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Performance evaluation of multivariate texture descriptor for classification of timber defect

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ABSTRACT

This paper presents performance evaluation of texture features based on orientation independent Grey Level Dependence Matrix (GLDM) for the classification of timber defects and clear wood. A series of processes including feature extraction and feature analysis were implemented to facilitate data understanding in order to construct a good feature set that could significantly discriminate between defects and clear wood classes. To further evaluate the discrimination capability of the features extracted, classification experiments were performed on defects and clear wood images of Meranti timber species using common classifiers. The classification performance were further compared between other timber species which are Merbau, KSK and Rubberwood. Results from the analysis reveals that the proposed texture features provide better performance than other feature sets from related works, performs acceptably well across various defect types and across multiple timber species.

1. Introduction

An issue that presents an ongoing challenge to the timber detection problem is selecting the most appropriate features to use to differentiate clear wood and defects. Visually, defect characteristics are mostly similar but a broad range of natural variations does exist across defects, even the same types of defect. These possible variations include the size and/or shape of the defect and tonal variations. In addition, there are differences in grain appearance across different timber species, with each timber species having a unique grain appearance. In response to the timber defect detection problem, colour or tonal information alone is not enough to characterise a specific defect, for example, knots can be as dark as bark pockets and some of them could have the same colour as clear wood [1]. Although most defects appear darker than clear wood, a defect can appear as dark as the wood grain itself in some cases. Therefore, tonal properties alone are not sufficient to characterise timber defects [2]. Furthermore, since the samples acquired are of multiple species, there will be variation in timber colour. Therefore, tonal measures are definitely not suitable to represent defects across various timber species. Shapes and texture features are of equal importance to differentiate between clear wood and defects as well as types of defect [2]. But the irregularities in the shape and size of defects minimises the usefulness of shape features in addressing the timber defect detection problem as representing the various possible shapes of a defect is quite difficult.

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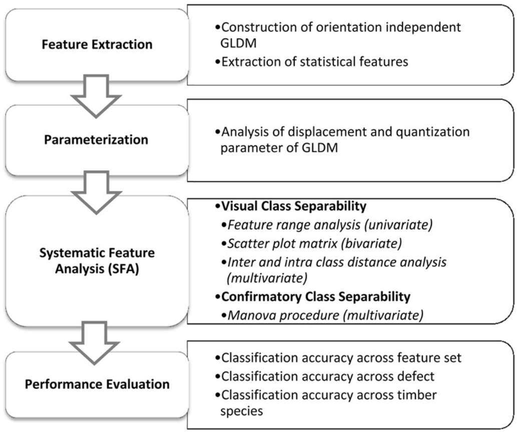

Fig. 1. Overview of approach in determining significant texture features for timber defect classification.

Timber often has no uniform surface, however, it will usually have a distinctive pattern. The pattern which characterises timber appearance is called texture. Human vision is capable of recognising this pattern and distinguishing between patterns but describing the difference precisely is not easy. In order to introduce species independent processing to overcome the issues of colour variation on timber species, use of texture features is proposed. Haralick et al. [3] claimed that texture is independent of tone, therefore, it is anticipated that it shall be independent as well of wood species tonal variation. Since the texture difference between clear wood and defect may well be distinguished visually via human eyes, texture features are expected to sufficiently represent defects regardless of timber species and types of defect Therefore, this study seeks to investigate the usability of texture properties for timber defect detection by looking at the potential of using texture to discriminate between clear wood and defects.

In this study, statistical texture features based on GLDM are investigated. The motivation came from the need to evaluate the performance of texture features on the timber defect detection task and the performance of GLDM on previous works of timber defect detection as discussed in Ref. [4]. Moreover, a recent review specified that a significant number of previous works in vision inspection are based on statistical texture feature extraction due to its popularity, good performance and ability to be applied directly without filtering [5]. The GLDM which was originally formulated by Ref. [3] has evolved over the years with variation in the way the dependence matrix is generated and variation in statistical features calculated from the matrix with numerous applications in multiple domains.

2. Method

2.1. Overview of approach

Fig. 1 shows the approach in constructing the significant feature set to characterise a timber defect. The process started with the construction of an orientation independent GLDM and subsequently, statistical features were extracted from the constructed matrix. Features were extracted at various quantisation and displacement values, producing multiple datasets for analysis of appropriate displacement and quantisation parameters. The images that we used comprised of samples from eight defect classes and the clear wood class of Meranti, Rubberwood Merbau and KSK timber species drawn from the UTeM database [6]. Samples of images for each class are shown in Table 1.

Next, the extracted features were further analysed for their class discrimination capability using exploratory and confirmatory analyses. In the exploratory feature analysis, visual discrimination was displayed using a graph of feature range for each individual feature (univariate), a scatter plot matrix for pairwise features comparison (bivariate), and a graph of inter class and intra class distances for all features collectively (multivariate). The purpose of this analysis was to examine the discrimination between defect and clear wood classes visually.

Then confirmatory analysis was performed to measure the class discrimination, statistically using Manova procedures. In pre-Manova, features are tested for linear dependency using Pearson's correlation coefficient. Features with high linear dependency will be eliminated prior to the next analysis. The remaining features are then analysed using Manova statistics to measure the ratio between inter class and intra class variances for the proposed feature set. The output of Manova statistics would confirm the significance of class difference, thus yielding a significant feature set.

Finally, in order to verify the effectiveness of the constructed feature set, their performance in term of classification accuracy was measured. Several feature sets were compared, consisting of various combinations of statistical features based on spatial dependence matrix used by other researchers in wood inspection domain. The classification accuracy of individual defect classes was also compared to analyse the generalization of the proposed features across many types of defects. Lastly,