Use and Future Development of Optical Measurement Technology in the Study of Wood Surface Roughness CiteSpace-Based Scientometric Analysis (2003 through 2022)

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Abstract

Although the contact probe measurement technique is excellent for wood surface roughness measurement, it is necessary to reevaluate the advantages and future development direction of optical measurement techniques in this field, given the emergence of optical measurement techniques such as laser technology and the increasing academic interest in wood surface roughness. The traditional review method, due to its rather limited research directions, only provides a macroscopic and qualitative description of certain laws and conclusions. The purpose of this review is to use the bibliometrics theory and method to comprehensively sort out the research hot spots in this field and explore them in depth.

The bibliographic analysis of 233 documents from the Web of Science database was carried out using CiteSpace's bibliographic network analysis, visualization analysis, and other functions.

We discuss in detail the advantages of optical measurement techniques in the characterization of wood surface roughness in two- and three-dimensional (2D and 3D) conditions, the research on the separation of structural roughness and machining roughness of wood using optical measurement techniques, and we explore the future direction of the development of optical measurement techniques in the study of wood surface roughness. The results of the study will act as important references for new researchers who want to enter into the field, to obtain an in-depth understanding of the research hot spots, and to acquire valuable scientific information.

Wood is a sustainable engineering material with a wide range of applications, including the production of a variety of wood-based panels. As one of the most essential and irreplaceable resources for national economic and social growth, the wood sector holds a significant place in the economies of developed nations (Mai et al. 2021). Nonetheless, the primary method of wood shaping is still cutting, and the quality of the cut surface finish has the greatest influence on the functionality and cost of the wood product, as well as the quality of the processed wood product. Hence, determining ways to quantify and define wood-cutting surface roughness more effectively has been one of the primary study foci among academics.

Although the basic information in international standards such as ISO-4287 (Geometrical Product Specifications Surface Texture: Profile Method) is widely used in the definition, measurement methods, and evaluation parameters of wood surface roughness, wood has a fibrous structure and surface roughness measurement with profilometers faces a number of problems. For example, the contact measurement principle used by profilometers is not suitable for on-line measurement and inspection, and the stylus of the profilometer may pierce the surface of the wood, making measurement impossible.

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Schadoffsky (2000) suggested that the contact force and the tip geometry of the stylus may distort the measurements. In recent years, many researchers have begun to explore the use of optical measurement techniques to measure and evaluate wood surface roughness.

Optical measurement technology integrates the latest research results of computer technology, physical metrology, and other disciplines. It has the advantages of being nondestructive, efficient, and nonpolluting, so it is widely used in the fields of surface quality assessment, surveying, and mapping, and in engineering project measurement. Light scattering is one of the commonly used methods for measuring surface roughness. In recent years, optical measurement techniques have made significant progress in the field of wood surface roughness measurement and surface quality assessment. For example, Fatemeh Razaei et al. (2020) successfully reconstructed the 3D image of the measured wood using a confocal microscope with Gaussian filtering and the image-stacking technique, the results of which are of great value in the assessment of wood surface quality. However, the limitations of the optical measurement technique mainly come from sensor performance. There is still a need to further improve the performance of sensors and to explore effective evaluation methods for the evaluation of dark and dense wood surface.

With the rising maturity of optical measurement technology, wood surface roughness measurement applications are becoming increasingly common. It is therefore necessary to undertake a comprehensive study on the current state of research in this area in order to clarify its development and future directions. Conventional review methods are mostly centered on summarizing relevant literature to organize research results and progress, but their research approach is rather uniform and simply explains and discloses specific patterns and conclusions from a macro and qualitative standpoint. Although these reviews are helpful for scholars to comprehend the field, they rely primarily on qualitative methods to categorize the content and themes of the existing literature, making it difficult to reflect the full picture of the research field and systematically present its development history.

Early in the 20th century, N. B. Iles and F. J. Cole originally proposed using bibliometrics to analyze the nature and direction of the development of a discipline (Zhang et al. 2022). Bibliometrics has played a significant role in anticipating the path of research in a particular topic and in advancing the fundamental theory of intelligence (Zhang et al. 2022), and it has become a vital branch of bibliography and intelligence. Scientific knowledge mapping is a research technique in the domains of scientometrics and informetrics that reveals the sources and development patterns of knowledge by visually displaying the structural relationships and evolution patterns of knowledge in linked fields (Chen et al. 2021).

This paper uses bibliometric methods and CiteSpace software to analyze the current development of optical measurement research on wood surface roughness at multiple levels, including publication volume, author-institution collaboration co-occurrence, and keyword co-occurrence, using 240 relevant journal articles from the Web of Science (WOS) core collection. With these data, new researchers can immediately comprehend the field's frontiers and hot spots and more easily assimilate significant scientific information. This work provides relevant scholars with a reference and helps to direct future research.

