MEASURING WOOD SURFACE ROUGHNESS WITHOUT CONTACT

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Abstract
The paper presents some possibilities of using diverse measurement approaches in to evaluation of the surface roughness of wood and wood based materials. An optimal selection of hardware and software dedicated for wood surface geometry on-line is proposed.

Key words: *wood surface roughness, measurement, triangulation, laser, shadow*

INTRODUCTION

The meaning of wood surface roughness may differ relating to diverse purposes [1]. Up to now, the stylus technique is the most popular for roughness assessment. Unfortunately, the stylus method posses some important limitations: contacting in principle, non-zero tip radius, cone angle of the tip and slow feed. An alternative method for surface roughness evaluation in industrial environments has been sought for some time. Taking into consideration in-process monitoring of the surface smoothness the requirements for the superlative method are as follows [2]: resistance to harsh environments, sufficient measurement range, satisfactory accuracy, capacity for performing measurements at very high scanning speeds, cost-effective installation and low maintenance costs, easy integration into existing production lines and simple operation.

Some commercial devices capable of describing surface roughness are already available on the market. However, these are usually designed for high precision applications. Such devices are both very expensive and overly-accurate for application on porous biomaterials such as wood. Moreover, measurement velocity and their fragility are sometimes appropriate only for laboratorial metrology. It should be also mentioned that due to the specific properties of wood not all sophisticated techniques could measure the roughness or provide results with a large error.

Surface smoothness can be evaluated in one, two or three dimensions (1D, 2D or 3D), but most methods are based on 2D measurements. Depending on application, the information regarding an area of surface provided by using non-reproducing of the profile device (1D measurement with a sensors such as pneumatic, capacitance, ultrasound, optical reflection or scatter), could fulfill requirements. However these only provide an average quantity over the surface area and much quantitative information about the relief cannot be extracted. Characterization of surfaces using 2D profiles is rewarding, but has important limitations. Some surface properties such as anisotropy cannot be measured and quantified, and assessment of the total surface area is also impossible in one pass of the sensor. The solution could be whole surface area assessment (3D evaluation).

Such system can base on the triangulation (laser line sectioning, shadow scanner, Schmaltz microscope), stereovision, depth of focus, interference, Moiré fringes or other. Utilization of 3D techniques creates new areas for mathematical evaluation of the surface, more accurate prediction of its performance, and better understanding of the varied phenomenon affected by the surface geometry.

The goal of this project is to develop an accurate scanner system capable of rapid three dimensional evaluation of the wood surface smoothness, dedicated for on-line measurement.

TRIANGULATION MEASUREMENT METHOD

The most promising techniques to be utilized for wood surface evaluation base on triangulation [3,4]. Examples of the direct implementation of the triangulation measurement approach are laser displacement sensors. These are produced in a variety of measurement ranges, different detectors, illuminates, signal processors, accuracy and price. In the field of roughness metrology laser displacement sensors are very popular replacements of the stylus. However important limitation of such sensors is their inability to rapid evaluation of the whole surface (in general limited only for 2D evaluation) and limited performance on pours (wood-like) surfaces. Some more details related to the performance and limitation of the laser displacement sensors could be found in literature [2,5,6,7,8].

The triangulation scanner could be constructed with different configurations; in term of light source, detector type or scanning method [4,9]. The light source could illuminate the surface with spot, line (stripe), multi spots or multi lines, scrutinizing one range point, one section, multi range points or multi sections at the same time respectively. The light emitted could be coherent either incoherent. Lateral effect photodiodes or charge coupled device (CCD) could serve as a light position detectors. The single scan might be performed with movement of sample, movement of light source or movement of the detector. The selection of the movement method depends on application and desired set-up.

Metrological applications of the triangulation vision systems are very challenging and demanding in terms of hardware and software selection. Several factors could limit the measurement accuracy and its repeatability especially issues related to camera, lenses, illumination, mechanics of the scanner, algorithms for image processing, data presentation, and interpretation of results.

