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Fast visual recognition of Scots pine boards using template matching

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ABSTRACT

This paper describes how the image processing technique known as *template matching* performs when used to recognize boards of Scots pine (*Pinus sylvestris* L.). Recognition of boards enables tracking of individual boards through an industrial process, which is vital for process optimization.

A dataset of 886 Scots pine board images were used as a database to match against. The proposed board recognition method was evaluated by rescanning 44 of the boards and matching these to the larger dataset. Three different template matching algorithms have been investigated while reducing the pixel densities of the board images (downsampling the images). Furthermore, the effect of variations in board length has been tested and the computational speed of the recognition with respect to the database size has been measured. Tests were conducted using the open source software package OpenCV due to its highly optimized code which is essential for applications with high production speed.

The conducted tests resulted in recognition rates above 99% for board lengths down to 1 m and pixel densities down to 0.06 pixels/mm. This study concluded that template matching is a good choice for recognition of wooden board surfaces.

1. Introduction

1.1. Problem statement

Traceability at sawmills includes tracking logs between processing steps, tracking boards to logs, and tracking individual pieces of wood. Members in the Swedish wood industry consortia WoodCentre North (TCN) express a wish to increase the control over each individual wood piece. Individualized processing of products requires traceability for feedback and local optimization of the process step in question. Tracking individual boards enables detailed control of the processes and the material flow. Diagnostics and process monitoring could then be based on statistics of each individual board instead of at a batch level. The drying process is one example where shrinkage and deformations could be monitored in detail. Without an automatic recognition system for boards, such studies can only be done by labor-intensive and process-disruptive manual tests. Another example is the EU project Hol-i-Wood Patching Robot, which partially financed this study. In that project, an entirely autonomous inspection- and patching system has been designed. This system needs to identify individual wood panels for customized treatment.

Traceability of boards could be a valuable tool for process optimization and for increasing the availability of data for decision making. Process operators could analyze the effect different process steps have on individual boards. By recognizing a board, all the data gathered about that board up until that moment would be available, and it would therefore be possible to reuse data gathered from expensive measurement systems earlier in the process, e.g. an X-ray imaging system.

There are two main categories of traceability methods: invasive and non-invasive methods. Invasive methods include using barcode labels, paint and radio frequency identification (RFID), while non-invasive methods include measurements in the X-ray, microwave and visual spectrum. It is preferable to utilize sensors already present in the plant, which usually means non-invasive board scanning equipment. It is the general conception that new pieces of equipment add new problems and increase the need for maintenance.

1.2. Related work

Invasive recognition and tracking in the wood value chain have, as mentioned, been studied previously using barcode labels, paint and RFID (Uusijärvi, 2000; Dykstra et al., 2002; Flodin, 2009). In the

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TCN report by Flodin (2009), both RFID tags and sprayed-on paint were incorporated for tracing logs and boards through a sawmill as a means of conducting continuous automatic test sawing. During a test run with a few production disturbances, 77% of the boards were traced back to their corresponding log. Flodin (2009) noticed a problem with the photocells that were calibrated for a specific color wavelength. Saw dust and dirt often covered the sensors, having a negative effect on their reading capability.

The biggest opposition against the invasive methods is usually not the cost issue, but the maintenance of the added equipment. Moreover, it is sometimes difficult to keep a readable barcode on the product through many of the processes, such as drying or planing. In the EU project Indisputable Key, 18×8 Data Matrix codes were printed on board ends using a Markem 9064 Touch Dry inkjet printer. Põlder et al. (2010) mentioned difficulties reading the labels due to vibrating boards and rough, dark or dirty marking surfaces. Vibrations sometimes caused the printer to partly miss the board ends or to produce distorted codes. It was found important that the printing surface was relatively bright and even in color to give a good contrast against the ink. It is therefore preferable if the board ends are finished uniformly to assure a clean and even background (Tamre et al., 2008). Large defects such as cracks and holes deteriorate the code readability substantially. Tamre et al. (2008) performed tests in sawmill conditions and reached a 70% code readability. This percentage might be high enough in the case of automatic test sawing, where a more holistic view is gathered, but in the case of individualized processing as in the Hol-i-Wood PR project, more than 90% recognition is at least needed. According to Põlder et al. (2012) it can be difficult to achieve a code readability level above 95% of painted labels on the rough end grain side of boards.