Research Methods and Data Sources

Data sources

This study uses the WOS database as a data source. This database contains high-quality academic journals, conference papers, and patents from around the world, covering literature from a variety of subject areas, including natural sciences, social sciences, engineering, and technology, as well as literature from interdisciplinary research. This makes it possible to obtain comprehensive information from different disciplinary areas when performing comprehensive analyses using CiteSpace software, and consequently better understand and explore the intersections and potential connections of related research. What's more, CiteSpace's data analysis functionality is based on the WOS database's text data format standard, and is constantly updated according to the Institute for Scientific Information database. This means that CiteSpace is able to process data directly from the WOS database without additional data format conversion or processing, which reduces the complexity and workload of the analysis process. Therefore, in this study we used the WOS database as the data source and searched it up to 30 December 2022 within the query timeframe. We selected "Web of Science Core Collection" as the search database and entered "TS = ('wood surface roughness measurement') and ALL = (optical methods)" in the search formula. First, the search results were screened by language (selecting English) and type of literature (selecting review and thesis, etc.) to initially screen the literature. The prescreened databases were then preprocessed by manually removing literature that did not match the topic of the article. In the end, a total of 233 relevant papers were selected for subsequent studies.

Research methods

Bibliometrics is a research method and discipline that studies the informetric properties, trends, and the relationship of scientific research and literature. It focuses on statistics, measurement and analysis of literature information to reveal the scope, field, popular research directions, and impact of scientific research. In this study, the research on surface roughness of wood based on optical measurement technology was reviewed under Windows 11 platform using CiteSpace software version 6.1 R3. CiteSpace is an information visualization software developed based on Java language, which mainly uses the theory of cocitation analysis to measure the collection of literature in a specific field, reveal the key paths and knowledge inflection points of discipline evolution, and form the analysis of the potential power mechanism of discipline evolution and the detection of discipline development frontiers by drawing visualization maps.

In the CiteSpace mapping, the research object is represented by a node, the size of the which usually represents its importance and influence. The lines between the nodes indicate the association relationships, which can be either citation relationships, which indicate that one piece of literature cites another piece of literature, or co-occurrence relationships, which indicate that two terms, keywords, or authors appear in the same piece of literature at the same time. The wider the connecting line between nodes, the closer or more frequent the association between the nodes. These mapping features can help us to analyze and understand the important themes in the literature network, the connections between research areas and the collaborative relationships between scholars. Researchers can selectively display the relevant information of a research area on the map according to their needs, so as to intuitively analyze the research process, research hot spots, and development trends of the area (Zhang et al. 2020). By analyzing high-frequency keywords, it is possible to understand the research hot spots in a particular field.

Research Results and Analyses

Analysis of literary publications

With the growth of the research field, the number of publications in the literature has become one of the most significant indices for gauging its development. The literature on measuring the surface roughness of wood using laser technology has been accessible since 2003, according to published data. In it, Sandak and Tanaka (2003) compare the results obtained using a commercial laser displacement sensor (LDS) and a stylus-based surface roughness measuring tool. The paper investigates the characteristics of wood surface roughness parameters obtained using laser displacement sensors and demonstrates that LDS has great potential for online measurement of wood surface roughness compared to stylus-based measurement methods.

From the line graph of the number of publications counted by CiteSpace (Fig. 1), we can see that the trend of published literature in the research field of wood surface roughness measurement using optical technology has gone through a changing course from a slow development phase (2003 through 2009) to a significant growth phase (2010 through2021). During the period from 2003 through 2009, the number of publications was relatively low, with an average of eight per year, and the number of publications during this period accounted for 23.1 percent of the total number of publications, indicating that the measurement of wood surface roughness using laser technology was in its infancy during this period. During the period from 2010 through 2021, with the increasing trend towards automation and intelligence of wood product processing equipment, higher demands were placed on the surface quality of wood products and their online inspection. This led to an increasing demand for nondestructive measurement of wood surface roughness using optical techniques (Sandak and Tanaka 2003). As a result, the number of publications in this phase increased significantly, accounting for 69.5 percent of the total number of publications.

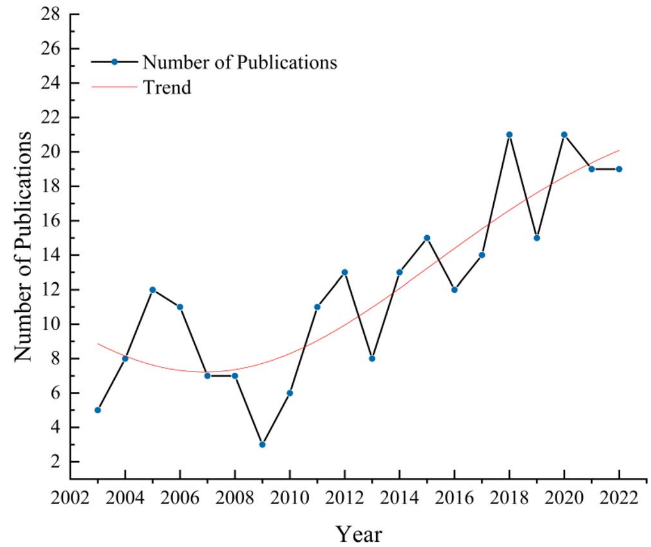

Figure 1.—Number of publications on optical technology for measuring surface roughness of wood, 2003 *through 2022.*

