

ABSTRACT METHODS TO CLASSIFY THE STRUCTURE OF WOOD

Nikolai Bardarov, Vladislav Todorov, Tanya Pancheva

University of Forestry, Sofia, Bulgaria

e-mail: niki_bardarov@abv.bg; vtodorov@ltu.bg; tanyapancheva@abv.bg

ABSTRACT

The construction of wood can be represented by both quantitative and qualitative characteristics. Each anatomical element has quantitative indicators. These are the size of the cell gap (lumen), the thickness of the cell wall, the diameter and the length of the cell. The arrangement of these cells relative to each other is very characteristic of each species and varies relatively slightly. It is a qualitative characteristic that can also be represented by quantitative methods. Although the structure of wood varies under the influence of environmental conditions and location in the stem, the most characteristic structures remain relatively constant.

The article considers the possibility of using a formal-analytical description of the wood structure, applying abstract measurement methods. The obtained data are identical and can be processed by different mathematical methods. The proposed abstract methods give different classifications of the wood structure. Thus, a tree species in one method falls into one group with some species, in another – with others.

Key words: vessels, classification of wood, wood structure, abstract methods.

INTRODUCTION

Wood is a product of the activity of woody plants, which is characterized by fibrous structure and anisotropy. There are three directions in it, which define three main sections (relative to the axis of the tree) – transverse, tangential and radial (Blaskova G. 2009, Enchev E., 1984).

When studying wood, one can choose at what level it will be described and studied. Depending on this level (ie increase) one can speak of (Wagenführ, R. 1984):

- Macroscopic (morphological) structure;
- Microscopic (anatomical) structure;
- Submicroscopic (nano-) structure.

However, there is another group that we can call meso-construction. The magnifications used here are from 10× to 20×. They show the conducting cells and their characteristics can be measured with relative accu-

racy. The cases they occupy can also be determined. In some species, the wood rays can also be measured. Exactly this "meso" structure has been used in recent years in an attempt to determine the tree species using various computer techniques. (da Silva N.R. et al. 2017; Yadav A.R. et al. 2017).

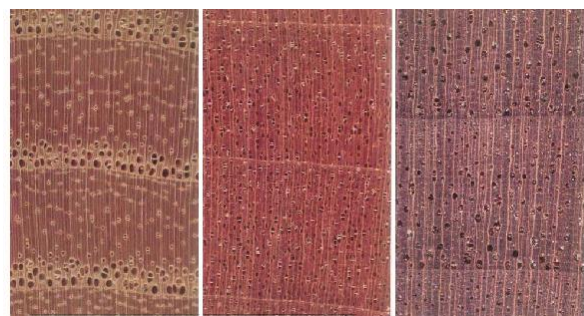


Figure 1: Ash, sycamore and walnut in a cross cut and magnification around 15x

The wood structure is relatively unique and permanent for each tree species. It changes depending on the climatic characteristics, the conditions under which the tree grows or the position of the studied wood in

the stem. However, it remains so constant that any student or specialist can identify the tree species by it (Schweingruber Fr.H. 2007).

Quickly identifying tree species is of great scientific and practical importance. It will be possible to determine the types of wood (juvenile or mature) in an attempt to improve the quality of materials. It will be possible to study various ecological and biological factors for their influence on the wood structure. Decisive resistance will be given in the fight against illegal logging (Fang F.Ch., et al. 2010).

Even when using the best technique, identifying involves a few difficulties – creating a database, finding a typical structure on the test sample, pre-qualification of the people who work with them, etc.

There are several main reasons why a formal-analytical description of wood is needed.

1) Any student who has completed a course in Botany or Wood Science can easily recognize the conducting cells;

2) The arrangement of these conducting cells is unique to each species;

3) Modern methods for scanning and pattern recognition (including neural networks) can recognize and separate vessels from other wood (da Silva N.R. et al. 2017; Yadav A.R. et al. 2017; Fang F.Ch., et al. 2010).

4) With the help of computer vision techniques, the characteristics of the vessels (diameter, density and location) can be determined quickly and accurately;

5) Classical recognition requires high qualifications. For example, the recognition of ash requires about 61 scars that need to be found and described (Bardarov N., 2014).

