

Design & Development of an Image Processing Algorithm for Automated Visual Inspection System

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ABSTRACT

Automated Visual Inspection is an important solution for manufacturing industries to decrease the investment in the inspection process for manufactured product. By the help of vision system the inspection process of the product is conduct, there is an increment in production rate and decrement in the required labour.

This research article is described to design and development of an image processing algorithm using MATLAB® software that can help to reduce the defect detection time and compensate for variation in the product for different production line. The developed algorithm uses image processing tool box and absolute mean deviation in MATLAB® software.

Keywords - Automated Visual Inspection (AVI), Image Processing Approach, Digital Image and Region of Interest.

1. INTRODUCTION

In manufacturing industries, product inspection is an important step in the manufacturing process. Since product reliability has importance in most mass production facilities, 100 % product inspection of all parts, subassemblies, and finished product is often being attempted [1]. Advances in technology have resulted in better, cheaper image analysis equipment, which enable the use of affordable automated visual inspection system [2].

In order to establish good company reputation and be more competitive in the marketplace, inspection system can ensure the optimum quality of product and help to improve the product quality. Therefore, a lot of industries pay attention to improve the inspection system, especially in automobile and textile industries [3].

AVI systems have the capability to counter these cost related problem in manufacturing industries. The aim of this research article is to improve the product quality inspection and quality control process in complex

manufacturing industries by the use of image processing tool box and mean deviation technique in MATLAB® software. A flexible inspection system such as is described in this research article should be faster to train, more adaptable to variation in the product and have the potential to expand AVI systems.

2. QUALITY CONTROL & INSPECTION

Quality control means the control of the excellence of a product as per requirement of customer standard. Quality control process in the manufacturing industries aims to reduce the variability in the produced product in order to meet the customer requirement and satisfaction. In these highly complex production industries if quality of the product is not maintained then it is difficult for the product to survive in the market. In manufacturing industries selection of raw materials to the produced finished product, the entire process of production is effectively linked through a quality control department. Quality inspection for a produced part can be classified into three main stages;

1. Part Location
2. Dimensional Analysis
3. Surface Condition

Quality control processes improve output and reduce the breakdown process. It looks for to ensure that the finish product meet the specified standards of performance, utility and reliability. Quality control has become an essential tool for modern manufacturing industries.

3. AUTOMATED VISUAL INSPECTION

Maintain the quality of the product visual inspection has been the way that product have been inspected by manufacturing industries. The visual image of the part can show surface defects, incorrect assembly and product damage. AVI systems try to use this same set of systematic data about the appearance of the product to complete the inspection process without the human interference.

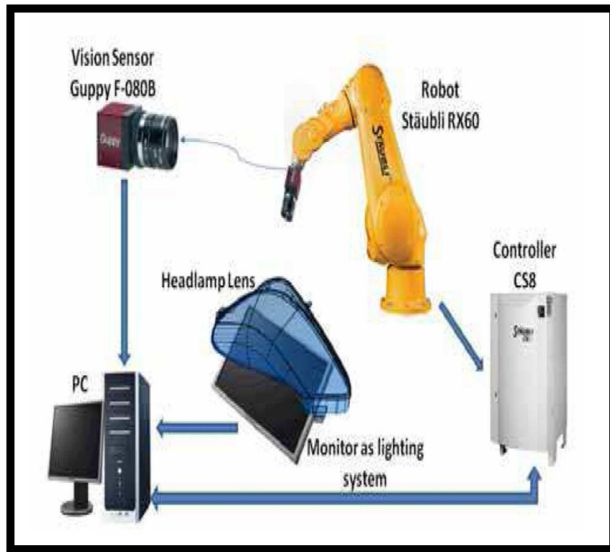


Figure 1: Main components of an AVI System [4]

Because of the large variety of operating environment in manufacturing industries, AVI system have different types of design, but almost all AVI system have three main section:

1. A Camera
2. An Illumination Device
3. A Processing Device

The step by which the appearance of the part is captured and then processed to determine a final accept/reject decision can be divided into main four steps as shown in figure and described below.