MATERIALS AND METHODS

The hardware of the 3D roughness scanner developed at IVALSA/CNR is presented in figure 1. Camera ① captures the image of the light profile thru camera lenses ②. The light source ③ illuminates the measured surface with a structured light. The measured sample is located on the motorized linear moving stage ④. Vertical moving stage ⑤ is used for adjusting the height of sample. Rotating arm ⑥ serves for regulation of the triangulation angle. To minimize an effect of the ambient light, the dark box ⑦ is constructed to cut-out external illumination.

A number of different light sources are under investigation: micro-focus lasers, red and green lasers with different nominal power, fibre optic sources with collimated light illuminator and linear illuminator wit rod lenses, LED illuminators and others. Moreover different types of lenses are under examination (telecentric, semi-telecentric, macro, etc). Such large set of components is a starting point for selection of the optimum set-up. Two main variations of triangulation sensors developed at IVALSA\CNR are: surface scanner with laser line measurement and surface scanner with shadow measurement (Figure 2).

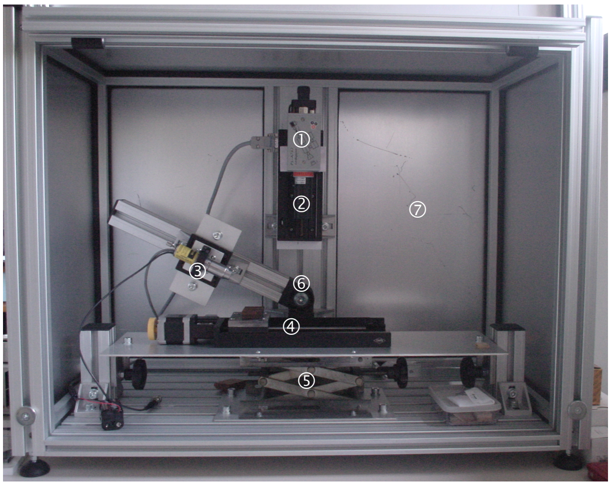

Fig. 1 Experimental platform for development of 3D roughness scanner for wood

3D SURFACE SCANNER WITH LASER LINE MEASUREMENT

Set-up of the laser line triangulation scanner is presented in Figure 2a. The laser line creates a profile section on the measured surface. The camera installed over captures an image of the line and the digital signal processor uses image analysis techniques to scrutinize the profile section. Single measurement provides information about one section of the surface. But by moving the workpiece under the sensor, next section can be scrutinized. By continuing this process a number of times, the total sample area can be examined and a 3D numerical map of the surface shape can be created.

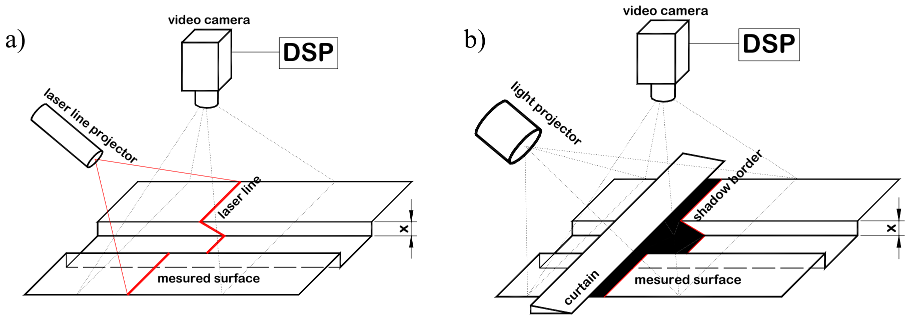

Fig. 2 General schematic of the laser line scanner (a) and shadow scanner (b).

Special software is an integral part of the developed system. Various algorithms are typically used to define the laser line section form the image: one threshold, multi-threshold average, median, mean, centre of gravity, derivative or other. In fact all these desire to calculate the “middle” of the line. Calibration of the system is performed using samples having known reference surface shape.

