Computer Vision System for Automatic Quality Inspection of Glass Products Used for Food Packaging

João David D. Cabral*, Sidnei A. Araújo*

* Industrial Engineering Post Graduation Program, Universidade Nove de Julho (UNINOVE), São Paulo, Brazil

Email: joaodavid@uninove.br, saraujo@uninove.br

Abstract

An important aspect in the process of glass production is the difficulty to predict all possible problems or defects before finalizing the product, being necessary a continuous inspection process of products to ensure their qualities. In addition, in the glass industry some defects transcend the product quality issues. It is the case of glass products to be used in food packaging, which can bring some risk to consumers such as a loose shard of glass or a sharp edge that can cause an injury. Despite the importance of the visual inspection processes of glass products, many of them are still performed manually. The problem is that human inspection presents some drawbacks such as the time consuming, high cost and the fact that the efficiency of human labor can be easily affected by environmental and personal factors. In this context, automated inspection processes are desirable. In this paper we proposed a computer vision system to identify a defect known as glass particle in glass products used for food packaging. Experiments using a low cost apparatus to simulate a real line of production were conducted to evaluate the efficiency of the proposed system.

Keywords: computer vision system; visual quality inspection; glass products; glass particle; glass sparkle.

1 Introduction

The production of glass, due to its characteristics of foundry and temperature, requires a constant production. Another relevant aspect in the process of glass production is that is not possible to predict all possible problems (defects) before finished product. Thus, it is necessary to keep an inspection process to improve the quality of the final product.

Many manufacturers are concerned about the appearance of their products since customers often assign the appearance of product with its functional quality. Thus, to ensure the success of a product in a long time market, it is desirable to perform a visual inspection of its appearance before packing and shipping (Vernon, 1991).

In the glass industry, the preoccupation with defects transcends the issue of product quality, mainly in the case of glass products used for food packaging, which can bring some risk to consumers such as a loose shard of glass or a sharp edge that can cause an injury.

Nowadays many products of the glass industry are inspected by manual process, which presents the inconvenience of time consuming and high cost (Nishu & Agrawal, 2011). Besides, the efficiency of human work is affected by environmental and personal factors (Pesante-Santana & Woldstad, 2000).

In most manual inspection processes in the glass industry, the incidence of defective products that are rejected usually is related to the fact that there is an incompatibility between the velocity of production and the analysis capacity of human workers. In these cases, the parameter that can be changed to human inspection is the number of workers, based on the speed of production, but this action is not interesting because of involved costs and necessity of adaptation in the production lines. In this context, automatic inspection machines arise as an alternative to improve quality of products and reduce costs (Vernon, 1991; Wang & Asundi, 2000; Batchelor & Whelan, 2002; Nishu & Agrawal, 2011).

Nevertheless, it is observed that many of automatic processes need a dedicated machine with many pre-established settings, which requires adjustments in the whole production line, such that only products that are constantly produced and in large scale justify these agreements and investments.

In the last years many computer vision systems (CVS) for quality inspection of glass products have been reported in the literature. Among them, we can found a system for detection of foreign materials included in LCD Panels proposed by Shimizu et al. (2000); a CVS for inspection of defect in wineglass developed by Wang & Asundi (2000); an application for inspection of defect in mouth of beer bottle developed by Yepeng et al. (2007); a method for automatic inspection of float glass fabrication proposed by Peng et al. (2008); a low-cost inspection system for online defects assessment in satin glass presented by Adamo et al. (2009); a system for glass defect detection developed by Nishu & Agrawal (2011) and a method for detection and recognition of glass defects in low resolution images proposed by Zhao et al. (2011). However, none of these works consider glass products used for food packaging.

The objective of this paper is to propose a CVS to identify a specific defect in glass products used for food packaging, called glass particle or glass sparkle. In the performed experiments a low cost apparatus including a conveyor belt and a camera controlled by a PC were used to simulate a real line of production.

2 Glass Products Defects

For glass products used as packaging there are different types of defects that are classified in the norm NBR 14910:2002 by Brazilian Association of Technical Norms – ABNT.

Among the main types of defects are: Calcined fund, Sewing salient, Bubble, Stuck, Sewing mismatch, Fold, Hammered and Micro bubbles, as can be seen in Figure 1.