Study of author collaboration network

The CiteSpace program contains an author collaboration network analysis tool that represents the main authors and their collaboration status and cross-citation relationships within a particular research topic (Chu et al. 2023). We acquired information on the collaboration network and related authors in the research field of laser assessment of wood surface roughness using the author analysis tool of CiteSpace (see Fig. 2 and Table 1). In Figure 2, each node represents an author, and the size of the node, the connecting line, and the width of the connecting line between the nodes represent the number of published literatures, the collaboration relationship, and the strength of collaboration between the authors, respectively. A total of 564 collaboration lines are shown in Figure 2, with a graph network density of 0.0064, indicating that some researchers in this field have formed a stable team and are collaborating more closely. Among others, L. Gurau, N. Ayrilmis, and R. Hernandez have maintained a close working relationship. According to Table 1, L. Gurau, from Romania, is the author with the most publications, 11 pieces. The fact that 10 of the top 18 authors are European suggests that European scientists place a greater focus on the use of optical measurement techniques to measure the surface roughness of wood. In addition, scholars from Canada, Japan, the United States, and Hungary have contributed significantly to the body of literature. According to statistics, as of 2019, the United States, Russia, and China are the top three countries in the world in terms of production of logs for industrial use, accounting for 19, 10, and 9 percent of the total global production, respectively (FAO 2019). Therefore, it is reasonable to assume that the research results of scientists in this field in Europe and the United States are to some extent correlated with the region's timber production.

Study of networked institutional collaboration

The institutional cooperation network analysis function can show the main institutions and collaboration status of the research field (Chu et al. 2023). We got the institutional collaboration network and related information for the study field of optical measurement of wood surface roughness through CiteSpace's institutional analysis tool (see Fig. 3; Table 2). In Figure 3, each node represents an institution, and the size of the node, the link between nodes, and the width of the link reflect the number of published works, the cooperation relationship, and the intensity of collaboration between institutions that have published works, respectively. A total of 240 collaboration lines with a graph network density of 0.0077 are depicted, showing that a number of research institutions

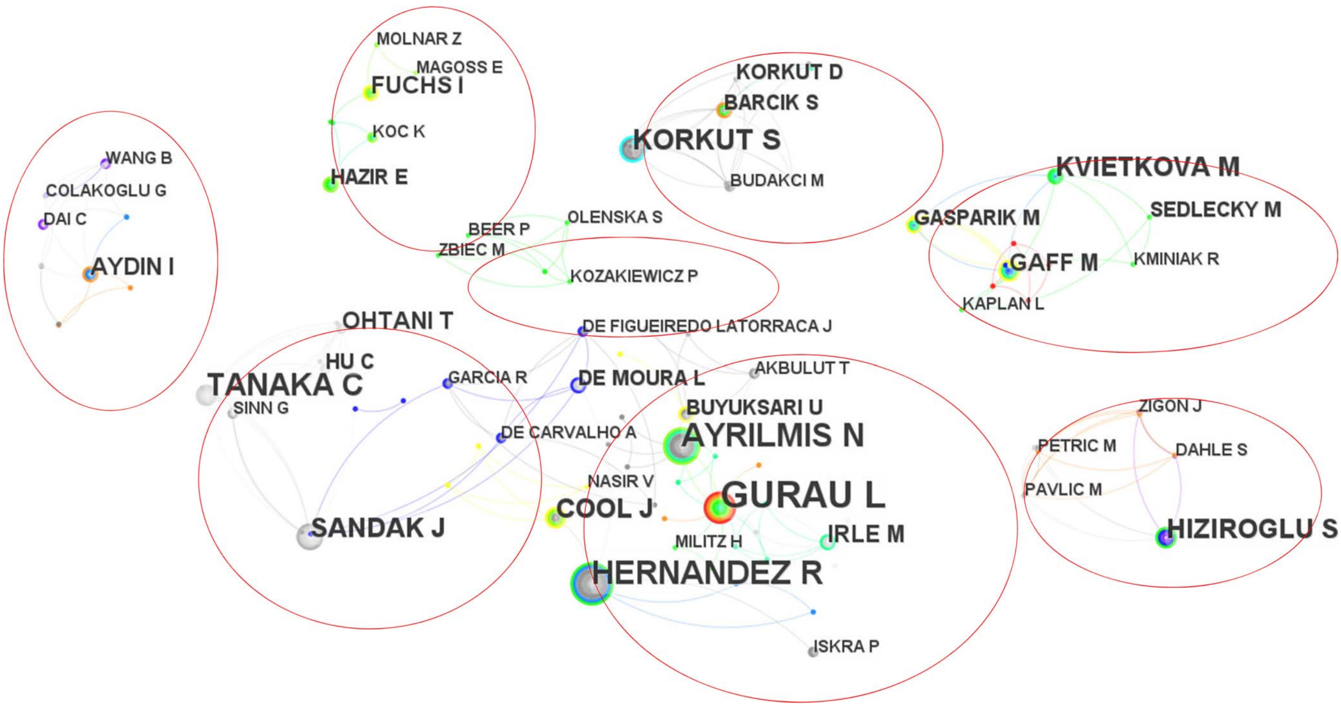

Figure 2.—Author collaboration network on optical measurement technology.

in this field have formed teams that work more closely together. For instance, universities such İstanbul Üniversitesi, Duzicho University, and Karadenizh Technological University have maintained strong ties. Moreover, among the top 10 research institutions by number of publications, İstanbul Üniversitesi ranks first with 13 publications, followed by Laval University, Transilvania University, and Duzicho University with 11, 11, and 9 publications, respectively. Europe is home to 7 of the top 10 research institutions, demonstrating the continent's dominance in this subject. In addition, centrality represents the importance or representation of the node in the domain. İstanbul Üniversitesi has the highest value of intermediate centrality, indicating that this institution has a greater influence in the field of wood surface roughness measurement using optical techniques.

