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A New Technique for Glass Quality Control

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Abstract - The paper deals with the problem of pointing out and then measuring the manufacturing defects (scratches and halos) of handmade satin glasses by an accurate, real-time and cheap method. A wavelet-based de-noising technique is used to obtain surface information about glasses under inspection. The proposed algorithm first obtains a two-dimensional wavelet transform of a high resolution image of the glass under inspection which, according to multi-resolution analysis, produces a suitable number of decomposition levels of the image, and then it carries out a thresholding operation on details. Finally, using the threshold levels estimated considering the present noise level, it assesses and characterizes the defects. The final aim of the work is the realization of an automatic and in-line computer vision system for glasses analysis; it must be able both to accurate inspection and to quality degree assessment of the final products as they come out from the production chain.

I. Introduction

Nowadays in many industrial fields there is a higher and higher interest in building automatic processing and analysis systems based on computer vision inspection methods; these techniques have many advantages over the common human-made inspection: absolutely objective inspection, significant rise in the speed of test, reduction of costs and error rate, good and adaptive levels of accuracy, and so on; all of these advantages are obtained without human presence. It is therefore quite obvious to suppose that in the next years most of visual inspection tasks for industrial applications will be performed by means of computer vision systems.

However, even though the automated inspection systems are successfully replacing the manual ones, enhancements of the analysis process methodologies and accuracy are still necessary to reduce the rate of false positives (products classified as good when they are defective) and false negatives (products classified as defective when they are good) as well as reducing the processing time.

In the latest years several techniques have been developed to accomplish glass inspection tasks (e.g. by means of *neural network algorithms,* the *Gabor filter* technique*,* the *scanning laser beam*, and so on), however no one of these methods is really accurate, low cost, and reasonably quick at the same time [1], [2], [3].

This work presents the preliminary results obtained by means of an experimental automatic and computer-based visual inspection technique that gave good results in the detection and classification of manufacturing imperfections in handmade satin glasses; in this study, the authors postulate that the defects, if present, are perceived as irregularities (mainly scratches and halos) with respect to a reference image and they examine the possibility to use some suitable lighting systems to obtain properly contrasted images so a suitable wavelet-based de-noising technique carries out the defect localization on the surface.

II. System description

A very simple and versatile system, able to perform analysis on sample glasses has been developed and tested in our laboratories; the working prototype of the system is made up of various elements (Figure 1):

- a high resolution grey scale area scan CCD camera (PULNiX type TM-6200); the distance of the camera from the surface of the glass is determined by the final resolution ones want to obtain on the acquired image. Due to the reduced dimensions of the typical scratches on the satin layer, the required resolution must be at least 0.1 mm.
- a National Instruments' PXI-1409 4 channels image acquisition plug-in card for PXI bus. This card is installed into a PXI-1000B chassis which in turn is linked to a PC running the analysis software; the link is obtained by means of an MXI-3 PCI-PCI bridge (National Instruments' PXI/PCI-8330 kit);
- a dark-field illumination system (upper light source) with a polarization filter;
- a bright-field illumination system (lower light sources);
- a custom application software developed in Microsoft® Visual C++® 6.0 to process the acquired images. In an early stage of the project the authors used a MATLAB® based software to accomplish the same tasks; however the processing time was too long to be acceptable for the foreseen in-line use of the system.

As for all applications of artificial vision systems, the correctness of the illumination system is of fundamental importance to obtain usable images; in the particular application we are talking about, the use of a wrong illumination system (erroneous localization of light sources, erroneous wavelength, etc.) can

