

ANALYSIS OF ANATOMICAL ELEMENTS AS WOOD TEXTURE CHARACTERISTICS

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ABSTRACT

In recent years, more and more systems for computer recognition of tree species are entering, which show good results in solving a certain group of problems. Some of them have already proven themselves in solving such tasks as quality control of wood materials. Studies also show that the classifications of tree species used so far do not allow to solve more general problems of structural wood science. The approaches, methods and means used in computer recognition for modeling the structure of the wood presuppose such a classification of the tree species, which should be based on a more general view on the structure of the wood in comparison with the methods used so far. This would allow to study and describe in a single formalized classification scheme all the anatomical elements that are observed with the corresponding increase in the samples of tree species. In addition, it is necessary to specify the term "texture", applicable in the computer structural anatomy of wood for the purposes of using the methods of computer vision.

The paper discusses the initial results of research related to the application of the requirements of computer modeling in solving some problems of wood anatomy. In particular, recommendations have been made for the quantitative characteristics of the study region in the wood samples and for the description of the anatomical elements making up the wood that will fall into this region and can be examined with sufficient accuracy.

Key words: identification of wood, wood texture, vessels, core rays, annual rings.

INTRODUCTION

In science of wood, the texture of wood is understood as the manifestation of its structure, presented at a certain magnification and in a certain plain of observation of the section of wood samples. This is a relatively homogeneous pattern of wood, including noticeable colour or optical effects (Wagenführ and Scheiber, 1996). The theory of wood science gives three main sections of wood, in relation to the three main directions – longitudinal, radial and tangential.

In these three sections the texture is very different and the differences between the

transverse section (discussed in this work) and the longitudinal section are extremely large. Given the application of wood, its texture has been studied mainly in the longitudinal sections. Ten main textures were considered and defined (Wagenführ and Scheiber, 1996). The texture is also affected by the presence of defects in the wood structure.

They can also help in identifying tree species (Stanko and Gorbacheva, 2010). Wood defect is any deviation of wood structure from the so-called „clear wood”. Most modern applications of computer vision

methods are focused on the study of the deviation of the texture from the normal structure of wood. The so-called "finger joint" technologies have been used in woodworking practice for many years, where a machine recognizes and discards all parts of the processed materials having defects.

In terms of computer vision, "texture" is used to define objects or concepts contained in an image. This type of analysis is one of the approaches for object recognition (characteristics), detection of surface defects and others (Laleh, 2019). Texture analysis methods are usually classified into four categories: statistical methods, structural methods, model-based methods, and transformed methods.

The purpose of „Texture Segmentation” is to divide the image into separate areas, each of which is different in texture. Texture segmentation compares the characteristics of boundaries and zones, and if their textural characteristics are sufficiently different, the boundary range is found.

The purpose of „Texture Synthesis” is to produce images that have the same texture as the input texture.

The purpose of „Texture Classification” is to provide descriptors for categorizing texture images. Texture classification means assigning an unknown sample image to one of the predefined texture classes (Laleh, 2019).

In computer vision methods, functions are derived using the gray-level co-occurrence matrix (GLCM), a local binary model (LBP), and other geometric characteristics classified with the Support Vector Machines (SVM) classifier (Yusof et al., 2018). The solutions of this problem represent a statistical processing of the development of each pixel in different degrees of gray (Materka and Strzelecki, 1998).

In addition, computer vision methods provide statistical information that reveals

new aspects of wood anatomy that have been neglected by conventional visual inspection (Kobayashi et al., 2019). According to the authors, although these methods ignore information of vessels location, which is very important for conventional wood anatomy, simple information about the shape or size of the elements is sufficient to describe the species specificity of wood.

However, we believe that most of the articles published so far report the results of a more limited number of tree species than those they have studied. In the science of morphology, the number of studied species determines the size and accuracy of the keys. And this can not be ignored by the methods used for computer vision and analysis of wood texture. We do not doubt the possibility of these methods distinguishing two or more species from each other. But when these species are in a group of 20 or 30 species, it is not very certain what the success will be.

REGION AND ELEMENTARY PRIMITIVE

One of the main problems with computer vision is how to define the region and the elementary primitive. In the structural anatomy of wood, a region in the wood texture is a small section in the form of a square including the annual ring in radial direction and the same size in the tangential direction (Fig. 1). The main requirement for the region is to be repeated in both radial and tangential directions. In this way, by copying it we will be able to restore the structure of the wood of the whole tree.

As it is shown in Fig.1, the microscopic photos presented are of a very high quality and depict the typical wood structure. However, they also illustrate a number of problems faced by the process of determining the region in the wood. The first one is the quan-

titative representation of tissues. An obligatory condition for the correct determination of the region is that the quantitative distribution of the main tissues in it should be close to that of the wood of the respective species.

Examining this distribution will probably provide an answer of the question for the minimum size of the region and whether it can be the one, shown in the square figure.

