Real-Time Cork Classification Method: A Colour Image Processing Approach

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Abstract: **This paper presents an automatic vision assortment method for cork classification. Cork is a natural material that is used to seal wine bottles due to its reliability and its chemical and mechanical properties. A colour image acquisition system is able to differentiate some cork defects.**

The developed and implemented system acquires images using a colour linear CCD camera, transmits that image through a fast acquisition card and processes that image to extract quantitative elements. This system can analyse and distinguish defects present on the surface of a cork-stopper: the size, form and position of the defects are analysed.

Key-Words: **- Visual Inspection, Artificial Vision, Quality Control**

1. Introduction

Cork-stoppers are used to seal wine bottles because, unlike man-made material, they avoid leakage even in presence of irregularities in the bottle neck. They show an excellent chemical inertia and avoid any reaction with the wine that changes its taste. Their best characteristic is the ability to allow gaseous exchange with the outside atmosphere. This is an important step that makes it possible to improve the wine quality as time goes by [1].

An artificial vision system capable of cork classification is an important step to the homogenization of cork classification parameters. In fact, some cork manufacturers do this classification manually and there are no criteria to selection. Furthermore, the human tiredness influences the decision.

So, each cork-stopper class is not uniquely defined, therefore a machine criterion can help in standardization.

The quality of a cork-stopper is decided by a function of several features, defects and the presence of insects [1]. Some cork defects are only discovered with colour vision and can appear in the form of cracks, random-shaped holes, and others. Cork-stoppers are grouped into eight classes according to the degree of defects on its surface.

The system is divided into acquisition and processing subsystems. The first one is composed by a hard real-time system that controls the camera and the second one is a soft real-time system with the software that deals with the processing and decision tasks. Both are connected through specific developed hardware.

The linear CCD camera and the signal conditioning system acquire and send the image's RGB components to the computer. Some difficult defects such as a potter's earth zone presented in Figure 1.1 can be detected with RGB components. These types of defects usually appear in form of longitudinal cracks that leak and cannot be detected with a black and white camera.

Figure 1.1 – Cork stopper body

The base algorithms are morphologic manipulation, convolution, binarization and clustering [2].

The real goal is to obtain an automatic classification system that allows a faster and right decision about the cork class [3].

The paper is organized as follows: initially, Section 2 describes the mechanical and hardware subsystem. Section 3 describes the main image processing algorithms and Section 4 describes the classification methods and presents an example. Section 5 describes the RGB selection criteria. Section 6 describes the real-time requirements of the system. Finally, Section 7 rounds up the paper with conclusions and presents the future work.

2. General System Description

The developed system comprises two main subsystems: the mechanical subsystem which is responsible for the handling of cork-stoppers and the hardware/software subsystem which is responsible for acquiring, processing images and classification tasks.

2.1 Mechanical Subsystem

The mechanical system that works as an assembly line is made up of three main parts: the feeder system, the inspection platform and the binning selection mechanism (with eight different outlets [4]) as illustrated in Figure 2.1.

The feeder system lines up cork-stoppers in the inspection platform. There, a set of three rollers, with a uniform rotation movement, assures the rotation of the cork-stopper in front of the camera as shown in Figure 2.2 [5].

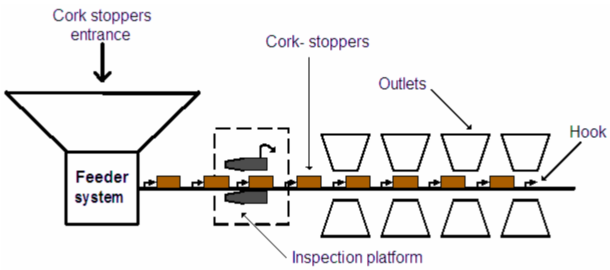


Figure 2.1. Mechanical subsystem.

The cork-stopper inside the inspection platform performs two movements simultaneous: one of translation, from the feeder system to the outlets, and a rotational movement produced by the rollers.

