Visual Inspection of Particle Boards for Quality Assessment

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Abstract — **The automatic visual inspection (AVI) systems are nowadays used with good results in a wide broad of applications. In particular we considered the problem of the defect detection of particle boards by means of a visual inspection of the printed surface. We propose an innovative defect detection approach capable to automatically extract the repetitive patterns that are generally present in the printed-matters. The extracted patterns are then used in the proper defect detection phase that can thus achieve high defect detection performances. Real wood patterns prove that our defect detection system achieves very high classification capability.**

Keywords - Surface Quality Assessement; Surface Defects Detection; Quality Control; Particle Boards

I. INTRODUCTION

Inspection of products on high speed manufacturing lines is boring, exhausting and dangerous for human operators. The automatic visual inspection (AVI) systems, which are automatic systems that perform visual inspection by means of machine vision [1], can play a fundamental role in quality assessment since they can guarantee a high and constant non invasive quality inspection. These systems are widely used in the quality analysis of industrial products [2,3]. Conversely the problem of the defect detection in printed-matter is not fully explored and only few researches tackled this topic [4-6]. The performance of these systems generally achieves the 90-92% (hardly overcomes the 95%) of defect detection.

The aim of this research is to consider the defect detection problem for melamine laminated particle board. They are boards, normally in particle (very small particles of wood, or refuse from wood working, pressed warm with the aid of a glue), that are covered with a paper of melaminic. These papers are usually printed so as to reproduce a wide broad of woods and solid colors.

The quality of a printed paper depends both on the number and on the size of defects it contains. Thus it is fundamental to detect all the possible defects that can happen. Conversely to the traditional approach, we aim to extract knowledge (the repeated pattern) by the printed-matter that can be used during the proper defect detection. This additional information will guarantee higher defect detection capabilities.

Section 2 tackles the classification of the wood defects. Section 3, 4 and 5 present respectively the AVI system, the pattern extraction phase and the indices used to evaluate the classification capability and the pattern recognition. Experimental results are described in Section 6.

II. PRINTED AND NATURAL WOOD DEFECTS

Even if we considered only the defects of the printed wood, it is interesting to take into account the classification of both printed and natural wood defects.

The natural wood defects can be divided into biological defects (that represent the natural defects of the wood) and mechanical defects (defects caused by the board creation mechanical process). Examples of defect detection in natural wood boards can be found in [2,3].

In case of printed wood defect detection, the possible defects can be grouped into two classes [4]: printing defects (defects related to the printing process of the melaminic covering paper) and mechanical defects (defects related to the mechanical process of the board processing). We focused on the detection of printing and mechanical defects that are typical of melamine laminated particle boards. The printing defects can be subdivided into shape and color defects. The shape defects are defects that can be detected by the analysis of their shape and can be summarized as follows: *white-spot* (drop-out of all inks due to the adherence of dust or scratching), *hickey* (drop-out of one inks due to adherence of dust), and *contamination* (scattering of inks or adherence of foreign matter on the printed paper). These defects are shown in Figure 1(b), (c) and (d).

The color defects are defects that can be detected by the analysis of their color. Examples of these defects are the color-plus and the color-minor defects that are respectively presented in Figure 1(e) and (f).

The mechanical defects represent all the other defects that may happen and that not related to the printing phase, such as tears and scratches.

III. AUTOMATIC VISUAL INSPECTION: AN INNOVATIVE APPROACH

Visual inspection is performed by AVI systems that aim to recognize the defects or to determine the properties of the material to be inspected according to deviating texture, color or shape features. The AVI systems are generally composed by three modules: image acquisition and preprocessing, feature extraction and classification. In case of printed wood quality

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analysis we must also consider that a printing pattern generally exists and that can be extracted to increase the defect detection. We called this peculiar approach *AVI with pattern*. Conversely when the defect detection is performed without the use of a pattern (i.e., the standard wood defect detection) we called this approach *AVI without pattern.* This last approach is widely discussed in the literature and examples can be found in [2,3].

