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IDENTIFICATION OF MARKS ON TIRES USING ARTIFICIAL VISION FOR QUALITY CONTROL

Article info:
Received 11.08.2014
Accepted 28.11.2014

UDC – 681.3:658.56

Abstract: *Tire inspection is presently done by workers who have as their main problems, besides identifying the defects, the time available for defect identification and the inherent costs. Companies can become more sustainable by adopting automated methods to perform such type of processes, such as artificial vision, with advantages both in the processing time and in the incurred costs. This paper addresses the development of an artificial vision system that aims to be an asset in the field of tyre inspection, having as main characteristics its execution speed and its reliability. The conjugation of these criteria is a prerequisite for this system to be able to be integrated in inspection machines. The paper focusses on the study of three image processing methods to be used in the identification of marks (red dots) on tires. In this work was used the free Open Computer Vision artificial vision library to process the images acquired by a Basler matrix camera. Two different techniques, namely Background Subtraction and Hough Transform, were tested to implement the solution. After developing the artificial vision inspection application, tests were made to measure the performance of both methods and the results were promising: processing time was low and, simultaneous, the achieved accuracy is high.*

Keywords: *Tire inspection, Computer Vision, Image Process, Hough Transform, Background Subtraction*

1. Introduction

Worldwide, there is currently a growing and exponential technological increase as a result of the need to produce more and with better quality. Only with such mindset of innovation and competitiveness can a place in a particular market be guaranteed.

Thus, automation and automatic control roles are increasing in industry. These

systems have diverse applications such as to take measurements, perform quality control, and make corrections if the product is not in accordance with the predefined parameters. The advantage of automation arises in that automatic processes are usually faster and more efficient than man controlled processes. In addition, these technological systems that aim replacing human operators by automatic systems present the advantage of reducing costs (Ambiente gráfico de desenvolvimento de sistemas LabVIEW). Allied to automation processes arises the concept of artificial vision (Building Vision

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for Business). Artificial vision, also known as computer vision, aims to introduce the concept of vision in automated systems. In artificial vision process the input data (images) are analyzed and evaluated according to a specific purpose.

The application of artificial vision systems is in the growth stage, a growth that is expected to continue, since an increasing number of new applications are appearing. From systems for quality control of industrial products, through license plate recognition systems, to applications in medicine, artificial vision converts actions that were previously performed by operators on actions that can be performed by automated systems, capable of accomplishing the same

task at a lower cost, with greater speed and reliability, thereby improving business sustainability (Building Vision for Business).

The objective of this work is to develop a tool able to automatically detecting a dot (whose example can be seen in the right picture of Figure 1), with a diameter of 10 or 12 ± 1 mm. The system shall provide proper operation when the tire diameter is between 550 mm to 800 mm. In the sequel are described two applications that have been developed in order to identify and perform the quality control of the red dots present on tires, with a maximum processing time (cycle time of the operation) imposed by the customer of 15 s.



Figure 1. Examples of letters and dots on tires

At the hardware level, it was chosen to use a Basler matrix camera, and the lighting system initially adopted consists by 6 high power LED RAY-RL50-F50 spots (Raytek). However, depending on the lighting conditions, the number of LED or even the form of lighting may change. At the software level was used the IDE CodeBlocks, where was inserted and used the Open Source Computer Vision (OpenCV) artificial vision library, and the programming was developed using the language C++ programming.

Bearing these ideas in mind, the next section presents a brief state of the art on artificial vision, followed by section three that presents the project development phase. Next, section four presents some results obtained with the applications implemented and a discussion of the results. Finally, section five presents the main conclusion of the work.

2. State of the art

As the problem to solve concerns the identification of red dots on tires and check its pixel density, the easiest solution, as a first approach, would be to hire a person able to check all these parameters. Another option, which reduces the likelihood of inspection failures, is the creation of a system that, through the use of an artificial vision application, is able to match all the requirements.

For satisfaction of this task, the need arose to use a multi-platform programming library called Open Computer Vision (OpenCV) (Find contours in your image), able to process real-time video/image. The choice of this library was based on being free. After a short market analysis it was found that, in addition to the already mentioned OpenCV

(Find contours in your image), there are a number of artificial vision software libraries to implement applications in industrial machinery systems; however there is a great disadvantage, since they are not free. Within these, a few stand out: Halcon (Matrox Imaging Library), Matrox Imaging Library (McFarlane and Schofield, 1995), Cognex VisionPro (Open Computer Vision), and the library of the National Instruments vision module/LabView (Pinheiro, 2004).

