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Classification of Meat-grinder Chucks using Image Processing

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ABSTRACT

The work performed includes an end-to-end solution to a product classification problem with machine vision. Meat-grinder chucks separated by manpower within the company cause loss of time and errors. To solve the problem, chucks are detected with an infrared sensor, and the photos are taken. First the outer diameter of the chuck is calculated by Hough transform, after that, focusing inside the chuck, the radii of the inner circles are found. The circles found (in order to evaluate more accurately) are trained via a machine learning algorithm Naive Bayes method, the model is obtained. It has been determined in the study that this problem can be solved by a simpler method, mode operation. The output of the trained model indicates which class the product belongs to. The pneumatic pistons in the system are triggered by the time cutter software running on it and the products are separated to determined box. As a result of the tests performed on the system with the method of taking mode, it was determined that the model works with 99.2% accuracy. In the tests performed with the Naive Bayes method, an accuracy of 95.8% was achieved.

1 INTRODUCTION

Today, product classification is done in different ways in industry. Although businesses use manpower in some cases, with the innovations that come with Industry 4.0, the classification process is performed with less cost and more reliability by using sensors that can measure different features such as weight, color and area measurement. Cameras come into play for more complex problems that cannot be solved with sensors. Classification, counting and quality control processes can be performed on the images obtained from cameras by using image processing technologies. The study includes the solution of the process of separating the products of a company that produces meat-grinder parts in the metal industry. The parts to be separated are metal parts called meat-grinder chucks with different inner and outer radii. Today, defective product classifications are carried out in these parts, which are separated by human power, and their meat-grinder chuck' properties cannot be understood with any sensor. In the study, the necessary hardware infrastructure was established, then the images obtained with the object detectors were processed and the correct classification of the meat-grinder chuck was carried out. The radii of the circles in the meat-grinder chuck were determined by the Hough transform algorithm. Results in different threshold values and ambient conditions are discussed. The class of the product was determined with the data analysis performed on the dimensions of the detected objects. In addition to the image processing application, information about the robotic process and hardware that the application runs on are explained separately in the third section.

2 RELATED STUDIES

There are many studies on flat detection procedures. The Hough transform, which technically forms the basis, was first used by Paul Hough in 1962 for "correct detection" [1]. In 1987, Davies used the Hough transformation for "determining circles" (Circular Hough Transformation-CHT) [2], followed by Yip in 1992 for "determining ellipses" [3]. In the book titled “Digital Image Processing” by Rafeal C. Gonzales, he explained in detail the basics of the Hough Transform [4].

The study detected axial shifts and length measurements with a 99.7% success rate. Kuang-Chao Fan et al. conducted a study in 2010 on the development of the "automatic defect classification in porous powder metallurgy products" [5] system. In the work carried out, 100 flawless 150 defective parts were tested in the test environment. Defective parts are classified as dents, cracks, broken corners, and only 2.08% of faulty detection has been made. Amit et al. Used CHT for the problem of "iris segmentation" [6] in 2012. They tried the success of the study in two different CASIA data sets and achieved a very high success rates of 99.8% and 99.7%. The work carried out by Wencheng Wang et al in 2015 is an end-to-end image processing application from hardware to software. Measurement is a very important factor in the production of gears. Thanks to this study, the radius of the gears, the radius of the circle and the formulas based on them and other properties of the gears are calculated. According to the results, the malfunction in the gears has been detected. When calculated with traditional methods, it has the same sensitivity as the device that measures with an accuracy of 0.1mm [7]. In the "Error Detection of Cylindrical Bodies with Image Processing" [8], which was published in 2018 by Kürşad Uçar, the error detection process occurred in cylindrical bodies measurements and production was carried out. In December 2018, K. Dhanalakshmi et al. used the CHT algorithm for smart farming and achieved 98% accuracy in their studies that count stock for orange production [9]. In April 2020, Chuan-Pin Lu et al. compared CHT with an algorithm based on convolutional neural networks. For the first example, it was observed that CHT gave better results. In other samples, it was observed that the results worsened because the CHT parameters were left constant. Here, the biggest advantage of the convolutional neural network is that the algorithm does not require variable parameters [10]. In October 2020, Shiluo Huang et al. proposed a new method for automatic measurement of circular fiber sections. In the study, fiber, metal and wood with circular properties are detected with CHT and the first measurement is made. An edge tracking algorithm is applied to improve the result. Considering the perception performance and size accuracy, 5 different methods were compared in the tests. The results of the tests including the modified CHT, 21CHT [11], EDCircle [12], Forna [13] and the proposed method are respectively 0.982, 0.863, 0.194, 0.128, 0.977 [14]. In the study of measuring gear size parameters based on CHT segmentation written by Xiong and He in 2020, the center of the gear was found using the Hough transform. Based on the distance from the contour point to the center point, a new coordinate system is established. The gear contour is expanded to a normal curve in the new coordinate. The vertex number of the curve is the number of teeth of the gear and the crest coordinate is the radius of the tooth tip circle of the gear. Then, other gear parameters are calculated according to the gear formula [15]. In August 2020, Manuel G.Forero et al. Carried out the detection and counting of the samples in petri dishes with CHT and RANSAC algorithms, eliminating a tiring and uncertainty problem in the field of biology [16].