Table 1.—Top 18 authors' information statistics on optical measurement technology.

No.	Author	Country	Count
1	Gurau, L.	Romania	11
2	Sandak, J.	Slovenia	10
3	Ayrilmis, M.	Turkey	8
4	Hernander, R. E.	Canada	8
5	Tanaka, C.	Japan	6
6	Korkut, S.	Turkey	5
7	Magoss, E.	Hungary	5
8	Molnar, Z.	Hungary	5
9	Cool, D.	Canada	5
10	Hiziroglu, S.	United States	4
11	Aydin, I.	Turkey	4
12	Fuchs, I.	Germany	4
13	Fujiwara, Y.	Japan	4
14	Gaff, M.	Czech Republic	4
15	Irle, M.	France	4
16	Hu, C.	China	3
17	Li, Y.	China	3
18	Moura, D. E.	Brazil	3

Evaluation of global cooperation networks

Using CiteSpace software, a map of national cooperation networks and associated statistical tables (Fig. 4; Table 3) on the assessment of wood surface roughness were created. The results indicate that 47 countries (regions) perform research in this sector, mostly in Europe, Asia, and North America, building an international collaborative network with Turkey, Canada, Germany, China, and the United States as its hubs. Turkey has 31 publications, followed by Canada, Germany, and China, which have 25, 21, and 20 publications, respectively. The United Kingdom, Japan, and Germany are pioneers in adopting important research in this field. In terms of centrality, Turkey is much less central than the United States, Canada, and Japan, indicating that these three nations are at the forefront of research in this field and are more representative.

Hot-Spot Analysis of Wood Surface Roughness Measurement Based on Optical Technology

Analysis of keyword co-occurrence

We set the node type to "keyword," the threshold to T = 50, and the remaining parameters to their defaults. We excluded invalid terms and merged numerous related phrases to produce the knowledge network of research hot spots displayed in Figure 5 and the list of the top 30 keywords in Table 4. In Figure 5, the size of the nodes indicates the frequency of keyword occurrences, whilst the degree of connectivity between the nodes indicates the co-occurrence intensity and relationship of the keywords. The larger the node, the

