# Automatic Sorting Machine Based on Vision Inspection

Robert Ciobanu, Dana Rizescu, and Ciprian Rizescu

***Abstract*—This work describes detailed an automatic vision system for quality control of small conveyed mechatronic components. The vision measurement has the advantages of non-contact measurement, high precision and high automation degree, thus it has become one of the important trends of development in modern measurement technique. The system highlighted in this paper sorts automatically the components inspected depending on the fabrication fault type detected by means of an electro mechanic system controlled through a serial port. The proposed system has been tested for a series of 608ZZ bearings which have been evaluated through a completely automated process. The proposed system can improve the control efficiency and can be integrated in to an existing fabrication line.**

***Index Terms*—Vision inspection, edge detection, sorting system, optics aberration.**

## I. Introduction

The current trend of the mechatronic systems and subsystems used in industry is to reduce its size and at the same time increase its performance. The miniaturization of the mechatronic components has produced a number of changes in the manufacturing flow. One of the objectives of the work is to develop a visual inspection system and optimize the process for checking diameters of small cylindrical components automatically and standardized. In terms of system development, the need for flexibility and adaptability was considered for a wide range of sizes. The results obtained are satisfactory from the accuracy point of view. Classic automated sorting systems are still a global problem due to the low degree of flexibility, which makes them extremely expensive.

Measurement of dimensional and geometrical deviations of circular profiles requires:

- Scanning at least 360 °of the piece in a circular section perpendicular to the axis of the piece;
- Precise axis of rotation;
- High precision transducers;
- performing data processing systems.

In order to measure deviations from the geometric shape of the circular profiles there are two groups of methods. The major difference between these two sets of methods lies in the reference element against which the form deviation is determined. The first group of methods, referred to as relative or intrinsic methods, refers to points on the surface of the piece as reference. The second group of methods, referred to as extrinsic methods or methods of measuring the variation of the beam uses a reference element outside the measuring piece.

Lately, industrial quality control has been achieved through vision systems[1]-[4]. Current trends are to sort objects according to certain features that define multiple levels of quality[5]. For these vision systems, a series of algorithms based on image processing have been developed[6][7]. In contrast to classical inspection systems, machine vision based on automatic inspection techniques have the advantage of high efficiency, low cost and high automatization degree [8], [9]. The work herein presents a constructive solution for the inspection of objects transported on a high-speed belt.

The solution proposes the implementation of a vision system characterized by a dedicated image analysis algorithm. The automatic visual inspection system has been benefited from the steady development of machine vision. However, for the dimensional control industry with high-speed requirements, how to integrate the automatic machine vision inspection system with the original production line is a challenging work. The vision inspection system propose in this paper was tested for bearing inspection. The solution proposed has been projected taking in to account that the time requirement for quality control in a production line needs to be small. Having a multi-objective optimization problem an image processing algorithm with low computational complexity and high efficiency was developed.

The propriety of this work is supported by a survey at the level of the local bearing manufacturers, which revealed that the process of the bearing rings dimensional control is performed in manual mode, with mechanical comparators, by sampling

## II. System Concept

The main objective of the work is to develop a visual inspection system and to optimize the inspection process of small cylindrical components automatically and standardized.

For system development, the need for flexibility and adaptability was considered for a wide range of sizes.

Figure 1 shows the proposed concept for the automated vision system that can be integrated into a manufacturing line. The inspected objects are placed on the conveyor and transported at a constant speed. The image building-up and acquisition system is fitted above the objects subject to control. The acquired images are analyzed by means of a computer. The parts feeding system is fully automated and controlled, the acquisition of the image taking place when the component to be controlled is at the center of the image. This reduces the possible radial and tangential distortions introduced by the optical system. Sorting out the analyzed

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objects is achieved by means of a servomotor controlled by the calculating unit, depending on the result obtained from the image analysis. The system also proposes a pneumatic subsystem to increase sorting flexibility, thus allowing integration into a wide range of applications.

The equipment is intended for controlling ball bearings on a row and cylindrical rollers by determining: circular bore deviation, concentricity of inner diameter with outer diameter, deviation from circularity of outer diameter.