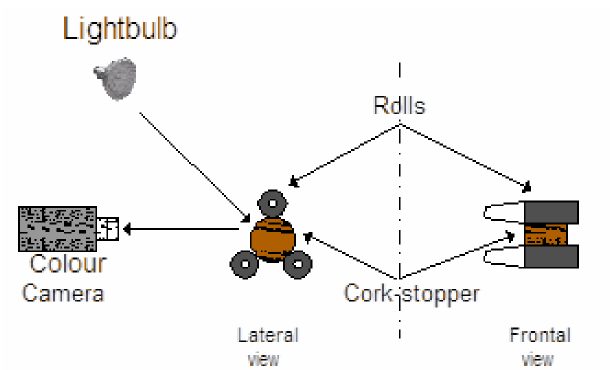


Figure 2.2. Lateral and frontal view of inspection platform.

The spin movement of the cork-stoppers allows the linear camera to acquire the cylinder surface completely like a flattened image.

Figure 2.3 presents a view of the developed system installed on real working environment.

Figure 2.3. Mechanical view of the developed system.

2.2 Hardware Subsystem

The developed electronic system is composed by several components. The global hardware architecture is described in Figure 2.4.

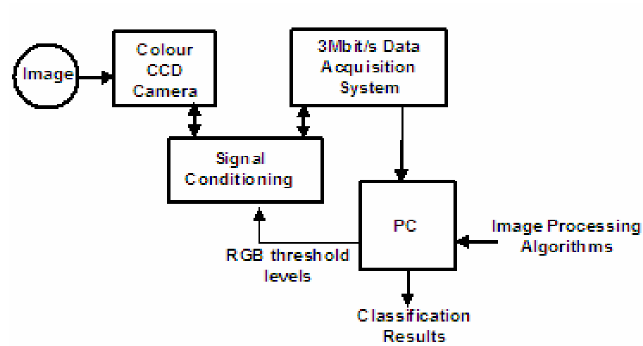


Figure 2.4. Hardware architecture.

The main sensor is a colour CCD camera, which captures the cork image. The requested signals to excite the CCD are produced by a microcontroller [6]. The three sixteen bit shift-registers [7] allow computer to acquire the sixteen pixels simultaneously [8] for each RGB colour component, after a threshold operation. The three threshold levels can be adjusted dynamically, from the software, depending on lightning conditions.

The image is acquired line by line. The camera operates with a colour linear CCD [9] that acquires the rotational image with 110 lines and sets up three flat images (RGB). Lines are formed by 256 Black or White pixels which are scanned through clock synchronization. Some initial and final pixels -dummy pixels- carry no light information. They are used to help in setting the voltage reference and noise minimization.

The real-time task is done by the microcontroller. The microcontroller has to scan pixels from the CCD and store each one in just 1 μs in the shift register. Here, the critical time requirements are all important. At the 16th pixel, the computer acquires the RGB components while microcontroller keeps the CCD synchronized.

The final image is made up of 110 lines. Each has 256 pixels with 1 Black or White bit for R, G and B components. Real and acquired green component images are shown in Figure 2.5. The green component chooses is presented in section 5.

(a) (b)

Figure 2.5. Cork-stopper image: (a) Real cork-stopper photo; (b) cork-stopper green component image acquired.

The illumination must be very carefully set up. It must be stable and include no 50/60Hz ripple. A DC/DC controller converter was developed in order to guarantee these requirements. The voltage controller gives an extra degree freedom to the light control adjacent to the iris lens control. To minimize the light intensity changes, a closed cabin accommodates the CCD camera. The stable light inside this cabin can be controlled by software too.

3. IMAGE PROCESSING

Well-known image processing algorithms such as the morphological manipulation, convolution, binarization and clustering are applied to the problem.

