IDENTIFICATION OF WOOD SPECIES BY USING COMPUTED TOMOGRAPHY

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ABSTRACT

In the work a method of wood species identification by using computed tomography was proposed. Computed tomography allows us to explore internal characteristics of wood and specific anatomical features of different species. A data base of variables was obtained, that was analysed by mathematic-statistical methods such as box plots, PCA, classification tree. The analysis revealed, that the method allows us to identify different wood species with good accuracy.

1. INTRODUCTION

In wood processing industry the correct identification of wood species is important. Different wood species have dissimilar physic-mechanical characteristics and vary greatly in price. It makes them appropriate to special applications. Tree species are usually identified at felling time but the information may be lost during the wood chain transformation. The identity of tree can be by proofed manually (visual), but it takes a long time to train a person to be competent in wood identification, and it can also lead to classification errors because of the human factor. In addition, sorting by manual measurements does not correspond to current industrial speeds of logs subsequent processing. These problems motivated to develop a system to identify wood species eliminating above mentioned difficulties.

X-ray scanning is the most recent technology in wood processing, yet there are not any studies on wood species recognition with X-ray. The study was aimed to develop X-ray technology for identification of wood species in order to obtain additional benefit.

2. MATERIALS AND METHODS

The proposed work, established upon data base, derived from CT scanner, was based on five species: Norway spruce (Picea abies), Douglas (Pseudotsuga), Scots pine (Pinus sylvesteris), Silver fir (Abies alba) and Larch (Larix decidua). Images examples are represented on the Figure 1.

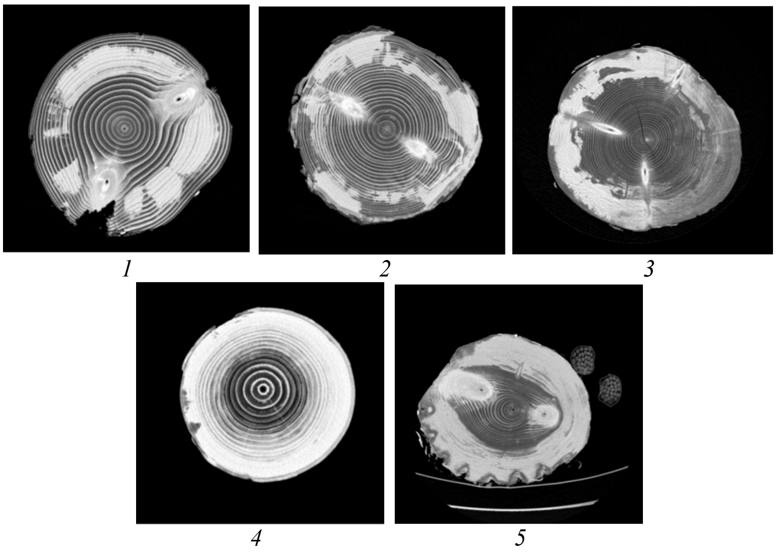

Figure 1: Examples of CT images
1 – Douglas fir, 2 – Silver fir, 3 – Norway spruce, 4 –European larch, 5 – Scots pine.

The logs were scanned with a medical X-ray scanner Bright Speed Excel by GE Healthcare. The system almost instantaneously delivers volumetric reconstruction of the sample in the form of stack of 512×512 pixels slices (the minimal pixel size was 0.2 mm for a field of view of 96 mm), with a slice thickness of 0.625-10 mm. Grey level is assigned to each pixel according to the linear attenuation coefficient of the material and can be converted easily to wood density value.
For processing of the images we used the "Gourmands" plugin (Colin et al., 2007) for ImageJ (http://rsb.info.nih.gov/ij/). It allows to the user to make and record manual measurements by using different proposed tools. Different coloured markers are used for coding the following elementary components. The "Gourmands" plugin allows us to measure characteristics such as knots, pith, bud traces and so on. Graphical views can be derived from a viewer (Bill3D) developed by Frédéric Mothe (1994) to present all measurements in single 3D model of the tree (Figure 2).
Based on the manual measurements described above, a set of variables were computed. The variables were as much as possible based on existing biological knowledge. For computation the chosen parameters we used parts of the logs with completed growth units (GU). The idea was to create a big number of variables which are potentially able to help for the species recognition by using such mathematic-statistical methods as box plots, PCA (Principal Components Analysis) or classification tree. We created the following variables: mean log grey level, median wood density in a 1 cm-diameter circle centered on the pith, mean standard deviation of gray level for all the log of the values per slice, bark thickness divided by mean log radius, resin pockets presence, mean relative knot diameters, mean relative knot length, mean included knot length per GU divided by mean log radius, coefficient of variation of knot diameters in part of the log with completed GUs, standard deviation of relative knot diameter for all completed GU in the log, standard deviation of relative knot length for all completed GU in the log, mean relative included knot length, number of knots per meter, mean number of knots per GU for all completed GUs in the log, mean number of knots in whorl for all completed GUs in the log, mean value of knots inclination for all completed GUs within log, mean length of completed GUs in log, mean value of maximum diameters for all completed GU in log, mean relative minimum knot diameter for all completed GUs in log, mean relative maximum knot diameter for all completed GUs in log, mean knot relative position, ratio of knot length (parameter c)

