

AUTOMATIC INSPECTION OF CRYSTAL GLASSWARE

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Abstract: This paper presents a new finish check inspection method for detecting defects for crystal glassware. The visual inspection system utilizes the image comparison approach that involves the well-known template matching techniques, where the pattern under test is compared with a reference pattern. The algorithm utilizes tonal measures of mean and deviation of the gray levels, combined with an algorithm that determines the discrimination factor between pattern under test and reference pattern; the tonal measures used for quality control of glass are the average image intensity of each row of the picture and the deviation of the average image intensity of each row from the general mean.

Keywords: Crystal Glassware, Automatic Inspection, Quality control

1 INTRODUCTION

In industrial manufacturing, product inspection is a basic requirement for quality control in the production process. The inspection procedure must ensure that the characteristics of the item under test conform with predefined specification standards within an acceptable margin of tolerance.

The desire to optimize manufacturing processes has led to a number of studies into the feasibility of automated inspection systems. These studies justify the need for industrial automation and show that automated systems will increase the productivity and improve product quality.

In order to achieve image understanding computer systems must relate the input data to the object being observed. The first step in this complex sequence of operations is to obtain a compact description of the input image. The necessary characteristics of the representation are that it must be complete and meaningful, that is to capture all of the information contained in the original image and to make explicit the important properties of the imaged scene.

A digital image is a spatial, intensity and temporal quantization of a real world scene. Precise determination of position in digital images is important for image metrology. Applications such as machine vision for automated assembly and inspection, photogrammetry and digital cartography rely on the geometric integrity of digital images. The analysis of digital images in terms of feature detection, recognition and classification requires to maximize the available information captured in the digital image and to utilize this information as fully as possible; this can be done by proper preparation of the object, effective using of digitizing resolution and use of geometry preserving image processing operations.

For applications where the inspection sequences are simple the number of points to be inspected is limited and a typical set-up consists of a camera, a monitor and a processing unit.

Figure 1 shows a simplified schematic diagram of an automated visual inspection system.

Such a system is able to take linear measurements by recognizing the object's high contrast boundaries.

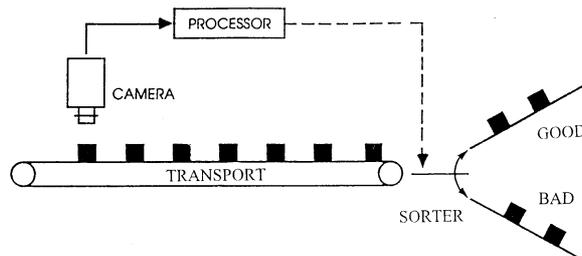


Figure 1. Schematic diagram of an automated visual inspection system.

This is usually done by simple edge detection logic circuitry, measuring controls and digital readout displays. The required information generally consists in identifying the object and determining its size or detecting its defects.

After analysis decisions are made and the processing unit directs the sorter to classify the objects according to the type, size and quality, while defective items are rejected.

2 APPROACH TO THE PROBLEM

In the crystal glass industry, the detection of defects on the finish, e.g. flaws, cracks or bubbles is one of the most important steps in quality control.

Several papers and reports have been published over the past years on automated inspection of glass [1]-[7].

In this paper a new finish check inspection method is proposed based on computer vision. The visual inspection system utilizes the image comparison approach that involves the well known template matching techniques, where the pattern under test (P.U.T.) is compared with a reference pattern (R.P.). Any difference from the reference pattern is considered a defect. A precise alignment is required before comparison and this is the most serious disadvantage of the method; however it can achieve high performances using simple hardware.

The algorithm utilizes tonal measures of mean and deviation of the gray levels, combined with an algorithm that determines the discrimination factor between P.U.T. and R.P. The tonal measures used for quality control of glass are the average image intensity of each row of the picture and the deviation of the average image intensity of each row from the general mean.

In actual work, to make clear outline images through the camera and videographics adapter is difficult under various surrounding light intensities. According to the experiments, however, the use of assistive light was found to be effective to compensate for the light variation and for the effect of the shadows.

The results obtained are presented with an analysis in terms of efficiency. Future developments of the proposed method are finally considered.

3 ALGORITHM IMPLEMENTATION

The tonal measures that are used for detecting defects in the crystal glassware are the average image intensity $\mu(r)$ for each row of the picture and the deviation $d(r)$ of the average image intensity of each row from the mean \bar{m} [8],[9]

$$m(r) = \frac{1}{P} \sum_{j=1}^P I(j) \quad r = 1, 2, \dots, N \quad (1)$$

$$d(r) = m(r) - \bar{m} \quad (2)$$

$$\bar{m} = \frac{1}{N} \sum_{r=1}^N m(r) \quad (3)$$

where $I(j)$ denotes the image intensity at pixel position j on the row r .
The deviation from the mean is Fourier transformed

$$D(m) = \sum_{k=0}^{N-1} d(kS) e^{-j2\pi mk} \quad (4)$$

where the N data points of the deviation are uniformly spaced of S and $m=1/NS$.

