Machine Vision based quality inspection for automotive parts using edge detection technique

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Abstract: This paper discusses the way in which the efficacy of inspection process can be improved. In the existing system the products are inspected manually to identify the defects. However, existing methodology is not efficient or accurate. On account of this the product is at a high risk of being rejected due to its low quality. This can lead to a hike in the production cost. In present industrial conditions there is an enormous competition in the manufacturing industry, therefore it is a necessity to maintain a high-quality inspection process to cope up with the competition. This can be achieved with the help of advanced technologies like machine vision. This technology uses a non-contact method of inspection. Compared to the existing technology this technology has improved efficiency and accuracy, while consuming less time. Thus, allowing the industries to keep up with the current competitive environment.

Keywords: Edge detection, machine vision, Inspection, industry automation, manufacturing.

1. Introduction
In the automotive industry the universal joint, plays a key role in power transmission. They are frequently used in heavy duty four-wheeler vehicles. These joints can be produced by various methods, to maintain its quality, it must be of precise dimensions. The process of inspecting through contact or manual method is time consuming, thus it greatly impacts the efficiency of the production process. Whereas in non-contact method different parts of the product can be identified effortlessly and instantaneously, additionally the accuracy of this process is high. Machine vision plays a main role in information technology, which aims to exploit computer vision techniques for industrial applications. This technique involves processing sequences of digital intensity images. Where these images are produced at a fixed frame rate irrespective of the dynamic content of the visual scene.
The efficiency of the edge detection is the leading factor, which decides the level of the computer vision. This edge detection is also a fundamental feature to reliably perform the low-level steps which are being a major issue till now and a fully automated task for machine vision has not been achieved yet. This paper deals with the accuracy in the measurement of the product during final delivery process. Machine vision has features such as dimensional object classification, optical character recognition reading, code reading part measurement and inspection in the automated discrete manufacturing process. Normally, all the inspection algorithms are implemented on a single image and special lighting are provided according to the analysis that is to be done on the image. Several visuals are used in the inspection of object measurements with respect to different illumination and processing techniques.

Conventional visual sources and sensors are unaffected by the dim light diffused by the surface of the object, which saturates rapidly when direct light is emitted by the specular reflection. The optimal lighting condition assures that there will be no additional noise added to the image, in result of which the image from the camera sensor will be sharp and clear. The camera is firmly placed on a special mounting and high-quality lenses are used. Depending on the type of the inspection the camera sensor can vary, it can also be mono chrome. At current times the quality of the inspection has become essential due to the zero-defect policy of today’s automotive manufacturing industry. The vision algorithms are expected to work effectively in real time and this sets constraints for parameters like overall performance, stability and resource usage. The results from the vision inspection are sent to the control modules for further commands from the common industrial machine vision algorithms.

The organization of a computer vision system is highly dependent on its application. Some system are used for stand-alone applications which solve a specific measurement or detection problem, while others constitutes of a sun-system of a larger design which also contains sub-system to control the mechanical actuators, planning, information databases and man-machine interfaces, the specific implementation of a computer vision system depends on its functionality as specified or some part of it can be learned or modified during operation.

1.1 Objective

The most important component in power transmission which is used in automotive industry is universal joint. It is a commonly used part in heavy vehicles. Precision is the parameter which is to be optimized to deliver a quality component and there are various methods in producing the joints. A traditional method which includes manual inspection has low efficiency in production process and consumes much time. An alternative method which can be adopted is non-contact type inspection system. The benefits include increase in efficiency and the process can be carried out effortlessly and instantaneously. Currently computer vision methods using machine vision technique are used in industrial applications. This process is a detailed manipulation of data which is acquired through digital images. Implementation of zero-defect policy, which imposes quality of inspection, makes automotive industries to produce parts in higher standards. Parameters like overall performance, stability and resource usage should extend their boundary by making effective use of vision algorithms.