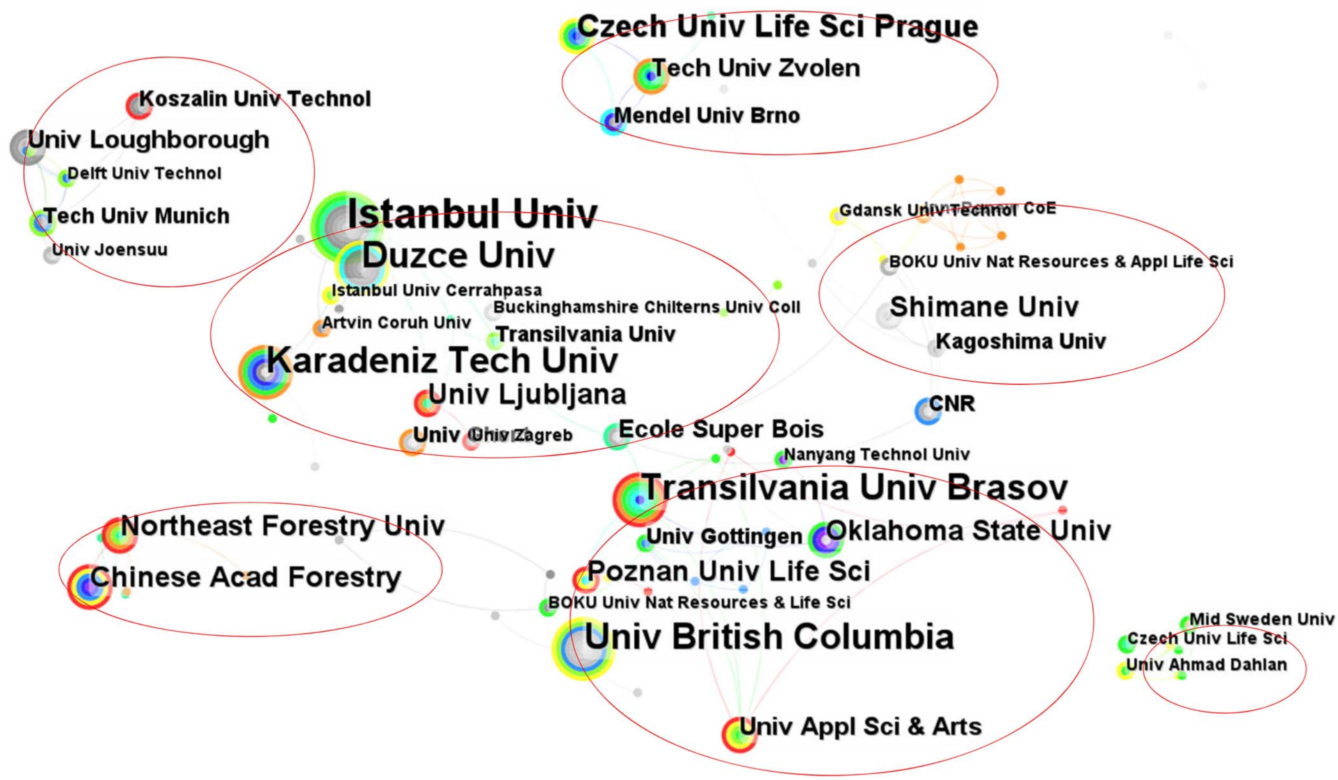

Figure 3.—Institutional cooperation network on optical measurement technology.

more frequently the term appears, and the thickness of the link line reflects the strength of the co-occurrence between keywords.

The keywords that appear most frequently in the WOS database in the research field of wood surface roughness measurement using optical measurement technology are surface roughness, roughness, quality, heat treatment, parameter mechanical property, color, surface quality, strength, and laser, as shown in Figure 5 and Table 4. The frequency of more than 10 instances of these keywords suggests that researchers have begun to focus on this research direction and that these keywords reflect the research hot spots in the field to a great extent. That is, the use of optical technology to measure the surface roughness of wood that goes through various processing treatments has become a mainstream research method in this field, which further indicates that optical technology–based wood surface roughness measurement methods have gradually become an important research tool in this field.

Analysis of keyword clustering

Table 5 displays the results of the cluster analysis, where "size" is the number of keywords contained in the cluster and some keywords are listed; "silhouette" is a measure of the homogeneity of the entire cluster members, and a larger value indicates that the cluster members are more similar; and "mean year" is the mean year of the documents in the cluster. Based on the analysis of the clustering results in Table 5 and the content of the documents in each cluster, the research hot spots for the measurement of wood surface roughness based on optical measurement technology consist primarily of the following: (1) measurement of 2D parameters of wood surface roughness based on optical measurement technology, (2) the reconstruction of wood surface topography in three dimensions using optical measurement technologies, and (3) the separation of wood's structural and processing roughness using optical measurement technology. These results indicate that the measurement of wood surface roughness based on optical measurement

Table 2.—The top 18 publishers of optical techniques for measuring wood surface roughness.

Ranking	Year	Institution	Count	Percentage	Centrality
1	2008	İstanbul Üniversitesi	13	5.58	0.12
2	2005	Laval University	11	4.72	0.07
3	2017	Transylvania University	11	4.72	0.05
4	2008	Duzce University	9	3.86	0.09
5	2014	Czech University of Life Science Prague	8	3.43	0.03
6	2007	Karadeniz Technical University	8	3.43	0.05
7	2007	University of British Columbia	8	3.43	0
8	2008	Consiglio Nazionale Delle Ricerche	7	3.00	0
9	2017	Northeast Forestry University	7	3.00	0.09
10	2013	Chinese Academy of Forestry	6	2.58	0.04

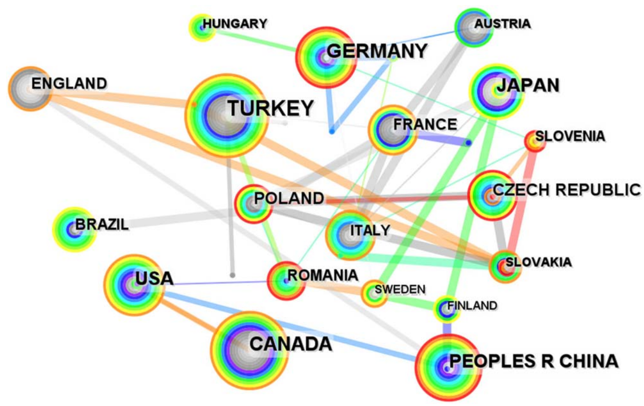

Figure 4.—Country cooperation networks on optical measurement technology.

Table 3.—Statistics of the 10 countries with the highest number of publications on the measurement of wood surface roughness by optical methods.

Ranking	Country	Count	Percentage	Year	Centrality
1	Turkey	31	13.31	2005	0.27
2	Canada	25	10.73	2005	0.43
3	Germany	21	9.01	2003	0.13
4	China	20	8.58	2014	0.12
5	Japan	17	7.30	2003	0.32
6	United States	17	7.30	2006	0.43
7	Poland	15	6.44	2006	0.03
8	Czech Republic	13	5.58	2011	0.01
9	Romania	12	5.15	2014	0.03
10	England	12	5.15	2003	0.06

techniques has attracted wide attention in the field of wood research.