to distance from the beginning of the knot to its end (parameter d) – knot sinuosity, standard deviation of knot inclination, ratio between number of included knots and number of knots and others.

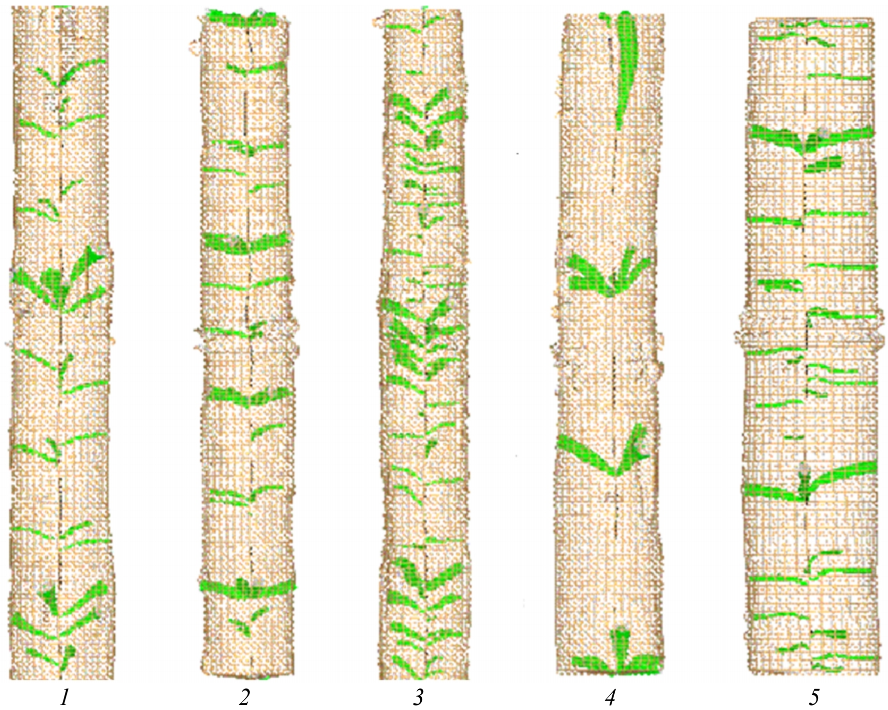

Figure 2: Examples of 3D views for one log of each species
1 – Douglas fir, 2 – Silver fir, 3 – Larch, 4 – Scots pine, 5 – Norway spruce.

3. RESULTS AND DESCUSSION

All possible variables were represented by box plots for the visualisation of the data. Several species could be recognised by means of the box plots. For example, Scots pine has dissimilar “mean log grey level”. Some of the pine logs have decay near the pith so we didn’t use the logs for evaluation “median wood density in a 1 cm-diameter circle centred on the pith. As evident from Bill3D models the Scots pine logs have big branches on the top part GU and almost don’t have branches on the bottom part just sometimes small buds. That is why the species is distinguishable by the variables related to knot sizes and number (“mean relative knot diameter”, “standard deviation of relative knot diameter”, “mean relative maximum knot diameter”, “mean number of knots”). Since it has only big branches on the top part “mean relative position” of the branches is high. The pine logs are also characterised by a more curved shape (“mean knot sinuosity”). Artificially pruned branches of Douglas fir increase “mean relative included knot length”. Norway spruce has many thin buds inversely to Scots Pine so “mean relative minimum knot diameter” is low value. Most of the European larch variables have temperate values and overlapped with another species. Silver fir could be recognised by low value of “standard deviation of knot inclination” and in the most cases it overlapped with another species.