Fig. 1. Realized system.

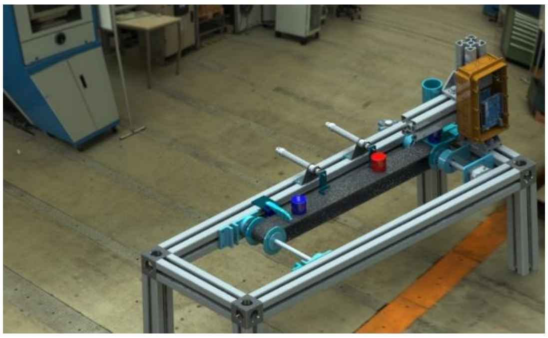

Fig. 2. Sorting system.

In order to ensure the proposed system efficiency, each unit must be checked for less than 2 seconds.

### A. Acquisition and Processing Image System

The proposed acquisition and processing image system consists of:

DCC3240C Camera - High-Sensitivity USB 3.0 CMOS Camera, 1280 x 1024, Global Shutter, Color Sensor, Optical Sensor Class 1/1.8", Pixel Clock Range 5 - 85 MHz, Frame Rate 60.0 fps, Lens Mounting Thread C-Mount (1.00"-32);

Objective: 1. Focal length: 25.0mm; 2. f/number: f/1.4~16; 3. Iris control: manual, lockable; 4. Focus control: manual, lockable; 5. Picture size: 8.8x6.6mm; 6. Diagonal full field of view: 24.3°; 7. Max TV distortion: -0.04%; 8. Minimum working distance: 0.2m; 9. Max object size at minimum working distance: 60mm;

Computer Inter Core i7, 7500GHz, installed memory 8 GB.

The camera is soft triggered, data transfer being made via USB 3.0. The uniform distribution of light is provided by the illumination system composed of three light sources circularly arranged at 120 degrees.

### B. Transport and Sorting System

In order to transport components passing through the camera for testing purpose and continuing their way to selection (according to or not), we chose to make a belt conveyor. We chose the belt conveyor because components under control are of reduced size and dimensions.

A linear pneumatic engine was selected to feed the sorting belt. Arduino type development plates were used in order to control the conveyor belt drive motor (Fig. 3 and Fig. 4).

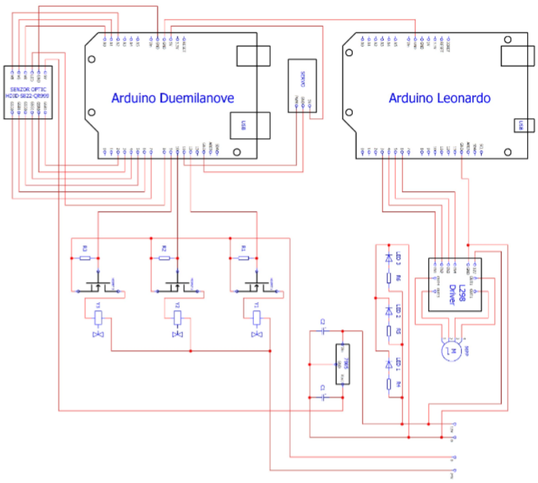


Fig. 3. Electronic circuit.

Following the tests, the step-up speed of the engine was synchronized with the image acquisition frequency, taking into account the minimum time required for image processing.

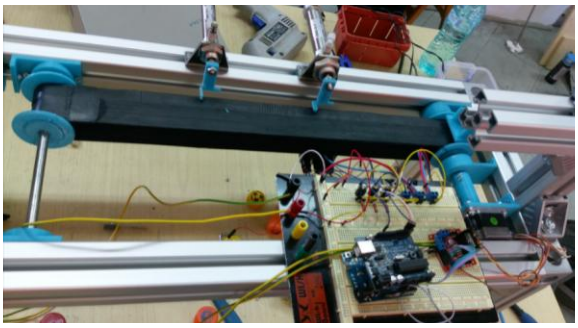

Fig. 4. Electronic control board.