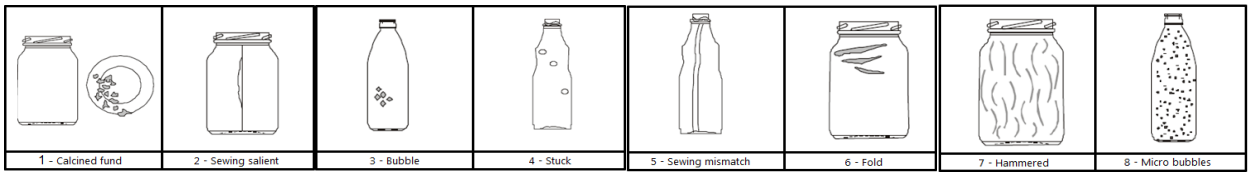


Figure 1: Examples of defects in glass products (ABNT, 2002).

The defects shown in Figure 1 represent only aesthetic problems. The CVS proposed in this paper is specific to deal with defect particle of glass, illustrated in Figure 2, which constitutes a risk to the final consumer since the particles can be detached and incorporated into food product, causing injury or be accidentally ingested.

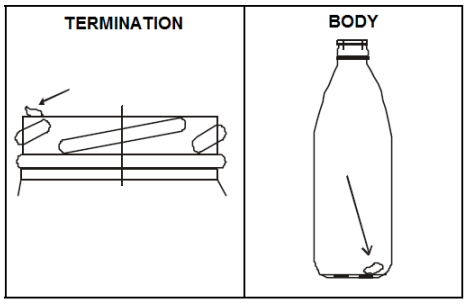


Figure 2: Defect particle of glass (ABNT, 2002).

As glass packages are not inspected by food industry before the food product packaging, there is the possibility of a consumer to purchase a food product in a package with glass fragments.

3 Computer Vision System Techniques

Computer Vision could be defined as a sub area of image processing whose main goal is the study and development of methods and techniques that allow machines to interpret digital images, imitating some capabilities of the human visual system (Conci et al., 2008). An efficient CVS must be able to accurately describe the scene with a processing time that makes feasible the development of practical applications such as robot vision systems, surveillance systems, automatic license plate recognition, industrial inspection and biometrics patterns recognition (Araújo, 2009). Some of computer vision techniques well as the definition of digital image are described throughout this section.

3.1 Representation of Digital Images

Mathematically, an image can be defined as a bidimensional function $f(x, y)$ with $(x, y) \in R^2$, where x and y are spatial coordinates that identify a point and the value of f at any point (x, y) indicates the intensity of the gray level value at that point.

A digital image is an image $f(x, y)$ discretized both in spatial coordinates and gray level values and may be represented by a matrix in which the index of lines and columns identify an image element (pixel) and element value identifies the gray level (Gonzalez & Woods, 2002; Conci et al., 2008).

In binary images the values of $f \in \{0,1\}$, while in grayscale images typically the values of $f \in [0,255]$. For color images, each pixel is represented by a set of three or four values depending on the considered color system. In RGB (Red, Green and Blue), for example, a color image can be viewed as a set of three grayscale images, each one representing one of the color components (Araújo, 2009).

3.2 Edge Detection

In an image, the edge of an object can be defined by an abrupt change in grayscale, that is, a discontinuity in the intensity of grayscale. Derivative-based operators are sensitive to these changes and are widely used as edge detectors. Based on the value of the gradient magnitude at a given point of the image it is possible to determine if that point belongs to the edge of an object. The gradient of an image point $f(x, y)$ is defined as:

$$\nabla f(x,y) = \left[\frac{\partial f}{\partial x}, \frac{\partial f}{\partial y} \right] \tag{1}$$

where $\partial f/\partial x$ and $\partial f/\partial y$ is the discrete partial derivatives in x and y directions, which can be defined by:

$$\frac{\partial f(x,y)}{\partial x} \approx f(x+1,y) - f(x,y) \tag{2}$$

$$\frac{\partial f(x,y)}{\partial \mathrm{y}} \approx f(x,y+1) - f(x,y) \tag{3}$$

The magnitude and gradient direction (perpendicular to the edge) can be obtained by equations 4 and 5.

$$\|\nabla f(x,y)\| = \sqrt{\left(\frac{\partial f(x,y)}{\partial x}\right)^2 + \left(\frac{\partial f(x,y)}{\partial y}\right)^2} \tag{4}$$

$$\theta(x,y) = \tan^{-1}\left(\frac{\partial f(x,y)}{\partial y} \Big/ \frac{\partial f(x,y)}{\partial x} \right) \tag{5}$$

Using a threshold L_m we can determine that every point where $\|\nabla f(x,y)\| \geq L_m$ is a point belonging to an edge. It is valid to remember that the equations 2 and 3 can be replaced by known and widely used gradient operators such as Roberts, Prewitt and Sobel (Gonzalez & Woods, 2002).