3.1 Cork-Stopper Boundary

The first processing algorithms find the localization of the cork-stopper image included in the acquired image. A skew algorithm [10] is applied in order to obtain a square cork-stopper surface image as presented in Figure 3.1.

These processing algorithms try to find the horizontal and vertical limits. The horizontal limit can easily be found because it can be assumed that the cork-stopper image is inside a rectangle.

Figure 3.1. Cork-stopper image after skew algorithm.

A varying distance between the camera and the cork-stopper modifies its perceived length. In industrial systems, the camera is fixed and the cork-stoppers go forward helped by a hook. This way, distance is correctly kept. Besides, the cork-stopper length is a very important setting to manufacturers and it must be included in classification.

The cork-stopper length parameter can be used to calibrate the system if an inaccurate distance was set for the camera. By using a known object, calibration can be done.

On the other hand, the vertical limit is more convoluted. In fact, the angular speed of the cork-stopper is not exactly constant over time. This problem arises from the sliding between cork surfaces and rollers that transmit movement to the cork-stopper. To solve this problem, the cork-stopper surface must be acquired more than once. Therefore, one has the guarantee that all the area is fully obtained. A correlative measure, k, between the three first lines and all the other lines, can be found. The minimum value of the measure of all lines gives the last line of the image. The formula for k where $p_{i,j}$ is the pixel value, of the i line and j column is:

$$k(line) = \sum_{i=1}^{A}\sum_{j=0}^{B}\left|p_{i,j} - p_{i+line,j}\right| \tag{3.1}$$

Where B is the image width and A the number of lines to compare (B=255 and A=3).

The final result is shown in Figure 3.2 where the cork-stopper limits are automatically extracted from the acquired image.

Figure 3.2. Cork-stopper image acquired and physically circumscribed.

The number *line/cork* is now known as the needed lines to represent the cork-stopper. If the angular speed was a closed-loop system, this number would be essential to feedback the angular speed.

This processing allows the system to work without an encoder attached to the cork rotation surfaces.

The defect measures should be done in millimetres. The pixel to millimetre transformation can be found by resorting to optics theory [11]. Horizontally, the size of projected image, H_{im}, in CCD can be found by equation 3.2.

$$H_{im} = \frac{H_{obj} \cdot D_f}{D_{obj} - D_f} \tag{3.2}$$

where H_{obj} is the size of object, D_f the lens focal distance and D_{obj} the distance from object to lens. This is possible because the barrel distortion can be ignored due to the quality of the used lens [12]. Vertically, object height in millimetres can be calculated from object in pixels by equation 3.3.

$$Obj_{mm} = k_2 \cdot Obj_{PIX} \tag{3.3}$$

Where

$$k_2 = \frac{\pi.d}{line / cork} \tag{3.4}$$

In equation 3.4, *d* is the cork-stopper diameter and *line/cork* is the number of acquired lines for a complete cork-stopper, as previously mentioned.

The advantages of the measures in millimetres than in pixels are more stable, invariable with rotation speed and camera distance and, as a standard measure, a reference in industrial surroundings.

3.2 Edge Detection

The main task of the processing is to extract features of the cork-stopper surface like the location, area and type defects. An edge detection algorithm is the base of all classification tasks. Before classification, other filters are applied to minimize the effects from noise found during acquisition.

Before classifying the longitudinal cracks, a convolution is applied so that the best results can be obtained.

Basically, the convolution is a window H that is scanned across the original image a. The output pixel value is the weighted sum of the pixels within the window, where the weights are the values of the filter assigned to each pixel of the window itself. The window H with its weights is called the convolution kernel. If the filter H[i,j] is zero outside the rectangular window (i=0,1,…I-1;j=0,1,…J-1), the convolution can be written as the finite sum presented in equation 3.5.

$$\begin{aligned} Y(m,n) &= a(m,n) \otimes H(m,n) = \\ &= \sum_{i=0}^{I-1}\sum_{j=0}^{J-1} H(i,j) \cdot a(m-i,n-j) \end{aligned} \tag{3.5}$$

Where Y is the resulting image and H is the convolution kernel (to vertical edge enhancement), given by equation 3.6 which gets very good results.

$$H = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 1 & 0 \\ 0 & -1 & 0 \end{bmatrix} \tag{3.6}$$

To eliminate small defects and some noise introduced during the acquisition process and to calculate the value of the total defects area, an open nonlinear filter algorithm (erode followed by dilate) was tested with good results. A median filter can withdraw eventual salt and pepper noise.

