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Performance analysis of colour descriptors for parquet sorting

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ABSTRACT

In this paper we consider the problem of colour-based sorting hardwood parquet slabs into lots of similar visual appearance. As a basis for the development of an expert system to perform this task, we experimentally investigate and compare the performance of various colour descriptors (i.e.: soft descriptors, percentiles, marginal histograms and 3D histogram), and colour spaces (i.e.: RGB, HSV and CIE Lab). The results show that simple and compact colour descriptors, such as the mean of each colour channel, are as accurate as more complicated features. Likewise, we found no statistically significant difference in the accuracy attainable through the colour spaces considered in the paper. Our experiments also show that most methods are fast enough for real-time processing. The results suggest the use of simple statistical descriptors along with RGB data as the best practice to approach the problem.

1. Introduction

Wood is a widely used and greatly appreciated material. Countless are its applications in various industrial sectors including construction, interiors, furniture and shipbuilding. Like other products such as natural stone, ceramics, leather and similar, wood is mostly appreciated for its appearance; a feature that determines, to a great extent, its price. When wood is used for flooring, decking or façade cladding (in this case we usually refer to it as *engineered wood*), strict selection procedures are needed to assure satisfactory aesthetic results. To obtain beautiful and uniform surfaces, wood has to be carefully graded by fibre type and colour tone. In an increasingly globalised and competitive market, it is mandatory that wood products – particularly those of high range – be virtually extent of any defects. In an endeavour to meet such requirements and increase market shares, producers are trying to drastically improve their quality standards. In this context quality inspection plays a central role.

As noted by Bombardier and Schmitt (2010), wood quality inspection involves two different and clearly separated problems: (1) detection, localization and classification of surface defects; and (2) sorting products into lots of similar appearance. In the parquet industry the two processes are usually carried out sequentially and in this order. Both can be performed either manually or automatically. Technically speaking the first problem is referred to as *grading* and is related to detecting, measuring and counting superficial defects like knots, pockets, stains, veins, cracks, etc. Domain-specific standards (DIN-1611, 2002; DIN-EN-975-1, 2011; DIN-EN-975-2, 2004) define different wood grades on the basis of the number and size of such defects along with procedures to their measurement and detection.

As for the second problem, we can find it referred to as *sorting* (Lu, Conners, Kline, & Araman, 1997), *colour classification* (Kurdthongmee, 2008), or, again, *grading* (Faria, Martins, Ferreira, & Santos, 2008; Vienonen, Asikainen, & Eronen, 2002). To avoid confusion, throughout this paper we use the term grading to refer to the first problem and sorting for the second.

When performed manually, grading is stressful and time consuming, though, in general, not particularly demanding, since defects are usually quite evident. In contrast, sorting products into groups of similar appearance is more subtle, since products of the same class may have differences in tone which can be very slight and difficult to detect even to a trained eye. In addition this process requires more than one slab to be observed at the same time. Subjective and environmental conditions, tiredness, boredom and other factors can significantly affect the outcome of the process. To this we should add that recent studies showed how colour perception can be significantly influenced by age and socio-economical level of the subject (Kose, 2008). Our personal experience indeed confirms that different operators can produce very dissimilar results. Beginning with these considerations, it is therefore no surprise that the agreement between different operators can be as low as 60% (Rožman, Brezak, & Petrovic, 2006). As a consequence, manual inspection procedures can produce batches of products with significant variations of the visual appearance, causing sales returns and significant economical losses.

Parquet producers are therefore more and more concerned with the development of computer vision systems capable of carrying

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out automatic quality control procedures. In this paper, in particular, we are concerned with the second problem, that of measuring and comparing the visual appearance of parquet slabs in order to sort them according to suitable similarity criteria. More specifically we focus on the problem of colour sorting slabs of the same grade and quality. This consists of dividing a previously graded batch of parquet hardwood into different colour tones, among which differences in colour are usually very slight, yet noticeable. To this end we experimentally compare the effectiveness of a set of colour descriptors and spaces. We also discuss issues related to image acquisition and processing including computational time, which are of primary importance when it comes to designing and implementing practical, real-time solutions.

The remainder of the paper begins with a brief survey of related research (Section 2). In the following sections we give a description of the materials (Section 3) and methods (Section 4) used in our research. In Section 5 we present the experimental activity followed by results (Section 6) and conclusions (Section 7).