The technique of Background Subtraction (How to Use Background Subtraction Methods) allows subtracting the background of an image to detect the presence of people or other objects in the scene. According to the inspection application, a good example of using this technique, is using a standard image without a tire, and an image with a tire, and thus restrict the tire as the area of interest.

The Hough Transform (Find contours in your image) emerged as a mathematical method known for its great efficiency in the detection of analytical curves, such as straight segments, circles, ellipses, etc.,

embedded even in heavily noisy images. A good example of the use of this technique is the detection of circular objects in an image, such as the dot intended to analyze, this way restricting an area of interest (making unnecessary to analyze the full image).

3. Project development

3.1. System overview

The system architecture is depicted in Figure 2. This system operates in a systematic way: the tire is placed on a conveyor belt moving at a nominal speed of 0.5 m/s; when the tire is detected by a photocell the camera (placed on a mechanical support) is triggered and an image is taken, sent through an Ethernet connection and processed by the image processing system which runs the application developed for the identification of the dot. In order to ensure proper lighting in the detection area where a snapshot is taken, were used six blocks of high brightness LED for illumination of the area.

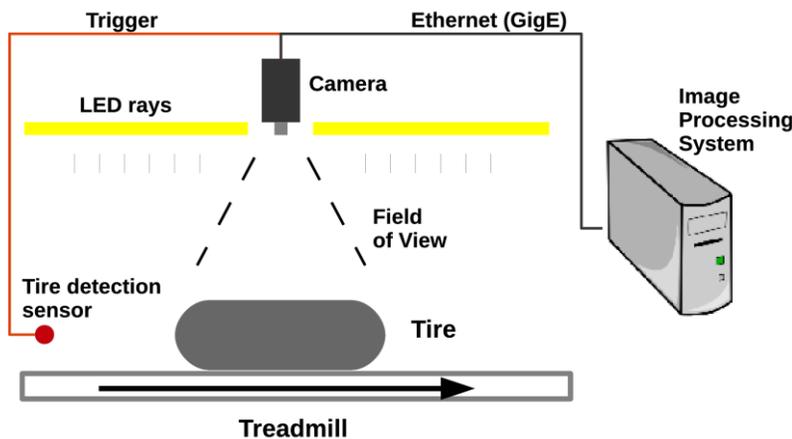


Figure 2. System architecture

In the initial proposed system, a linear camera was part of the solution due to the capability of acquiring images with high quality and sync with the treadmill speed for image reconstruction. However, due to

budget constraints, the camera used is a Basler matrix with a resolution of 1270×958 pixels. With the proposed camera it is not necessary to give the speed of the treadmill, but instead of that is integrated an

external triggering, through a photocell, in order to produce a snapshot only when the tire passes the field of view.

Next 106 images were taken, in substantially the same lighting conditions with the tire at several positions (Figure 3, right) as well as images without the tire (Figure 3, left).

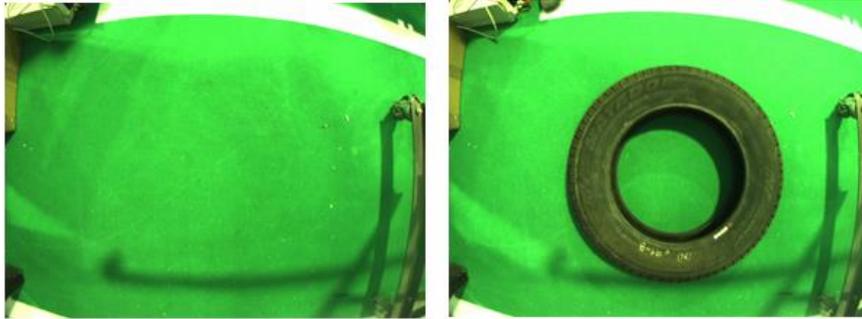


Figure 3. Left: Image of background; Right: Image of the background plus the tire

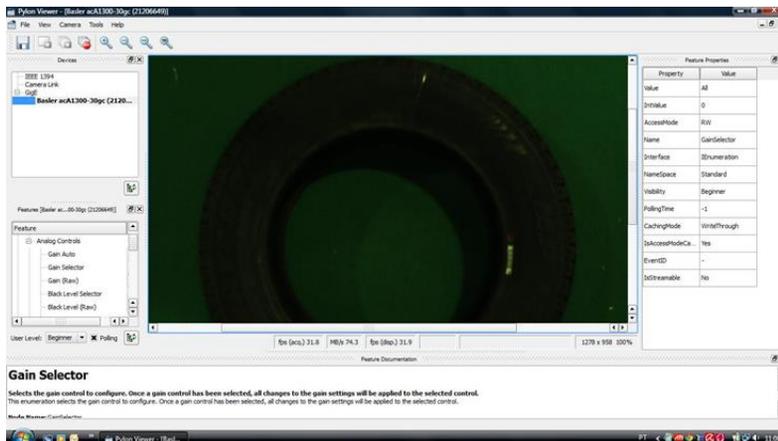


Figure 4. Print screen of the Pylon software user interface.