4. CLASSIFICATION

The class decision of cork quality by human experts is established according to very complicated rules and each person can have his own ones.

Basically, cork-stoppers are grouped into eight classes according to the degree of defects on the cork-stopper surface. There must be a configurable system because each cork manufacturer imposes his own “rules”. Moreover, the worst class is cheaper and less profitable. So, cork manufacturers try to shift worst classes the best they can.

The classification process is to pick up a class for each cork-stopper based on the measure of the defects, such as: total area, maximum area, maximum longitudinal crack, maximum transversal crack and top or bottom maximum (border) defects [13]. This classification should only be done if the cork-stopper length belongs to the programmed range. Otherwise, the cork-stopper should be rejected from all classes [14]. The implemented decision software algorithm allows the user to program the claimed values [15].

“The worst case criterion” is performed. The user inserts a table containing the maximum acceptable values for each class and for each parameter. The resulting values from the processing algorithms are compared to the inserted values from the user. Each parameter chooses a class. The worst classification decides the final class of the cork-stopper.

An example of user configuration is presented in Table 4.1. Length measures are in millimetres and area measures are in squared millimetres.

Table 4.1. User configuration example.

	1st class	2nd class	3rd class	4th class	…	7th class
Total Area	32	95	210	290	…	2000
Max. Area	23	52	130	190	…	490
Max. Long. Crack	7	11	16	22	…	28
Max. Transv. Crack	14	29	37	44	…	57
Max. Border Area	18	31	45	65		140

Bearing in mind the example given above, if a cork-stopper had the parameters presented in Table 4.2, the final classification result would not be the 7th class (the worst) but the 4th instead. In this particularly case, the cork-stopper had a fewer defects area but a longitudinal crack of 20 millimetres aggravated classification.

Table 4.2. Parameters values given from image processing.

Parameters	**Values**
Total Area	80
Maximum Area	25
Maximum Longitudinal crack	20
Maximum Transversal crack	15
Max Border Area	30

5. RGB Components Selection

A first approach to the cork classification using image processing was made with a black and white camera. Two problems were observed during acquisition. The first one, a potter's earth zone in cork stopper, presented in Figure 5.1, could not be detected bringing in a good class cork selection instead of a bad one. The second one, a blue speck zone in cork stopper, presented in Figure 5.2, was detected as a defect but was a mistake because this zone avoids leakage.

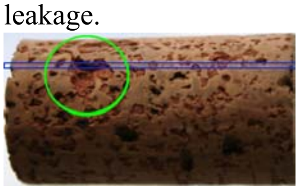
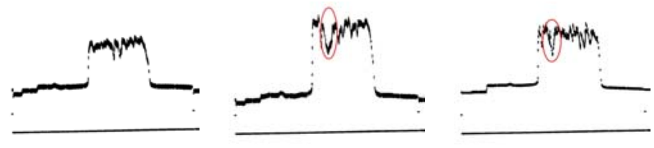


Figure 5.1. Potter's earth zone

Figure 5.2. Blue speck zone

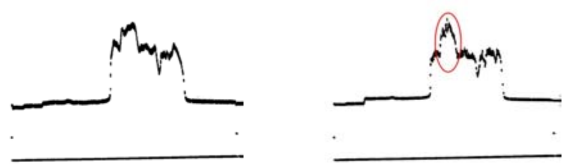
The green component of a colour camera is able to distinguish the first problem, the potter's earth zone, from the cork stopper body remainder. The figure 5.3 presents the red-R, green-G and blue-B oscilloscope wave's components presented in the real cork of figure 5.1, and the G and B components carries the earth potter zone information as presented in the red ellipses. The end of line synchronism signal is also presented in the wave below. The R component presents lesser information than G or B.



