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 aimed 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 overall 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.
- Inconsistency 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, 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 used 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.

The DSS is aimed to decide proper action if the defective product detected. DSS will analyze manufacturing process which causes the fails in the wrong process could be from CAD, CAM, and CAPP. The CAD is aimed to perform design analysis, and evaluate the prototype, and production drawings. The CAM and CAPP is aimed to select the proper material, process and equipment for fabrication product. All over the system is integrated into computer integrated manufacturing (CIM) which is to control the entire production process. CIM provides 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 software subsystem. The hardware subsystem as shown in Figure 1 consists of conveyor, lighting system, web camera, fuzzy logic controller, and sorter. The lighting system is using dark field illumination which is controlled dimmer. The camera has resolution 480 x 640 pixels. The conveyor has maximum speed up to 10 meters per minute. The hardware controlled is AT89 microcontroller based. The handling equipment consists of plate metal mounted into stepper motor.

To test the algorithm, we use hexagonal part 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. The routines aim to extract the feature descriptors to characterize the part. There are two features extracted of our part sample, which are diameter length. The following flow chart will show the algorithm of the visual inspection, which is using the DSS.
Figure 3. The image processing stages

1. **Acquisition** – This step is aimed to capture and transmit the image from the scene to the computer host.

2. **Noise Reduction** – This step suppresses noise introduced by the acquisition process.

3. **Edge Detection** – This step detects sharply changing edges in the image.

4. **Feature Extraction** – This step is aimed to extract feature descriptors about the dimension of the part specification.

5. **Classification** – This step compares feature descriptors from the previous step with their standard requirements. Then, the part is claimed as either accepted or rejected.

**Acquisition**

Notice that the image quality is significantly influenced by the illumination. Fortunately, the lighting can be set fixed for industrial inspection. Under illumination, part surfaces will reflect some amount of intensity from the light source. Then some part of reflectance light will be recorded by CMOS sensor cells and converted into an electric signal. Unfortunately, each optical sensor will introduce statistical nature which attaches noise in the image and creates discrepancies of interpretation. CMOS-based cameras have 10 times of pattern noise than CCD [6]. However, we can suppress the noise 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 modeled as additive and random. In this step, we use Wiener filter to estimate the local mean ($\mu$) and variance ($\sigma^2$) around each pixel and described as follows [7]:

$$\mu = \frac{1}{N} \sum_{n_1, n_2} a_{n_1, n_2} \frac{1}{N}$$

$$\sigma^2 = \frac{1}{N} \sum_{n_1, n_2} \left( a_{n_1, n_2} - \mu \right)^2$$

**Edge Detection**

Now, we have a better image from noise reduction step. This step is aimed to detect edges or sharply changing brightness in the image. One of the most accepted methods for edge detection in the 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 a threshold of 0.93. Note that only the 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 setting the threshold value equal to 0.60.

**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 a noisy image (threshold = 0.1). The left image is worse than the right one. If the threshold value is more than 0.2, the edge is almost gone.

**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 $(r, \theta)$, the parameter $r$ represents the distance between the line and the origin, while $\theta$ 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

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

which can be rearranged to $r = xc\cos \theta + ys\sin \theta$.

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.

**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 filter. After smoothed, edges in the image are detected using canny and sobel edge detection. It is obvious canny is better than sobel (see figure 4 and 5). Adjusting the threshold value, we can extract feature descriptor of the part. Figure 4(a) shows that our perimeter can be detected by setting the threshold value equal to 0.93. The other feature descriptor, diameter circle, can be obtained by setting the threshold value equal to 0.6. Comparing to Sobel edge detector, figure 5 shows the edge is not smooth and resulting false 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. Finally, 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 implementation of computer vision in metal-based industry. It is shown that the above algorithm can be used to perform real-time inspection system for metal-based industry. The routine consists of digital image acquisition, noise reduction, edge detection, feature extraction and classification. However, the system should be enhanced covering the following aspects:

- Integrate the adaptive lighting control for real-time system.
- Inspect object with higher complexity.
- Inspect other parameter of press part such as straightness, flatness, roundness, angle, profile and weight.
- Capability of inspect 3D object.
- In addition, client/server application should be used to provide networking system between DSS, CAD, CAM and CAPP for total control.

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7. References