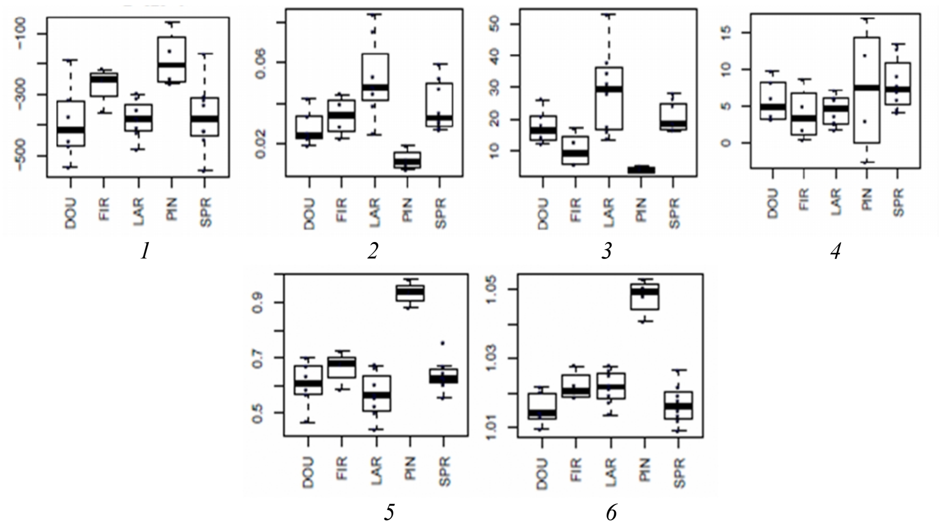

Figure 3: Box plots examples 1 – mean log grey levels, 2 – number of knots per meter, 3 – mean number of knots per GU for all completed GUs in the log, 4 - mean value of initial knots inclination for all the completed GUs within log, 5 - mean knot relative position, 6 – ratio of knot length to distance from the beginning of the knot to its end

PCA analysis is represented on Figure 4, where the obtained plots allow us to distinguish Scots pine, silver fir from a group of other species.

Classification tree (Figure 5) divided all the represented data into classes (species) with 100% accuracy. “Mean number of knots per GU for all completed GUs in the log”, “standard deviation of relative knot length”, “mean number of knots per meter”, “mean relative minimum knot diameter for all completed GUs in log”, “ratio between number of included knots and number of knots” are parameters, which were used for classification tree construction. The tree also has pure leafs. Impurity of nodes was computed and the splits that most decrease impurity were selected by testing the different variables (Gini index). Thereby the tree was pruned on the basis of misclassification rate and a complexity parameter (CP) of 0,05 (Figure 6). All logs of Scots pine and silver fir were classified correctly. 7 logs of Norway spruce and the same number of European larch were classified correctly. Eighth logs of spruce were misclassified into larch group and eighth logs of larch were misclassified into Douglas fir group. Douglas fir logs were distributed within three different leafs of the classification tree.

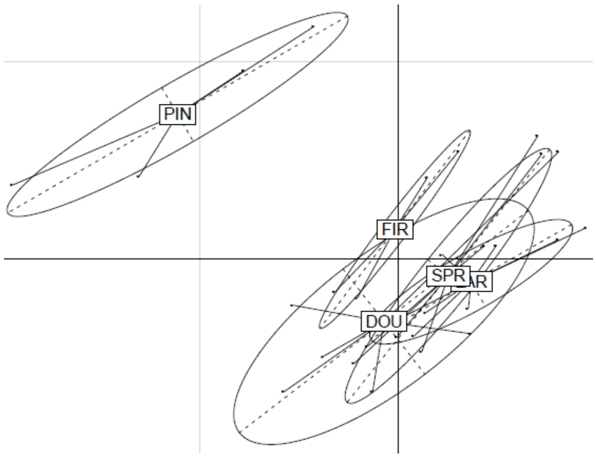

Figure 4: PCA plot

4. CONCLUSION

Throughout the study, we aimed to develop a method of wood species recognition based on the X-ray technology. Available biological material was processed and the obtained data was analysed. Box plots, PCA and "Classification tree" statistical methods were applied for wood species identification.
1. Results of the analysis proved possibility of using wood species identification by computed tomography in wood processing industry.
2. Using of the three statistical methods gives one more additional application to computed tomography. By using big train dataset the method can be submitted for developing automatic algorithm of wood species recognition based on X-ray technology.