Analysis of quotations

An essential bibliometric method for analyzing the content of the body of information in a field of study and its influence on that subject is citation analysis. Table 6 lists the top 10 documents in the subject of measuring wood surface roughness using optical measurement technology that have received the most citations. One of these is "Recent improvements in X-ray microtomography applied to materials," which was written by S. R. Stock (2008) and reviews the development of X-ray microtomography in scanning various materials and examines the precision of microCT reconstruction. The signal change theory discussed in this study is comparable to the basic idea behind optical measuring technology, suggesting that the latter offers a lot of promise for the assessment of wood roughness. Additionally, in the study "Structural analysis of photodegraded wood by means of FTIR spectroscopy," by X. Colom et al. (2003), the researchers performed chemical modification analysis of cellulose and lignin on two photodegraded woods through FTIR spectroscopy, and they observed slight changes in the two woods' structural levels. This study also demonstrated the accuracy of optical measurement technology in the assessment of wood surface quality. These highly cited works of literature serve as a valuable foundation for future research in this area and serve as vital guidelines for current work in the field. The specifics and citations for these texts are listed in Table 6.

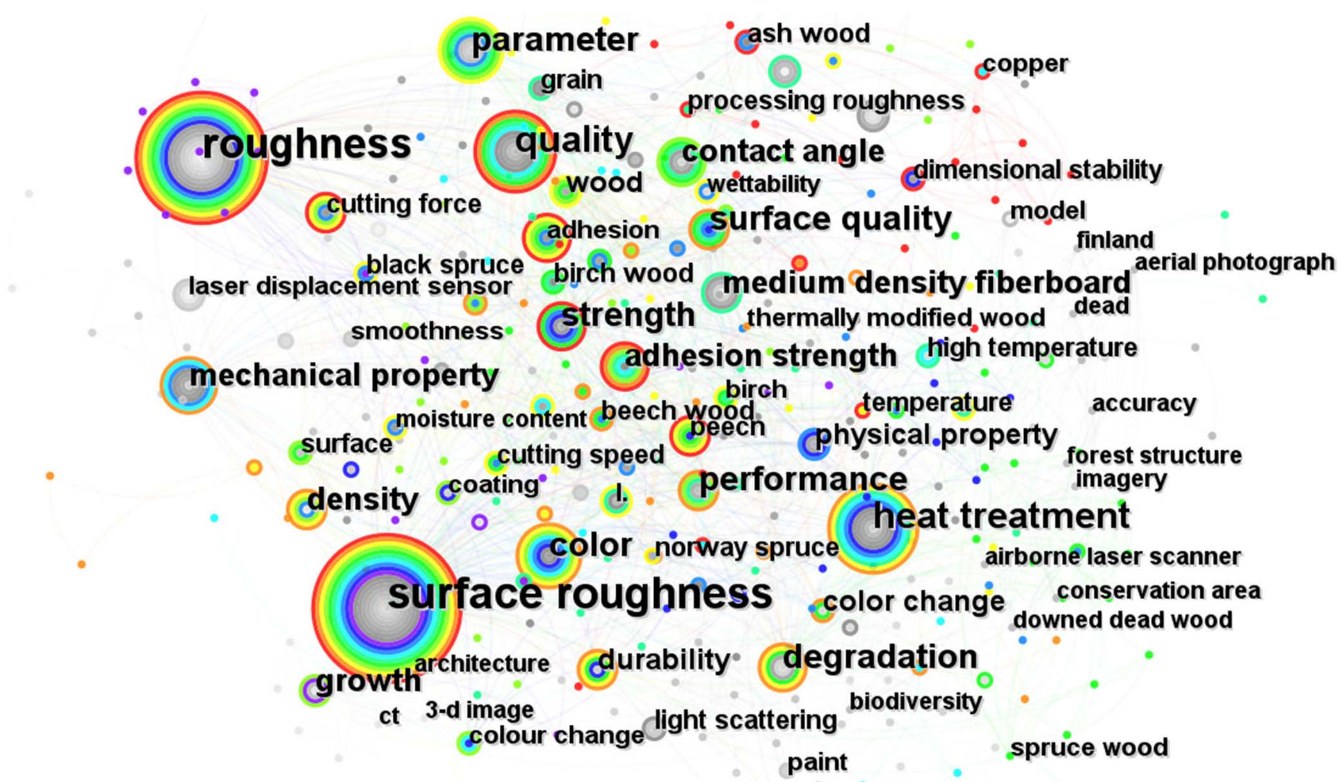

Figure 5.—Keyword co-occurrence network on optical measurement technology.

Table 4.—Top 30 keywords related to optical methods for measuring wood surface roughness.

Keyword	Year	Centrality	Count
Surface roughness	2005	0.28	69
Roughness	2003	0.34	51
Quality	2007	0.17	22
Heat treatment	2005	0.14	20
Parameter	2006	0.21	15
Surface quality	2014	0.24	14
Strength	2008	0.18	13
Mechanical property	2006	0.28	12
Color	2010	0.12	11
Performance	2007	0.09	10
Contact angle	2005	0.1	9
Wood	2009	0.1	9
Density	2004	0.04	9
Beech	2014	0.06	8
Physical property	2008	0.1	7
Medium density fiberboard	2003	0.06	7
Degradation	2005	0.06	7
Adhesion	2011	0.18	6
Surface	2007	0.08	6
Adhesion strength	2012	0.09	6
Wettability	2005	0.06	6
Birch wood	2012	0.04	5
Tactile roughness	2003	0.07	5
Laser displacement sensor	2003	0.02	5
Moisture content	2011	0.03	5
Cutting force	2011	0.03	5
Durability	2006	0.03	5
Prediction	2010	0.05	5
Norway spruce	2015	0.03	5
MDF	2017	0.02	4

