The first table based on the left image shows separability of different variables using DN

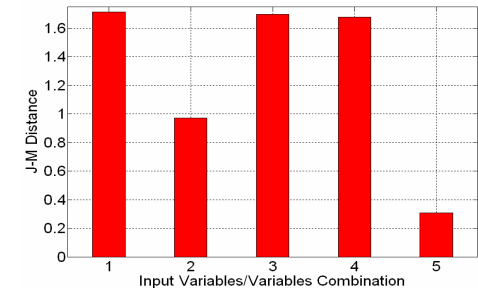
Value	Classes		Difference between the same variables for the two classes	Separability for sapwood and heartwood
	Sapwood	Heartwood		
Mean gray level value of the raw image	164.647*	106.862	Distinct difference	Good separability
Homogeneity	82.563	76.781	Small difference	Moderate separability
Contrast	20.681	31.826	Moderate difference	Moderate separability
Dissimilarity	70.875	85.856	Moderate difference	Moderate separability
Mean	179.883	63.711	Great difference	Very good separability
Standard Deviation	55.076	69.909	Moderate difference	Moderate separability
Energy	8.218	7.755	Very small difference	Bad separability

* All units are in DN, i.e., Digital Numbers (0-255)

Results of the identification



- Accuracy analysis: Overall Accuracy: 88.0%; Overall Kappa Coefficient: 0.759.
- As the overall Kappa coefficient is close to the maximum value, i.e., 1, more accurate are the results of the classification.



Separability analysis using J-M distance (the right image), the number 1, 2, ..., 5 represents variables or combination of variables shown as follows:

- 1: all seven variables combination;
- 2: only mean gray level values of the raw image;
- 3: all seven variables but mean gray level values of the raw image;
- 4: all seven variables but mean gray level values of the raw image and standard deviation;
- 5: all seven variables but mean gray level values of the raw image, mean and standard deviation.

The second table based on the right image shows separability of different variables or combination of variables using J-M distance

Parameters or combination of parameters	J-M distance* between sapwood and heartwood for each parameter or combined parameters	Separability for sapwood and heartwood
1	1.712	Good separability
2	0.970	Bad separability
3	1.697	Moderate separability
4	1.678	Moderate separability
5	0.309	Very bad separability

* As the J-M distance is close to the maximum value, i.e., 2, better the capability of the variable or combination of variables in separating sapwood and heartwood classes.

- ✓ The purpose of the separability analysis was to evaluate different variables in order to select the suitable variables, which have good separability for sapwood and heartwood, to establish the classifier.

Conclusions

- Using the combination of the seven variables as the input parameters has good separability for the class sapwood and the class heartwood;
- **Mean** has a very important influence on the classification accuracy. Every classifier should use this variable as one of the input parameters;
- Maximum likelihood classifier produced an accurate result for recognition sapwood and heartwood based on using the combination of the seven variables.