3 MATERIALS AND METHODS

The work carried out is generally examined under 2 different main headings: hardware and software activities. The general purpose of the study is to separate 6-7 different combinations of 47 kinds of meat-grinder chucks during the production phase between the dryer and grinding machine.

3.1 Hardware

Embedded system consists of camera, conveyor belt and pneumatic arms in the study, which is examined in 4 different subjects as hardware (Figure 1).

In order for the image processing models working on the background to work effectively, not only computers with central processing units but also Nvidia Jetson Nano development boards, which are integrated platforms with Nvidia graphics processing unit, were used. Using the graphics processing unit here, accelerating the works 3 times [17] thus preventing the production line from slowing down. It is also used because it takes up less space in the factory and can be adapted to the industry more easily. It has an integrated 128-core Maxwell GPU and a 4-core ARM Cortex-A57 CPU as well as 4 GB of RAM.

Since the products have a metal and shiny surface, a softening filter was applied to prevent specular light reflections on the image.

A camera with a CMOS sensor is used to obtain image data that adds value to the work. Camera features are of great importance in image processing. A 2.8-12mm varifocal camera with SONY IMX179 CMOS capable of 30 FPS image transfer with 8mp resolution is used.

The conveyor system on which the products will move, direct and discharge the products will be located on the pneumatic arms 3 meters length, 80-95 cm adjustable height, body width 30cm, body sheet 4mm. Band width 20cm, belt material is rubber and matte black. Drums are rubber coated, rubber feet to reduce vibration and 9-16 m / min. adjustable speed motor is used. Selected values were calculated considering product weights, widths and vibrations.

6 Arduino Uno, which enable the pistons to be triggered by receiving the signals coming from the main computer, are used. It provides power to the pistons by means of a roller, ensuring that the product is thrown at the right time.

Pneumatic systems, which are frequently preferred in automation, use air pressure as a working principle. The most optimal selection was made depending on the weight of our products to be classified, the friction losses occur with the rubber, the width of the belt, the expected exit time of the product from the band and the speed factors. It used 5/2 size spool valve for pistons with 32 cylinder diameters. To supply air, an air preparation supporting up to 12 bar was chosen.

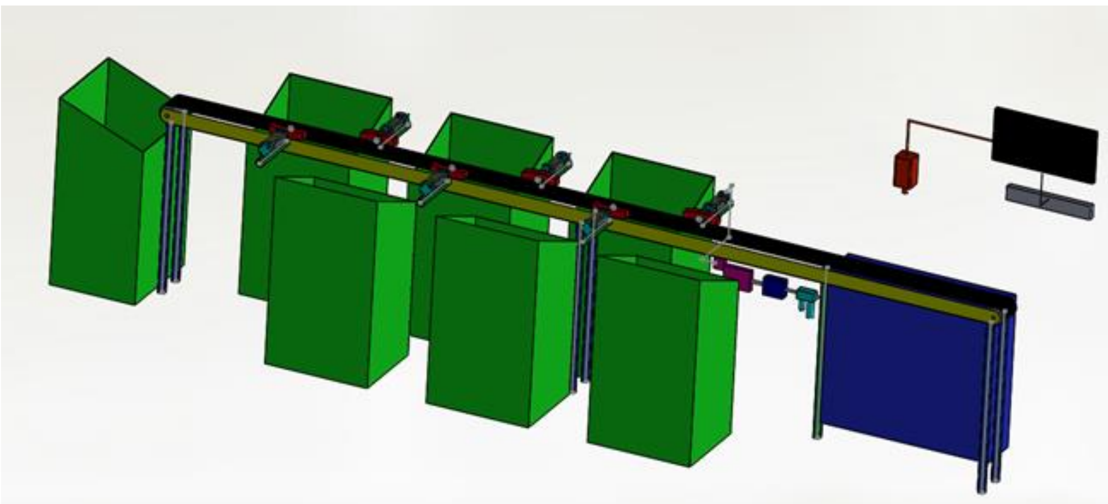

Figure 1: Technical Drawing of the Implemented System

3.2 Software

In the software part of the article, the software that works as a multi-thread application that will capture and process image and to trigger the pistons is explained.