Another problem is that these quantitative methods that are possible require the measurement of the characteristics of each

vessel. This is very slow and difficult by classical methods. That is why all attempts so far to classify or recognize wood are aimed at the automatic recognition of vessels. Last but not least, there is the problem of interdisciplinarity. It is difficult for a specialist in wood anatomy to present the problem convincingly enough to specialists in mathematics or electronics, and for them this is probably not disconcerting enough. In addition, a streamlined database acquisition system (similar to chess games in Chess Base) needs to be created.

After all that has been said so far, it can be concluded that not the identification of the species but the categorization of the wood structure is the right way to conduct research.

The aim of the work is to find abstract methods that can analytically describe the structure of wood in digital form, using them to classify tree species according to their anatomical structure.

PROBLEM STATUS

The main problem in classifying the wood structure is finding ways for its formal-analytical description. It has already been stated that identifying tree species with the help of computer techniques requires the creation of a sufficiently large database. The problem with the effectiveness of these methods is that the bases created so far are mainly for industrially used wood species (da Silva N.R., et al.). Trees banned from felling are significantly less common and less studied. The methods used so far are for such species. There are automated systems in place that can answer the question of whether a shipment is included in the banned logging lists (eg CITES).

Therefore, not the obligatory identification of each studied species, but its classification according to its anatomical characteristics is an achievable goal. The question is,

to what extent can existing sciences and scientific methods be used to describe the structure of wood analytically. Then we can talk about such a classification. It should be noted that the studied species are currently only deciduous, due to the presence of vessels. Vessels can be represented as small, numerous objects connected to each other. We will look for ready-made mathematical solutions that are applied in various parts of science and practice.

METHODOLOGY

The methods discussed in this paper will be applicable to magnifications of $20 \times$ to $100 \times$, but some methods may require a larger one. For greater applicability of the methods, a database with about 50–70 tree species can be created and gradually expanded.

Each of the methods can be asked identical questions and tasks:

- Question 1. Reliability: How to calculate their reliability?
- Question 2. Representativeness. In what range of the number of measurements can sufficient accuracy of the obtained results be expected?
- Question 3. Optimality: How to show the minimum number of measurements?
- Question 4. Repeatability: Do they use a database based on measurements of a reference photo showing the best structure or do they work regardless of the quality of the photo?
- Question 5. Continuity. The accuracy of the resulting model should not be affected by the accuracy of positioning of the measured area in the photo. If the photo is positioned slightly to the left or right, the values of the data which the model is based do not change significantly.

There are other issues, such as sampling requirements and standards, such as:

- To determine which of the methods can be applied to all sections and which only to the cross-section.
- To determine which methods process the data from one line and which from a wide strip (or the whole field of view).
- To determine whether a small number of lines in the most characteristic places of the photo with detailed measurements on them or a large number of lines with few measurements (thus covering a larger measurement area) are the appropriate way to study the structure of wood.
- What is the continuity of the spatial arrangement of the vessels? If by slightly „moving” the measured area of the photo a little to the left or right, and the input data changes, how much will the resulting change?

In some methods, all vessels in the visual field need to be measured, while in others only a few cells can be measured. They can also perform the work on the classical measurements, while the former will require computer vision techniques. In anatomical tests for identification, something very important must be pointed out. With some methods, it will be possible to measure any photos. We do not call them accurate, because it is not the quality of the photo, but the typicality of the structure that makes one photo good and another not.

Some of the methods will have to develop a database of the best representatives of microscopic slides. Many slides can be found. The initial data obtained will be used to compare each subsequently measured sample. An approximation will then be made and it will be determined with some probabil-

ity what the species is. Most methods, however, will not be able to give a definite assessment of what the tree species is, but will bring it to some range, but this is not a small amount. Each of the methods examines easily measurable anatomical parameters and divides all tree species into different groups.

