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Towards the applicability of biometric wood log traceability using digital log end images ☆

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ABSTRACT

Log traceability in the timber based industries is a basic requirement to fulfil economical, social and legal requirements. This work introduces biometric log recognition using digital log end images and explores the robustness to a set of log end cross-section (CS) variations. In order to investigate longitudinal and surface CS variations three tree logs were sliced and captured in different sessions. A texture feature-based technique well known from fingerprint recognition is adopted to compute and match biometric templates of CS images captured from log ends. In the experimental evaluation insights and constraints on the general applicability and robustness of log end biometrics to identify logs in an industrial application are presented. Results for different identification performance scenarios indicate that the matching procedure which is based on annual ring pattern and shape information is very robust to log length cutting using different cutting tools. The findings of this study are a further step towards the development of a biometric log recognition system.

1. Introduction

Many efforts had been made in the past in order to investigate illegal logging, its associated causes and how to prevent from illegal logging in future. Besides corruption on different governmental authority levels and land reclamation for mining, plantations or agriculture, illegal logging is known to be one of the main driving forces promoting deforestation (Richards et al., 2003; Smith et al., 2003; Kuemmerle et al., 2009). Deforestation is a phenomenon comprising timber harvesting, timber trade and disposal occurring around the world and affects biodiversity, hydrological cycles and contributes considerably soil erosion.

These problems were officially addressed at the UN Conference on Environment and Development (UNICED) held in Rio de Janeiro in 1992 and concluded in a document called Agenda 21. This document provides voluntary commitments on sustainable forest management and development and offers a basis for non-governmental, independent forest certification (United Nations, 1992). According to a report supported by the World Bank in 2003, illegal logging is still considered a major threat to the environment (Dykstra et al., 2003). Efforts in fighting illegal logging on the EU level led to the Forest Law Enforcement Governance and Trade Action Plan (FLEGT) defined in 2003 and the EU Timber Regulation (EUTR) prohibiting the trade of illegally harvested timber and wood products derived therefrom. This regulation, initially proposed by the Commission in 2008, is legally binding on all EU member states, each being responsible for national implementation, and has come into force since March 2013. This regulation claims traceability of timber and timber products throughout the supply chain providing information on operators, traders and, if possible, of retailers (EuropeanParliament, 2010).

Traceability of timber and wood products is generally expected to restrict illegal logging and is supposed to benefit companies and consumers (Tzoulis and Andreopoulou, 2013). In fact empirical information on quantities, and links to internationally traded wood are indispensable in order to assess causal relationships for illegal logging and to take effective steps preventing deforestation in future (Kastner et al., 2011). A contemporary managed database in conjunction with log labelling would certainly provide this information and serves as basis to impede illegal logging, fraud and misuse in future.

Abbreviations: CS, cross section; MS, matching score; SD, score distribution; NK, no knots; SDG, slice distance group; EER, equal error rate; CMC, Cumulative Match Characteristic; F(N)MR, False (Non) Match Rate.

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A wide variety of log traceability systems have been applied in order to identify and track logs in the past. Each method so far has shown limitations due to costs, practical implementation or weather conditions. The applications range from punching, coloring or barcoding log ends to more recently developed techniques as DNA fingerprinting and usage of RFID transponders (Tzoulis and Andreopoulou, 2013).

Another approach is to track logs using biometric log characteristics. Investigations on the hypothesis that logs are separate entities on the basis of biometric log characteristics were presented in the works of Chiorescu and Grönlund (2003, 2004), Flodin et al. (2007, 2008a,b), which highlight the potential of biometric log recognition. The approaches presented in Chiorescu and Grönlund (2003, 2004) and Flodin et al. (2008a) utilized 2D and 3D scanners to extract geometric wood properties for tracking logs within the sawmill environment. The utilized capturing devices are however, not applicable at forest site. Furthermore, Flodin et al. (2007, 2008b) showed that knot positions as biometric features are suited to enable traceability between logs and the cut boards, reaching a recognition rate of 95%. On account of the fact that timber offers characteristics on log end faces in terms of annual rings, pith position, shape and dimension it is assumed that cross-section images of log ends can be used as biometric characteristic for log identification. Approaches for pith estimation and annual ring measurements in images of rough log ends were presented in Norell and Borgefors (2008), Schraml and Uhl (2013), Marjanen et al. (2008) and Norell (2009), respectively. Images containing a cross-section (CS) of a wood log are denoted as cross-section images (CS-Images) throughout this work.

