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Recognition of boards using wood fingerprints based on a fusion of feature detection methods

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ABSTRACT

This paper investigates the possibility to automatically match and recognize individual Scots pine (*Pinus sylvestris* L.) boards using a fusion of two feature detection methods. The first method denoted *Block matching method*, detects corners and matches square regions around these corners using a normalized Sum of Squared Differences (SSD) measure. The second method denoted the *SURF* (Speeded-Up Robust Features) *matching method*, matches SURF features between images (Bay et al., 2008). The fusion of the two feature detection methods improved the recognition rate of wooden floorboards substantially compared to the individual methods. Perfect matching accuracy was obtained for board pieces with more than 20 knots using high quality images. More than 90% matching accuracy was achieved for board pieces with more than 10 knots, using both high- and low quality images.

1. Introduction

The motivation for this work is: (i) to find out if it is possible for a machine vision system to correctly re-identify wooden boards using only their biometric “fingerprint”, and (ii) to find out exactly how small wood pieces can be recognized using a fusion of so called *feature detection* methods.

This is a continuation of the work done by Pahlberg and Hagman (2012) and is likewise a part of the *Hol-i-Wood Patching Robot* project. The project outcome will consist of several different *holonic* modules. Holonic, means that something is simultaneously a part of something whole, but can still work by itself, e.g., like a human cell. The wood fingerprint recognition system is such a part.

This particular application is supposed to run in real-time, meaning that the processing unit is only allowed a few hundredths of a second to correctly identify the wood piece when it arrives at one of the patching robots. The search space will consist of all the scanned wood products that are, so to say, in the flow and on their way to being patched. This is therefore a so called *closed-set* identification task, where the sought “individual” is known to be in the database.

1.1. Traceability in the wood chain

The wood industry has been investigating solutions to a few traceability problems in the past. Efforts have been put into investigating the possibility of tracking trees between harvesting and sawmills using RFID tags (Björk et al., 2011; Häkli et al., 2013), tracking logs between the log sorting station and the saw intake (Chiorescu and Grönlund, 2004) and identifying which boards originate from which logs (Flodin et al., 2008). Attempts to recognize boards using board end images have also been carried out (Põlder et al., 2012). Other invasive technologies like barcode stickers and sprayed on paint have also been investigated (Dykstra et al., 2002).

One big gain with traceability of wood products would be the possibility for direct error feedback (Grönlund, 2008). If something is wrong with the end product, if it has the wrong moisture content, if the yield is low, there are possibilities to trace back through the chain and easier localize the origin of the problem. Traceability would make it possible to do on-line and instantaneous calibration of machines. Today, time consuming and expensive test sawings are needed to calibrate machines and measurement equipment.

A wish, as expressed by industrial actors and researchers in the consortium WoodCentre North, is to generate a controlled flow for each individual wood component. This need is for example expressed by saw millers wanting to move away from bulk production to a more dynamic customer-ordered production process in order to utilize the biodiversity of wood better.

For the past decades, the trend has been to group similar logs into bins and sawing batches in the same way (Uusijärvi, 2000). However, in order for the wood industry to take the next step, there is a need to connect the information through the whole chain and adjust processing parameters by means of customer demands and optimizing for value.

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Each log can be divided into several different products. Therefore, a high precision control is needed. The value added to each product, through different processing steps, will be lost if it ends up in the wrong bin. However, high precision control contradicts with keeping a low amount of equipment. It is much more effective to use in-process sensors as monitoring tools than adding new ones which are likely to not get the full service and care by the staff (Flodin, 2009).

A great advantage has emerged due to the possibility to look into the interior of logs with high precision at industrial speeds. The breakdown process can now be carried out virtually and a fingerprint extracted to later be recognized by a surface scanner.

Today, there are image sensors available in the process chain for sorting of logs by quality: 3D shape, discrete X-ray and computed tomography (CT). Surface scanners are present within green and dry sorting of the lumber and a number of process feedback sensors that can be utilized to track and control each individual product in the process. The sensors have different outputs and show different properties or mechanisms depending on sensor type. The problem which remains to be solved is to find appropriate fingerprint parameters and matching algorithms such that the wood products can be recognized at every point in the process.

Can this be done using sensors already present in the chain today, e.g., surface scanners? This article deals with the final stages of a wood value chain, i.e., so called tracking or re-identification of boards.