DESCRIPTION OF METHODS

The use of the studied methods aims to assess their usability in solving the general problem of classification of tree species according to the peculiarities of the anatomical structure of their wood. The location of the vessels is studied as the main distinguishing feature. In addition to a qualitative description of the construction, the methods allow this structure to be described quantitatively. The formal-analytical description of the wood shows that its structure can be recorded in different ways.

MATRIX METHODS

Here is worked in the cross-section, and different magnifications can be used. The field of view is divided into strips with a width and height of 60 μm . In the cells of the obtained table, a specific indicator of the anatomical structure of the wood is recorded. The formal-analytical description of the wood shows that its construction can be recorded in different ways. A random matrix of the spatial arrangement of the vessels can be created. In the cells in which the center of the vessel falls, a value of 1 is recorded, and in those which do not fall, nothing is recorded.

In the second variant, a characteristic matrix of the distribution of the vessels by diameters is created. In the cells in which the center of the vessel falls, the value of its diameter is recorded, and in those which do not fall, nothing is recorded. In another variant, a characteristic matrix of the distribution of the vessels and the fibers according to their wall is created. Thus, in each cell of the table, the

value of the cell wall thickness (in German „Wandigkeit“; Wagenfuhr, R., 1996) of the vessel, fiber, or parenchymal cell is recorded.

A ratio of the distance between the centers of the vessels and their diameter (μ/d) can be created. This number for the various anatomical elements can then be written in the matrix cell. The matrix method provides another possibility. If only parts of the annual ring are measured, typical wood structures such as radial groups, clusters, tangential bands or dendrites can be examined.

In practice, the accuracy of recording the center of the vessels here is $\pm 30 \mu\text{m}$. High-precision recording is unnecessary, so if a vessel is not recorded correctly with its Cartesian coordinates but with a close deviation, this does not significantly affect the result. This achieves continuity of the spatial arrangement of the vessels.

Probabilistic methods. Characteristic number method

This method examines the diameter and density of the vessels as a mean and coefficient of variation. To achieve this, the density of the vessels is represented by the distances between them. Several main groups are identified according to these anatomical indicators.

For each group, according to the diameter or density, three subgroups of coefficient of variation are determined. For more precision, the ratio of the smallest and largest value to the arithmetic mean is studied. The method is simple and reliable for the classification of species according to the studied anatomical characteristics.

It can also be successfully applied to wood rays. The only question is whether the subgroups will have the same values of the coefficient of variation. In case of insufficient number of experiments, the Mann-

Whitney method can be used to compare the studied tree species.

Probabilistic methods

Here again we work in the cross-section, but at a higher magnification (at least 100×). This method can also be applied to the tangential section. Several lines parallel to the boundary of the annual ring and several parallels to the core rays are drawn through the field of view.

The cells of the conducting (vessels), mechanical (fibers) and reserve (parenchyma) tissue are recorded. The layout of the lines can be even and uneven. With an even arrangement, more lines must be drawn to cover the wood structure more fully. In case of unevenness, only 2-3 lines can be drawn through the most characteristic areas in the wood.

After describing the cells, a probabilistic model is created to answer several questions: What is the probability of a fiber, vessel, or parenchymal cell next to the fiber. The same is repeated for the other cells. The other questions are related to the accumulation of cells, namely: What is the probability of two, three, etc. fibers to have a fiber, vessel or parenchymal cell located.

Tetris method

The cross-section is examined, but it can also be applied to the tangential section. The arrangement of the cells is arbitrary in itself, but repetitive in each species. One annual ring or a previously accepted relative width (for tropical species) is examined. A dense strip of cells are formed, and the vessels „move”, similar to the popular game. The path of each cell to its appropriate location is analyzed using the methods of linear algebra.

End group method

This method is similar to the probabilistic one. The difference is in the way data is recorded and analyzed. These two methods

are used first in microscopic slides showing the typical structure of the wood of a given tree species, and then the variation of the structure within the species is studied.

Here the data are recorded sequentially, for the different types of tissues. The longer the record, the greater the variety of wood structures. The match of the records is examined by monitoring the cell type.

This method is a continuation and development of another, in which was developed earlier, based on the main elements of the anatomical structure are presented as chemical elements. A similar description is used in botany, where the taxonomy divides the individual families. Its purpose is to describe the particular species in short records showing the ranges of variation of each element.

