A low cost method for determination of wooden board distortion

R. Lagaňa

Technical University Zvolen, T. G. Masaryka 24, 96053 Zvolen, Slovakia
lagana@vsld.tuzvo.sk

ABSTRACT

A method for evaluation of shape distortion of wooden boards has been developed for quality assortment. The contactless method is based on a low cost web camera - semiconductor laser system and fast image analysis. A position of a laser line illuminated on the board surface is reproduced in virtual 3D space. The location of the line with respect to the board edges or other reproduced lines gives information about basic assortment characteristics a wooden board such as twist, cup, bow or crook. The method gives sufficient accuracy for determination of distortion according the EN standards. The method and it's applicability in wood processing industry are further described

INTRODUCTION

The scanning methods have been rapidly developed over the last decades. The shape determination techniques have been found in many various industry applications (computer graphics, industrial design, medical diagnostics, quality control, etc). Different kinds of 3D visualization techniques presently exist in the field such as single point scanners, slit scanners (Fig. 1), pattern projection scanners or time-to-flight systems for large structures scanning (Blais 2004).

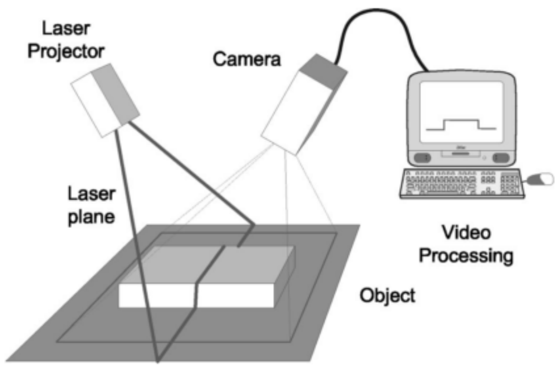


Figure 1: Example of a slit scanner (courtesy of Blais 2004)

The most of the laser scanning systems use camera, laser beam or laser plane. Virtual surface is created using triangulation of the illuminating laser beam on the object surface and rays projected to the camera. Winkelbach et al. (2006) have presented the self calibration laser scanner system used together with the known calibration target (background). The laser ray has to intersect unknown surface as well as reference calibration background. The projected laser line on the background is used for laser calibration resulting in the exact position of the laser plane. This is used in calculation of the virtual 3D surface by triangulation of the laser plane with projected rays. Their system consists of low-cost CCD camera and hand-held laser scanner. Prior to use, the camera has to be calibrated in order to get internal and external camera parameters. 3D scanning technique can be used for quality control of the wooden boards. One of the characteristics for quality assortment is shape distortion of boards (STN EN 1611-1 or STN EN 975-2). Four types of wooden board distortion are recognized (Fig. 2).

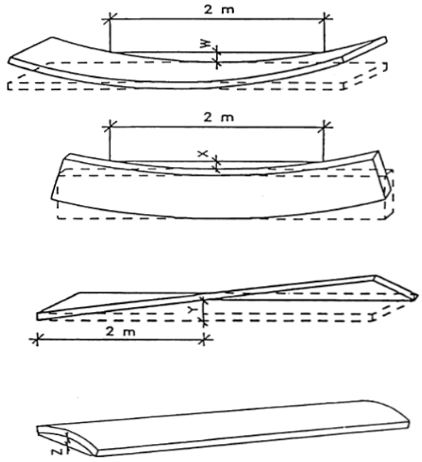


Figure 2: Distortion of wooden boards

Cup is characterized by curvature across the width of the board 'Z'. Bow is the distance of the board surface from the flat surface 'W'. Crook (spring) is similar to the bow distortion. It is given by the distance of the edge from flat surface 'X'. The last one, twist is given by the deviation of the opposite ends 'Y'.
The objectives of this study were to develop a low cost scanning system and to test the precision of the system on the wooden surface.

METHODOLOGY

Camera calibration

The camera calibration was performed using the Camera Calibration Toolbox for Matlab (Bouguet 2008). The author modified an internal camera model used by Heikkillä and Silvén (1997). Extrinsic parameters of the calibration were used for the transformation from 3D world coordinates (background coordinates) to the camera 3D coordinate system centered at the optical center of the camera lens. Some of extrinsic parameters directly characterize background planes' position with respect to the camera. Intrinsic parameters were used for the transformation of 3D object coordinates from the camera coordinate system to the image coordinate system.
For camera calibration, 10 – 15 images of calibration grids were taken by the camera. Two of the grids were placed on the surface of the corner backgrounds, so that after calibration, the background parameters became known (Fig. 3).

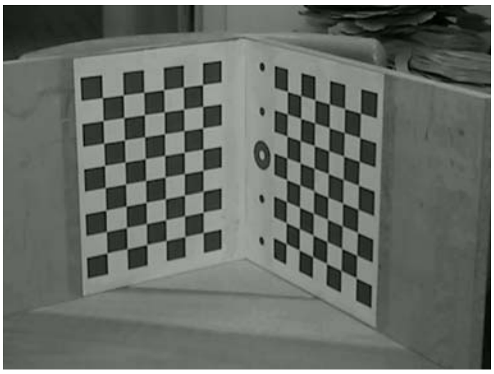
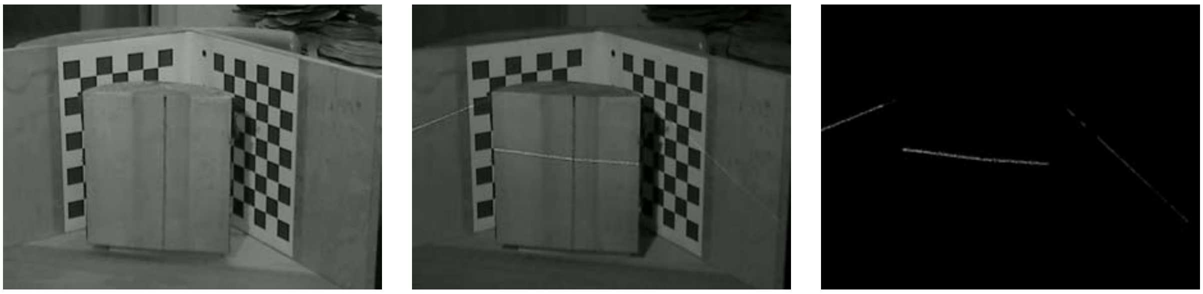