5. REFERENCES

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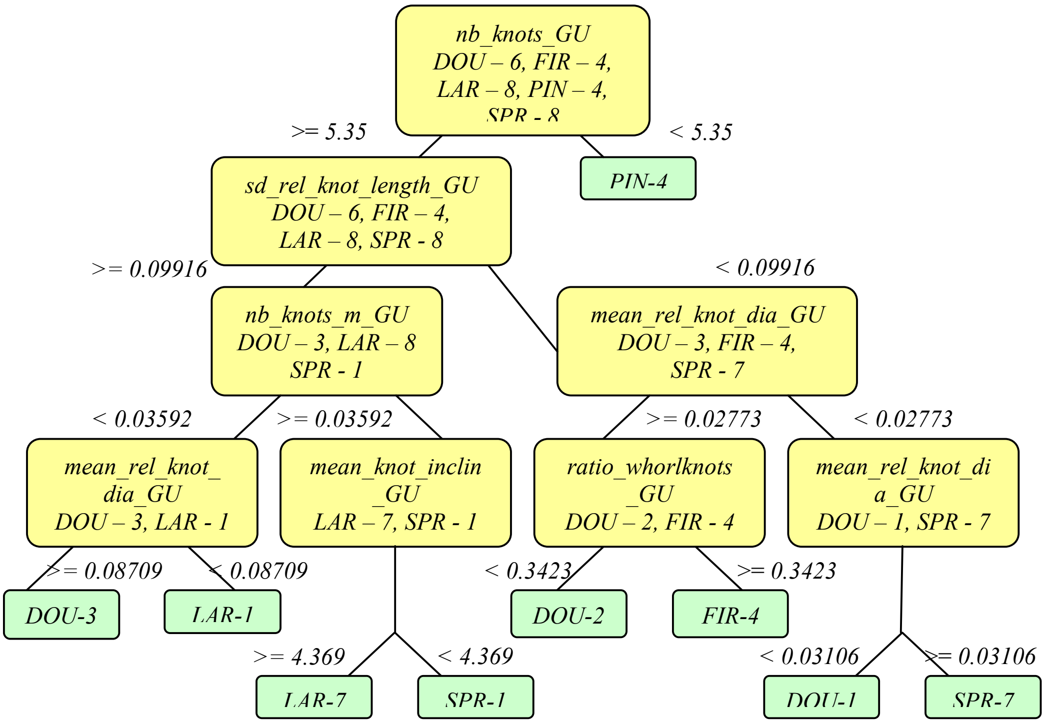

Figure 5: Classification tree

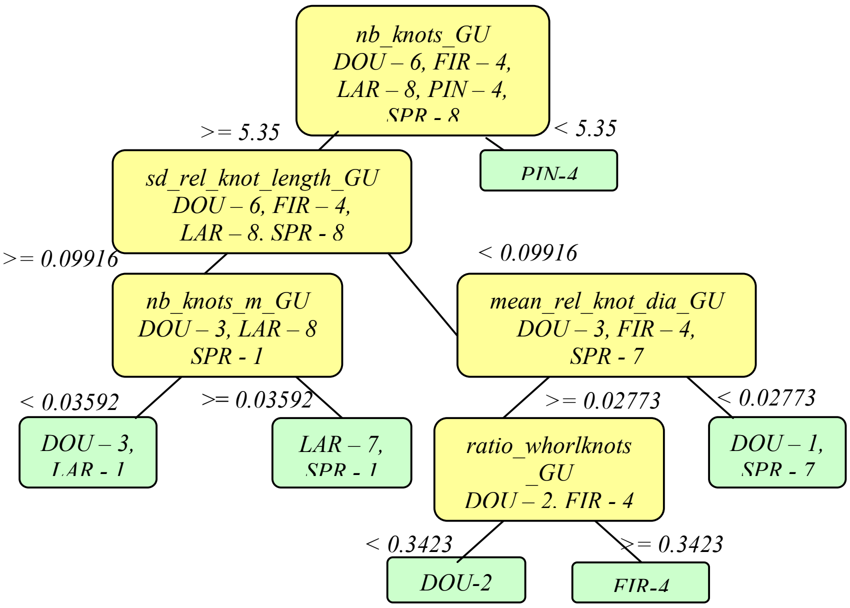

Figure 6: Pruned classification tree