2. Related research

The first applications of computer vision to the wood industry date back to the 1980s (Conners, McMillin, & Lin, 1983; Sobey & Semple, 1989). Literature review shows that, since then, research has mostly focused on the problem of grading. Studies have confirmed that it is possible to replace manual graders with automatic systems improving production effectiveness and product quality (Kline, Surak, & Araman, 2006; Lycken, 2006). A preliminary step to automatic grading is defect detection and characterization. This has been typically approached using spectral features (Åström, Åstrand, & Johansson, 1999), spectral and X-ray features (Bond, Kline, & Araman, 2002), colour features (Ciccotelli & Portala, 1992; Conners et al., 1992) and combinations of colour and texture features (Gu, Andersson, & Vicen, 2010; Kyllönen & Pietikäinen, 2000). Other authors focused on how to deal with the grading problem once defects have been detected and located (Castellani & Rowlands, 2009; Lycken, 2006). For an up-to-date survey on automatic wood grading readers are referred to the work of Jabo (2011).

A more recent application of computer vision to wood products is the automatic identification of wood types (Labati, Gamassi, Piuri, & Scotti, 2009). This is about identifying the different types of wood that make up wood shipments; a procedure that has been used to detect illegally-traded timber (Hermanson & Wiedenhoeft, 2011).

Herein we are concerned with the problem of sorting parquet hardwood into different colour tones. We therefore assume that hardwood has been already graded, either automatically or manually. A round-up of the methods presented in this paragraph can be found in Table 1. Piuri and Scotti (2010) noted that approaches to colour-based sorting can be divided into two groups: *image-based* and *spectrum-based* processing systems. Both groups have pros and cons. Spectrum-based systems have the advantage of relying on device-independent data, but the disadvantage of a limited inspection area, which does not allow for full-field measurements. Conversely, image-based systems enable full-field inspection, but need colour calibration to produce device-independent data. Vienonen et al. (2002) described a spectrophotometric system which takes four circular samples of approximately 20 mm radius from each parquet block. A 56-bin spectrum (from 275 to 965 nm) is computed from each block and used as feature vector. Classification is based on two approaches: minimum distance classifier and a subspace classifier. Likewise, Buchelt and Wagenführ (2012) used a spectrophotometer to evaluate colour differences of native wood surfaces. In their approach spectral data are converted into CIE Lab to estimate the intra-class colour difference (ΔE^*_{ab}) of different species. In the same way, Schnabel, Zimmer, and Petutschnigg (2009) use spectrophotometric data and convert them into CIE Lab to model colour changes that wood undergoes during its lifetime.

Methods based on image processing work with the output of industrial cameras, which is usually a set of RGB triplets. These can be either used ‘as is’ or converted into different colour spaces, such as HSV, CIE Lab, etc. In both cases the aim is to extract global statistical descriptors that characterize the colour content of the images. In the design of an expert system for wood sorting based on image processing, one has to deal with the choice of the right colour space and the appropriate descriptor. Related literature shows that various solutions have been proposed in the past. Lu et al. (1997) described a system based on 3D RGB histograms and minimum distance classifier for real-time colour sorting of edge-glued panel parts reporting an accuracy ranging from 83.0% to 99.1%. Kurdthongmee (2008) described an approach for colour-based classification of rubberwood boards for fingerjoint manufacturing in which a neural network is fed with a normalized histogram of hue (H). In a qualitative study Hrčka (2008) investigated the use of colour features to classify between common beech and European spruce, showing that colour coordinates in the CIE Lab space separate the two species rather well. Faria et al. (2008) employed both device-dependent (HSV) and device-independent (CIE Lab) colour coordinates for sorting three different types of wood, namely cherry tree, beech tree and oak. Their method employs a fuzzy classifier based on a bell membership function for each of the colour coordinates. More recently Bombardier and Schmitt (2010) used mean and homogeneity extracted from CIE Lab and HSV channels as colour features, and a fuzzy reasoning classifier as the building blocks of an expert system for wood colour recognition.

This review of image processing-based methods shows that a wide variety of approaches have been proposed in literature, but, at the same time, leaves the reader uncertain about which is the ‘best practice’ when it comes to designing and implementing an automatic sorting system. The results presented in the papers cited above look in fact rather scattered, inhomogeneous and therefore difficult to compare to each other. Even more difficult is to reproduce the results presented in them, for data and algorithms used in the experiments are not available. Lastly, it is worth noticing that

Table 1
Summary list of methods for colour-based wood sorting.

Reference	Method	Colour descriptor	Colour space
Arden (1991)	Image-based	Marginal histograms	RGB
Lu et al. (1997)	Image-based	3D histogram	RGB
Vienonen et al. (2002)	Spectrum-based	Spectral histogram	Spectrum
Kurdthongmee (2008)	Image-based	One marginal histogram (hue)	HSV
Hrčka (2008)	Image-based	Mean + standard deviation	CIE Lab
Faria et al. (2008)	Image-based	Approx. marginal histograms	HSV, CIE Lab
Schnabel et al. (2009)	Spectrum-based	Mean	CIE Lab
Bombardier and Schmitt (2010)	Image-based	Mean + homogeneity	CIE Lab + HSV
Buchelt and Wagenführ (2012)	Spectrum-based	Mean	CIE Lab