3D SURFACE SCANNER WITH SHADOW MEASUREMENT

The surface profile scanner with laser line calculates the height of the surface profile in each section as the “middle” of the laser line thickness [4,9]. Unfortunately, significant misrepresentations may result due to the complex interaction between laser light and wood surface, as noted above. Moreover, this method cannot distinguish fine surface roughness components, particularly when the profile wavelength is smaller than the thickness of the laser line and the surface roughness amplified a laser speckle. The attempt to improve this triangulation method is through eliminating the factor of line thickness through creation of an alternative sectioning technique. In this method, a collimated white light projector (incoherent light source creating less speckle) is installed with a fixed angle to the measured surface (Figure 3b). A sharp-edged curtain made from metal eclipses half the measured surface. The curtain creates a shadow on the measured surface, and the shape of the border between bright (highly lighted area) and dark (shadow area) is a profile section of the surface. Analogically to the laser line scanner, the camera installed over the measured surface captures an image of the border and the digital signal processor uses image analysis techniques to scrutinize the profile section.

Signal pre-processing of the shadow image is identical to the laser line. However in the next steps, the shadow image is segmented (binarized) into two sections corresponding to shadow (pixels with low intensity) and illuminated areas of the measured surface (pixels with high intensity). It was proven experimentally that use of the red plane for binarizing the shadow image give the superlative results. Threshold function offers the simplest and the most effective separation of those areas. The boundary value of the threshold can be obtained dynamically through histogram analysis. Next, the border between the shadow and illuminated surface must be mapped. The edge detection algorithm could be applied for this purpose. A single calculation of the edge position provides the location of the pixel for only one column, therefore for the total surface section the edge is detected for each column of the image, one-by-one in a loop formula. Numerical coordinates of the 2D section of the surface are thus obtained. If a 3D model of the surface is required, the workpiece must be moved under the sensor a certain distance and the next section can then be scrutinized. This process must be continued to the end of the measurement length, and all operations are therefore performed in the loop. Finally, the matrix of data obtained can be visualized on a graph, be used for future calculation/analysis of surface smoothness indicators, or it can be analyzed in other ways depending on the application (e.g. surface defect detection). Some more details regarding the shadow scanner, specification of set-up and image processing algorithms are presented in the paper [11].

MEASUREMENT ERRORS

The result of triangulation measurement is affected with various sources of errors: perturbations of the shape of light section, CCD noise, finite sensor resolution, optical blurring and electronic filtering, quantization errors, calibration errors, surface-surface inter-reflections and others [9]. Figure 3 presents examples how the laser spot is deformed on the specific situations. Every deformation of the spot distributions on the detector creates measurement error. It has to be mentioned that such laser spot deformations on porous materials is particularly complex. The light illuminating wooden surface is partially reflected in specular manner, partially reflected diffusively, absorbed, reflected internally or transmitted. These influence the laser spot deformation and in consequence increase the measurement uncertainty. This problem has been researched and some outcome of the investigations are presented in literature [5,6,7].

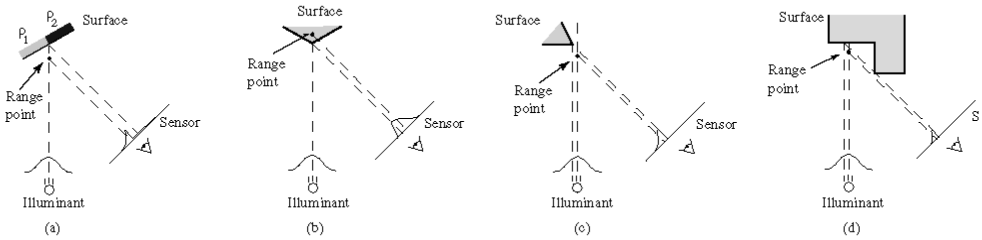

Fig. 3 Range errors using triangulation methods; reflectance discontinuity (a), corner (b), shape discontinuity with respect to the illumination (c) sensor occlusion (d) (Note: reprinted from [10])

To reduce an effect of the spot deformation on the measurement a novel algorithm for triangulation measurement with laser line, called spacetime analysis, has been proposed by Curless [9,10].

