An automated industrial conveyor belt system using image processing and hierarchical clustering for classifying marble slabs

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ABSTRACT

Although there are many industrial machines used in marble industry, classification of marble slabs in terms of quality is generally performed by human experts. Due to economic losses of this rather subjective process, automatic and computerized methods are needed in order to obtain reproducible and objective results in classification. With the aim of remedying this insufficiency in marble industry, a new electro-mechanical system, which automatically classifies marble slabs while they are on a conveyor belt and groups them with the help of a control mechanism, is proposed. The developed system is composed of two parts: the software part acquires digital images of marble slabs, extracts several features using these images, and finally performs the classification using clustering methods. The hardware part is composed of a conveyor belt, a serial port communication system, pneumatic pistons, a programmable logic controller (PLC), and its control circuits, all employed together for grouping the marble slabs mechanically. Although similar studies exist, this paper proposes three novelties over the existing systems. Firstly, a new hierarchical clustering approach is introduced for quality classification without requiring a training set. Secondly, a new feature set based on morphological properties of marble surface images is proposed. Finally, an electro-mechanical system is designed for accomplishing the task of sorting out the classified marble slabs. It has been observed that although the performance of the developed system is not as high as neural network based systems that use training, it could still be employed in industry when there is no available training set of samples. With this advantage, it provides an increase in the quality control standards of marble slab classification, since marbles are classified with an objective and uniform-through-time criterion.

1. Introduction

Thanks to the recent developments in data acquisition, processing, and process control systems, efficiency of many of the industrial applications (i.e. automobile, electronics, rock, and metal industries) has been improved with the help of automated visual processing and classification systems [1]. Technological advances in digital image acquisition [2,3] and processing [4] have allowed building automated visual inspection (AVI) systems [5–7]. Feasibility studies [8] and different applications of AVI systems are presented in the literature for classification of several products/materials of industrial value [6–11].

As for moving conveyor belts, design and implementation of such a system is very challenging and consists of several difficulties, [12,13], which necessitate employing different approaches for overcoming these problems [14]. In quality classification tasks, the classification output determines the category, or quality group, of a particular item. A typical classification process comprises five main steps:

(i) Locating or recognizing the items on the conveyor belt via some type of a sensor such as a camera, scanner, etc.
(ii) Acquiring the necessary data from the item (i.e. taking pictures, measuring the amount of reflected light,
electromagnetic wave, or another type of signal). The acquisition device is usually located above the conveyor belt to view the items orthographically.

(iii) Processing the data to extract several useful features.
(iv) Classification of the item using the extracted features and a classifier.
(v) Performing the necessary action following the classification result of the classifier.

Marble quality classification is based on some physical, mechanical, and technological properties required by universal standards [15]. At the same time, the classified marble slabs should reflect attractive color and pattern choices. Important constraints for aesthetic appearance are homogeneity, texture, color, distribution of limestone (beige colored regions in Fig. 1), cohesive material (red–brown colored regions in Fig. 1), and thin joints filled by cohesive material (red–brown colored veins in Fig. 1). Thus, two marble slabs, one containing unified cohesive material regions (Fig. 1(c)) and the other containing vein-like cohesive material structures (Fig. 1(b)), should be treated as belonging to different quality groups even if they have the same amount of cohesive material.

Since false classification of marbles can result in major economic losses, it is necessary to classify marble slabs correctly according to their quality and appearance. The classification process is mostly carried out at the end of a production line, where human experts evaluate and classify the products visually according to the parameters mentioned above. However, using human experts for classification can be error-prone owing to subjective criteria of the operator (even different operators due to shift work) and the visual fatigue after a period of time, which degrades the classification performance. Thus, it is necessary to use an automated system capable of performing the same classification tasks that are currently carried out by human experts.

Several different feature extraction methods (i.e. sum and difference histograms, statistical texture based features, wavelets, etc.) and classifiers (i.e. clustering methods such as K-Means, fuzzy C-Means, or neural networks such as multi-layer perceptron and support vector machines with various distance measures) have been employed for quality classification of marble slabs [16–21], but only the method in [21] is implemented in an industrial facility. Although the results were successful in [21], the data set was not quite diverse (i.e. extra, commercial, and low

![Fig. 1. Typical marble slab images from four different quality groups: (a) Group 1, (b) Group 2, (c) Group 3, and (d) Group 4.](image-url)
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