Chiorescu and Grönlund (2004) compared two non-invasive methods for identifying debarked logs between the log sorting station and the saw intake using a pair of identical 3D log scanners. Variables such as volume, length, taper and bumpiness were used and gave an average recognition rate of 89% of the 773 studied logs. Flodin et al. (2008) investigated the possibility to connect the center yield planks to the correct X-rayed log. The fingerprint was first extracted at the log sorting station using a one-dimensional X-ray log scanner and later using a cross-fed surface scanning system for the planks at the green sorting station. The results showed that over 95% of all planks could be matched to the correct log.

Fuentealba et al. (2004) investigated a method to recognize boards using the signature obtained from a microwave sensor. The identification error rate according to their study was 1.5%. However, microwave imaging systems are not standard equipment in sawmills.

Hietaniemi et al. (2013) compared two low-level features: Center-Symmetric Local Binary Patterns (CS-LBP) (Heikkilä et al., 2009) and Upright Speeded-Up Robust Features (U-SURF) (Bay et al., 2008) as means for recognizing boards between the beginning and at the end of the manufacturing process. They obtained a recognition rate over 95% with a high confidence level.

Another study of recognizing boards using feature descriptors was presented by Pahlberg et al. (2015a). That study used a fusion of SURF and block descriptors in combination with a geometric transform estimator, and achieved a matching accuracy between 90% and 100% depending on the number of knots on the board surfaces.

For wooden panels, the intrinsic geometry of knot patterns has been used for recognition (Pahlberg et al., 2015b). That method is unfortunately dependent on a relatively high knot count and a well working knot detection algorithm. The required knot count is probably too high for the method to be feasible in many industrial applications.

Although there exists some related work on recognition of boards, there are still other image processing tools that would be interesting to evaluate. One particular tool is template matching.

1.3. Template matching

In digital image processing, *template matching* is a common method for detecting and recognizing objects. The method tries to locate a sub-image (a template) in a larger search image by comparing the pixel intensities. Either a similarity or a dissimilarity measure is calculated for every position in the search image. Template matching is often used in areas such as biometrics, industrial inspection, robot navigation, multimedia retrieval, and motion tracking. The normalized variants of template matching are robust in the sense that they, besides being able to detect objects in noisy environments, also can handle uniform illumination changes. Template matching does not depend on the object having any particularly distinct features to be able to detect it. However, a distinct and unique look of the sought object often improves the identification accuracy.

To speed up the matching step, templates and search images are often downsampled in an image pyramid to initially find promising possible locations for the template (Gharavi-Alkhansari, 2001; Wei and Lai, 2008). Unlikely regions for a good match can be pruned away from further processing, greatly reducing the computational cost. Places in the search image that are still promising can be traversed at increasingly higher pixel density to improve the precision of the best matching location. Another way of finding good initial guesses is by initially searching for low-level feature descriptors or contours.

1.4. Objectives

The objective of this paper is to investigate if template matching can be used to recognize board images under realistic conditions and in a reasonably short time. To minimize the computational cost and the memory requirement for a board fingerprint database, we want to investigate the effects of reducing the pixel densities of the images (downsampling the images). Our board recognition method is not scale invariant and only handles even 180° rotations, but this is what is needed for most applications, since the orientation and scale in sawmills are often well defined. Since our method recognizes board images, it can also be used to identify which face of the board that is directed towards the camera. The robustness of our template matching method will be evaluated further by using pieces of boards of different lengths and different template matching algorithms. Also, the computational time will be measured to evaluate if the investigated recognition method is fast enough to be viable in practice.

2. Materials and methods

2.1. Database and query images

The image dataset in this study comes from 443 floorboards of Scots pine (*Pinus sylvestris* L.) with the cross-sectional dimensions 21×137 mm and length between 3 and 5 m. The floorboards were sawn from 222 logs with top diameter between 201 and 215 mm that were randomly collected from Bollsta sawmill in central Sweden. Two center boards in the position next to each other were collected from each log, which brings the total number of floorboards to 443 (one was lost). The boards were planed, sanded and finished with white pigmented oil and a thin layer of varnish. Both faces of the boards were scanned in 2006 using a high resolution color line camera at a pixel density of 2.5 pixels/mm lengthwise and