In order to obtain the images from the camera, the Pylon software, whose user interface can be seen in Figure 4 was used. This program automatically recognizes the camera. In this software it is possible to configure various camera parameters, such as changing the resolution, the gains and speed of image acquisition, ie, change the frame rate.

3.1. System overview

Detecting the tire in the image is essential for the application developed, since this is recommended to facilitate the detection of the region of interest (in this case the tire) to continue with the application. For detecting the tire, two techniques were used, namely the Background Subtraction (How to Use Background Subtraction Methods) and Hough Transform using OpenCV (Find contours in your image) (Figure 4).

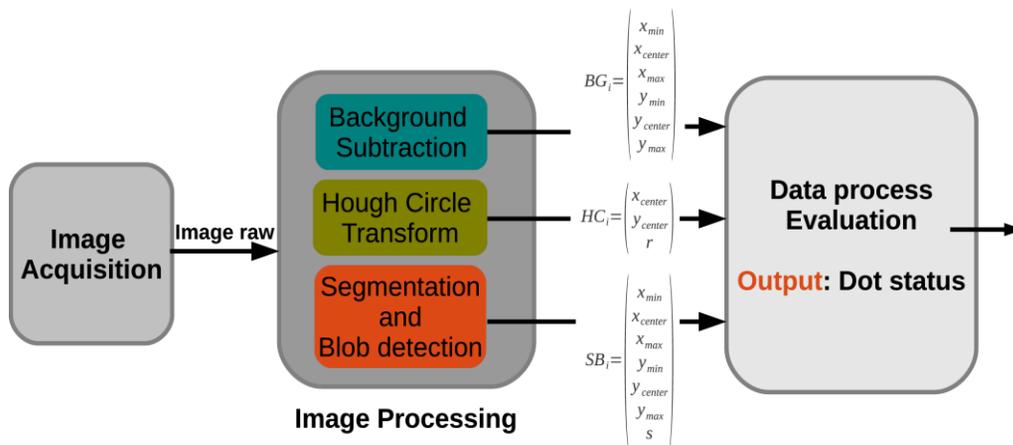


Figure 4. Image processing layer

3.2.1. Background Subtraction

The Background Subtraction technique is widely used in dynamic systems, i.e. systems where there is movement of the subject (How to Use Background Subtraction Methods). Thus, given that the goal is the detection of a particular dot on a tire in motion, it became logical to test this technique. According to this technique, the moving objects are detected by the difference between the background model and the current model - in this case the current model refers to the passage of the tire. Usually a binary segmentation mask is designed to classify any pixel as being or not from the moving object. If the difference between the current image and the reference image for a given pixel exceeds a certain threshold (corresponding to the threshold parameter), that pixel is classified as foreground. There are different models of Background Subtraction, and the main difference among them lies in how they build the background model and how they upgrade it.

It is important to note that there are certain classical problems that should be avoided or addressed by the technique of Background Subtraction, including the variation of light,

camouflage problems, and the existence of shadows in the environment.

Regarding the technique of Background Subtraction (How to Use Background Subtraction Methods), four methods were tested: Mean Background Subtraction (How to Use Background Subtraction Methods), Gaussian Mixture (Sistema de visão por computador: VisionPro), Adaptive Median (Software de Visão Artificial) and Adaptive Gaussian Mixture (Zivkovic, 2004), followed by the application of a Contour function (How to Use Background Subtraction Methods) (according to Figure 2). The choice of technique to be used took into account two decision factors: the processing time of the CPU in the application of the technique of Background Subtraction and extracting the contour of the tire as well as the quality and reliability of the results obtained. After using the Background Subtraction models is used a Contour function whose objective is to use the image resulting from the previous function, and detecting the existing contours that satisfy the condition of having more than “x” dots in a row, being $x = 3700$ in this case, taking into account the tire size and the distance between camera and tire (Segmentação (processamento de imagem)).

This ensures that only the tire has sufficient points to be considered a valid boundary.

The image contours (edges) are obtained through significant colour transitions (Edge) by incorporating a Canny filter (McFarlane and Schofield, 1995). This is a crucial step since extracting the image contours, are extracted the tire contours, which subsequently are used to identify it. The contour function gives as output a rectangle where there is a valid contour, and prints the pixel value BG_i at the coordinates (x, y) from the centre of the square, and the x/y maximum and minimum (Segmentação (processamento de imagem)); the numeric index i is used to identify each image that is taken. Later, this list is traversed and are only accepted those areas that present a number of pixels greater than the number of pixels representing the object under study.