RESULTS

Exemplar 3D maps of the wooden surfaces scanned using the triangulation scanners are shown below.

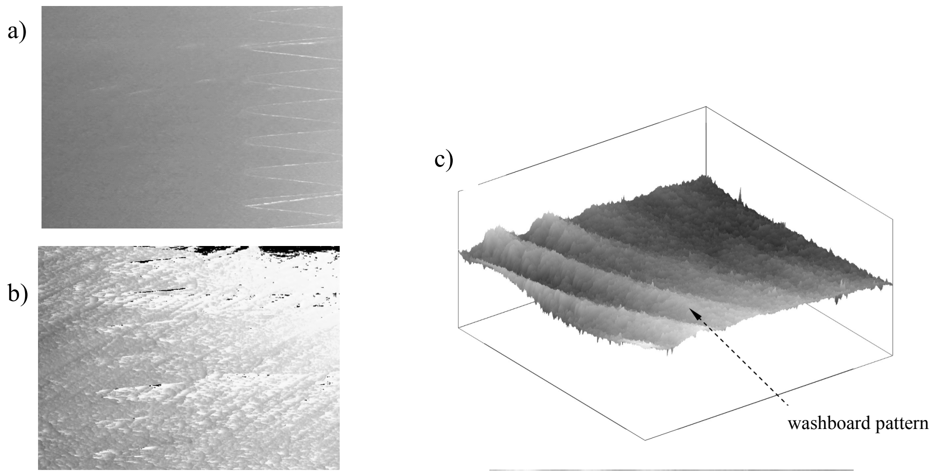

Fig. 4 Examples of the profiles scanned from the surface of wood after sawing with circular saw at varied feed speeds: 1m/min (a) and 10m/min (b) and surface containing washboard pattern generated during band-sawing (c).

Figure 4a and 4b presents images of two surfaces of glued lumber created by a circular saw when cutting speed was kept constant, but feed speed varied between 1 and 10m/min. Intuitively, when feed speed is low, the surface is smooth. This was also confirmed in the experiment. The intensity of each pixel in the figure indicates the height of irregularities in its particular coordinates. Dark pixels indicate valleys and bright pixels represent surface peaks. When the intensity variations (differences between bright and dark pixels) are small, the surface is smooth (Figure 4a). Conversely, high contrast between pixels indicates elevated roughness (Figure 4b). As seen in the figure, the resolution of the sensor was good enough to distinguish tiny saw marks created during cutting. Zigzag pattern on both surfaces correspond to the finger joints. The shadow scanner was able to accurately scrutinize very rough surfaces (washboard pattern) produced during unstable processing on a band saw (workpiece: Sugi (Cryptomeria japonica), ~12% M.C.). Both smooth and wavy parts of the surface were clearly differentiated (Figure 4c).

CONCLUSIONS

The triangulation profilometer developed at IVALSA/CNR presented here could be used for rapid and accurate scans of the surface of various porous materials, particularly wood, veneer, paper, fiberboards, leaves, and the like. This type of sensor allows rapid three dimensional evaluations of surface geometrical properties both in laboratories and industry. The resolution of the sensor is appropriate for both isotropic and porous bio-materials. The simplicity of the sensor is also a great advantage because it makes the system easy to maintain, resistant to breakage, and inexpensive. Surfaces are scanned without contact; thus surface damage during measurement is avoided. Its straightforwardness and high accuracy enables the method to be utilized for on-line measurement, and therefore it is suitable for industrial application.

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