easily cause normal in-homogeneities to appear as large defective areas or, on the contrary, truly existing halos areas or small scratches to disappear at all.
The particular illumination arrangement experimented in our system (Figure 1) seems to guarantee an adequate compromise for the correct acquisition and analysis of the images; in particular, the dark field with polarization illumination source is very effective in the correct acquisition of halos images that, by their nature, are regions without the satin layer at all or with a decreased depth of that layer (they appear mirror-like). Due to the high degree of reflectiveness of the halos, the power of the dark field source must be adequately low to avoid the saturation of the CCD sensor in the camera when the acquired image contains large halos; an alternative method to avoid this phenomenon is the use of an *auto-iris* camera that automatically adapts the diaphragm aperture to the brightness of the scene. Halos can be present only on the satinized face of the glass, that is on the upper face; on the contrary, scratches can be present on both the surfaces of the glass then, using only the dark field illumination source, the camera would correctly see only scratches on the upper surface but it would be totally blind for the scratches on the lower surface. The bright field illumination sources solve this problem.

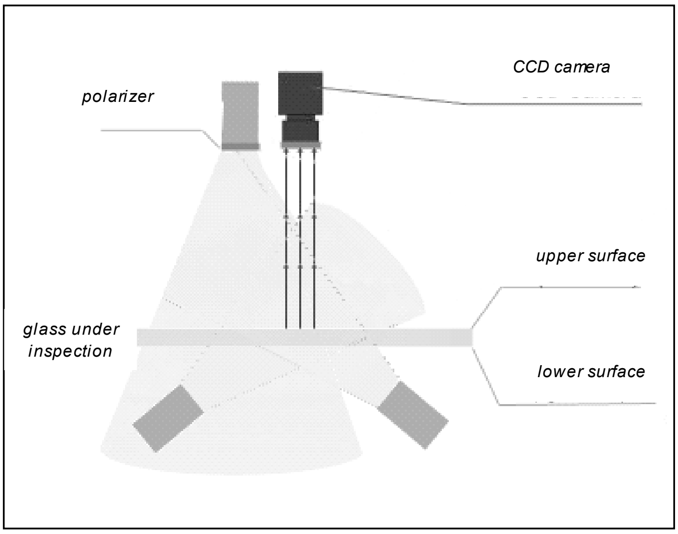

Figure 1 - Scheme of the image acquisition system.

In the following paragraph we will shortly examine and discuss the analysis technique.

III. The proposed analysis technique

The main steps of the analysis technique are:

1. image acquisition;
2. image decomposition in approximations and details by means of wavelet analysis;
3. thresholding operation on details;
4. de-noised image reconstruction;
5. defect detection by means of a final thresholding phase.

The *first step* obtains a grey scale image of the glass surface in form of a bi-dimensional array of bytes; every byte corresponds to a point of the image and is digitized with 256 grey levels and transferred to the processing software thanks to the support software bundled with the image acquisition card (National Instruments' IMAQ API).
In the *second step* the software applies the two-dimensional wavelet transform to the image and obtains a decomposition in approximations and details (Figure 2) by keeping unchanged the number of samples; in this case, for each decomposition level, it is necessary a double filtering, one along the rows and one along

the columns. The preliminary and in-depth analyses carried out in the early stage of the project allowed us to determine that the best suited wavelet is the modified spline-biorthogonal one; it is symmetric, nearly orthogonal with a class of continuity greater than one and with a mother function similar in decomposition and reconstruction. Some analysis results for glasses images containing typical manufacturing defects are shown in Figure 3 and Figure 4.

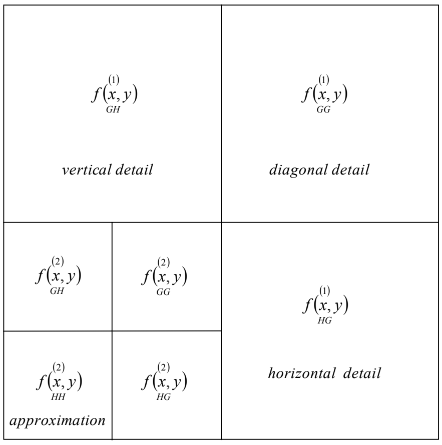

Figure 2. Image decomposition into details (horizontal, vertical and diagonal) and approximation.