3.2.2. Hough Circular Transform

The Hough transform has emerged as a mathematical method known for its high efficiency in the detection of analytical curves of the types line segments, circles, ellipses, etc., built up in strongly noisy images. Thus, in the last decade the Hough transform has become a common tool used in projects of artificial vision for the recognition of these characteristics.

Another way of performing the detection of the tire has been through the circular Hough transform (see Figure 4). Before being applied the Hough transform, the Red Green Blue (RGB) images are converted to Hue Saturation Value (HSV) in order to better detect the color transitions, since under these circumstances the algorithm is more sensitive to light.

When this technique detects a possible tire, returns as outputs HC_i , that give information about the coordinates (x, y) of the circle centre and its radius (see Figure 4). The index “ i ” identifies the used image.

3.3. Image segmentation and Blob detection

The image segmentation method could be used to cluster pixels into salient image regions, like the colour dots that are intended to be detected on the tire. The procedure to detect these dots is composed by the following steps:

Convert the raw image from RGB colour space to HSV. Although the available LED lights allows the system to be robust to light variations, the images are converted to HSV colour space to ensure that will have a clearly separation between colour components and the light intensity;

Cluster into regions pixels that share the pixel value;

In a heuristic manner, discard clusters with a pixel size s below a define threshold.

This method provides a colour based approach to extract the dots pixels positions $(x, y) - SB_i$ - to the data process block (see Figure 4).

3.4. Technique used for validation of dot

After the detection of tire and dot, it must be verified if the detected dot is contained in the tire. Using this block is guaranteed that possible red objects that could be present in the treadmill are not confused as a red dot in a tire.

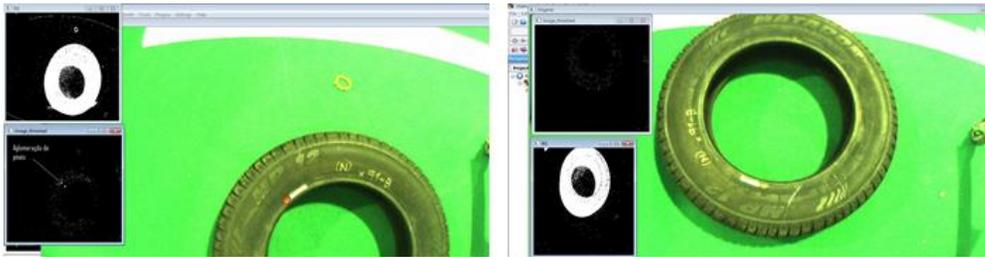


Figure 5. Left: Example of a valid dot; **Right:** Example of an invalid dot

The first step of this software block is to check if the dot presents the minimum acceptable value of quality - if this is not achieved the dot is considered invalid. In case the first condition is ensured, is tested if the pixel values of SB_i are contained in BG_i or HC_i ; if this condition is true for one of the techniques of tire detection, the dot is considered valid (Figure 5, Left); if this does not happen, this dot is considered invalid (Figure 5, Right).

4. Results

The computer in which was developed and tested the application was an HP Pavilion

dv6 Notebook manufactured by Hewlett-Packard. The processor is an Intel® Core™ 2 Duo CPU T9600 of 2.8 GHz, having 4 GB of DDR2 RAM and the Windows Vista 32-bit operating system.

Figure 6 shows an example of the application of the Background Subtraction with Adaptive Gaussian Mixture model (at left side) and tire BG_i output (right side). In case of tire detection using Background Subtraction (How to Use Background Subtraction Methods), this block presents as output a rectangle that bounds the area of the detected tire.

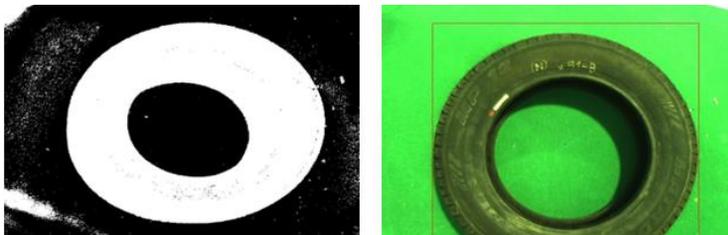


Figure 6. Left: Background Subtraction result with Adaptive Gaussian Mixture method; **Right:** Tire BG_i output

Referring to Figure 7, this shows the Hough Circular Transform result HC_i in tire detection process. Using Hough Circular Transform (Find contours in your image) in order to detect the tire, if this block finds a possible region of tire, returns as output two circles that define the tire. Concerning the dot detection is used segmentation and blob detection; if this block of the application detects a possible dot, this function returns a rectangle that delimits the dot detection area.