2. Materials and methods

The accuracy for computation of the lead displacement and the combined classification process, where the individual lead displacement classifications are viewed as measurement of the same physical quantity
The machine vision-based inspection for electric contact materials like relays, switches and breakers, using roundness analysis for the inspection of deckle edge, extra metal and edge break [12]. The machine vision method used in 3-D coordinate measurement of feature point on the surface of a large work piece, the monocular vision algorithm used for locating the camera, the calibration algorithm of the charge coupled device camera, the image processing algorithm of cross-cutting feature points and the calculation of their 2-D image coordinate [9]. The reviewed quality control, during the mass production of percussion caps. These caps are used in firearm ammunition so it is essential for these elements to have minimum tolerance during their fabrication process[10]. This paper discussed about the machine learning algorithm, which is used to obtain feasibility in the quality check of the percussion caps. The machine vision development using a 3D camera for the inspection of mass production of percussion caps, using the neural networks to eliminate the errors such as metallic reflections, mechanical errors and irregularities in percussion cap[2].3D reconstruction of objects which are smaller than 1cm using binocular machine vision system, provided with a standard deviation of 0.04 and with the crucial movement of Z-axis, the need for further calibration is removed[4]. The neuromorphic dual-line vision sensor and signal processing concept for the recognition and classification of objects, where the vision sensor on the pixel level and the concept of real-time embedded vision processing are used for the efficient edge extraction of moving objects[1].The automatic detection system based on machine vision technique, the least square fitting and annulus scan are used for the detecting the bearings and the regions which are to detected and enhanced, low-pass filtering are used to improve the quality of images, finally the features of the image is used for the recognition of defects[3]. The computer vision of novel method which combines the feature of embedding for the fast retrieval of surface descriptors[6]. The technology of machine vision to design the sequences process with proper functioning of each system and sub-system in term of high-quality images [5]. The automation of visual inspection, process control, part identification plays an important role in the robotic guidance and control. Machine vision technique is used to find defects in printed circuit boards (PCBs), where he templates image is subtracted from the inspecting image to detect the defects [13]. The detected defects are classified into 7 types based on three indices namely object type, differences in the object numbers, and difference in background numbers between the inspected image and the template. A robot mechanism with machine vision system is used to find the cracks in bridges [14]. The robotic mechanism consists of three main parts to detect the cracks present in the bridge. A car specially designed for this application, a robotic mechanism with control system for mobility and a machine vision system for the detection of the cracks. With the images of the cracks its length and breadth can be determined. A machine vision system is used to detect the defects in the bearings[15]. Defects such as deformations, rust etc., present on the cover of the bearings. The system consists of an enhanced image acquisition system to maintain a controlled image acquisition environment and to detect the defects. An effective inspection algorithm is used to improve the efficiency and the accuracy of the system mainly to find the defects in the seals. A speed laser range camera is used for the inspection of the railways[16]. The proposed method is simulated using NI LABVIEW after multiple checks on a similar railway the real time set up is built using high speed 3D camera, which is placed under the railway carriage for the inspection of the railways.

Machine vision along with artificial neural networks is used in inspection of thermal fuses [17]. The proposed system is used to find common defects like black-dot, small-head, bur, and flake which are mainly produced during the production of thermal. This system can be used to replace four to six human inspectors. Thus, the proposed system does not only improve the accuracy and efficiency of the
production but it also helps to reduce its cost. Automatic optical inspection system (AOI) based on machine vision is used to find defects in the drilled holes of a PCB board[18]. The proper working of the hardware and software leads to the results at an accuracy of 5 μm. In previous methods only one or two defects of the holes could be detected however with this method multiple defects such as excessive holes, missing holes and holes which are located in the wrong position can be detected. A machine vision-based approach to find the defects in the gun barrel [19]. Here a charged coupled device camera attached with a miniature microscopic probe is used to acquire the images of the gun barrel from which defects like normal wear, corrosive pitting, rust and erosion can be identified. The normal wear appears bright while other defects are dark in the captured image. Overall, the system will be able to find surface defects and classify it automatically and effectively. The detection of defects in steel balls. The proposed system has a dual lighting system, an unfolding mechanism and inspection algorithm for the detection of defects present in the steel balls with a detection rate of 99.94% and a minimum error rate of 0.10%[20].