The proposed system was also equipped with a pneumatic sorting system for implementation in complex applications[10].

In terms of working routine, the camera performs an image capture of the inspected item. The acquired image is transmitted via USB 3.0 to a PC in order to be analyzed. Image analysis involves performing some steps such as changing the counter, applying filters, in order to get a precise contour for the inspected component. After extracting the contour, the results are compared with a theoretical standard, establishing the quality of the inspected component.

After sizing and checking the piece, the PC sends an electrical signal to the actuator control board operating the electromechanical sorting system. If the piece conforms, the actuator remains in the OFF position, and the component continues its way until it falls into the compliant piece collector. If the piece is inconsistent (information resulting from image processing and checking), then the PC sends an electrical signal to the actuator. The actuator switches to the ON position and removes the inconsistent component from the conveyor belt, allowing it to reach the scrap collector. After removing the defective component, the actuator returns to its original position.

### *C. System Calibration*

In order to reduce radial and tangential distortions, the component supplying subsystem has been synchronized with the camera image acquisition frequency in order for the inspected element to be close to the camera optical axis perpendicular to the conveyor belt plan (Fig. 5).

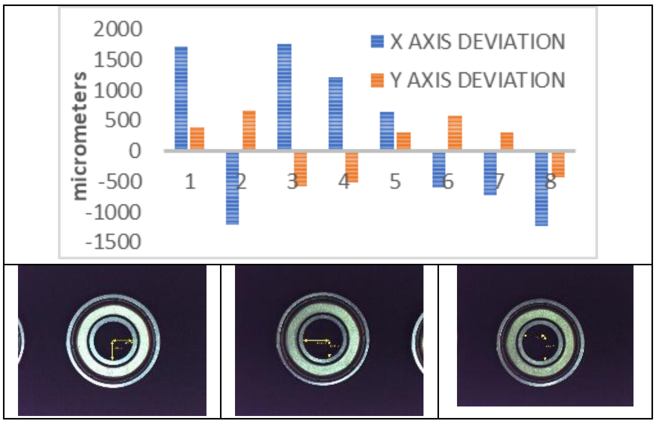


Fig. 5. Deviation from the center of the image.

Because the optical system introduces image distortions, camera calibration is critical to the accuracy of the measurements. Calibration represents the process whereby the theoretical model where through an object point is transposed into a pixel is determined. The transposition of an object point Q from the object plane into the $Q_S$ sensor plane is carried through a rotation R and a translation T:

$$Q = (x, y, z) = R * Q_S + T \quad (1)$$

Given the known focal distance f, the 2D image results in a projection in perspective.

$$v = (v_x, v_y) = (f\frac{x}{z}, f\frac{y}{z}) \quad (2)$$

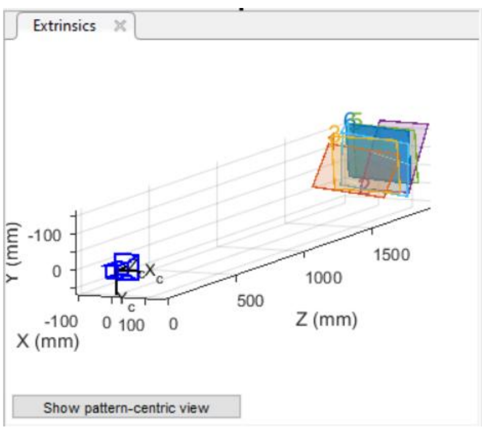


Fig. 6. Camera calibration.

The resulting image is corrected by the radial distortion coefficient, resulting in a geometric image of the object. The optical system formed by the lens and the video camera was calibrated using a 7x9 chessboard using the single calibration camera function in MATLAB (Fig. 6). The chess board accuracy is extremely important, the squares being drawn with an accuracy of 1 µm.

## III. Edge Detection

Edge detection is the process defined by an algorithm of finding the exact pixels in the digital image where the image brightness changes suddenly[11]. By filtering the image, the contours of the parts under control is defined more clearly. For vision measurement technique, how to implement the high-precision edge detection represent the critical point of research[12].

The algorithm flow chart proposed for edge detection is shown in Fig. 7.