3.3 Binarization

The binarization (equation 6) consists in converting a grayscale image into a binary image, in which pixels with value 1 (white) represent the objects and pixels with value 0 (black) represent the background or vice versa (Gonzalez & Woods, 2002).

$$b(x,y) = \begin{cases} 1, \; if \; f(x,y) > L_b \\ 0, \; otherwhise \end{cases} \tag{6}$$

where: b is the output binary image, f is the input grayscale image and L_b is the threshold selected as reference for the grouping of pixels.

3.4 Connected Components

The concept of connectivity between pixels is largely explored in the characterization of regions in an image. Two pixels p and q are connected if they have any adjacency relation and their gray levels satisfy some criterion of similarity (Gonzalez & Woods, 2002). The two most common ways to define connectivity between pixels are connectivity-of-4 (Figure 3a) and connectivity-of-8 (Figure 3b).

	(x,y-1)	
(x-1,y)	(x,y)	(x+1,y)
	(x,y+1)	

(a)

(x-1,y-1)	(x,y-1)	(x+1,y-1)
(x-1,y)	(x,y)	(x+1,y)
(x-1,y+1)	(x,y+1)	(x+1,y+1)

(b)

Figure 3: Neighborhood between pixels.

In connectivity-of-4 are considered the four neighboring pixels connected horizontally and vertically, in terms of coordinates, i.e. (*x+1, y*), (*x-1, y*), (*x, y+1*) e (*x, y-1*). In connectivity-of-8, pixels connected horizontally, vertically and diagonally are considered, i.e. (*x+1, y+1*), (*x+1, y-1*), (*x-1, y+1*) e (*x-1, y-1*). A set of connectivity-of-4 or connectivity-of-8 pixels is called connected component.

3.5 Hough Transform for Detecting Circles

The Hough Transform (HT), proposed by (Hough, 1962), is a method widely used in image processing and computer vision for detecting parameterized shapes such as lines, circles and ellipses. HT is usually used after the detection of edges in images you want to detect shapes.

For detection of circles, which is the shape of interest in this paper, they may be parameterized by (*x*, *y*, *r*), where (*x*, *y*) indicates the central position of the circle and *r* the length of its radius, as shown in Figure 4.

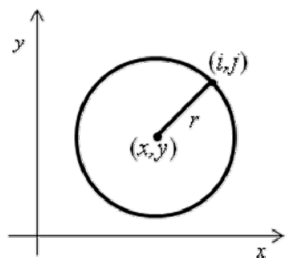


Figure 4: Parameters of the circle.

The radius of the circle is defined as follows:

$$r = \sqrt{(i - x)^2 + (j - y)^2} \tag{7}$$

where: (i, j) denote spatial coordinates of any edge pixel and (x, y) coordinates of the pixel that represents the center of the circle.

Assuming you want to find circles in the image I of size $M \times N$, with maximum radius (r_{max}) = $\sqrt{M + N}$, the HT algorithm can be described by the following steps:

1) For each pixel (x, y) of image I, an accumulator vector with size r_{max} is created and all elements are initialized with value zero.

2) For each pixel (i, j) classified as edge in the image I, is calculated its distance r (equation 7) for all other pixels of the same image, increasing 1 in the element value of the vector assigned with the pixel (x, y), located at position r.

At the end of these two steps, the maximum values of the vectors indicate the centers and radii of the detected circles. For example, if a value above the threshold L_c is found at position 30 of the vector associated with pixel (50, 50), this indicates the occurrence of a circle with radius 30 centered at position (50, 50) of image I.

Clearly, the implementation of the described algorithm becomes its use prohibitive in most cases. Thus, some authors like (Ballard, 1981) and (Davies, 1986) proposed enhancements to the method. However, the HT algorithm for circles can be accelerated when you have some prior information. For example, location of possible regions of center of circles, minimum and maximum radius.

4 Methodology

This paper is based on a case study from a real problem of a Brazilian industry, in which were considered defects in glass products used for food packaging, the deficiency in the manual inspection process and the difficult adaptability of automated equipment for visual inspection in some lines of production.

The considered company currently produces around 10 thousand tons of finished products per month, including glass products for domestic use and packaging.