Cluster analysis method

This method is mainly used for cross-sectional vessels. By measuring the coordinates of each of the vessels, this is their „real” location in a given tree species. They are located according to the rules of biology, ecology and genetics. However, if their centers are taken, a network can be built in which they are completely evenly spaced. This uniform network on the field of view, we can call the „ideal” location. The analysis of the differences between the real and the ideal location shows different characteristic numbers. They can categorize the construction of wood. In this method, both the number of vessels in the field of view and their location will be important.

Botvinnik method

The chess method is aimed at cluster analysis. The vessels are considered to be chess pieces placed on the board. Each of them has a different weight and threatens (attacks) a different maximum number of fields depending on its location in the field of view. Like the figures, the vessels have a different

number. Considering the weight of the cells, their number and the fields that can attack, different ratios can be obtained for each cell (vessel).

The obtained results can be presented graphically, and analyzes can be performed. For more in-depth analyzes, a known method for analysis of chess pieces and positions can be used (Botvinnik, M. 1968). This method has been successfully applied in several very different areas of chess.

Cell wall thickness method

In this method, only the cross-section is examined. Several parallel lines are constructed in the radial direction. The cell wall thickness of each cell (not only the vessels) that fell below the line is calculated. Cell wall thickness diagrams are constructed to compare the results. Fourier frequency analysis for data processing is used. These lines can be longer and cover more than one annual ring.

Thus, the analysis can be traced to the influence of environmental conditions on wood structure. The differences between juvenile, central and peripheral wood can also be sought. The construction of lines in the tangential direction is related to the cross-analysis of the data, as well as to the methodology of placement of these lines.

Method on diagrams on Voronoi

This method examines the cross-section, but it can also be used to study the location of the core beams in a tangential section. The space is decomposed, taking only the center of the cell for analysis on each vessel. The distances between the cells are examined, and they are assumed to be multiple points. In its simplest form, flush with the vessels, the Voronoi diagram is a set of convex polygons, the boundaries of these polygons being

the closest lines to both points. The most successful solution of this method is with partial differential equations of de Lune.

Coordinate method

In this method, the coordinates of each of the vessels refer to the initial coordinates of the image. The fact is used that each of the images is oriented so that the core beam (which is the carrier of the radial direction) is parallel to one of the sides of the image. Thus the other side becomes the bearer of the tangential direction. In addition, in the tangential direction (ie left or right) the structure of the wood remains relatively constant.

That is why the selection of the preparation (photo) with the most typical structure is made for anatomical reasons. Relationships are created between the coordinates of the vessels and the initial coordinates of the photo. The ratios of the distance to each subsequent vessel and its diameter are calculated. In this way its belonging to a given group to determine. The variance of the coordinates in the radial and tangential directions is calculated for the vessels that are located closest to each other.

Graphic method

This method is applied only in cross-section. The ability of the computer to quickly analyze the cross-sectional shape of the cells is used. Most of them (not only the vessels) are irregularly shaped, with a predominant diameter. It analyses the dimensions of the diameters and the orientation of the large diameter that depends on the tree species, the group structure, etc.

For example, the shape of the fibers and parenchymal cells varies depending on their distance to the vessel. Studying these anatomical features over time (ie in the radial direction) can lead to the description of a sequence in the structure of tropical wood.

Music box method

This method is borrowed from the texture they leave in the plane, and the spikes of the music boxes. This texture is very similar to the structure of tropical wood in cross-section. A description of the mutual arrangement of the vessels is made. The location of each of the vessels relative to the others is investigated, looking for the repeatability of the model. Mathematical dependencies are used in the construction of the shaft of music boxes. Like musical works, every vessel has a precise arrangement. If the repeatability of the model is established, the annual rings in the tropics can be successfully delineated (which is very difficult for now).

