Computers and Electronics in Agriculture 152 (2018) 269–280

Contents lists available at ScienceDirect

Computers and Electronics in Agriculture

journal homepage: www.elsevier.com/locate/compag

Original papers

Three-dimensional virtual reconstruction of timber billets from rotary peeling

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ARTICLE INFO

Keywords:
Mathematical modelling
Visualisation
Forestry
Southern pines

ABSTRACT

Accurately determining the timber properties for products prior to cutting the tree is difficult. In this work we discuss a method for reconstructing a timber billet virtually, including internal features, after it has been peeled into a full veneer (ribbon). This reconstruction process is the first stage in developing a mathematical model for the variation in timber properties within a given tree. The reconstruction of internal timber features is typically achieved through the use of computed tomography (CT) scanning. However, this requires the use of equipment that may be cost-prohibitive. Here we discuss an approach that utilises more readily available equipment for timber processors, including a spindleless lathe and digital SLR camera.

In comparison to conventional scanning methods, this reconstruction method based on a destructive process has the key advantage of delivering high-resolution colour images. This reconstruction serves two purposes. Firstly, we are able to generate three-dimensional visualisations of the timber billet, to uncover internal structures such as knots, defects, insect or fungi attack, discoloration, resin, etc. Secondly, the reconstruction allows us to map timber properties measured on the veneer to their original location within the billet. This allows us to locally inform the mapping with wood properties and subsequently derive their distribution throughout the billet. From this information it is then possible to extract any part of the billet and obtain the appearance and wood properties of any processed products. To validate our reconstruction process we show that we can obtain reasonable agreement between our predicted billet modulus of elasticity and that measured on the original billet.

1. Introduction

This work focuses on the commercial southern pine estates of southeast Queensland and northern New South Wales. The term ‘southern pines’ refers to approximately ten species of the genus *Pinus*, whose natural distribution spreads across the south-eastern region of the United States of America and the Caribbean region of central America. They are one of the most important groups of commercial timbers due to the scale of forests, both natural and plantations, which are utilised for wood and paper products (Southern Forest Products Association, 2013). Planting trials in the early decades of the twentieth century resulted in selection of varieties of slash pine (*Pinus elliottii*) and Caribbean pine (*Pinus caribaea* var. *hondurensis*) for establishment of timber plantations on suitable sites in sub-tropical Australia. There are several nodes of plantations in the state of Queensland, including near Ingham in north Queensland and the Capricorn coast in central Queensland; however 75% of the estate is concentrated around the coastal lowlands in south-east Queensland.

These plantations provide the feedstock for a range of products ranging from glued-laminated beams and structural framing for house frames and roof trusses, to landscaping timbers and reconstituted panels (The Queensland Government, 2016). The Queensland estate has environmental certifications and provides many economic benefits such as regional employment and import substitution.

The internal features of a tree have direct impacts on the physical, mechanical and appearance properties of wood products. For example the knots (remnants of the branch architecture) detract from strength, creating a site of potential rupture under load (Hanhijärvi et al., 2005). Grain deviations developed during wood formation can result in sloping grain in a sawn board which can also have a negative impact on wood properties. The internal core of wood in a tree is commonly referred to as juvenile wood, as it forms in the early development of the crown. This zone of wood provides important support for the young tree, and for the tops of growing trees, for example allowing the tree to bend

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https://doi.org/10.1016/j.compag.2018.07.018
Received 19 January 2018; Received in revised form 4 July 2018; Accepted 8 July 2018

under wind loading without breakage. Although important for the survival of the tree, this juvenile zone of wood typically has low stiffness and low wood density, making it unsuitable for structural wood products (Zobel and Sprague, 1998). The outer cylinder of wood formed during the mature stage of a tree's life is typically higher in density and stiffness properties. Again, these are evolutionary traits developed to ensure survival of the tree, providing the structure to support the weight of the tree's branches and foliage and withstand lateral wind loading.

The physical, mechanical and visual properties of timber products are of critical importance to the forestry industry. These properties, such as basic density, stiffness and shrinkage, are directly linked to the value of the timber. However, accurately determining these properties for the timber prior to cutting the tree is difficult. The first stage in developing a mathematical model for the properties within the tree is to develop a virtual reconstruction of any given tree. Typically, this is done by either computed tomography (CT) scanning (Schmoldt et al., 1996; Berglund et al., 2013; Stängle et al., 2013; Fredriksson et al., 2015; Fredriksson, 2015; Giudiceandrea et al., 2016), or the so-called flitch method, where logs are sawn into sections (Pinto et al., 2003, 2005; Lin et al., 2011; Knapic et al., 2011) (flitches) and each section is scanned to build up a three-dimensional image of the log.