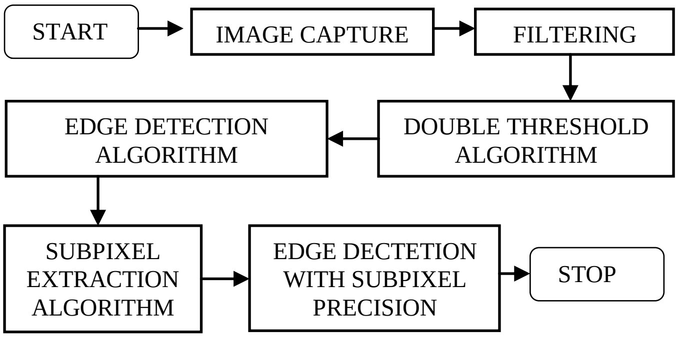


Fig. 7. Edge detection algorithm.

In a general classification, subpixel edge detectors are divided in three types: based on interpolation, moment-based approaches and curve-fitting methods [13]. Analyzing the precision and complexity of most subpixel edge detection methods, a cubic spline interpolation method was selected to improve the accuracy of the results [14]. The cubic spline interpolation method is to define an interpolation formula that is smooth in the first derivative and continuous in the second derivative within an intervalnb [15].

To determine the interpolation node exactly, the location of the image edge was approximated by double thresholding algorithm. Around each edge pixel was generated a square matrix of 5 pixels and four directions were defined as gray gradient direction in this rectangular area: 1, 2, 3, 4. The angle of adjacent direction is 45 degrees (Fig. 8).

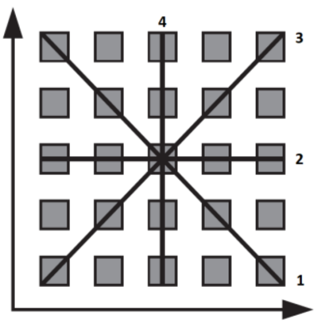


Fig. 8. Canny edge detector.

The direction is determined by the absolute value sum of difference between the pixel gray scales, which is calculated as:

$$D_i = \sum_{k=0}^{4} |p_{k+1} - p_k| \tag{3}$$

After that, cubic spline function for direction detected was created. Using MATLAB, the zero point at second derivative of the interpolating function defined were calculated in order to determine sub-pixel points (Fig. 9).

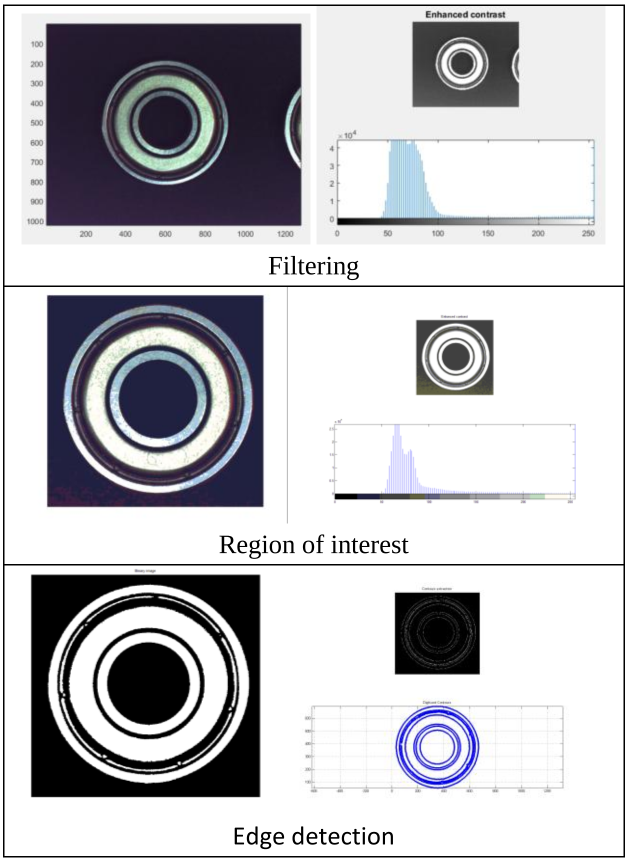


Fig. 9. Edge detection algorithm.