Then $D(m)$ is divided by the square root of the summation of $D(m)^2$ to obtain the normalized FFT deviation $R(m)$

$$D = \sqrt{\sum_{m=1}^M D(m)^2} \quad (5)$$

$$R(m) = \frac{D(m)}{D} \quad (6)$$

Vector $R_{PUT}(m)$, relative to the P.U.T., is compared with the homologous vector $R_{RP}(m)$, relative to the R.P.

$$D_R(m) = R_{PUT}(m) - R_{RP}(m) \quad (7)$$

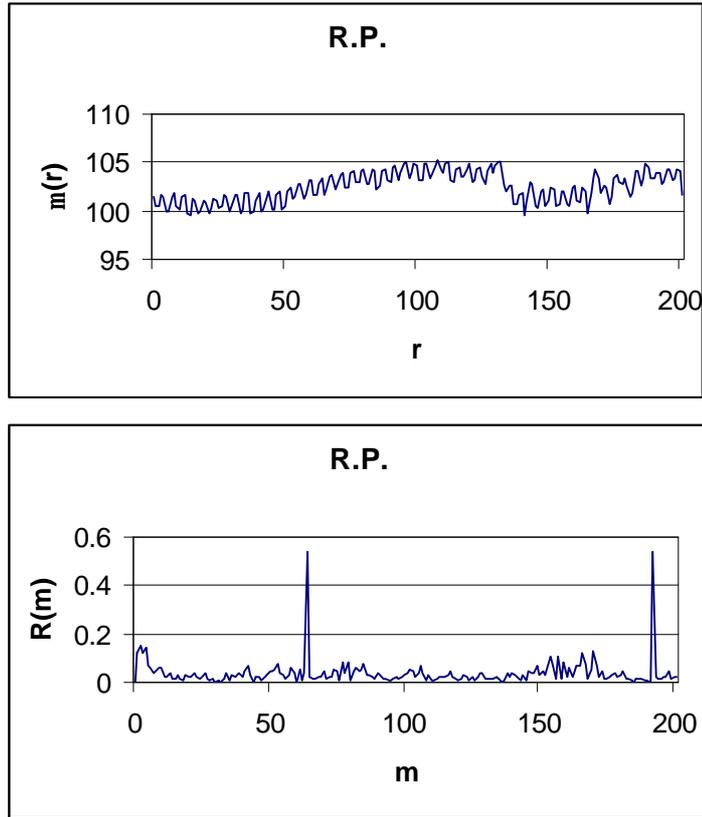


Figure 2. Results of $\mu(r)$ and $R(m)$ relative to the R.P.

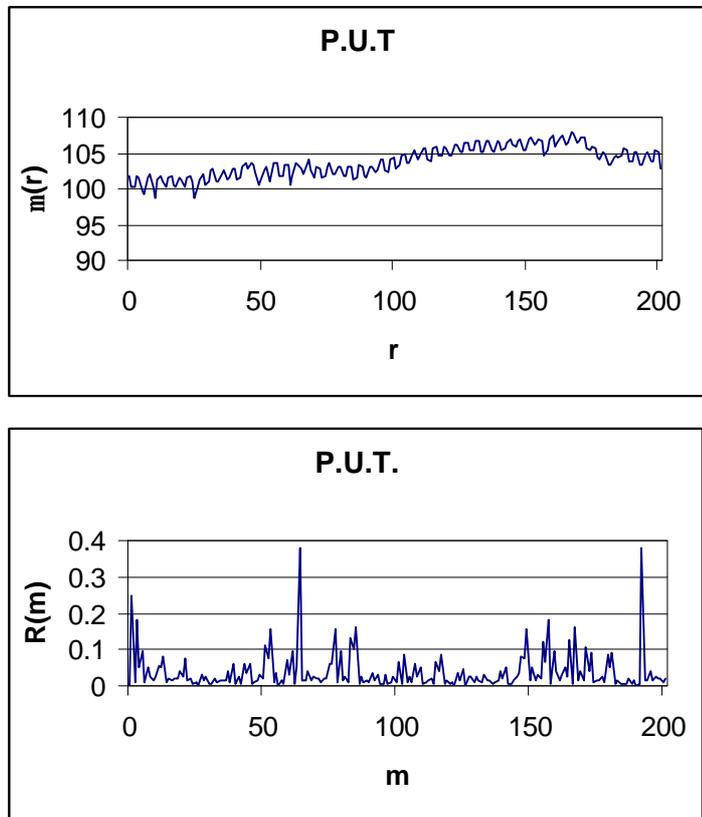


Figure 3. Results of $\mu(r)$ and $R(m)$ relative to the P.U.T.