To choose the product to be inspected (cup of 405ml, ø 97 mm), we took into account the speed of production and variety of glass products for packaging produced by the company, based on historical information.

In the implementation of the proposed CVS it was used the C/C++ programming language and the libraries for image processing and computer vision ProEikon (Kim, 2010) and OpenCV (Intel, 2007).

For the experiments described in this paper we used a low cost apparatus composed by a conveyor belt and a camera controlled by PC (Figure 5), to acquire and process 80 images of glass packages varying the amounts of particles inside them.

The acquisition of images was conducted considering a focal length of approximately 40cm from glass product placed on the conveyor belt.

The exact moment for acquiring the image of the product placed on the conveyor belt is computed by analyzing the signature generated by gradient variation along the columns in each frame. This technique is widely used by systems of license plate vehicles recognition, to determine the plate position.

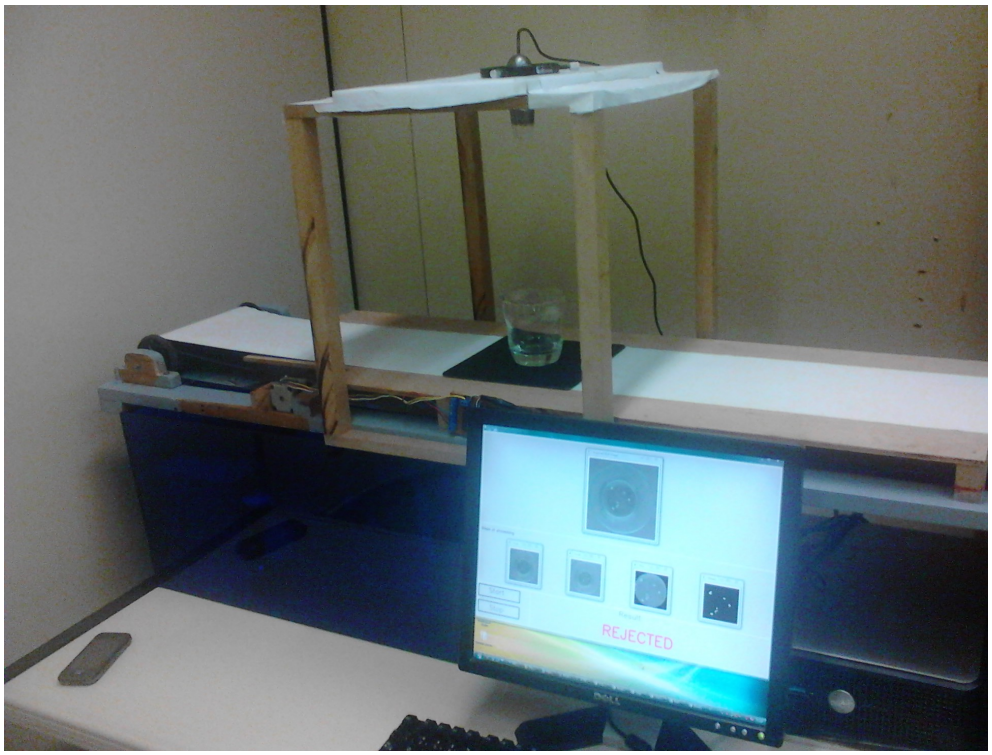


Figure 5: Apparatus used to simulate the production line.

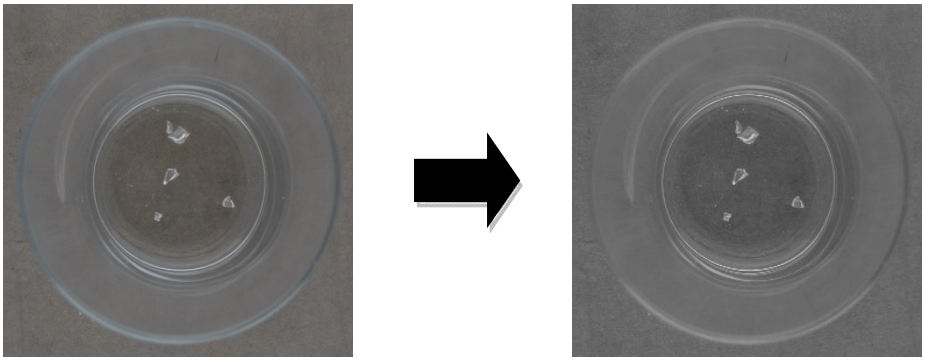
5 The Proposed Computer Vision System

The input of the proposed CVS, whose the interface is illustrated in Figure 6, is an RGB color image acquired by using the apparatus previously described.