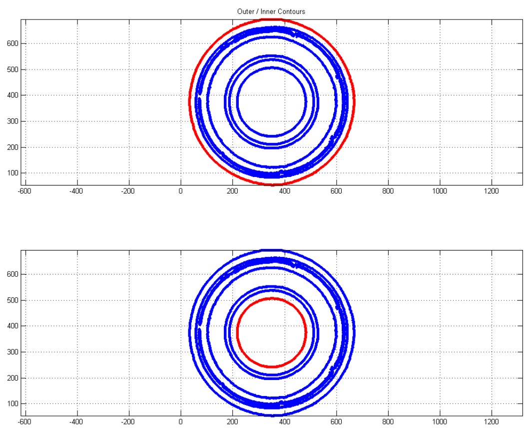


Fig. 10. Inner and outer ring contour definition.

Using the edge detection algorithm, boundaries of the inner and outer ring were identified (Fig. 10).

Once the boundary of the inner/outer ring was localized, the size as well as other features of the bearing can be determined (Fig. 11).

For circular cylindrical profiles, digital metrology has allowed the development of assessment programs that are based on Fourier series analysis.

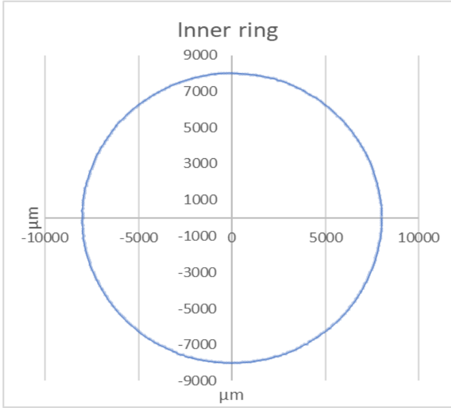


Fig. 11. Circular profile of inner ring.

For a number of N points measured in a cross section of a revolution surface(fig. 12), N measured values result, ie N numerical samples $x_n$, where n = 0,1, ... (N-1). For all of these samples the DFT was determined with the relation:

$$X_k(n) = \Delta T \sum_{n=0}^{N-1} x_n e^{-ikn\theta}, \ k=0,1..., N-1, \ \Delta T = T/N \tag{4}$$

The measured points being evenly distributed on the periphery of the profile, the sampling period is:

$$\theta = 2\pi/N \tag{5}$$

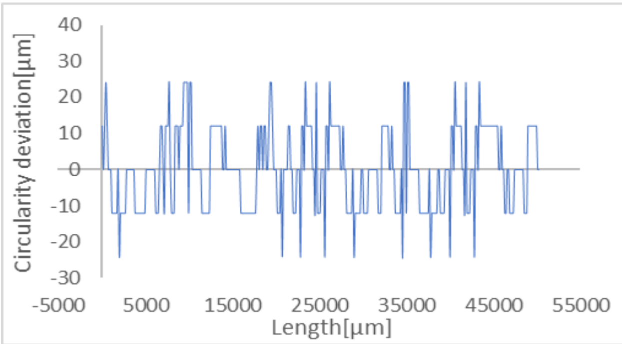


Fig. 12. Circularity deviation for inner ring.

The N components of spectrum $x_n$ ($n$ = 0,1, ... $N$-1) are calculated. To determine rays unaffected by eccentricity, deviations shape deviation, coefficient of order 1 of Fourier series is eliminated (Fig. 12).

## IV. Conclusion

The proposed system can run as line equipment, reference equipment (without a handling system) or as a device in a closed loop manufacturing system, contributing to the adjustment of the manufacturing process.

The experimental results demonstrate that such a system is effective for measuring and inspecting cylindrical bodies with excellent accuracy.

The experimental results show that the proposed system is capable of achieving precise dimensional control in automatic mode while providing high flexibility for distinct types and sizes of mechatronic components.

This work presents a fundamental approach to modeling and manufacturing an automated inspection and control system in a manufacturing line.

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