(a) (b) (c)

Figure 5.3. Oscilloscope waves for one cork stopper line. (a) Red, (b) Green and (c) Blue components.

The second problem, the blue speck zone, can be detected by the blue component and the green component stays more stable as presented in Figure 5.4 that shows cork stopper of picture 5.2. Once again, the red component carries little information too.



(a) (b)

Figure 5.4. Oscilloscope waves for one cork stopper line. (a) Green and (b) Blue components.

So, the green component is able to handle both problems: the detection of potter's earth area and less unchangeable to the blue speck zone.

By this way, a colour camera could be used in order to acquire the RGB components of defects thus improving the selection and classification of a varied type of defects. Colour calibration is difficult because each cork has its own tonality.

6. Real Time Requirements

Cork manufacturers and cork quality supervisors, ask for a stable and fast system. The industrial system requires a speed of 12000 cork-stoppers per hour. It means about 300 ms for each cork-stopper to be acquired, processed and classified. The developed hardware gives us the guarantee of real-time requirements. The hard real-time requirements such as pixel acquisition and conditioning are done with a microcontroller. The 280 pixels (effective and dummy) are acquired in 280 μs. That is the time to complete the acquisition of one line. While scanning, the line is introduced in the computer simultaneously.

After, the end of line signal must be introduced by the microcontroller to the CCD during 2 μs. So, 110 lines take nearly 30 ms to be scanned and introduced in the computer. The remaining time is about 270 ms and must be used to process and classify the cork-stopper image on a soft real-time system. Therefore, the processing system, a real-time OS, like QNX, RTLINUX, VxWorks, or any other could be used, but is unnecessary because the hard real-time requirements are dealt with by the microcontroller. If the processing system could not conclude the task for one image and another one arriving, that would not necessarily be a serious problem because the system stores the cork-stoppers in a buffer before the command to store them in the right bins is given. This buffer gives some freedom to the soft real-time system as shown in Figure 6.1. Of course, the average time of processing should be lesser than 270 ms. In practice, a time of 40 or 50 ms is enough to perform this processing task in a 1GHz processor.

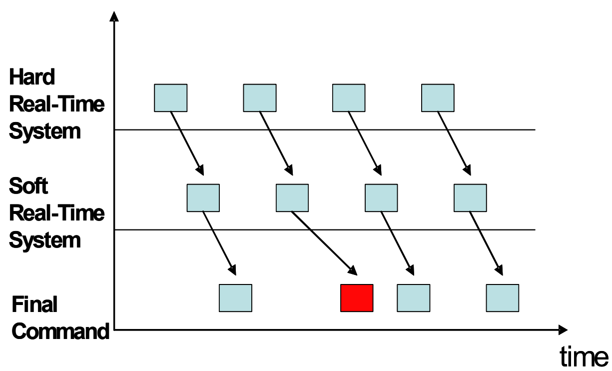


Figure 6.1. Real-time requirements. Microcontroller controls the Hard Real-Time System and the computer controls the Soft Real-Time System.

7. CONCLUSION

The developed system acquires and processes images of the cork-stoppers surfaces. The images are acquired through a real-time microcontroller and introduced in a computer by a developed acquisition system. The captured image is processed in a PC so that a qualitative classification for the cork-stopper can be obtained. The quality of the results validates the strategy and algorithms applied.

The right decision about RGB components can detect some otherwise unclassifiable defects.

As a future work, the double camera acquisition can solve some peculiar crack: a deep sloping crack where its detection depends on the way the cork stopper enters the inspection platform.

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