AUTOMATED VISUAL INSPECTION (AVI) RESEARCH FOR QUALITY CONTROL IN METAL STAMPING MANUFACTURING

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Automated Visual Inspection (AVI) Research for Quality Control in Metal Stamping Manufacturing

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Abstract

This paper presents a set of techniques in Automated Visual Inspection (AVI) system to perform quality control for metal stamping industry. AVI system is aim to confirm whether a product match its quality standard and requirement or not. The system consists of 2D image sensor, lighting system, computer, image processing routines, networking, and handling mechanism. The system is expected to be integrated in the over all process in industry. This paper is focusing to the algorithm aspects of the AVI system. It consists of digital image acquisition, noise reduction, edge detection, feature extraction and classification. The result shows the potential implementation to improve the quality control in manufacturing environment.

1. Introduction

In metal stamping manufacturing, inspection tasks usually performed by human inspectors or experts. This method also classified as post-process inspection because the measurement done after the product has been produced. The measurement is performed by using conventional instruments such as rules, calipers, micrometers, and checking fixture. The weakness of this method is listed below.

- Time consuming.
- Inconsistent as evaluators of product.
- Contribute up to 10% of total labor cost for manufactured products [1].

In fact, it has been reported that human visual inspection is, at best, 80% effective and furthermore, this effectiveness can only be achieved if a rigidly structured set of inspection checks is implemented [2].

In this paper, we present our current focus research efforts in the field of automated visual inspection for metal stamping manufacturing. Within the Computer Vision and Robotics Research (CoVisBot) Group at UTeM, we develop non-contact inspection system based on computer vision for metal part.

In this research, we perform real-time inspection for quality inspection while the part has been produced in the production line over conveyor [3]. The system checks whether product to be assembled or released fits its standard and requirement or not. Once metal part is claimed as rejected, then part will be dissociated. With this mechanism, industry can reduce cost of producing defective products which also creates difficulties in assembly operations, necessitating repairs in the field and resulting in customer dissatisfaction [4].

The paper is organized as follows. In section 2, the concept of visual inspection system is presented. In section 3, the algorithm to extract feature descriptors of the press part sample is given. In section 4, we describe the result and discussion of the AVI system implementation.

2. Visual Inspection System Design

As stated earlier, the purpose of visual inspection system is to perform quality assurance by separating accepted part from rejected product. To do this, a careful planning should be taken in the design stage. The orientation is based of the object to observe. The system should cover the following aspects to perform total quality control [5].

1. Adaptive lighting control.
2. Flexible software development approach to accommodate changes in the future.
3. Networking system for communication between decision support system (DSS), computer aided design (CAD), computer aided manufacturing (CAM), and computer aided process planning (CAPP) in manufacturing environment.

However, our main focus in this paper is the requirement for the AVI. The system consists of digital image acquisition, computer, image processing routines, and handling mechanism.

Firstly, the choice of image acquisition devices is based on minimum requirement of pixel accuracy. For instead, low resolution web camera can be using because it is very cheap. The disadvantages is the high noise but can be smoothed in image processing routine. The result of image captured from the camera is significantly relies on lighting condition. We must avoid direct illumination to reduce specular effect of metal surface. Fortunately, the light intensity is controllable since we have indoor application.

Since we are dealing with real time application, the computer hardware to be used should be fast enough to calculate the routine task. The time consumes of accepted or rejected decision depends on the computer speed. Generally, the faster the computer, the less time required to process the data.

Finally, the part status is used to trigger the handling mechanism to separate accepted part from defect part over production line or vice versa. This scenario is commonly used for developing AVI system in manufacturing environment.

In addition, if there is a defective part, then the report can be transmitted to DSS to be analyzed. The visual inspection system should be integrated within other manufacturing process to perform total quality control and reduce cost of producing defective product. The typical networking system showed below which is using wireless networking for computer integrated manufacturing.

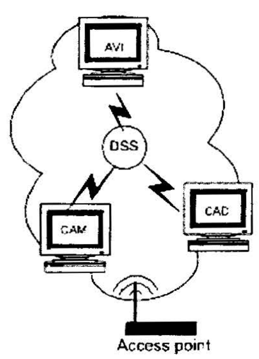


Figure 1. Visual Inspection Networking System

The DSS is aim to decide proper action if th defective product detected. DSS will analyz manufacturing process which causes the fail pr The wrong process could be from CAD, CAM (CAPP. The CAD is aim to perform design analysi and evaluate the prototype, and production draw The CAM and CAPP is aim to select the p material, process and equipment for fabricate product. All over the system is integrated ir computer integrated manufacturing (CIM) which i to control the entire production process. CIM pr the data storage, sensing state and modifying manufacturing process.