The discrimination factor between P.U.T. and R.P. is given

$$\sigma = \sqrt{\frac{1}{M} \sum_{m=1}^M D_R(m)^2} \quad (8)$$

The automated inspection system indicates a defective item when σ exceeds a pre-established threshold value.

Figure 2 and Figure 3 show typical results of the average image intensity $\mu(r)$ and normalized FFT deviation $R(m)$ relative to R.P. and P.U.T., respectively, for a crystal ash-tray.

4 SYSTEM APPARATUS

The apparatus of the automated image inspection system is shown in Figure 4.

The equipment used to obtain and analyze the images consists of a PC with a Truevision Videographics Adapter TARGA 16 AT&T characterized by 512 pixel x 512 row resolution, connected to a CCD video camera.

The video camera is located perpendicular to the object about 40 cm above it.

The images from the camera are stored and processed as 512 by 256 by 16 bit pixels arrays and displayed on a color monitor and on a composite video monitor.

The lighting arrangement is very important for detecting defects of glass. Illumination must be sufficiently diffuse, intense and uniform during inspection.

For this work it has been found that two 200 W lamps give an illumination pattern that is acceptably uniform and enables images with good contrast to be captured.

The video camera, with appropriate optics, subtends an area of 136x79 square mm on the picture surface. In this configuration the features can be resolved to about 0.3 mm.

The incoming image data are then processed according to the procedure illustrated in previous section.

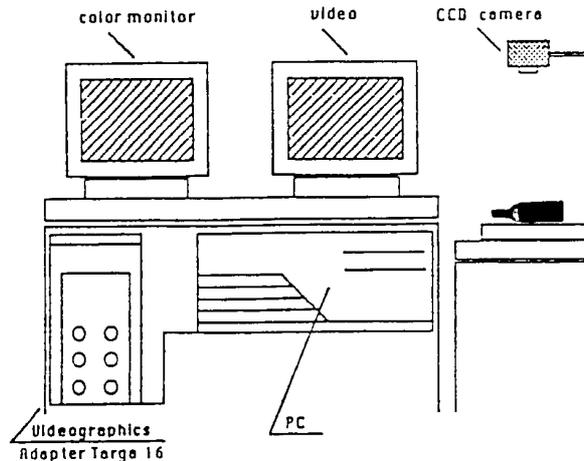


Figure 4. Automated image inspection system

5 RESULTS

The image processing algorithm presented in this paper has been verified extensively in laboratory tests. To measure the performance of the inspection system, the following four quantities are determined:

- CC - the number of items correctly classified;
- Misses - the number of defective items classified as acceptable;
- False alarms - the number of acceptable items classified as unacceptable;
- %CC - percent of items correctly classified.

We considered in the experiments some crystal ash-trays and we carried out about 200 tests. The results obtained are tabulated in Table 1.

Table 1. Performance of the inspection system

Total items	CC	Misses	False alarms	%CC
200	192	2	6	96

Figure 5 shows the results of the discrimination factor.

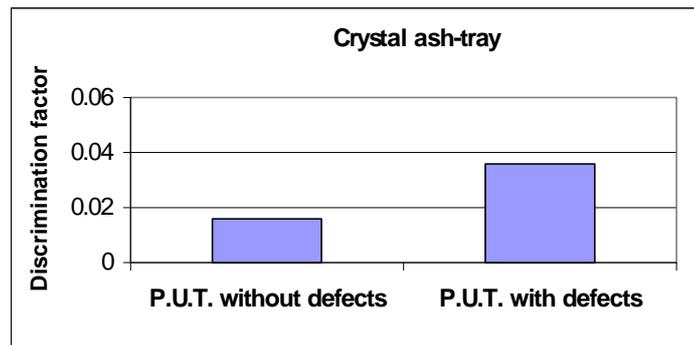


Figure 5. Discrimination factor for crystal ash-trays

Ninety-six percent of items were correctly classified out of the 200 in the total test set, on the basis of the discrimination factor; we assumed correct classification of defective items when comparing P.U.T. and R.P., we obtained a value of discrimination factor greater than 0.02.

6 CONCLUSION

This paper has described a new algorithm for the automated detection of defects of crystal glassware.

Any standard CCD camera and associate processor able to produce good quality images can be used.

The results show that the required information can be reliably obtained using tonal measures of mean and deviation.

Laboratory results show the good performance of the proposed system, which improves the efficiency of the inspection and increases considerably the speed of detection. The success of the results on crystal glassware indicates the approach presented here can be powerful for a wide range of pattern inspection tasks.

However, some problems remain; the most apparent is the difficulty in detecting defects of small dimension. Work is currently underway to improve the efficiency of the method.

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