3.2.1 Triggering with Sensor

Infrared sensors (Figure 2) are used to detect the product coming to the production line. After the signal transmitted through the sensor is interrupted by any object, it performs the detection process by reflecting the signal back. Counting [19] is used in many applications such as locating and obstacle detection [20]. It is used for the camera to take the image at the right time in the study. When the change on the analog value coming through the sensor detecting the object exceeds a certain threshold value, the camera is triggered with a delay of 1 second through the microcontroller.

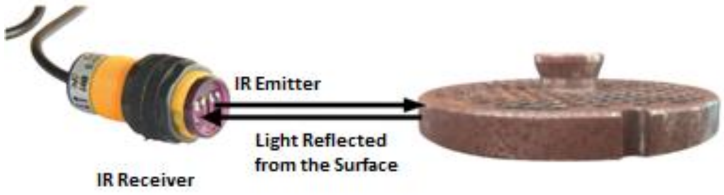

Figure 2: Infrared Sensor Operating Logic

3.2.2 Classification by Image Processing

47 different meat-grinder chucks are classified with the data received from the camera triggered by the sensor. As a result of the examinations carried out, the distinctive features of the products are sufficient information for the classification process, the diameter of the hollows inside the chuck (Dø) and the diameter of the chuck itself (Aø).

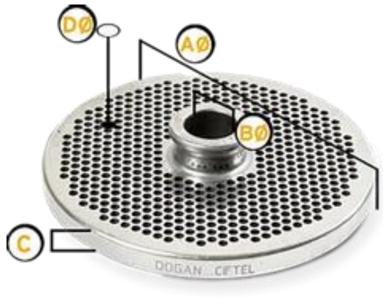

Figure 3: About Mincer Plates

The features such as Aø and Dø are used for classification, and these features are shown in Figure 3.

The images obtained from the camera are processed using OpenCV libraries with Python. The resizing process is performed because the images that come with 3264x2448 pixel resolution will increase the processing time. When the image is reduced below a certain resolution, it will lose its properties, so the optimal range (1600x1200) is found by trial. Although the same threshold values are used in the realized circle detection algorithm, the performance comparison in size change is shown in Table 1.

Table 1 Resolution Dependent Performance Comparison

Resolution	Processing Time
3264 x 2448 px	0,727 ms
1600 x 1200 px	0,302 ms
800 x 600 px	0,200 ms
400 x 300 px	0,178 ms

The resizing process with a resolution of 1600 x 1200 px is sufficient not to lose the features on the image, and at the same time, the process time, which is approximately 2 times faster, has been the reason why the lower resolution is preferred. The images obtained are read with RGB color channels. This color model, which holds the values of red, blue and green colors, is more complex for image processing than grayscale. Calculation complexity in the images that are returned to gray level is also eliminated, thus reducing the processing time [21].

$$Y = R * 0{,}299 + G * 0{,}587 + B * 0{,}114 \tag{1}$$

With the formula shown in Equation 1, the image with RGB color values is transformed into gray tones as shown in Figure 4.

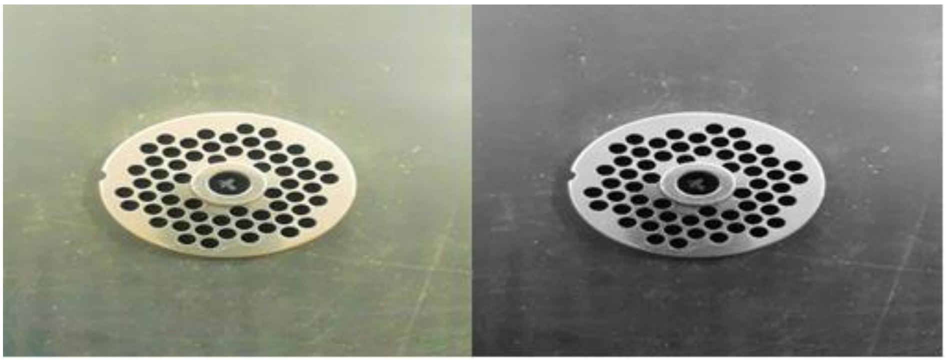

Figure 4: Color and Grayscale Image

The image is blurred to remove the noises and sharp lines on the image. It is realized by applying a filter matrix over the whole or a region, not pixel-based [22].

$$K = \frac{1}{matrixWidth * matrixHeight} \begin{bmatrix} 1 & \cdots & 1 \\ \vdots & \ddots & \vdots \\ 1 & \cdots & 1 \end{bmatrix} \tag{2}$$

A simple level smoothing algorithm (Equation 2) was used in the study. The filter matrix used is 3 * 3. In cases where the 3 * 3 filter matrix, which is optimal for all classes, is not applied, the number of flats found increases, and erroneous determinations have been made. In cases where the size was increased more than necessary, the number of flats found decreased. The smoothed image is given in Figure 5.