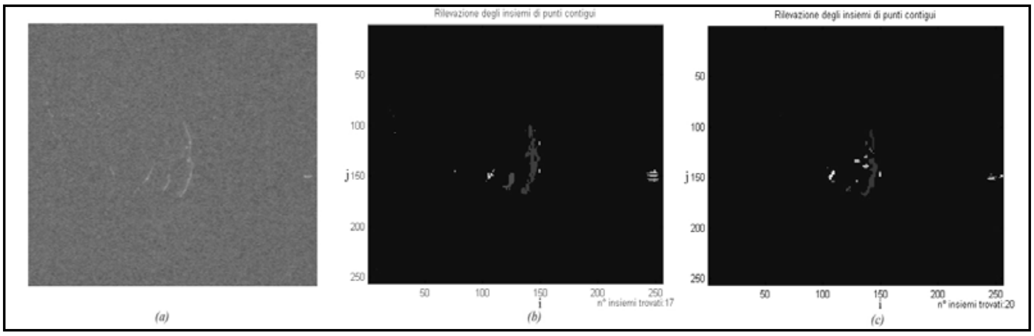

Figure 3 – A glass specimen with a small scratch (a), thresholded image obtained using a wavelet-based de-noising with a modified bi-orthonormal wavelet (b) and with a Daubechies wavelet of 4th order. (c).

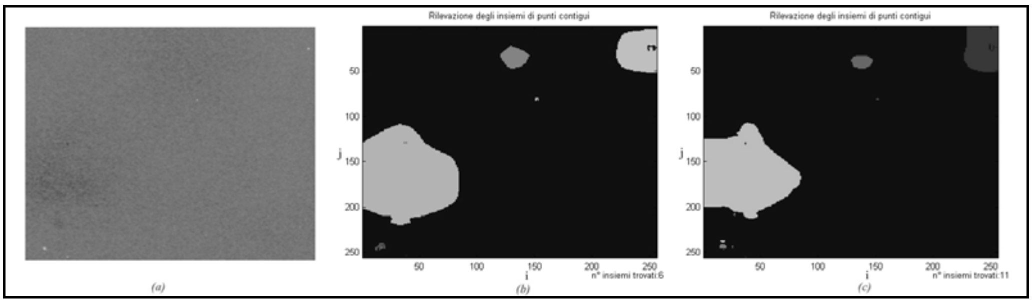

Figure 4. A glass specimen with a halo in the lower left corner (a), thresholded image using wavelet de-noising with a modified biorthonormal spline (b) and with a Daubechies wavelet of 4th (c).

The *third step* implements a soft-thresholding function:

$$\delta_\lambda(x) = \operatorname{sgn}(x)\max\left(\left(|x| - \lambda\right), 0\right) \tag{1}$$

which yields the threshold values λ_i for each detail with a low mean square error.
The *fourth step* thresholds the image using the threshold values previously estimated so that, in the fifth stage, a database of revealed defects can be obtained.

The main steps of the analysis process are:

1 *reference image acquisition*: acquisition of an image known to be without defects; this step is to be executed only once for every glass type. Many different types of glasses are produced in the factory where the system has been installed and tested; they differ from each other by the colour of the satin layer (white, light cyan, light magenta, etc.), by its granularity degree and for the degree of reflectivity of the surface.
2 *setup stage*: acquisition of an image of the area to be analyzed, thresholds initialization or update + image thresholding;
3 *detection stage*: defects are located and classified by means of the procedure previously exposed.

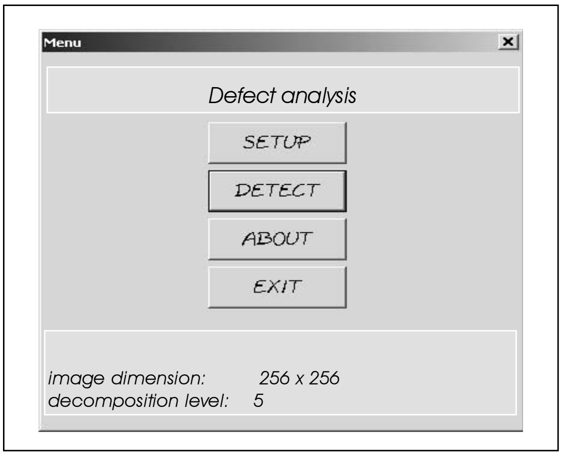

Figure 5. Main menu of the image analysis software.