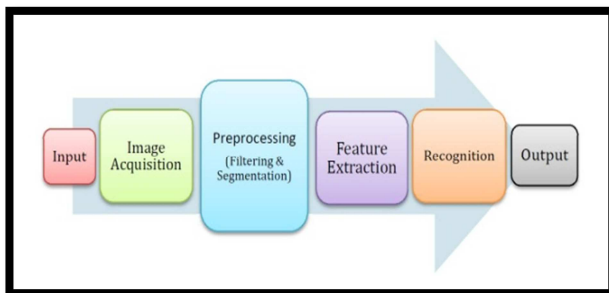


Figure 2: Main steps in automated Visual Inspection Process

3.1 IMAGE ACQUISITION

The choice of the image acquisition technique is strongly connected to the characteristics of the flaws, the nature of the surface, e.g. shiny machined surfaces versus inhomogeneous scale covered surfaces, and the required spatial resolution [5].

Acquiring the image include not only of the image optical capturing process obtaining within the devices, but also setup of the lighting system that makes the product to easily visible and explore the region of interest.

In setup of an AVI system the most difficult stage of the process is to find an image capturing device and lighting arrangement that gives the best view of the feature to be visually inspected. The lighting system should highlight the interested feature in a way that emphasise the need.

3.2 PRE-PROCESSING

In an AVI system pre-processing steps include the transformations such as modifying the contrast, highlight the edges, or changing the quality of acquired image. The aim of this stage is to highlight the features of interest and reduced the background noise. In some cases, pre-processing can be used to remunerate for deficiencies in the physical conditions of acquired image. For many industries, the correction of illumination consists of having an auto iris or auto gain control on the image capturing device in order to maintain the overall intensity constant.

3.3 FEATURE EXTRACTION

In feature extraction process, generally seek invariance properties so that the extraction process does not vary according to chosen conditions. That is, techniques should find shapes reliably and robustly whatever the value of any parameter that can control the appearance of a shape [6].

In order to obtain the simplest image, image is typically broken into simple features. These features are representations of a pixels group with common characteristic like that colour, texture or intensity. Some other complex features group pixels which use to represents the edges, line or other shapes. The parameters of each feature are defined in terms of scalar values which can be aggregated to form a feature vector (FV) for the entire image. The FV can be considered a compact representation of the contents of the image. Thus, a feature-based approach reduces the quantity of information that needs to be processed.

3.4 RECOGNITION

In the last stage of the AVI process the FV is processed to obtain the result that the part is acceptable or not. This step includes a fairly simple test like that presence or absence of a required feature, or it may involve very typical processing.

4. THE OPTICAL SYSTEM

In order to get a good image from the optical device with the most significant information, the optical device must be configured. After having illuminated the point of interest present in the product, the light reflected from the point of interest now has to be captured by the optical system. In the path of the reflected light if a sensitive material is placed near to the object, an image of the product will be captured.

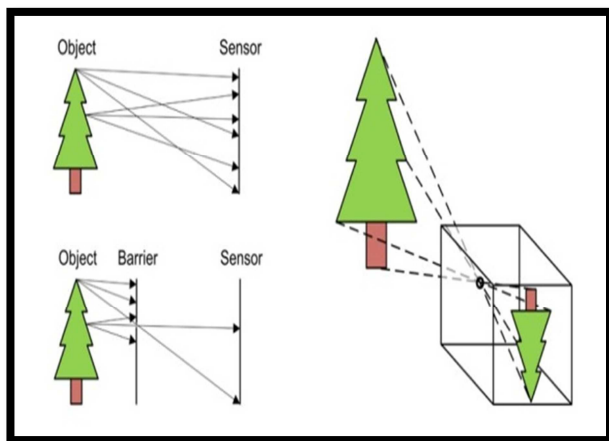


Figure 3: Effect of introducing a barrier [7]

When light coming from different points on the product will mix, it will result in a useless image and light from the surroundings will also be captured resulting in even bad results. The solution of this problem is to place some type of barrier between the point of interest in product and image capturing device. This barrier is generally called lens as shown above in the figure 3.

5. DIGITAL IMAGE

A Digital image may be defined as a two-dimensional function $f(x, y)$, where x and y are spatial coordinates, and the amplitude of $f(x, y)$ at any pair of coordinates is called the intensity of the image at that point [8]. A computer image is a two-dimensional array of pixels. The value of each pixel is proportional to the brightness of the corresponding point in the scene; its value is usually derived from the output of an analogue-to-digital (A/D) converter [9].

Digital image is composition of pixels. Each pixel in the digital image represents the colour code in the digital image. So a pixel can be defined by a tiny dot of a certain colour code. The main types of digital images are described below.