Figure 6: Interface of the proposed CVS.

The working of the system can be described by following steps of processing:

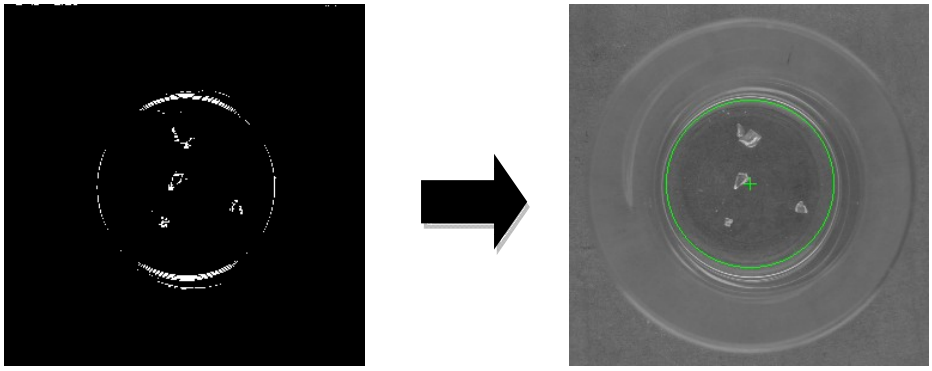
The first step is responsible to convert the acquired color image to grayscale one, by averaging the RGB components of each pixel, as showed in Figure 7.



(a) Input color image (b) Grayscale image

Figure 7: Conversion of the input image to grayscale.

In the sequence, it is performed the edge detection using the information of the gradient magnitude (equation 4) and, based on the found edges, the detection of the circle that represents the bottom of the glass package (Figure 8) using HT algorithm.

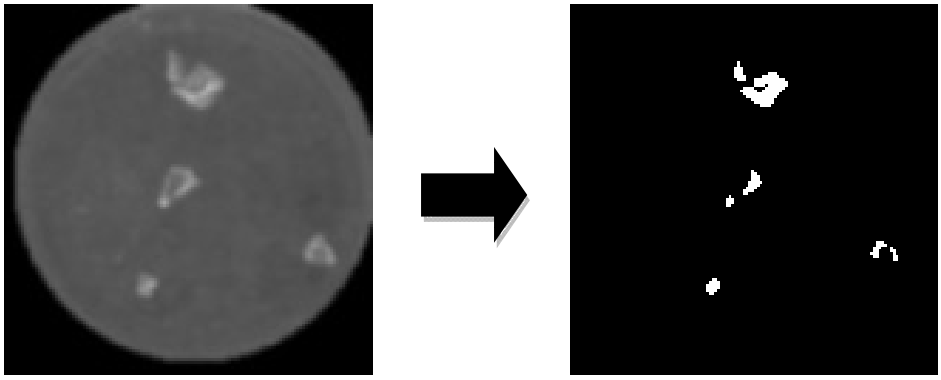


(a) Output of edge detection process (b) Detection of the glass package bottom by HT

Figure 8: Steps to detect edges and the bottom of glass package.

For these two steps it was determined $L_c = L_m = 128$. To accelerate HT algorithm it was determined that only pixels within a region of 20 × 20 pixels in the center of the image could represents the circle center. Moreover, in all cases the radius should be approximately ¼ of the width of the image with a standard deviation of 10 pixels.

In the following steps, illustrated in Figure 9, the region of interest (ROI) is finally segmented (Figure 9a) and binarized (Figure 9b).



(a) Segmentation of the ROI (b) Binarization of the ROI

Figure 9: Segmentation and binarization of the bottom of the glass.

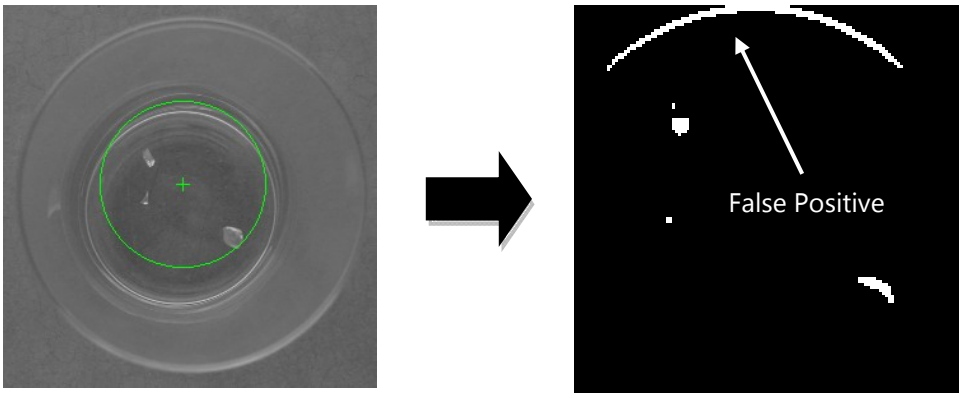
In the last step of the algorithm, the connected components considered too small or too large are removed since that these components probably represent noise. Then, the reminder components indicate the existence of sparks.