Figure 5 is an image of the user interface of the developed analysis software; in the experimental setup used to evaluate the correctness and effectiveness of the analysis algorithm, the various phases are executed under the manual control of the operator; obviously in the final system the analysis procedure will be totally automatic without any human presence Figure 6 shows the results of the detection phase applied to an image containing a small scratch (image in the upper left corner of the figure).

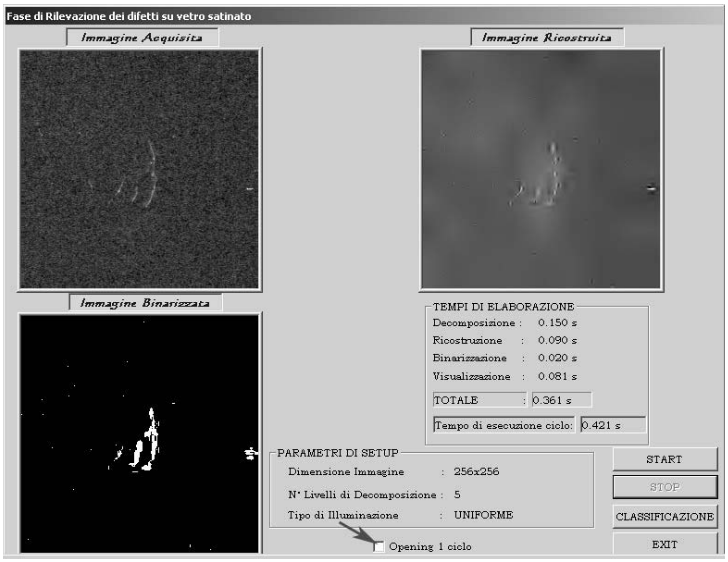

Figure 6. Dialog box of the detection phase.

The image in the lower left corner of Figure 6 is the result of the thresholding of the acquired image; it clearly demonstrates a great enhancement in the defect visibility.
The time required to complete the analysis procedure for a 256 x 256 pixels image is less the 0.1 s on a common Pentium III-733 MHz PC non-optimized for real-time applications.

IV. The used mother wavelet

In order to carry out the defect on the glass surface a multiresolution representation is used, which uses a two-dimensional wavelet transform in order to obtain a decomposition of image in approximations and details.
The idea is that an analysis at different resolutions, permits a suitable image interpretation and produce different perceptions of the glass texture. Like this, increasing the resolution of the image details can be useful for defect localization since the details of the image at the resolution r_j are the difference of information between its approximation at the resolution r_j and its approximation at the resolution r_{j-1} [4].
The fundamental importance for a good localization of both scratches and halos is the mother wavelet choice. An in-depth analysis of the problem shown that good results are obtained using a bi-orthogonal, symmetric mother wavelet with a high number of evanescent moments [5, 6]. Besides, several numerical tests which are carried out, have shown that larger SNR are obtained by using a Daubechies and Spline-modified mother wavelet for glasses with scratch or halos. The former is preferable for a minor computational charge and for a major preservation of the details.

V. Conclusions

In this paper the authors present the first results of a new technique useful for the automatic and in-line implementation of a quality control for handmade satin glasses; the proposed technique is based on image analysis techniques by means of wavelet transforms. The paper gives also a clear description of the experimental setup and of the software used to acquire and elaborate the images.
Future development of this work concern improvements in the speed of analysis and classification of images; actually the authors are working on the “parallelization” of the procedure, which consists in the use of multiple cameras to increase the dimension of the analyzed surface in every step.

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