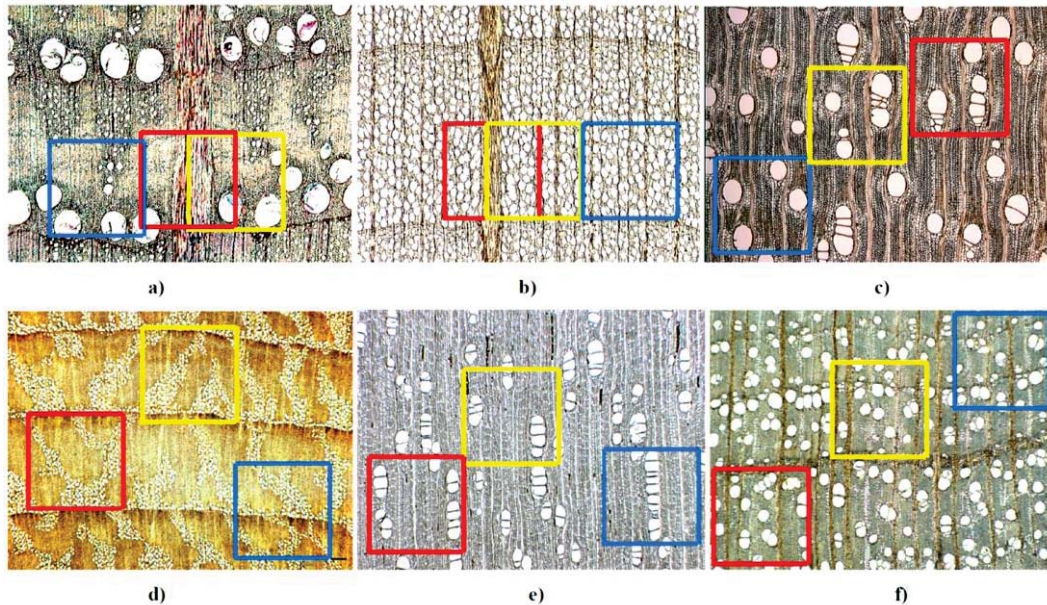


Figure 1: Typical wood structure of: a) Oak (Quercus), b) Beech (Fagus), c) Ako (Antiaris), d) Buckthorn (Rhamnus), e) Longi (Gambusia) and f) Kanalete (Cordia) with three exemplary regions of wood (depending on the characteristics of the structure), marked with blue, yellow and red square (Richter and Dallwitz, 2000)

The second problem is the expression of the width of the annual ring. An important question here is how to proceed if the ring is wider than the field of view. When it is too narrow, it can strongly change (deform) the typical wood structure and this will not allow the structure to be copied (multiplied). Probably it will not meet the first condition. This is a common problem in the ring-porous tree species. From the point of view of computer vision, some questions arise here, i.e. can the depicted regions have the same area for all tree species? It is obvious that for some species (Fig. 1. d) both boundaries of the annual ring fall in the region, while for other species they do not. An appropriate solution should be to include more annual rings in one region. The most typical question is how to determine its location in species that do not have

outlined (visible) boundaries between the rings (Fig. 1. c, e).

There are also several problems with the expression of core rays. They mainly occur in species with broad or aggregate core rays. The location of the region when the distance between the rays is too large is very important. For example, when observing the blue square in the first two species (oak and beech, Fig. 1. a, b), it does not include core rays.

In order to comply with the requirements of computer vision methods, this condition must be met by all species. It is also clear that it cannot be met in ako and kanalete (Fig. 1. e, f). In that case the region must be so small so that no vessels can be seen in it. Even if we increase the square by the size of the annual ring, in oak and beech the ray can be in the middle or at the end.

In both cases, the multiplication will result in a different tree species, e.g. plane instead of beech). Probably one of the solutions is to define a rectangle instead of square region with longer side in tangential direction or to be large enough to contain several broad rays. In that way the machine will be able to recognize them.

An important problem is the expression of the mutual arrangement of vessels. Here the problems are both quantitative and qualitative. When determining the region, the minimum number of ducts that it must include, should be indicated. It must provide the same statistical excerpt that applies to the whole sample (the number of large, medium, and small vessels, etc.). To some extent, this issue is also related to the optical zoom applied.

Another quantitative problem is how to include characteristic groups in the region, as they also have their quantitative measurement, i.e. how many single, paired and large group vessels. The problem here is to define the main pattern, i.e. the mutual arrangement of the vessels and to what extent will it be present in the region (Fig. 1. c-f).

The problems specified so far suggest a number of solutions, each of which should comply with the requirement that the regions have to be large and shaped in order to cover several boundaries (at least 2) between the annual rings and at least a few broad rays. Given the size of the average width of the rings in most species, as well as the average size of the distance between two wide rays, then if a square region is chosen, it should have a side of about 1–2 cm.