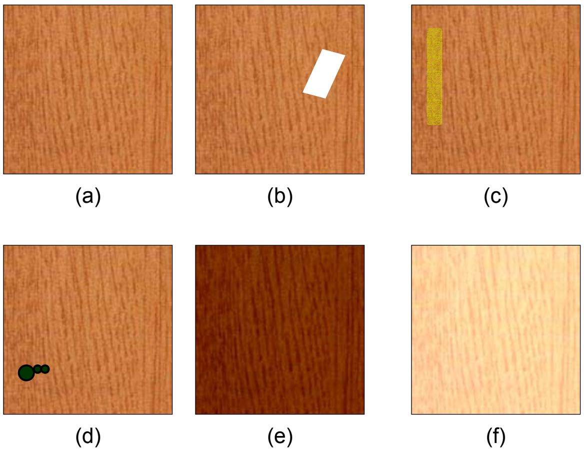

Figure 1 - Example of printing wood defects. (a) Original image, (b) White-spot defect, (c) Hickey defect, (d) Contamination, (e) Color-plus defect, (f) Color-minus defect.

We decided to focus on the AVI with pattern defect detection. This innovative approach can exploit the advantages to know the printing pattern since the detect detection is not performed directly on the image to be inspected but on the difference image between input and pattern image. In case of AVI with pattern two different situations may arise:

- the pattern is initially available to the defect detector (i.e., patterned wafer, printed wiring boards, printed prepaid card, textile web, printed paper…),
- the pattern is initially not available to the defect detector and must be extracted by the boards (i.e., melamine laminated particle boards, printed photos…).

In case of AVI with available pattern the defect detection can be performed in a more direct way by analyzing both the pattern image and the images to be inspected (this is the case, for instance, of patterned wafer or printed wiring boards) or by providing all the reference images. In this last case the AVI systems need also to recognize the correct pattern for the current inspected image (i.e., objects with CAD models).

Our research aims to overcome the limitations caused by the need to have initially available the pattern since this may not always be true in the practice. Thus we focused not only on the defect detection but also on the pattern extraction. The *AVI with extracted pattern* is a specific approach for printed materials in which the pattern changes quickly (i.e., melamine laminated particle boards). This approach implies that a pattern must be extracted before the defect detection.

As presented in Figure 2, the AVI system we developed is thus composed not only by the three traditional phases (preprocessing, feature extraction and classification) but also by a pattern extraction phase, which is computed during the training of the system.

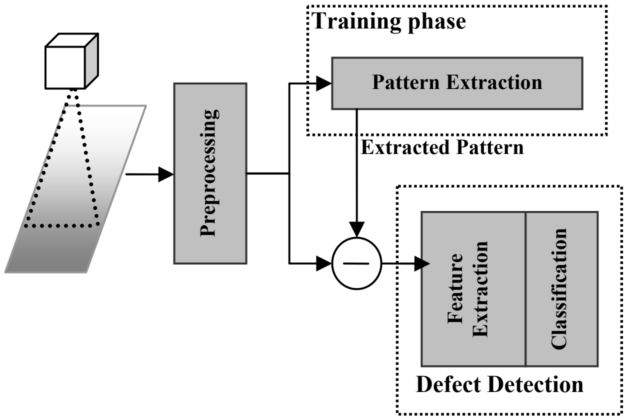

Figure 2 - The AVI system with extracted pattern.

The preprocessing phase aims to increase the signal-to-noise ratio and is composed by a median filter. The difference between the filtered image and the extracted pattern is then computed. During the feature extraction phase both geometrical (such as size, ratio and area of the object) and graphical (such as the color) features could be extracted by the objects present in the difference image. The proper defect detection is performed by a simple classifier capable to detect the presence of objects in a binarized image according to the pixel intensity.

IV. Pattern Extraction

To explain the pattern extraction phase we must present how the melaminic papers are generally printed starting from a reference pattern. This process is now presented in Figure 3. Starting from a reference pattern (step 1), the board is created by tiling copies of the pattern (step 2) and subsequently by cropping to the specific sizes (step 3). In our approach we considered boards composed only by an integer number of pattern rows.

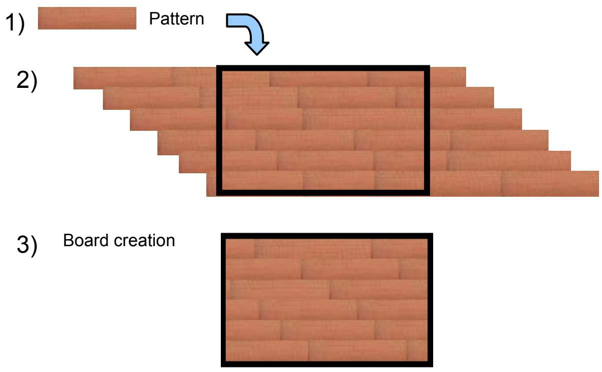

Figure 3 – Creation of a wood printed board starting from a reference pattern.