CONCLUSIONS

The stage of Wood Science shows that research related to structural wood science solves problems for which the achievements of other basic and applied sciences are needed and are rapidly and widely mastered. This is especially true of the use of computer vision methods in the analysis of wood structures. Interdisciplinary research is being conducted more and more successfully, in which two or more sciences are engaged in solving scientific and applied problems in this and similar fields of Wood Science. Using methods from similar sciences and scientific directions makes Wood Science a modern interdisciplinary science. It should be noted that this process is in its infancy. It is yet to be developed, and by combining various sciences related to the quantitative anatomy of wood, it will establish and develop its own issues and methodology related to computer structural Wood Science.

There are successful achievements at the level of micro and meso structure of wood. Abstract methods will be developed separately to develop independent methods for

the classification of tree species. Many scientific institutes are already developing methods for automatic recognition. Suppose these methods using computer vision are placed on a routine basis with the considered abstract methods. In that case the effectiveness of solving one of the critical problems of wood science, namely – visual recognition of species, will increase. We cannot predict which of the methods will be most effective at this stage.

REFERENCES

- BAAS P. 1986. Terminology of imperforate tracheary elements -in defence of ubriform fibres with minutely bordered pits. IAWA Bulletin n.s., 1986, Vol. 7 (I).
- BARDAROV, N. 2014. A guide to the identification of tree species by the anatomical features of wood. Publishing house at LTU, Sofia.
- BLUSKOVA, G.ST. 2009. Wood science, textbook. University of Forestry Publishing House, Sofia.
- BOTVINIK M.M. 1968. Algorithm of the chess game, Science, Moscow.
- BREINIG, L., LEONHART, R., BROMAN, O. ET AL. 2015. Classification of wood surfaces according to visual appearance by multivariate analysis of wood feature data. *J Wood Sci* 61, 89–112 (2015). <https://doi.org/10.1007/s10086-014-1410-6>, <https://jwoodscience.springeropen.com/articles/10.1007/s10086-014-1410-6>.
- CARLQUIST SH. 2009. Non-random Vessel Distribution in Woods: Patterns, Modes, Diversity, Correlations. *Aliso*, 2009, Volume 27, Issue 1, Article 4.
- DA SILVA N.R., ET AL. 2017. Automated classification of wood transverse cross-section micro-imagery from 77 commercial Central-African timber species. *Annals of Forest Science*, 2017, 74:30
- ENCHEV, E. AT. 1984. Wood science, textbook. Publishing house of Zemizdat, Sofia.
- EWERS FR.W., ET AL. 2007. Vessel redundancy: modeling safety in numbers. *IAWA Journal*, 2007, Vol. 28 (4), 373–388.
- FANG F.CH., R. EVANS. 2010. Automated measurement of vessel properties in birch and poplar wood. *Holzforschung*, 2010, Vol. 64, pp. 369–374.