We also have been developing the production simulation for testing the inspection system. system is divided into hardware and soft subsystem. The hardware subsystem as shown b consists of conveyor, lighting system, web can fuzzy logic controller, and sorter. The lighting sy is using dark field illumination which is controlle dimmer. The camera has resolution 480 x 640 pi The conveyor has maximum speed up to 10 meters minute. The hardware controlled is AT89 microcontroller based. The handling equipn consists of plate metal mounted into stepper motor.

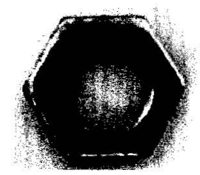


Figure 2. Hexagonal part

To test the algorithm, we use hexagonal part wh shown above. The part can be characterized by circle diameter and hexagonal perimeter.

3. Algorithm

The main aspect in the computer vision inspection is the image processing processes. routines is aim to extract the feature descriptors wh characterize the part. There are two features to extracted of our part sample, which are diameter length. The following flow chart will show algorithm of the visual inspection, which are usi the system.

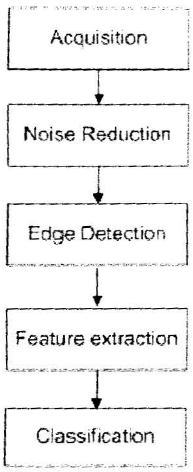


Figure 3. The image processing stages

1. *Acquisition* – This step is aim capture and transmits the image from the scene to computer host.
2. *Noise Reduction* – This step suppress noise introduce by acquisition process.
3. *Edge Detection* – this step detects sharply changes in image.
4. *Feature extraction* – This step is aim to extract feature descriptors about dimension of part specification.
5. *Classification* – This step compares feature descriptor from previous step and its standard requirement. Then, the part is claimed whether accepted or rejected.

Acquisition

Notice that the image quality is significantly influence by the illumination. Fortunately, the lighting can be set fixed for industrial inspection. Under illumination, part surface will reflect some amount of intensity from the light source. Then some part of reflectance light will be recorded by CMOS sensor cell and converted into electric signal. Unfortunately, each optical sensor will introduce statistical nature which attaches noise in image and creates discrepancies of interpretation. CMOS-based camera has 10 times of pattern noise than CCD [6]. However, we can suppress the noise in by using Wiener filtering.

Noise Reduction

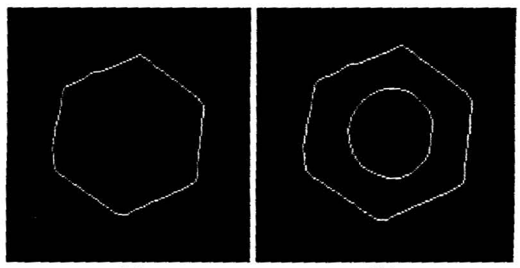
After image acquisition process, the image is converted into grayscale from RGB mode. This is necessary since we do not need the color information. We assume that the noise can be a modeled as additive and random. In this step, we use Wiener filter to estimates the local mean (μ) and variance (σ^2) around each pixel and described as follow [7].

$$\mu = \frac{1}{NM} \sum_{n_1, n_2 \in \eta} a(n_1, n_2) \quad (1)$$

$$\sigma^2 = \frac{1}{NM} \sum_{n_1, n_2 \in \eta} a^2(n_1, n_2) - \mu^2 \quad (2)$$

Edge Detection

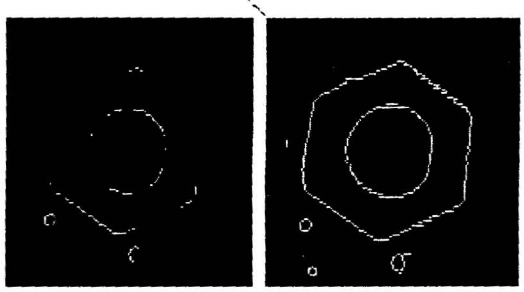
Now, we have better image from noise reduction step. This step is aim to detect edge or sharply changes of brightness in image. One of the most accepted method for edge detection in computer vision community is the Canny edge detector. Canny is more precise than others such as Sobel operator [8]. The figure below is the result of Canny edge detection. The left image is edge detection with threshold 0.93. Note that only outer perimeter which detected and the circle is not detected. In the right image, both outer perimeter and circle are detected. This is obtained by set the threshold value equal as 0.60.