3. Real time processing
In this section the real time process with image acquisition, pattern matching, circle edge detection, point edge detection and length measurement are explained below. The main factors considered for the real time processing are image acquisition, image processing, edge detection and the database. Figure 1 shows the sequence of the machine vision process.

![Figure 1. Machine vision process sequence](image)

3.1. Image acquisition
The camera used for image acquisition is NI1742 model smart camera. The camera has a sensor of 640 X 480 pixels capable of acquiring 2D and 3D images simultaneously by dividing the sensor in different zones. It can be obtained at a rate of 35 k per second. The image size of the CCD smart camera is 1/3 of an inch and it has a memory capacity of 128 MB. The RS 232 is used for the communication between the personal computer and the smart camera, an ordinary setup of the camera and the required lighting effect is issued for the image acquisition. This setup is used to obtain maximum resolution. Figure 2 shows the real time implementation of the proposed system.
The system is capable of acquiring 2D and 3D images simultaneously. This image is used for the visualization process. With the help of a diffused red-light unwanted noises in the 2D image are removed. Here the lighting configuration is one of the major challenges. Figure 3 shows the image acquired from the smart camera with high resolution and without blur. This image is used as the reference image during image processing.

![Machine vision experimental setup](image2)

**Figure 2.** Machine vision experimental setup

![Eccentric work piece image](image3)

**Figure 3.** Eccentric work piece image acquired through CCD camera

### 3.2 Image processing

The image acquired initially is used as the reference image. The gray processing technique is also used in the image processing devices, which is based on the gradual brightness of the image captured through a camera. The binary conversion method recognizes based on all the data, which offers a much improved and precise detection. A ROI is a specification structure that is used for the definition of the arbitrarily shaped regions within a given image, it is only used to remember a defined location in the given image, it does not acquire any new images instead it points out a specific location in already acquired image. Pattern matching is a tool, which will scan the incoming image according to the pattern that has been stored in the system (reference image).
The XY position angle and the correlation of the detected pattern is obtained. It is essential for the substantial processing of the resources, processing the entire selected image consumes less time. As the pixel is processed, the volume of the data can be reduced and processing time can be minimized. The related image is searched and scanned at a set of certain intervals to have high correlation values. This interval is referred as step with simply interval. For the rotational correction the image is set to rotate accordingly and searched for normal. The area immediately surrounding each point is found by the first search and is used for lower compression ratio to find the highest correlation values. This process may be repeated several times using a progressively lower compression ratio each time, until the detected points are found in the process of searching, using the uncompressed pattern and are then subjected to sub pixel processing. To match the image of the product by comparing the different angle image of the product with their coordinate point should be set in the image. It helps to find the image of the product to be identified and false rate by using the coordinate point. This improves the accuracy in identifying the product. The figure 4 shows different angle of matching images acquires.

![Figure 4](image)

**Figure 4.** The eccentric work piece acquired through CCD camera in different angle

3.3. Edge Detection

The edge detection process is to change the brightest and darkest image in accordance to the gray scale image which has a range value of 0 -255. The threshold range is to be varying from low values and vice versa. The limited variation of the 100 value complicates the variation of brightness and darkness of the image. The line of draw and pace plot is used to find out the current position. These plots are plotted according to the reference index images. Basically, number of edges can be created in the plotted line. It may contain unwanted edges like falling and raising edges. By falling and raising edge the filtration we can obtain the first and last edges by simply viewing the plot. Mostly the line default edges are not accurate. To give more accuracy the image is mounted for the edge strength to have falling and raising edges. While the kernel size may increase and decrease of minimum adjustment, we can get maximum accuracy of the edge strength. Totally 12 edges can be identified as shown in the figure 5 and 6 strength profile sample of four edges.
The Figure 7 shows the edge measurement of the image. The reference image is used in finalizing the products in the inspection process.