- HWANG, SW., SUGIYAMA, J. 2021. Computer vision-based wood identification and its expansion and contribution potentials in wood science: A review. *Plant Methods* 17, 47 (2021). <https://doi.org/10.1186/s13007-021-00746-1>.
- JOHANNES A.J. HUBER, OLOF BROMAN, MATS EKEVAD, JOHAN OJA, LARS HANSSON. 2022. A method for generating finite element models of wood boards from X-ray computed tomography scans, *Computers & Structures*, Volume 260, 2022, 106702, ISSN 0045-7949, <https://doi.org/10.1016/j.comp-struc.2021.106702>. (<https://www.sciencedirect.com/science/article/pii/S0045794921002248>)
- KHELIFA, M. & LOPERENA, N. & BLÉRON, LAURENT & KHENNANE, AMAR. 2013. Analysis of CFRP-strengthened timber beams. *Journal of Adhesion Science and Technology*. 28. 1–14. 10.1080/01694243.2013.815096, https://www.researchgate.net/publication/271801281_Analysis_of_CFRP-strengthened_timber_beams .
- PETER J. CAMERON. 2013. Notes on finite group theory, October 2013, p. 103, <http://www.maths.qmul.ac.uk/~pjc/notes/gt.pdf>
- PETROU M., P. G. SEVILLA. 2006. *Image Processing: Dealing with Texture*. Wiley.
- PRIESTLEY H.A. 2011. *Introduction to Groups, Rings and Fields*, HT and TT, 2011, p. 41, <https://people.maths.ox.ac.uk/flynn/genus2/sheets0405/grfnotes1011.pdf>
- RICHTER H.G., M. J. DALLWITZ. 2009. Commercial timbers: descriptions, illustrations, identification, and information retrieval. In English, French, German, and Spanish. Version: 25th June 2009. DELTA Home, (www.deltaintkey.com/wood/)
- SCHWEINGRUBER FR.H. 2007. *Wood Structure and Environment*. Springer-Verlag Berlin Heidelberg, pp. 284
- STEFANUS SANTOSA, R. A. PRAMUNENDAR, D. P. PRABOWO, AND YONATHAN P. SANTOSA. 2019. Wood Types Classification using Back-Propagation Neural Network based on Genetic Algorithm with Gray Level Co-occurrence Matrix for Features Extraction, May 2019, *IAENG International Journal of Computer Science* 46(2):149-155.
- THELANDERSSON, S., ISAKSSON, T., HÄGLUND, M., & FRÜHWALD, E. 2011. Probabilistic methods for performance based service life evaluation of wooden components, <https://www.semanticscholar.org/paper/Probabilistic-methods-for-performance-based-service-Thelandersson-Isaks-son/090c87e49158051de604691498bd093da9a8412f> .
- TOLERA B. T. 2021. Cluster analysis for forest and wood-processing industry sector development in Ethiopia, PhD Theme, 28.10.2021, TU Dresden, p. 190, <https://tud.qucosa.de/api/qucosa%3A76842/attachment/ATT-0/>.
- TOU, JING, TOU, PHOOI, LAU, PHOOI YEE, TAY, YONG HAU. 2007. Computer Vision-based Wood Recognition System. *Proc. Int'l Workshop on Advanced Image Technology*, https://www.researchgate.net/publication/264886592_Computer_Vision-based_Wood_Recognition_System.
- WAGENFÜHR, R. 1984. *Anatomie des Holzes*. VEB Fachbuchverlag Leipzig.
- WAGENFÜHR, R. CHR. 1996. *Scheiber. Holzatlas*. VEB Berlin: Springer-Verlag.
- WHEELER, E.A., P. BAAS, S. RODGERS. 2007. Variations In Dicot Wood Anatomy: A Global Analysis Based on the Inside wood Database. *IAWA Journal*, 2007, Volume 28, Issue 3, pp. 229–258.
- YADAV AR.R., R.S. ANAND, M.L. DEWAL, SANGEETA GUPTA. 2017. Binary wavelet transform-based completed local binary pattern texture descriptors for classification of microscopic images of hardwood species. *Wood Sci Technol*, 2017, 51:909–927.
- YUSOF, R.B., ROSLI, N.R., & BAKAR, F.N. 2017. Non-wood anatomy image detector for tropical wood recognition system, <https://ijafp.com/wp-content/uploads/2017/01/FR-48.pdf>.



UNIVERSITY OF FORESTRY

FACULTY OF FOREST INDUSTRY



INNOVATION IN WOODWORKING INDUSTRY AND ENGINEERING DESIGN

1/2022

INNO vol. XI Sofia

ISSN 1314-6149
e-ISSN 2367-6663

Indexed with and included in CABI

INNOVATION IN WOODWORKING INDUSTRY AND ENGINEERING DESIGN

Science Journal

Vol. 11/p. 1–74

Sofia 1/2022

ISSN 1314-6149

e-ISSN 2367-6663

Edition of

FACULTY OF FOREST INDUSTRY – UNIVERSITY OF FORESTRY – SOFIA

The Scientific Journal is indexed with and included in CABI.