The purpose of the pattern extraction phase is to estimate the pattern by analyzing a set of boards that are provided to the AVI system during an initial training phase. This procedure, presented in Figure 4, is composed of three steps: row extraction, column extraction and pattern estimation.

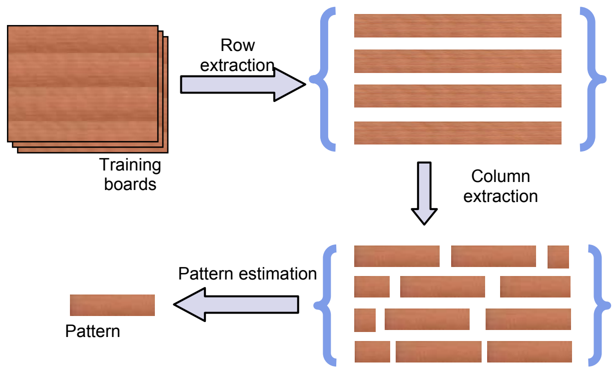

Figure 4 – Pattern extraction phase: row extraction, column extraction and pattern estimation.

Being T_1,..,T_K, the number of boards used for the training (that we can consider defect-free since manually inspected by an operator) and considering *L_board* and *H_board* respectively the length and the height of the board, we apply the following procedure (*row_extraction)*:

```
{R_1,R_2,..R_N}  = row_extraction {T_1,T_2,..T_K}
   for i=1:K
      calculate the autocorrelation of T_i and
      store it in A_i
      for j=1: H_board
         M(j)= compute the mean value of
         the row j in the image A_i
      end
      compute the distances between the peak
      values in M and  store them in the
      vector row_ext(i)
   end
   a voting procedure on the K vectors row_ext
   identifies the most probable pattern row
   height Hp. The boards are cut according to
   Hp and a set of row images R_1, R_N is created
end
```

The second step (*column_ extraction*) decomposes the rows in single pattern images by analyzing the similarity between *S* randomly selected columns with the others. Experimentally a good value of *S* was found in 10% of the board length *L_board*. The procedure is now presented:

```
{P_1,..,P_W} = column_extraction {R_1,R_2,..R_N}
  for i=1:N
      for j=1:S
          for k=1:(L_board -S)
              diff(j,k)=compute the
              difference between the
              column S(j) and the
              k-th column in R(i)
          end
      end
      compute the distance between the peak
      values in diff  and  store them in the
      vector col_ext(i)
   end
   a voting procedure on the N vectors col_ext
   identifies the most probable pattern length
   inside the row Lp. The row boards are cut
   according to Lp and a set of pattern images
   P_1,..,P_W is created
end
```

The proper pattern estimation is performed in the last step (*pattern estimation*): from the (P_1,..,P_W) pattern image set only the images with length and height equals respectively to *Hp* and *Lp* are extracted and subsequently averaged to reduce the random Gaussian noise (that is generally caused by the acquisition process). At the end of this step the estimated pattern is available to the AVI system.

V. AVI System Accuracy

The defect detection accuracy can be evaluated by means of two indices:

Missed Error (E) = $1 - (N_{det\_lab}/N_{lab})$

False Alarm (F) = $(N_{det} - N_{det\_lab})/N_{det}$

where N_{lab} represents the number of real labeled defects, N_{det_lab} represents the number of detected labeled defects and N_{det} represents the number of detection produced by the inspection system. These two indices evaluate the capability to recognize correctly the defects by means of the number of corrupted boards that were not recognized (E) and the number of free-defect boards that were incorrectly identified as corrupted (F).

To evaluate the pattern estimation capability of our AVI system we should compare both contents and sizes of the original and the estimated pattern. Since the evaluation of the contents can be implicitly considered in the defect detection accuracy, we focused on the comparison of the sizes by defining two indices:

Height_error (HE) = abs(H_{est_pat}- H_{orig_pat})

Length_error (LE) = abs(L_{est_pat}- L_{orig_pat})

where H_{est_pat} and L_{est_pat} represent respectively the height and the length of the estimated pattern, H_{orig_pat} and L_{orig_pat} represent the height and the length of the original pattern. These two indices simply measure the difference (in pixels) between the sizes of the estimated pattern and the original pattern.