5.1 BLACK & WHITE IMAGE

A black & white image is group of pixels, which holds a single code corresponding to grey code level of the digital image at a certain location. These grey code levels span the complete range of code from black to white in a combination of very fine steps, basically 256 different greys.

5.2 COLOUR IMAGE

A colour digital image is group of pixels each of this contain three numbers corresponding to the RGB code of the digital image at the particular pixel. RGB (Red, green, and blue) are the primary colours for mixing light. Any colour can be obtained by the combination of correct quantity of red, green, and blue light.

5.3 BINARY (BI-LEVEL) IMAGE

Binary digital image require only a single bit to interpret each pixel. A bit can only save two values 0 or 1. Each pixel in a binary coded digital image must be containing only two colours. These colours are black or white colour.

6. THE REGION OF INTEREST

As digital cameras are presented in the market in larger and larger variety the development within the sensor technology has become in many new products include larger numbers of pixels by one sensor. This is generally defined as the resolution of the image that can be captured by a sensor of digital camera; the resolution can be defined as the number of pixels presented in the vertical direction multiplied by the number of pixels presented in the horizontal direction. An image having a large number of pixels can create a high quality images. In AVI system the image processing step, an image of high resolution is not always recommended. However, the tiny details or a very accurate measurement is required in the image then the better option is using a small resolution image. The reason behind it when the image processing is start and each pixel is processed; some mathematical operation is performed on each pixel. The large number of pixels includes mathematical calculation at a maximum level, due to this a high computational load on the processing device.

7. IMAGE INTERPRETATION

All computer images are stored the digital image as an array of pixel values, then all the computations on digital images must be start from the pixel values. The

main types of image interpretation are discussed below:

7.1 COLOUR IMAGE

A colour image can be represented as a 2D array of Red, Green and Blue colour one by one. In MATLAB® software default representation of a colour image is similar as explained above. In few cases these value of individual colour intensity written as group of [R, G, B] such as [53, 66, 19]. In MATLAB® software colour image is represented as a 2D array.

```
>> a = imread('F:\My M. Tech Thesis\Image\X (1_2).jpg')
a(:,:,1) =
  192  166  113   56   62  148  123
  179  114   55   12   67  111  116
  201  145  112   73  123   86  143
  182  169  159  136  152   67  140
  141  144  118  128  143   76  117

a(:,:,2) =
  197  169  111   52   55  142  117
  184  117   53   8   60  105  110
  204  147  110   69  116   80  137
  185  171  157  132  145   58  132
  144  146  114  122  133   67  109

a(:,:,3) =
  175  158  124   77   89  170  129
  162  106   66   33   94  133  122
  183  136  123   94  150  108  149
  164  160  170  157  179   87  145
  123  135  128  148  168   96  122
```

Figure 4: Colour Image Interpretation

7.2 GREYSCALE IMAGE

Greyscale object is visualized as a shade of grey denoted by a grey scale value ranging from the colour black (0) to white (255).

```
>> b=rgb2gray (a)
b =
  193  167  113   56   61  147  120
  180  115   55   12   66  110  113
  201  145  112   73  122   85  140
  182  169  159  136  151   64  136
  141  144  117  127  140   73  113
```

Figure 5: Greyscale Image Interpretation

7.3 BINARY IMAGE

A binary image is a form of a digital image that has contains only two possible values for every pixel. The two colour used for a binary image is black and white.

Binary image is also interpreted in MATLAB® software form of a 2D array of pixel value. In binary image there is only 2 pixel value that is 0 and 1.

```
>> c = im2bw (b)
c =
   1   1   0   0   0   1   0
   1   0   0   0   0   0   0
   1   1   0   0   0   0   1
   1   1   1   1   1   0   1
   1   1   0   0   1   0   0
```

Figure 6: Binary Image Interpretation

8. IMAGE PROCESSING APPROACH

All the digital images are represented as an array of pixel values, all the computations on digital images start from the pixel level. There are mainly three ways to image processing.

8.1 PIXEL BASED APPROACH

The easiest digital image processing technique is to implement the processing technique directly on the basic component of the image that is pixel values. Digital Image properties like that average intensity, intensity deviation, colour histogram, ratio of dark intensity to light intensity pixels and similar over all measures are fast to processing and in some approach this can deliver all the necessary information regarding with the digital image.