However, these approaches may be deemed too expensive, cumbersome or not accurate enough, and it therefore becomes difficult to create a virtual representation of a log. In this work we investigate a method of building a virtual reconstruction of timber billets based on their peeled ribbon, as the first step towards a mathematical model of property variation within the southern pines. We note that similar approaches have been used to model the peeling process of a log (Girardon et al., 2016), however to our knowledge this process has not been applied to reconstructing a log from a peeled ribbon.

We have conducted a trial on 30 trees from a 29-year-old hybrid pine plantation near Maryborough in south-east Queensland. The hybrid was the second generation cross (F_2 hybrid) of slash pine with Caribbean pine (*Pinus elliottii* var. *elliottii* × *P. caribaea* var. *hondurensis*).

These 30 southern pine trees have been cross-cut (see Fig. 1) into two peeler billets (approximately 1.2 m each) that will have density, stiffness and shrinkage measured at different positions; one sawlog (approximately 4 m) that will be sawn and dried into structural boards and tested for distortion (correlated with variation in grain geometry and shrinkage), strength and stiffness; and four discs to be used for cambial age, wood density, stiffness and shrinkage measurements at different heights in the tree.

2. Data collection

The 30 trees were delivered to Salisbury Research Facility (SRF) in Brisbane, Australia, where they were cross-cut into the discs, peeler billets and sawlogs. Prior to sawing, a reference cut was made along the length of the tree. The peeler billets were drilled on the reference cut through the diameter at the butt end to facilitate alignment of images for stitching and for reconstruction. The billets were peeled on an Omeco spindleless veneer lathe at a thickness of approximately 2.5–3.0 mm. An initial "round-up" peel was conducted to remove significant variation from the surface of the billet and to obtain a near-cylindrical billet, however we were careful not to remove too much timber from the outside of the billet. This is because the highest quality timber (i.e., the highest stiffness) is generally found in the outer layers (Lachenbruch et al., 2011). The rounded-up billet was then peeled until a core of approximately 50 mm diameter remained. Following peeling of the billet, the ribbon was placed over a light table to provide illumination through the ribbon, allowing features to be easily detected.

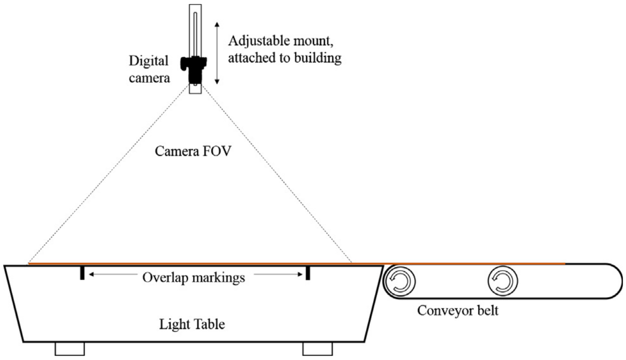

Fig. 2. Diagram showing the camera setup and light table.

Fig. 2 shows the set-up for the photography of the ribbon. The light table was positioned at the end of a conveyor belt to allow for easy handling of the full ribbon. A perspex sheet was placed on top of the light table to diffuse the light evenly across the sections of ribbon. An adjustable rig was constructed to position the camera, and this was attached to the steel frame of the workshop housing the equipment. This ensured consistent positioning of the camera across all images. High resolution images of the ribbon were captured using a Canon EOS 600D with a 20 mm f/2.8 lens, ensuring approximately 25% overlap with each subsequent frame. An example image of one section of the ribbon is shown in Fig. 3.

Following photographing, strips of the ribbon (100 mm width) were clipped at one metre intervals. These strips were further processed to obtain measurements for modulus of elasticity (MOE), density and shrinkage. MOE measurements have been obtained using resonance frequencies through the vibrational technique known as BING (Beam Identification by Non-destructive Grading) (Brancheriau and Baillères, 2002; Paradis et al., 2017; Faydi et al., 2017). BING consists of a microphone, an acquisition card (Pico Technology), two elastic supports and a hand-held hammer. Fig. 4 shows the BING configuration used to measure the MOE of the veneer strips. The geometric characteristics and the mass of the sample were measured with a calliper and a weight scale. This device, originally designed for small samples (360 mm × 20 mm × 20 mm), can be used with a wide range of shapes

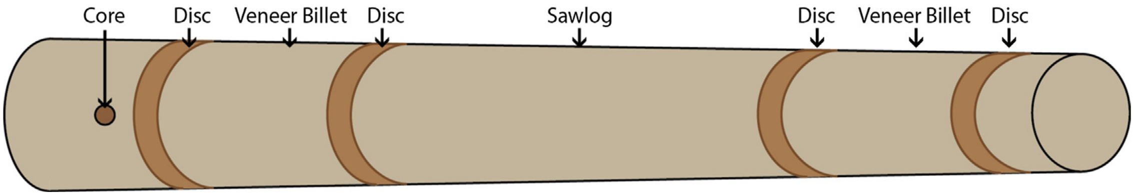

Fig. 1. Diagram representing discs, peeler billets, and sawlog.