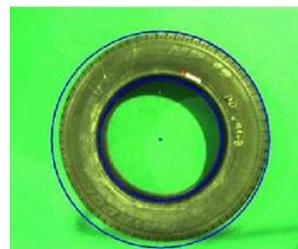


Figure 7. The Hough Circular Transform results HC_i in the tire detection process

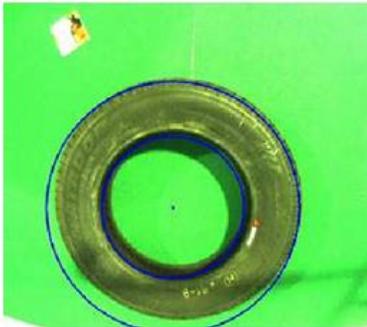


Figure 8. Image segmentation SB_i and Hough Circular transform HC_i output result

After the tire detection, as well as of the dot, is checked if the detected dot is contained on

an area that represents the tire that has been detected – if it’s true the dot is considered valid (see Figure 8). Using two different techniques to tire detection is reduced the probability of tire failure detection.

4.1. Discussion of the results

The choice of the technique to be used took into account two decision factors: the processing time of the application, as well as the success rate in the dot detection. These performance measures, for the different methods tested, are presented in Table 1.

Table 1. Summary table of the final outputs of the application

| Technique | Model | Percentage of successful dot detection | Average processing time per image (ms) |
|--|------------------------------------|--|--|
| <i>Background Subtraction</i> | <i>Mean Background Subtraction</i> | 10 % | 243 |
| <i>Background Subtraction</i> | <i>Gaussian mixture</i> | 90 % | 650 |
| <i>Background Subtraction</i> | <i>Adaptive Median</i> | 89 % | 224 |
| <i>Background Subtraction</i> | <i>Adaptive Gaussian mixture</i> | 90 % | 405 |
| <i>Hough Transform</i> | - | 71% | 600 |
| <i>Image Segmentation and Blob Detection</i> | - | 80% | 60 |

Given the data in Table 1, it can be concluded that the application of the model developed based on the Mean Background Subtraction was the one that presents lower performance, having a success rate of 10%. On the other hand, the other three models grant a large success rate, between 89% and 90%, and the Adaptive Median model is the one presenting better performance with regard to reliability ratio / speed. However, the other two models, although slower, had also a very good success rate. For the application that appealed to the Hough

Transform technique, the success rate is 71%. In the case of application of the Background Subtraction using Adaptive Gaussian mixture model, in addition to presenting a good reliability/speed relation, it also presents the advantage of being able to be installed in different scenarios without the need to make changes in order to obtain a new background (automatically generated). This is the main reason why it was selected for this application.

5. Conclusions

In this work were developed two applications, aimed at performing the detection and quality control of a dot on a tire. Different techniques were used, namely the Background Subtraction and Hough Transform. The development and testing of both applications allowed determining the best technique for the case study. In order to solve the problem of identification of red marks in tires, other techniques could be used, for example, Template Match (Find contours in your image) such as Training Classifier (Find contours in your image).

The project developed yielded good results, with success rates of 90% for three of the four models applied. The processing time of the application is very positive, since it is needed an average of 500 ms to evaluate each image, which is a value much lower than the maximum time of 15 s defined by the company. Thus, it was obtained an excellent quality/processing time ratio. This allows increasing the business sustainability of companies that need to perform repetitive inspection tasks, such as the case in the tire industry.

With respect to future developments, the first one will be the integration of the entire

system, i.e. hardware and software. Moreover, the developed application detects only the red dot – a function can be developed in the same application to detect a white dot. Another possible development would be the implementation of a database which would keep real time outputs of the developed application. This would allow checking at the end of a production day the number of tires that passed with the dot well marked, and the number that came on the production treadmill without the dot or with the same poorly marked. The identification of the brand and model of tires that are on the line could be also interesting and its integration in the database suggested. Other possible future implementation could be using real parameters despite of use of pixels values.

Acknowledgment: The authors would like to thank Gislotica-Mechanical Solutions, who welcomed us to develop this project, and all the people who are part of it. Special thanks are due to Eng. Rui Fazenda for all his help and support during this work. Thanks are also due to the Autonomous Systems Laboratory at ISEP for allowing performing all tests on its premises and for lending some needed equipment.

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