Discussion

Based on the results of visualization and analysis of wood surface roughness studies based on optical measurement techniques, this study focuses on the study of 2D profile roughness measurement of wood surface based on optical measurement techniques, 3D morphology reconstruction of wood surface based on optical measurement techniques, and separation of structural roughness and machining roughness of wood based on optical measurement techniques in this field. These studies mainly used the technique of emitting an optical beam and receiving the reflected light through a sensor (Magoss et al. 2020). In contrast, some contact stylus measurement tools can cause scratches on the wood surface when measuring surface roughness (Sandak and Negri 2005), whereas noncontact optical measurement methods rule out the possibility of damaging the wood samples at all.

2D wood surface profile roughness measurement using laser technology

The 2D profile roughness of the wood surface is an important characterization tool when measuring the surface roughness of wood. Commonly used measurement methods include contact probe measurement and noncontact optical measurement. Noncontact optical measurement mainly uses the emission of a light beam and reception of the reflected light to achieve rapid scanning and accurate measurement of the wood surface without the need for the measurement system to be in direct contact with the wood surface. This noncontact method avoids the problems of sample damage that can be caused by traditional contact methods. In the field of automated production and intelligent manufacturing of wood products, the efficiency of optical measurement technology is of great importance for real-time monitoring of processing status, ensuring product quality and improving production efficiency. By quickly and accurately obtaining information on the roughness of wood surfaces, factories can adjust production parameters and optimize the machining process in a timely manner, leading to more efficient production and resource utilization.

Sandak and Tanaka (2003) measured the roughness of 15 woodworking surfaces using a probe gauge and a laser and compared the profile curves obtained by the two methods. The results of the study showed that the profile curves obtained from the laser measurements were highly similar to the theoretical profile curves. The optical measurement has the advantage of higher efficiency with the same accuracy. In recent years, optical measurements have become increasingly prevalent in the scientific investigation of wood surface roughness. Table 7 shows the number and percentage of publications on the measurement of wood surface roughness using probe and optical methods over the last 5 years. It can be clearly seen that the optical method is gradually becoming the dominant measurement method in the relevant research fields.

Despite the differences in the direction of the research, the technology is based on the emission of a laser beam and the reception of the reflected light by a sensor is the key, which in combination with an electronic detection and identification device, makes it possible to carry out a nondestructive inspection of the surface roughness of the wood.

Table 5.—Keyword clustering information statistics on optical measurement technology.

Size	Silhouette	Mean year	Typical clustering results (LLR)[a]	Cluster label	Secondary manual naming
27	0.68	2003	Surface roughness; noncontact; measurement	2D	Research on 2D contour roughness measurement
25	0.77	2014	Processing roughness; 3D; evaluation	Three-dimensional topography	Research on 3D morphology reconstruction
19	0.74	2016	Machined surface roughness; profile filtering; FFT	Signal analysis	Separating wood anatomical roughness from processing roughness

[a] LLR = log-likelihood ratio; 2D = two dimensional; 3D = three dimensional; FFT = fast Fourier transform.

Table 6.—Literature focusing on optical measurement techniques in wood roughness studies.

Frequency	Centrality	Year	Literature
349	0.06	2008	Recent advances in X-ray microtomography applied to materials (Stock 2008)
232	0.12	2007	Influence of steam heating on the properties of pine (*Pinus pinaster*) and eucalypt (*Eucalyptus globulus*) wood (Esteves et al. 2007)
174	0.04	2015	A review of recent application of near infrared spectroscopy to wood science and technology (Tsuchikawa and Kobori 2015)
159	0.46	2013	Chemical changes of heat-treated pine and eucalypt wood monitored by FTIR (Esteves et al. 2013)
152	0.02	2017	Influence of surface roughness on nonlinear flow behaviors in 3D self-affine rough fractures: Lattice Boltzmann simulations (Wang et al. 2017)
143	0.03	2008	Pine wood modification by heat treatment in air (Esteves et al. 2008)
123	0.08	2003	Structural analysis of photodegraded wood by means of FTIR spectroscopy (Colom et al. 2003)
112	0.25	2014	A review of recent near-infrared research for wood and paper (part 2) (Tsuchikawa and Schwanninger 2014)
98	0.02	2012	Study of the degradation behavior of heat-treated jack pine (*Pinus banksiana*) under artificial sunlight irradiation (Huang et al. (2012)
86	0.17	2013	Visualizing wood anatomy in three dimensions with high-resolution X-ray micro-tomography (MCT)—A review Brodersen et al. (2013)

Research on the development of 3D wood surface profiles utilizing laser technology