Figure 5: Smoothing Applied Image

The preliminary processes have not only improved the image before the circle detection was done, but also provided serious improvements in the accuracy results. The most important part in the classification process is the determination of circles. The proven hough transform is used in this regard. Although it has high accuracy, it requires high calculation and memory. The resizing and gray transformation that we have applied to the data in the preprocessing part reduces the calculation and memory requirements.

Hough Transform is one of the most important methods used when detecting objects. It is used to find the shapes, locations and angles of simple objects. Simple objects (line, circle, rectangle, etc.) can be explained with more than one parameter. The parameters for a circle are center coordinates and radius.

The Circular Hough Transform, an extension of the Hough transformation, is one of the feature determination techniques on digital image processing. Edge of the image is detected and circular shapes are determined by applying Hough Transform. The basis of the Circular Hough Transform CHT is finding the points that form the edges. We apply an algorithm that can extract the border lines of our source image. After this application, only the borders of our circle are highlighted with 255 pixel code (white) and the remaining pixels are converted as 0 (black). To understand the next step, the most important thing is to know the equation for drawing a circle. If we know this equation, we can draw a circle on each point that makes up the edge. Circle centers are highlighted for each point. After completing the circle drawing process on all edges and finding the circle centers, the one with the big circle center is selected as the circle center. There is primarily an outer circle for the chuck. First of all, the reason for the outer circle is to search for small circles in a narrower area, thus saving memory and calculations.

Figure 6: CHT Applied Product

In the pixel-based measurements made on the image, the small circles radii were calculated as 15. It was seen that the most common circle radius in the detection process made with the CHT algorithm was 15. Due to the fact that there are many different classes, extra, missing or not correct circles are detected in the circle detection via image processing. This problem, which causes incorrect classification, has been solved with machine learning algorithm. The Naïve Bayesian classifier greatly simplifies learning by assuming that the properties are independent of the given class [23]. The radii of the first 20 circles detected after the CHT measurement process of the sample images taken on the line are recorded (Figure 7). In this way, the calculation process is accelerated and the memory usage is reduced. The probability calculations that will determine which class the mirror belongs to by performing the labeling process are calculated with Equation 3 [24].

$$P(c \mid x) = \frac{P(x|c)P(c)}{P(x)} \tag{3}$$

30 data were obtained for 8 classes. The training performed with the data gave 95.8% accuracy. Although the accuracy value seems theoretically high, a device operating in the industry also causes serious problems. The prediction process performed with Naive Bayes takes half a second for 8 classes. However, when this number reaches 47 classes, the accuracy value decreases and the processing time is longer. Also, when a different product type is added, re-labeling and training of the entire model will be required from the beginning.

Although naive bayes allows measurement with simple calculations, it has been observed that the calculation of the mode after keeping the circles obtained in the study as a series gives simpler and more accurate results.

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[49, 49, 49, 49, 48, 47, 47, 15, 16, 15, 15, 16, 15, 15, 16, 15, 16, 19, 15, 16, 16, 15, 15, 16, 16, 15, 15, 15, 19, 16, 16, 15, 15, 15, 15, 15, 19, 16, 16, 16, 15, 15, 15, 16, 15, 15]
Hole Size : 15
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Figure 7: An Example Circle Radii List For All Circles Found

The most repeating number in the data series with the circle diameters we obtained from the CHT algorithm is called “mode”. The number of repetitions of radius number is called frequency. The output of the data series and mode value is shown in Figure 7 for the tested product. Mode values for 47 products are calculated and stored in the database. In this way, the data obtained from the camera in the next stages is compared with the mode values in the database by CHT operation and the classification process is performed. As a result of the tests, the classification process was carried out with an accuracy of 99.2%. The test result for 1000 products is shown in Figure 8.