1.2. Biometrics

In the field of biometrics there has been an enormous amount of effort put in improving the recognition of humans (Jain and Kumar, 2012). A lot of different recognition techniques are today being researched in the field of biometric identification for security and prevention of identify theft (Komogortsev and Karpov, 2013; Yang et al., 2013; Czajka and Bulwan, 2013). As wood recognition and wood traceability are relatively unexplored areas of research there is a lot to learn from the human biometrics field. There, the most research and effort has up until today been put into fingerprint, face and iris recognition. However, there are also other applications, for example, palm print, vein, handwriting, sound, gait and ear recognition, that provide inspiration and push the biometrics field forward.

Luckily within wood fingerprint recognition we are spared from problems such as identify theft. However, some similar difficulties can still be present, as well as a few problems which are specific for the recognition of sawn wood products. Like humans, wood can age, which can lead to changes in color but also add crookedness, bow and cracks and so on (Sandberg, 2005). Wood products can also be dried, planed, sanded, treated by some reagent or cut into smaller pieces of different shapes during the processes within which we want to track it. In addition, measurements of wood in industrial processes can be subject to dirty, humid and other adverse environmental conditions. Things like sawdust or dirt, but also lighting can cause problems especially if we are using intensity information directly as feature representation.

The image acquisition can also be negatively affected by loss of traction of conveyor belts or improper clamping of the wood pieces in combination with line scan cameras.

Moreover, while there is a common saying that all trees are as unique as humans, there are also bound to be similar ones, that can cause problems. If thin veneer is cut from one log there will be several similar sheets, or "twins". The front and back of a board can also sometimes look very similar, though the sides will in that case be mirror images of each other.

1.3. Automatic fingerprint identification systems

Most often fingerprint identification systems, for humans or wood, need to address the following design steps (Jain et al., 1997):

1. Image acquisition.
2. Fingerprint representation.
3. Feature extraction.
4. Matching.

Systems usually use minutiae and their relative positions as fingerprint representation (Yager and Amin, 2004).

To be able to quickly match against very large databases, a great deal of care must be taken when choosing representation. Identification would often have to be made in haste since modern wood factories have very high flow speeds. For instance, modern sawmills run their conveyors at three meters per second.

Although speed is important in our real-time application, and though speed is always there in the back of our heads, it has not been top priority in this work. There are always strategies to speed up the final identification system. A more thorough optimization of the code will be done at a later stage, after proof of concept.

1.4. Interest points and feature matching

Interest points are regions in an image that are likely to be recognized in other images of the same scene or object. Typical interest points include, for example, corners, line endings and blobs (Schmid et al., 2000). Corners, which are positions in an image where there is a strong intensity change in at least two directions, are very good objects to track (Moravec, 1980; Shi and Tomasi, 1994; Rosten and Drummond, 2006).

Usually, a representation of the intensity information in a region around the interest point is stored. These feature representations, or *descriptors*, can later be used for recognition of objects by matching several feature descriptors between two images.

Criteria for good points to match were described by Förstner (1986) as having the following attributes:

1. *Distinctness*: The points should be distinguishable from their neighborhood, e.g., consist of a pronounced gradient in intensity or color.
2. *Invariance*: The points should be invariant with respect to expected geometric and radiometric distortions.
3. *Stability*: The points should be robust to noise.
4. *Seldomness*: There should not be several similar points in the same image to avoid confusion. (If a point is part of a repetitive pattern, the possibility for a false match is high.)
5. *Interpretability*: The points should preferably be interpretable, such as an edge, corner or blob.

Edges however, are usually not good interest points; the region information looks similar along the edge and hence does not fulfill the seldomness requirement. Another example are smooth untextured regions, which do not uphold the distinctness requirement.

There exists a lot of different feature detectors and descriptors. Lowe (2004) proposed an approach called Scale-Invariant Feature Transform (SIFT). SIFT detects the dominant gradient orientation of interest points in an image and saves the gradient information around these points. Since the dominant orientations of the features are calculated, the descriptor becomes rotationally invariant. SIFT features can also be matched between different scales since the images are downsampled iteratively while leaving the kernel size unchanged. A fast and robust detector/descriptor, which in many ways is similar to SIFT, is Speeded-Up Robust Features (SURF, (Bay et al., 2008)). SURF has similar performance as SIFT, but the