3.4. Database
The database is a collection of a record of the memory region containing a list of objects and their features that is built from the learning process. The learning process stops for very new target and updates it into the database. It is used in the recognition process of the object.

4. Inspection Calculation and Results
Total capacity of a CCD smart camera (NI 1742) taken for the proposed method is 1/3 of an inch. For understanding purpose here inch is converted into mm as shown below.

\[
1\text{ inch} = 25.4\text{mm} \\
25.4/3 = 8.4\text{mm}
\]

Hence the proposed method CCD camera's capacity is 8.4 mm.
The camera has a length and width of 640 X 480 and the resolution of the camera is 640 X 480. The single pixel length of the camera for calculation is 7.5micron. The aspect ratio is the length and width ratio for the rectangular boundary of the region. The ratio can be calculated for the camera and the picture with respect to the total length of the camera.

\[ \text{Ratio} = \frac{\text{Picture length}}{\text{Camera lens length}} \]

\[ \frac{170}{4.8} = 35.41 \text{ pixel} \]

The above ratio formula is used in to find real time length of the object

\[ \text{Total length in mm} = \text{single pixel length} \times \text{given result} \times \text{Ratio} \]

The work piece with pixel size greater than or smaller than the reference image is rejected. The inspection results are tabulated as follows

| Table 1.Inspection Result |
|---------------------------|
| Image no/edge no 1 & 2 in pixel | 1 & 2 Length in mm | 3 & 4 in pixel | 3 & 4 Length in mm | 5 & 6 in pixel | 5 & 6 radius in mm |
|---|---|---|---|---|---|
| 1 | 441.11 | 117.16 | 441.45 | 117.26 | 98.29 | 27.02 |
| 2 | 441.09 | 117.21 | 441.14 | 117.17 | 98.51 | 27.09 |
| 3 | 441.76 | 117.35 | 441.14 | 117.17 | 98.49 | 27.08 |
| 4 | 441.13 | 117.17 | 441.32 | 117.22 | 98.29 | 27.02 |
| 5 | 441.18 | 117.18 | 441.25 | 117.20 | 98.42 | 27.06 |
| 6 | 441.29 | 117.16 | 441.51 | 117.27 | 98.35 | 27.04 |
| 7 | 441.08 | 117.16 | 441.53 | 117.28 | 98.22 | 27.01 |

| Image no/edge no 7 & 8 in pixel | 7 & 8 radius in mm | 9 &10 in pixel | 9 &10 radius in mm | 11&12 in pixel | 11&12 radius in mm |
|---|---|---|---|---|---|
| 1 | 98.23 | 27.01 | 98.47 | 27.07 | 98.27 | 27.07 |
| 2 | 98.18 | 26.99 | 98.58 | 27.10 | 98.69 | 27.13 |
| 3 | 98.29 | 27.02 | 98.49 | 27.05 | 98.77 | 27.16 |
| 4 | 98.47 | 27.07 | 98.36 | 27.04 | 98.15 | 26.99 |
| 5 | 98.38 | 27.05 | 98.41 | 27.07 | 98.42 | 27.06 |
| 6 | 98.35 | 27.04 | 98.65 | 27.13 | 98.47 | 27.07 |
| 7 | 98.38 | 27.05 | 98.38 | 27.11 | 98.34 | 27.04 |

### 5. Conclusions

The proposed method a new model is developed for the automatic machine vision-based quality inspection process. The images are captured from different work pieces, with same dimensions. Based on the above images, the accuracy of the work piece is determined. Edge detection is used in the preprocessing and the post processing of the image, to find out the accuracy of the product during quality inspection process. With significant development in the edge detection techniques the accuracy of the inspection process is improved. The information stored in the data base is retrieved, to identify the defective work pieces. Also, the automatic inspection can be done using various resolution achieved, thereby improving product quality and process time.
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