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A reference measurement system for roundwood based on fringe projection

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Abstract

Roundwood scanners in sawmills measure diameters and lengths of roundwood with light curtains, by laser triangulation, or by ultrasound. In order to assess the metrological performance and durability of roundwood scanners, a reference has to be provided. For this purpose, PTB is currently establishing a reference system based on close-range photogrammetry and fringe projection. Two types of standards are proposed to validate the reference measurements. Discs made of wooden material are employed to quantify the influence of the optical behaviour of the wooden surface. An elliptic cylinder in combination with a gauge is used to find the influence coming from the fringe projector and the measuring strategy.

close-range photogrammetry, fringe projection, roundwood scanner, roundwood calibration

1. Introduction

Roundwood scanners in sawmills measure diameters and lengths of roundwood with light curtains, by laser triangulation, or by ultrasound. As the diameters and lengths are employed for billing of delivered raw wood, suppliers and sawmills expect roundwood scanners to have adequate metrological performance and durability.

Test measurements are essential for the assessment of performance and durability. Pipes made out of cardboard, plastic, or metallic materials are frequent, but poor choices as standards for the test of roundwood scanners, as they provide only information on the trueness of measured diameters and lengths, but no information on capabilities of the scanners to cope with the shapes and surfaces of roundwood. Feeding lines in sawmills often have difficulties to move forward objects with smooth surfaces like pipes, as they rely on the rough and soft surfaces of raw wood.

Roundwood taken as representative sample from the intake of sawmills promise to be more suitable as test standards. Nevertheless, roundwood has to the used with caution, as its dimension strongly depends on temperature and humidity and exhibits only low stability. The weak surface of freshly cut wood may be easily damaged by the feeding mechanisms. Therefore, roundwood employed in tests should be calibrated immediately before and after use.

2. Fringe projection for calibration of roundwood

German sawmills process debarked conifer roundwood with diameters between 100 mm und 1000 mm. The average diameter is about 250 mm. The length of roundwood ranges from 2 m to 6 m. Roundwood scanners are required to have accuracies of several millimetres for diameters, and several centimetres for lengths. Therefore, roundwood used as transfer standard should have calibration accuracies in the order of 0.2 mm for diameters and 1 mm for lengths.

Close range photogrammetry using fringe pattern projection is a mobile measurement technique especially suited as reference, as it allows for the areal measurement of large objects with high surface resolution. A state-of-the-art fringe projection sensor with a measuring volume of 0.56 m^3 (1000 mm width × 750 mm height × 750 mm depth) and equipped with 8-MPixel-cameras offers a spatial resolution of 330 µm and reaches a maximum permissible error (MPE) of 100 µm for length measurements according to the VDI 2634 guideline [1]. In combination with a photogrammetric camera measuring volumes of up to 40 m^3 (2 m width × 2 m height × 10 m depth) can be covered.

Manually operated instruments such as callipers for measurement of diameters and measuring tapes for the measurement of lengths do not offer the measurement accuracies required here. Although tactile coordinate measuring machines have higher measurement accuracies, they do not offer the spatial resolution required for the measurement of roundwood.

3. Challenges in the measurement of roundwood

3.1. Definition of the roundwood diameter and length

The German roundwood scaling rules characterize roundwood by midpoint diameter and length [2]. Modifications and clarifications have to be made for the measurement by roundwood scanners, and in consequence, for the use of roundwood as test standard. As roundwood scanners usually cannot detect irregularities on roundwood surfaces, the midpoint diameter is replaced by the smallest pair of diameters found in a specified longitudinal range, e.g. ±150 mm around the midpoint (midsection).

As the longitudinal axis of roundwood is only obvious in manual measurements, a more precise definition has to be found. It is suggested to use the numerical association of a cylinder to the points recorded on the lateral surface.

3.2. Influences from fringe projection measurement

Fringe projection is a complex measurement process. These type of measurements start with the projection of light patterns onto the surface of the object to be measured, followed by their recording with electronic cameras. From the recorded images the sensor determines the spatial coordinates of surface points using the orientations of the projector and the cameras determined by a preceding test field calibration [3].

If not all parts of the object surface can be recorded from a single sensor viewpoint, measurements have to be made from different viewpoints around the object. The raw point clouds recorded from the different viewpoints are then merged into a single triangulated point cloud using control points.

In most cases the control points are provided by additional markers, which are placed on the object surface and are recorded simultaneously with the fringe patterns. Often, a photogrammetric camera in combination with scale bars is used to establish a control point network, before the actual fringe projection measurements are made. Finally, the measurands of interest are determined from the recorded points.

A wide range of influences affect fringe projection measurements. These influences come from the measured object itself, especially from the shape and the optical behaviour of the surface, from the pattern projector and the cameras, the test field calibration, but also from the extraction of the surface points from the images.

An often underestimated influence in fringe projection measurement comes from the measurement strategy, which includes the distribution of control points across the object surface, the establishment of the control point network, and the selection of viewpoints for the fringe projection measurements. Most fringe projection sensors allow the user to balance the resolution and the precision of the recorded surface points and give various options for the post-processing of the point cloud.

Due to the complexity of fringe projection measurements, the analysis of influences is difficult to perform even for relatively simple geometries like roundwood.

4. Assessment of calibration by fringe projection

In order to validate the fringe projection system for its use as reference for roundwood scanners the measurement is assessed using calibration standards, that are representative for roundwood and can be calibrated independently with sufficient accuracy.

Discs made from veneer laminate are employed to characterize the influence coming from the optical behaviour of roundwood surfaces, which are determined by the surface colour and subsurface scattering [4]. Veneer laminate was chosen as material, as its optical behaviour is similar to grown wood, but provides much better dimensional stability. Figure 1 shows an example of such a standard, which simulates a round shaped slice of a tree with a nominal diameter of 500 mm.

Figure 1. Disc made from veneer laminate to characterize the influence of surface colour and subsurface scattering in fringe projection measurements (nominal diameter 500 mm, thickness 100 mm)

In order to investigate the optical behaviour, including subsurface scattering, test measurements of diameters were performed with and without opaque surface coating (TiO_2 spray). In a series of measurements, a systematic deviation of approximately -0,1 mm was found.

Characterisation of the influences arising from the measurement system and the strategy requires a test object with close resemblance to roundwood. Figure 2 shows a proposed design, built from an elliptic cylinder accompanied by two round tubes and a gauge. The cylinder with its irregular shape simulates the midsection, while the tubes simulate the other parts of the lateral roundwood surface and bear the control points. The cylinder can be calibrated on a coordinate measuring machine to produce reference values for diameters, while the gauge serves as reference for the roundwood length.

Figure 2. Test object resembling roundwood, built from an elliptic cylinder accompanied by two round tubes and a gauge. (nominal diameter 250 mm, overall length 2 m).

5. Summary and future works

The reference measurement of roundwood by fringe projection is a complex process underlying many influences coming from the roundwood itself, the fringe projector as measuring instrument and the measurement strategy. Here, two types of standards are proposed to assess the accuracy of such a measurement. Discs made of wooden material are employed to quantify the influence of the optical behaviour of the wooden surface. An elliptic cylinder accompanied by two round tubes and a gauge is used to find the influence from the fringe projector and the measuring strategy.

Future work will include repeated measurements to take care for a better separation between systematic and random effects.

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