SCIENTIFIC EDITORIAL BOARD

Alfred Teischinger, PhD (Austria)
Alexander Petutschning, PhD (Austria)
Anna Danihelová, PhD (Slovakia)
Antonios Papadopoulos, PhD (Greece)
Asia Marinova, PhD (Bulgaria)
Biborka Bartha, PhD (Romania)
Bojidar Dinkov, PhD (Bulgaria)
Danijela Domljan, PhD (Croatia)
Desislava Angelova, PhD (Bulgaria)
Derya Ustaömer, PhD (Turkey)
George Mantanis, PhD (Greece)
Ivica Grbac, PhD (Croatia)
Ivo Valchev, PhD (Bulgaria)
Ján Sedliačik, PhD (Slovakia)
Julia Mihajlova, PhD (Bulgaria)
Hubert Paluš, PhD (Slovakia)
Hülya Kalaycioğlu, PhD (Turkey)
Ladislav Dzurenda, PhD (Slovakia)
Luboš Krišták, PhD (Slovakia)

Marius Barbu, PhD (Romania)
Muhammad Adly Rahandi Lubis, PhD (Indonesia)
Nencho Deliiski, DSc (Bulgaria)
Neno Tritchov, PhD (Bulgaria)
Pavlin Vitchev, PhD (Bulgaria)
Pavlo Bekhta, PhD (Ukraine)
Petar Antov, PhD (Bulgaria)
Regina Raycheva, PhD (Bulgaria)
Roman Réh, PhD (Croatia)
Ružica Beljo Lučić, PhD (Croatia)
Silvana Prekrat, PhD (Croatia)
Štefan Barčík, PhD (Slovakia)
Svetoslav Anev, PhD (Bulgaria)
Valentin Shalaev, PhD (Russia)
Vasiliki Kamperidou (Greece)
Vesselin Brezin, PhD (Bulgaria)
Victor Savov, PhD (Bulgaria)
Vladimir Koljozov, PhD (Macedonia)
Zhivko Gochev, PhD (Bulgaria)

EDITORIAL BOARD

N. Trichkov, PhD – Editor in Chief
D. Angelova, PhD – Co-editor
N. Minkovski, PhD

V. Savov, PhD
P. Vitchev, PhD

Cover Design: DESISLAVA ANGELOVA

Printed by: INTEL ENTRANCE

Publisher address: UNIVERSITY OF FORESTRY – FACULTY OF FOREST INDUSTRY

Kliment Ohridski Bul., 10, Sofia, 1797, BULGARIA

<http://inno.ltu.bg>

<http://www.scjournal-inno.com/>

CONTENTS

BUILDING EXPERT MAPS FOR ERGONOMETRIC, COMPOSITIONAL AND COLORS SCHEME EVALUATION OF MACHINE CONTROL PANELS	5
Aleksandrina Bankova, Zoya Tsoneva	
THE TRIPOD: A RARELY MENTIONED FURNITURE TYPE.....	13
Regina Raycheva, Desislava Angelova	
CHANGE IN THE DURATION OF AUTOCLAVE STEAMING REGIMES OF NON-FROZEN PRISMS AT DISPATCHING INTERVENTIONS IN THE PRODUCTION OF VENEER	25
Nencho Deliiski, Dimitar Angelski, Pavlin Vitchev, Natalia Tumbarkova	
IDENTIFICATION OF THE COLOR FALSE HEARDWOOD OF <i>FAGUS SYLVATICA</i> L. IN THE COLOR SPACE CIE L*A*B*	33
Ladislav Dzurenda, Michal Dudiak	
RECYCLING OF MEDIUM DENSITY FIBREBOARDS – A REVIEW	39
Christian Panchev, Viktor Savov	
PROPERTIES OF PARTICLEBOARDS WITH THE PARTICIPATION OF HEMP AND VINE PARTICLES IN THE CORE LAYER – PART I: EFFECT OF THE COMPOSITION.....	47
Rosen Grigorov, Viktor Savov, Slavcho Alexandrov	
ABSTRACT METHODS TO CLASSIFY THE STRUCTURE OF WOOD	57
Nikolai Bardarov, Vladislav Todorov, Tanya Pancheva	
STUDY ON DURABILITY OF TUNGSTEN CARBIDE CUTTER HEADS	65
Zhivko Gochev, Pavlin Vitchev, Georgi Vukov	
SCIENTIFIC JOURNAL „INNOVATIONS IN WOODWORKING INDUSTRY AND ENGINEERING DESIGN“	72