If the final output image contains white pixels, there is the incidence of sparks and the CVS print a red message on the screen indicating the rejection of the product, as depicted in Figure 6. In the contrary case, a green message is displayed to indicate that the product was accepted.

6 Results

The experiments were conducted as follows: for each product put on the conveyor belt, the algorithm should acquire the best frame (when the product was positioned in the center of the image), perform the analysis of the acquired image and indicate if the product was accepted or rejected, as illustrated in Figure 6.

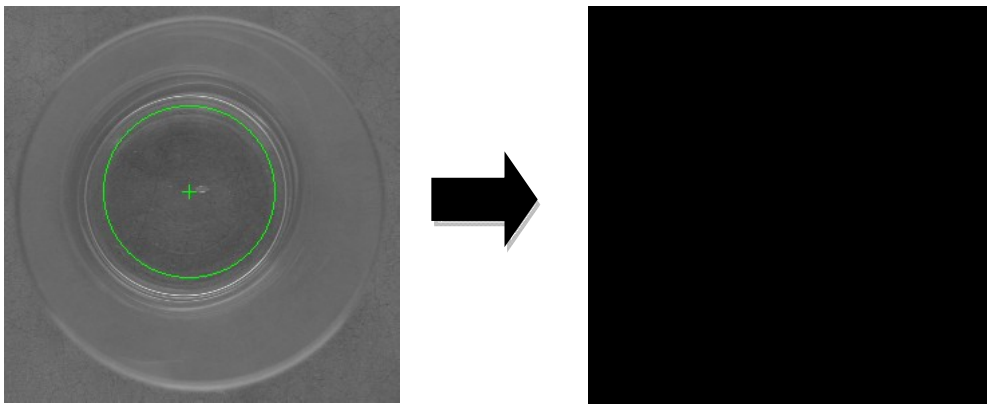
In the performed tests the hit rate was 90.0%. The cases of false positives (Figure 10) and false negatives (Figure 11) were originated, in general, by errors of circle detection and the low contrast between pixels representing the particle and others representing the bottom of the glass, due lighting conditions.



(a) ROI marked in green (b) Result of ROI binarization

Figure 10: Example of false positive case.

As can be seen in Figure 10, because of lighting problems, false circles are originated decreasing the robustness of HT algorithm and affecting the proposed CVS output. The false negative example, illustrated in Figure 11, is a typical case of low contrast problem. However, the results show that even in non-ideal lighting conditions, the CVS presented a good hit rate validating the proposed approach.



(a) ROI marked in green (b) Result of ROI binarization

Figure 11: Example of false negative case.

Concerning the time processing the proposed CVS took, in average, 1.5 seconds to process each acquired image. It is valid to remember that this time can be accelerated by adjusting some parameters such as location of possible regions of center of circles, amount of candidate pixels to compute HT, minimum and maximum radius, among others.

7 Conclusion

In this paper, it was proposed a CVS to identify a defect called glass particle in glass products used as food packaging. Based on the experiments, we can conclude that the proposed CVS can be used for the investigated purpose, considering its hit rate (90%) and the cost in time to process an image. Unfortunately, as we did not find other methods with the same goal than the proposed CVS, we could not compare the obtained results.

It was observed that lighting conditions and the choice of some parameters may affect drastically the performance of the CVS. Thus, we are currently working to improve its robustness, mainly regarding lighting conditions.

Concerning the apparatus used to conduct the experiments, since we used controlled conditions such as velocity of the conveyor belt and the position to put the glass product in the belt, no problems were detected.

In future works we intend to adapt the proposed approach to deal with other glass products such as dishes and bottles, investigate a way for automating some CVS configuration parameters, conduct a set of exhaustive experiments and, finally, apply the proposed CVS in a real situation in the company used as case study.

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