With the help of laser triangulation systems, the 3D morphology of wood surfaces can be accurately reconstructed to show the contours of woodworking surfaces. Scholars such as Giacomo Goli and collaborators have proposed a complete methodology for measuring wood surface roughness by applying the principle of optical measurements, which can obtain the 3D data and resurface the surface morphology in a fast and intuitive way. The researchers validated the method on a round sample of Douglas-fir (*Pseudotsuga menziesii*) and developed a corresponding numerical algorithm to facilitate the subsequent processing and comparison of surface topography data (Goli and Sandak 2016). Another important study was carried out by Yuhang He et al. (2022). They compared the machined surface roughness of three types of sawn timber, Sitka spruce (*Picea sitchensis*), larch (*Larix*), and beech (*Fagus* L.), and used 2D and 3D roughness parameters, respectively, to characterize the surface roughness of the wood. The results show that under the given parameters, the 2D roughness parameter Ra can only reflect the two2D roughness curve, which is better for periodic surfaces, but for irregular surfaces the measured values are relatively random. Meanwhile, the values of the 3D roughness parameters Sa and Sq indicate the distance relationship between the points on the surface contour of the selected area and the mean plane, which analyzes the characteristics of the height parameter in the surface topography from a 3D perspective. Compared with the 2D roughness parameter Ra, they are more suitable for the overall evaluation of the surface roughness of wood with random characteristics and can objectively characterize the morphological features of the wood surface, although it should be noted that the reconstruction of the 3D topography takes more time than the 2D contour measurement and also requires more extensive data processing techniques (He et al. 2022).

Table 7.—Statistics on the number of applications of probe versus optical methods for measuring wood surface roughness in scientific research (2018 through 2022).

Year	Count (P)[a]	Count (L)	Count (P + L)	Percentage
2018	4	6	4	0.71
2019	2	5	1	0.75
2020	2	7	4	0.84
2021	4	8	2	0.71
2022	2	8	3	0.80

[a] P = probe; L = laser.

At present, the use of optical technology to determine the 3D morphology of the wood surface has become one of the most important means to evaluate the surface roughness of wood, and in the future, with the further development of technology and the improvement of data processing technology, the optical 3D measurement technology will be more mature and reliable, which will bring more research opportunities and application prospects to the field of wood science and engineering.

Structure and processing roughness separation of wood using optical technology

In practical solid wood processing, differences in wood species can have a substantial effect on the surface roughness of the processed wood, and it is difficult to differentiate between structural roughness and processing roughness. Igor Dukic et al. (2022) propose a method that combines Fourier transform for roughness analysis and Fourier transform-based signal filtering by separating the signal describing kinematic roughness from the signal describing structural and processing roughness and using standard roughness parameters to describe the individual signals, thereby quantifying the effect of the individual components on the overall roughness.

Lidia Gurau argues, however, that in the field of distinguishing structural roughness of wood, measuring areas (multiple parallel lines) can provide more information about the wood surface topography than measuring profiles (single lines) (Gurau and Irle 2017). Goli and Sandak (2016) combined laser triangulation with wavelet filtering to precisely filter the structural roughness of uneven wood surfaces. Notably, the regional roughness parameters of the wood surface were obtained by extrapolating the 3D roughness parameters of the laser. This investigation can be utilized to evaluate the processability of wood materials.

Consequently, while 2D profilometry is currently more prevalent in the field of separating wood structural roughness from processing roughness, it is certain that 3D optical measurement provides more options for separating wood structural roughness from processing roughness and has the potential to become a significant measurement technique.

Conclusion

This paper uses CiteSpace software to visualize and analyze the research on the measurement of wood surface roughness using optical measurement techniques from 2003 through 2022. The results of the analysis indicate the following: (1) The number of publications on surface roughness measurement of wood using optical measurement technology exhibits an increasing trend year by year, indicating that research in this field is receiving more and more attention. (2) There are a large number of researchers and research institutions working in this field, forming a number of core researchers and core institutions. Most of the top 10 research institutions and personnel are from Europe, indicating that European countries conduct more research in this field. (3) Turkey has the highest number of publications, but Canada and the United States have the largest intermediary center values, indicating that Canada and the United States have high-quality scientific research results in this field and cooperate closely with other countries in this field. (4) Through keyword co-occurrence and clustering analysis, it is found that the research hot spots in this field mainly focus on the study of 2D profile roughness measurement of wood surface based on optical measurement technology, the measurement of 3D profile roughness of wood surface based on optical measurement technology, and the study of separation of structural roughness and processing roughness of wood based on optical measurement technology. This paper discusses the research hot spots in these three areas and provides some references to help related personnel understand the current research status in this field.

By analyzing and discussing the research hot spots, this study concludes that the study of wood surface roughness based on optical measurement technology has obvious advantages in terms of nondestructive, efficient, and intelligent production. By introducing optical measurement technology, an advanced and reliable method of surface roughness assessment is provided for the wood field. Additionally, the application of optical measurement technology also helps to solve the problem of sample damage that may be caused by traditional contact measurement methods, thus providing a more sustainable means of wood surface quality assessment. However, due to the specificity of different wood materials and structures, optical measurement techniques may face challenges in some cases. Therefore, future research should further improve the performance of optical sensors and explore more effective evaluation methods to ensure the widespread use of optical measurement techniques in wood surface roughness studies and their successful application in wood science and engineering. The findings of this essay will provide an important scientific basis and technical support for quality control, processing and application of wood materials.

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