Figure 3: Corner background with calibration grids

System description

The system, similar to the one showed in Fig. 1, consists of the simple CCD web camera (max resolution 1200x1600pixels), simple hand-held laser and calibration corner background consisting of two planes placed approximately in the right angle to each other. Prior the measurement, the camera was calibrated (see details above). The video was captured during swiping of a laser line over the scanned wood surface in a dark room. The angle between the camera and laser was at least 30 degrees.

For testing purposes, a wooden sample of the non-flat surface was used (Fig. 4a). Object covered approximately 1/3 of an image. Therefore, approximately 2/3 of laser line was illuminated on the background (Fig. 4b) and was visible all the time during capturing a video (Fig. 4c).



A **B** **C**

Figure 4: Setup of the experiment. a) wooden sample, b) illumination of laser line on the corner background and a sample, c) one frame from captured video.

Image analysis of the video frames

An image of each video frame was analyzed using software Matlab®, which includes Image Processing Toolbox. An image of the acquired video was converged to 8 bit grayscale image and the low value (black color) were threshold in order to remove noise of the image. Since the laser line of a wooden board was more or less horizontal, it was averaged over the y axis of the image. Points of the background lines were approximated with two lines, transformed into 3D camera coordinate system (using background plane parameters in camera coordinate system and intrinsic camera calibration parameters) and then used for calculation of the laser plane in the space. Points of a laser line on the object (wooden board) were similarly transformed into 3D camera coordinate system using laser plane parameters in camera coordinate system and intrinsic camera calibration parameters. A 3D points' coordinates (X_i, Y_i, Z_i) created the scanned surface and were ready to used for characterization of distortion.

Precision of the method

The scanned surface (intersections of the laser plane and the board surface) in 3D space was approximated by smooth curves. The precision of the method was determined from differences of scanned 3D surface points and points of fitted approximation of this surface ($Dif_i = Z_i' - Z_i$). A line parallel to the surface was approximate by 4th order linear equation:

$$Z_i' = a_0 + \sum_{n=1}^{4} b_n X_i^n + \sum_{n=1}^{4} c_n Y_i^n \qquad (1)$$

where Z_i' is a coordinate of a fitted line *i* in camera coordinate system and a_0, b_0, c_0 are parameters of a fitted line *i*.

The precision was evaluated as 95% confidential limit of these differences according to the following equation:

$$P = \pm 1.645 \cdot STD_{Dif} \quad (2)$$

where STD_{Dif} is standard deviation of the differences. More than 100 line approximations were taken into the account.

RESULTS AND DISCUSION

The created surface of the wooden sample is showed in Fig. 5.

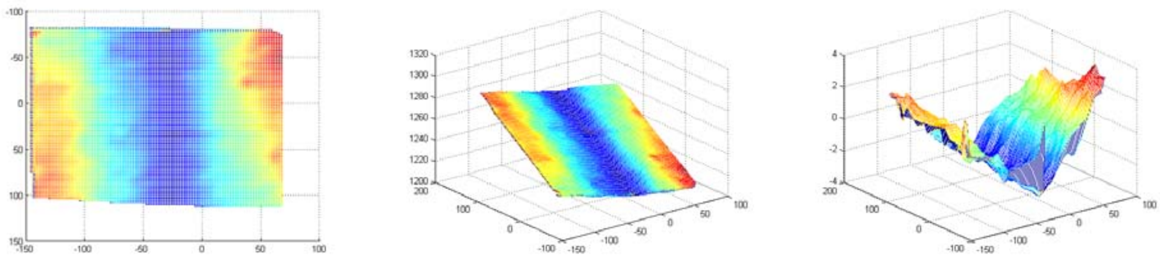


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Figure 5: The projected surface of the wooden sample, a) camera view, b) bottom side view, c) difference of the projected surface from the flat surface. The camera is placed in the origin [0,0,0], units are in mm

The reconstructed surface of the wooden sample showed non-flat origin of the sample. Differences of the original surface and flat surface (Fig. 5c) could be use for evaluation of cup, bow and twist distortion with respect to the flat surface. The flat surface perpendicular to the board surface can be use for evaluation of crook. The result of the scanned sample showed cup distortion only.
The precision of the method was ±0.298 mm. Comparing to the camera-object distance (1.5m), the precision represent 0.02%. Inline scanning of 2 m length of interest can give precision of ±0.8 mm. This can be improved with a laser of thinner line, lighting conditions or better optics. The reasonable changes should not dramatically change the total costs of the system.

CONCLUSIONS

The study presents a low cost optical method for evaluation of wooden board distortion characteristics. In laboratory conditions, the method showed to be reliable enough for simple inline scanning process. The precision of the system is 0.02% of the camera – object distance. Further development of the method is expected in the near future.

ACKNOWLEDGEMENTS

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STN EN 1611-1: Sawn timber. Appearance grading of softwoods. Part 1: European spruces, firs, pines and Douglas firs.

STN EN 975-2: Sawn timber. Appearance grading of hardwoods. Part 2: Poplars

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