In some species, such as poplar and redwood, the annual rings are so wide that a larger region might be recommended. Since this cannot be achieved in microscopic examinations, a regular practice in wood anatomy

is placing the border in the middle (as a diameter) of the visual field. However, in order to cover the different groups of vessels, the magnification should not be very small (15–20x).

Multiplying this region in the three main directions, will result in the so-called "ideal tree", which will have the most characteristic pattern, both throughout the range of the species and at each point of the stem.

IDENTIFICATION OF TREE SPECIES

The main problem with recognition methods is the creation of a sufficiently complete database. According to some authors, the tree species are about 70 000, according to others – 100 000 (Bluskova, 2009). Most authors select their representative samples depending on the number of species they can study. While the number of European tree species of industrial importance is limited to about 120, the total number of tropical tree species is between 40 000 and 50 000, of which about 5 000 can be found in the tropics of Africa (da Silva et al., 2017).

Other authors identify their samples from CITES-listed species with the aim of answering the question of whether the species they study has a yield restriction (Zhang Fang-Da et al., 2016). This is because one of the main problems in preserving plant abundance is that in large genera such as rosewood (*Dalbergia*) and ebony (*Diospyros*), some species are allowed for harvesting and others are not.

All these types are very similar, the differences are mainly of quantitative character, making them very difficult to manage with the means of the classical recognition. In addition, in order to obtain a realistic picture, the samples must be taken from different trees and from different parts of the range in the habitat.

In Botany, “key” is defined as a set of successive questions and answers that lead to the final definite conclusion, e.g. which is the studied species. The method of the dichotomous table (diagram) is used. However, these keys are applicable to a limited number of species. Therefore, it is not possible to use a single key for all tree species, especially in wood anatomy.

Despite their significant variance, the structural characteristics obey to certain rules for each species. In the course in Wood Science, taught at the University of Forestry, Sofia, a key for about 35 species, mainly native ones, is used. In this key, all types are divided into 5 main structural groups. Each of them is divided into five subgroups, and only those with a transitional device are divided into two – semi-ring-porous and semi-diffused-porous.

The possibilities for classification provided by the computer vision should be aimed precisely at discriminating these main groups (and possibly subgroups). In addition, the group of tropical species is conditionally divided into five subgroups, subsequently arising additional questions.

It is supposed that different tree species having different structure (and texture) will give different results obtained from the descriptors. In order to improve the quality, the descriptors should be increased and/or the extraction of texture functions from the images from the respective frequency range should be increased. Since the main task is to identify tree species, this can be done through an appropriate classification algorithm. If single characteristics are used as an input to the classifier, then relatively better classification accuracy can be achieved (Yadav et al., 2015).

Vessels have been mainly analyzed with different types of magnification. However, it is not clear to what extent the increase affects

the accuracy of the work. Significant progress has been made in texture analysis at 25 × optical zoom (da Silva et al., 2017). Some of the studied 77 Central African tree species are characterised with a very high rate of identification, while others – with a very low rate. Those with a high rate showed characteristic diagnostic features of the images used, while low-rate species often had distinctive anatomical features at other microscopic zooms or orientations.

Wood is composed mainly of three types of tissues – conductive, mechanical and reserve. The quantitative distribution and the combinations between them determine both the affiliation of the tree species to a given taxon and the physico-mechanical properties. The mutual arrangement of these tissues is unique to each species. Apart from the species, it also depends on the habitat conditions, the age of the cambium and the position in the stem.

In order to successfully apply a method using computer vision techniques, the cells of all tissues – vessels, fibers, longitudinal and transverse parenchyma – must be measured and analyzed. There is still no systematic procedure for classification and identification of wood, so in order to identify species, the combination of microstructure characteristics must be considered (Yadav et al., 2017). According to some authors, if the classification is correct at the family level, it is also correct at the genus level; similarly, if the classification is correct at the genus level, it is also correct at the family level (da Silva et al., 2017).

This shows that the principles of classification in computer vision are similar to the botanical classification, i.e. pyramidal arrangement, and not to the division of species into construction groups. It should also be noted that most methods take into account the fact that it is necessary to describe the wood

at different magnification on which descriptors such as LBP and Gabor filters are used (Cavalin and Oliveira, 2017). The fact that the image may contain repetitions with the same texture pattern is also considered.

In computer recognition, many data sets have first been proposed to solve a specific problem and later have become benchmarks for texture recognition systems. Probably, when working with wood, a classification should also be created, specially adapted to the needs of the structural anatomy of the wood, which has to be recognizable by the descriptors and used as a database.

CONCLUSIONS

Examination of wood using computer vision methods and techniques requires proper selection of the area and anatomical elements examined. While the size and location of the area depends more on finding wood with the correct and typical structure, the choice of anatomical elements depends more on the optical zoom at which it will be studied. These two indicators are contradictory and the correct solution requires a compromise.

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