(a) **(b)**

Figure 4. Canny edge descriptor: outer perimeter or feature obtained with threshold 0.93 (a) and 0.60 (b)

The figure below is edge detection using Sobel operator. The right image shows noisy image (threshold = 0.1). The left image is worse than the right one. If the threshold value more than 0.2, the edge is almost gone.



(a) (b)

Figure 5. Edge detection using Sobel operator with threshold 0.2 (a) and 0.1 (b)

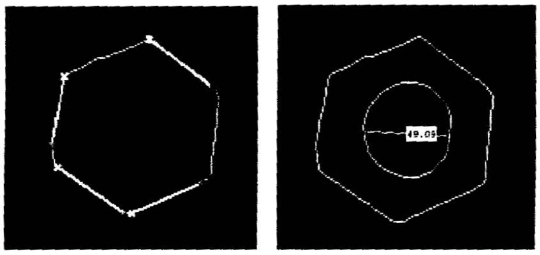
Feature Extraction

In this stage, features regarding to the part requirement and standard is extracted. There are two important features to be analyzed which are lines and diameter of the part. To extract the line we use hough transform. In Hough transform a, line y = m(x) + n can be represented as a point (b, m) in the parameter space [9]. Generally, we can use coordinate polar (r,θ), the parameter r represents the distance between the line and the origin, while θ is the angle of the vector from the origin to this closest point. Using this parameterisation, the equation of the line can be written as

$$y = \left(-\frac{\cos\theta}{\sin\theta}\right)x + \left(\frac{r}{\sin\theta}\right) \qquad (3)$$

which can be rearranged to $r = x\cos\theta + y\sin\theta$.

The result for line detection is shown in figure below. To extract diameter, we calculate the pixel length of the hole or circle in the image.



(a) (b)

Figure 6. Line detection using hough transform (a) and diameter measurement using pixel based method (b)

Classification

In classification, the feature descriptor is compared with its requirement and standard. The comparison is based on the tolerance of part design. If the result shows that significant or intolerable error such as out of length and diameter, then the part should be dissociated before entering the assembly process. For instead, we use if-then rule to classify accepted and rejected part. Rule-based systems classify data to if-then rules. This method use causality to perform classification of object. For example shown in the following rule:

IF feature diameter < 95 and > 85 THEN part is rejected. Otherwise, part is accepted.

This rule would reject hexagonal part if the diameter is not in the range of 85-95 mm.

4. Result and Discussion

Firstly, we smooth the image using Wiener fi After smoothed, edges in the image are detected using canny and sobel edge detection. It is obvious t canny is better than sobel (see figure 4 and 5). adjusting the threshold value, we can extract featu descriptor of the part. Figure 4(a) shows that ou perimeter can be detected by setting the threshold val equal to 0.93. The other feature descriptor, diameter circle, can be obtained by setting the threshold valu equal to 0.6. Comparing to Sobel edge detector, figur 5 shows the edge is not smooth and resulting fals contour. If the threshold value more than 0.2 then edge is disappear.

After edge detection, we approximate the line of the outer perimeter diameter of the circle. Firstly, we use hough transform to detect line by finding the maximum counting of cell in parameter space. The result show there is four lines which can be detected. The diameter of the hole then approximated by calculates the amount of the pixel of the longest possible part inside the hole.

5. Conclusion and Further Research

The result shows the potential implementin computer vision in metal-based industry. It is sho that the above algorithm can be used to perform r time inspection system for metal-based industry. T routine consists of digital image acquisition, no reduction, edge detection, feature extraction classification. However, the system should be enhan covering the following aspects:

- Integrate the adaptive lighting control for r system.
- Inspect object with higher complexity.
- Inspect other parameter of press part su straightness, flatness, roundness, angle, p and weight.
- Capability of inspect 3D object.
- In addition, client/server application sh used to provide networking system betwe DSS, CAD, CAM and CAPP for total control.

6. Acknowledgment

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7. References

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