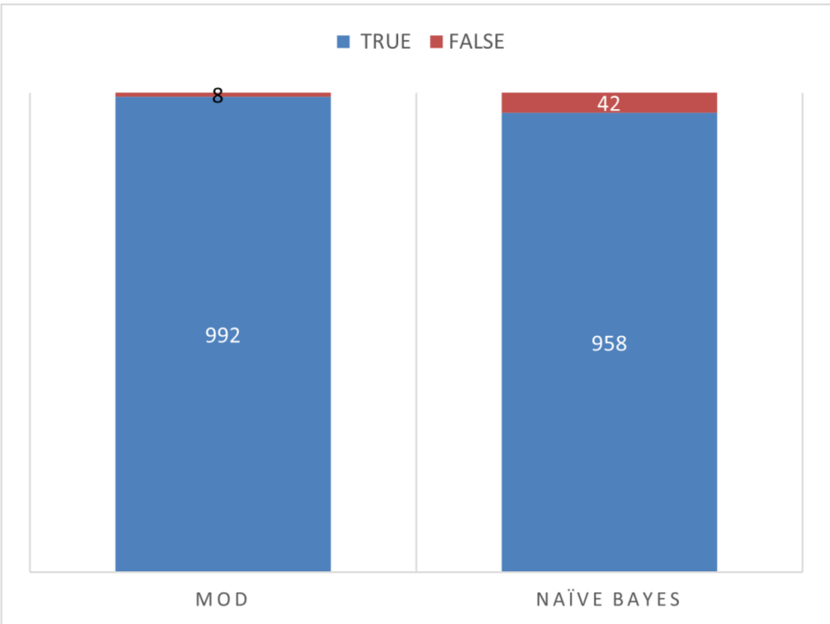

Figure 8: Test Results for 1000 Products

As a result of the tests, it has been determined that erroneous classifications are carried out, especially in the data that the surface glare and the camera cannot capture the image clearly. In Figure 9, visuals giving incorrect results are exemplified.

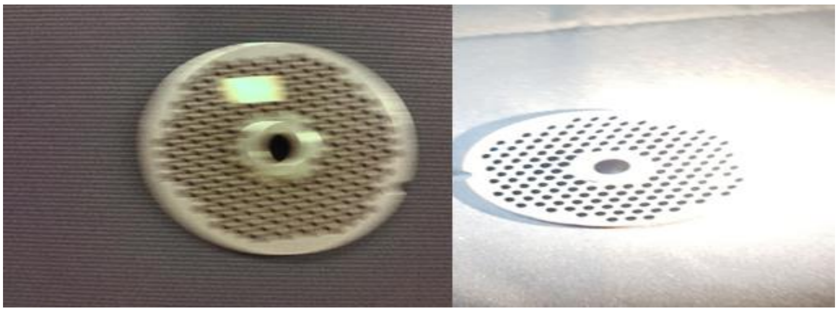

Figure 9: Incorrect Images

3.2.3 Pistons Triggering

Since the products for which the classification process is completed come one after another, our controller with a single microprocessor causes temporal shifts, which causes piston triggers at the wrong time. In order to eliminate this problem, a microprocessor was connected to all pistons. In this way, the correct pistons could be triggered in cases where different products came in succession. However, when products belonging to the same class come one after the other, the shifts continue. Since there is no multi-core concept in the system where Arduino nano is used as a microprocessor, more than one operation can be performed almost simultaneously by using a time breaker [25].

4 CONCLUSION AND DISCUSSION

The software controlling the machine designed and manufactured in the work carried out classified the circle diameters obtained from the CHT algorithm using the Naïve Bayes method and the mode process. As a result of the classification, the products were transferred to the correct boxes. Due to the accuracy of 99.2% and the speed of the mode taking method, it was preferred over the Naïve Bayes method, which gives an accuracy of 95.8% and has difficulties in terms of speed and training.

In order to use the CHT algorithm more quickly, parallel calculation methods can be preferred. In this way, it can be used in production lines with much faster flow. Studies in the field of deep learning have been increasing day by day. Deep learning algorithms can be used in cases where the images are more complex. In this way, studies can be carried out to increase the product quality in production lines. CHT and deep learning algorithms can be processed with CUDA and high-speed calculations can be applied.

Since the products to be classified have metal and shiny surface, dome lighting can be used to minimize specular light reflections and irregular color distributions in the image.

Camera hardware, on the other hand, creates serious differences in image processing. Since the shutter mode of the camera used is roller, the image taken on the flowing tape is not clear. Cameras with global shutter mode capture moving objects much more clearly. Here, a camera with a shutter mode, which is more cost-effective, was chosen. It would be appropriate to use global mode cameras in faster bands.

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