A first work on log biometrics using CS-Images (log end biometrics) was presented in Barrett (2008) as an effort to curb poaching of trees. In the experimental evaluation digital images of tree stumps and the corresponding log ends are utilized, both showing up strong saw kerf patterns. Results show that the combination of log end shape and saw cut pattern information, represented by Zernike polynomials, achieves a high accuracy for log to stump recognition. In Schraml et al. (2014) temporal and longitudinal annual ring pattern variations were investigated based on time-delay captured CS-Images of 35 slices from a single log.

By using CS-Images from 150 different logs (Schraml et al., 2015a) showed that fingerprint based and iris-recognition based approaches are suited to achieve 100% identification accuracy. It turned out that, in addition to annual ring pattern information shape information is required to achieve this accuracy. Based on this observation in Schraml et al. (2015b) the discriminative power for a set of geometric log end features was validated.

In this study we elaborate the robustness of log end biometrics to practical issues of an industrial application. Different CS-Images of the same log end show up strong variations. For example, CS-Image capturing and weather conditions may lead to strong variations: e.g. varying image quality caused by motion blur or different lighting conditions and snow or dirt which covers parts of the CS. These variations are not considered in this work. Furthermore, industrial log processing causes specific types of CS variations. For this work we focus on longitudinal and surface variations of cross-sections (CSs). Longitudinal variations result from log end cutting and surface variations arise when different cutting tools are utilized for the first cut, in the forest, and the clearance cut, by further processing company (e.g. chain-saw and circular-saw).

The experimental evaluation is based on a testset which consists of 99 CS-Slices from three different tree logs. In addition to the 35 CS-Slices from the single log used in Schraml et al. (2014), 64 CS-Slices from further two logs are utilized. By assessing two objectives this work contributes to the ongoing research on log end biometrics.

The first objective is to investigate the verification performance with respect to the impact of surface and longitudinal variations on the intraclass variability and the separability between the intra- and interclass score distributions. In this context we also assess whether the CS surface has an impact on the longitudinal variations of each log.

The second objective is to investigate the identification performance. Initially, the basic impact of surface and longitudinal variations on the identification performance is assessed. Second, different real world-like identification scenarios are evaluated.

First, Section 2 introduces the computation and matching of biometric templates from CS-Images. The experimental setup is presented in Section 2.4 followed by the results in Section 3. Section 4 concludes this work and in Section 5 directions for future work are outlined.

2. Materials and methods

By superficially comparing the patterns of human fingerprints to annual ring patterns of wood log ends, one finds a close resemblance. Human fingerprint recognition is well-investigated and there exist mainly three groups of approaches: Minutiae-based, Correlation-based and Feature-based approaches (Maltoni et al., 2009). Apart from the presence of the pith as detectable feature, CS patterns do not exhibit further constant features like minutia's in fingerprints. Hence, minutiae-based approaches are not qualified for log CSs.

Basically, the scheme of a biometric recognition system is set up on five components: Data acquisition, Preprocessing, Feature Extraction, Template Generation and Template Matching. In case of log end biometrics, data acquisition is the capturing of digital CS-Images of log ends. For preprocessing the CS in the CS-Image is separated from the background, aligned and subsequently the CS is enhanced. Due to the ability of feature-based methods to capture information of the fingerprint ridge pattern they can be extended to work with CS patterns. We have adopted the texture feature-based FingerCode approach by Jain et al. (2000, 2001) to extract features from CS-Images. The extracted features of a CS-Image are stored as feature vector into the biometric template which we denote as cross-section code (CS-Code). The CS-Code of a CS-Image is composed by a set of feature vectors which are computed for differently rotated versions of the CS-Image.

Finally, template matching is the task of verification or identification of an individual or subject. In case of wood logs, identification is required. For this purpose, the individual/subject must be enrolled in the biometric system. In Fig. 1 exemplary enrolment and identification schemes are depicted. Enrolment could be done during the harvesting procedure in the forest. A digital camera mounted on a

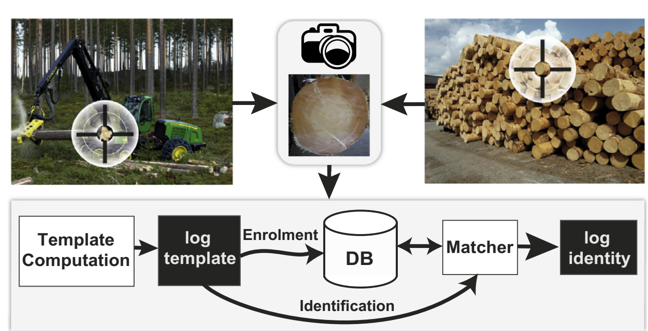

Fig. 1. Exemplary enrolment and identification schemes for a biometric log recognition system. The enrolment can be done in the forest using a digital camera mounted on a harvester.