VI. Results

The capability of our AVI system was evaluated using a set of 636 wood boards generated by 12 real wood patterns. Each wood pattern generated 53 boards that were then corrupted by a random Gaussian noise (mean 0, variance 12 pixels) to model the acquisition noise. A defect typical of the printing process (a hickey spot – modeled with an rectangular shape wide 0.7% of the board area - decreases the intensity of the involved pixels of a randomly value selected between 5% and 10%) was then applied on half of the generated wood boards.

The test was performed by initially providing 3 training boards to the system and subsequently inspecting the other 50 boards to evaluate the defect detection capability. We repeated this experiment 100 times for each wood pattern and we then averaged the results.

The results of these experiments are now presented: the percentage of correct recognition of boards without defects is

98.4% and the percentage of correct recognition of board with defects is 94.9%. Thus the defect detection capability of the AVI system achieves the 96.6%. These results can be summarized as follows:

E = 5.1%	F = 1.6%

Figure 5 shows an example of correct classification for a hickey printed wood defect. In particular Figure 5(a) presents the panel to be inspected (the defect is visible in the left part of the image), Figure 5(b) shows the difference image between the panel to be inspected and the reference image (computed with the pattern extraction procedure). This difference image is then filtered (with an *opening filter*) and binarized with an adaptive threshold. The result is presented in Figure 5(c). The classification is finally computed on the features extracted from the binarized images.

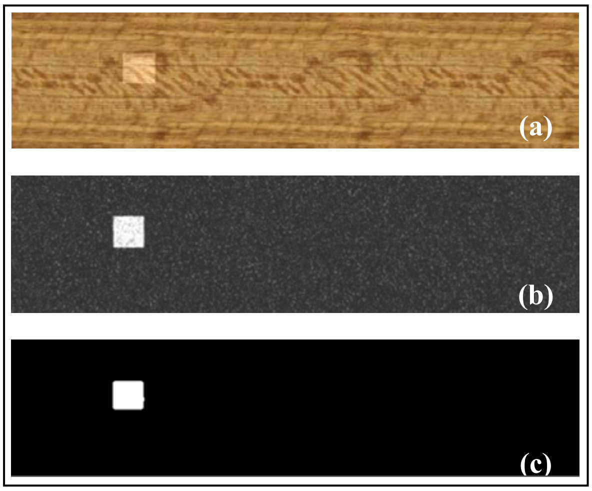

Figure 5 - Example of correct defect detection

Most of the classification errors happened when the patterns were incorrectly identified and small defects have to be detected on very streaked woods. In such cases the classifier was not able to distinguish correctly between the defects and the natural streaks of the wood.

We also calculated the percentage of pattern recognition: the original pattern was recognized exactly in 85.4% of the cases, while an error of 1 pixel in the length recognition (*LE*) happened in 12.3% of the cases. Only in 2.3% of the cases the length error (*LE*) was greater than one pixel. Most of the errors happened in the analysis of boards with incorrect illumination (see Figure 6) that caused problems in the row and column extraction steps.

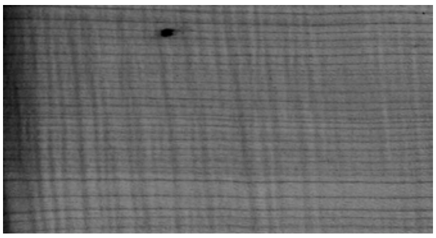

Figure 6 - Board with incorrect illumination (the left part of the board is darker then the right one).

This problem could be solved by means of correct illumination techniques and by correcting the effects of illumination errors on the images, but this is out the aims of this paper. The results are summarized in Table 1.

TABLE 1 - PATTERN ESTIMATION CAPABILITY RESULTS

Error	**0**	**1**	**>1**
HE	100%	0%	0%
LE	85.4%	12.3%	2.3%

VII. CONCLUSIONS

The aim of this paper was to present an AVI system for the defect detection of melamine laminated particle boards. The novelty of our approach is the pattern extraction phase that precedes the proper defect detection and that allows to estimate the original pattern used to print the melaminic papers that cover the particle boards. This innovative approach allows increasing the defect detection performance by means of a more accurate image comparison between the image to be inspected and a reference image. A set of real wood patterns proved that our AVI system is able to guarantee defect detection capabilities higher than the ones presented in the literature.

The joint use of defect detection techniques with pattern and without pattern would increase the performance of the overall defect detection system. This joint approach could guarantee satisfactory performance even when the pattern estimation phase fails to recognize the original pattern.

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