8.2 PATTERN MATCHING APPROACH

For the condition where the product appearance is well known and is completely different from the environment, then we normally recommend the pattern matching technique for image processing for automated visual inspection. Pattern matching technique gives the result by comparing a model of the product against the product source image. By comparing all possible locations of the product at all possible scales and/or rotation, the most suitable location of the product can be found. The important issue with this approach is that the pattern matching technique becomes computationally expensive.

8.3 FEATURE BASED APPROACH

For quality inspection process where specific relationships and dimensions between products are important, it is generally necessary to extract feature is high level features from the digital image such as

circles, lines and colour patches. These techniques try to mimic the process that human visual processing technique is applied to break down images into fundamental shapes before these processing technique are used for recognition step. As such, it is too much intuitive to see a digital image in form of colours, outlines, and basic shapes.

9. IMAGE PROCESSING ALGORITHM

In this research article image processing technique is based on processing of a binary image. The reason is that the binary processing of the image is very fast and is easy to implement into hardware. It also helps to measure the properties of regions without too much computational load. These reasons make binary processing popular for high speed inspection where there is an only limited processing time available specially manufacturing industry where high speed production of the product occur. Binary image processing is accomplished using a fixed threshold value. Pixel intensities above this threshold are set to white and those below, to black.

9.1 IMAGE DATABASE

First of all for image processing approach a set of images is stored in MATLAB® software to train the image processing algorithm for AVI system. In this process initially a sample image is loaded to make a comparison between two images. Further few OK and few NOT OK images are save one by one in software database.

In this research article to train the algorithm, seven images is load in MATLAB® software in which four images are pass and three images are fail. These images are shown below;

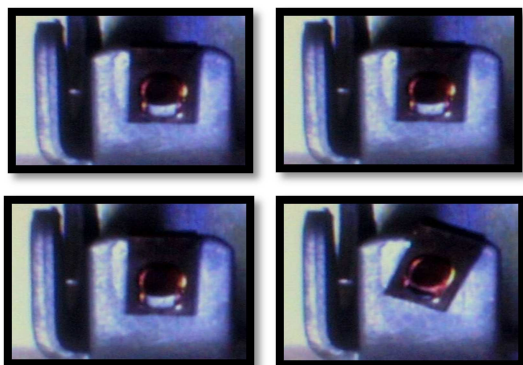


Figure 7: Set of OK image respectively called A1 (Sample Image), A2, A3 and A4

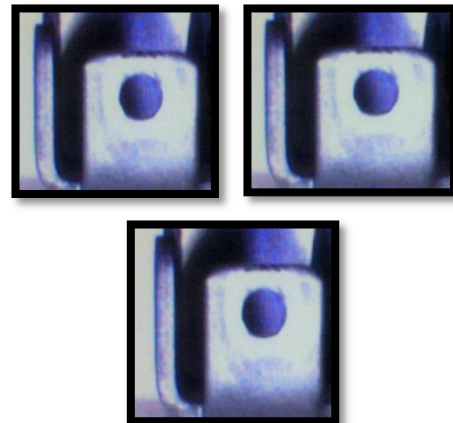


Figure 8: Set of NOT OK image respectively called B1, B2 and B3

9.2 IMAGE CONVERSION

The images save in image database is initially converted in to greyscale image from RGB image. Similarly all the images in database are converted into greyscale image by using the command `rgb2grey` in MATLAB® software. After completion of this image processing step all greyscale image are converted into binary image by the command `im2bw` for mathematical operation on these images. The conversion of the images use the threshold factor 0.8 for pixel value in 2D array such as pixel value greater than this value [$255 \times 0.8 = 204$] is converted into pixel value 1 in binary image and the value below it store by 0 in binary image.

9.3 IMAGE DIFFERENCE

After the successful conversion of the colour image into binary image difference between sample image and input image is calculated by difference operator in MATLAB® software. The difference obtained by this operation is a form of 2D array. This 2D array is also representing a binary difference image of sample and input image [10].

9.4 MEAN ABSOLUTE DEVIATION

The difference image obtain in last processing is processed by another MATLAB® software command “`mad`” which calculate the “Mean Absolute Deviation” of that image. The value obtain in this processing step is a row image vector.

9.5 MEAN DIFFERENCE

At the end of the image processing algorithm we calculate the mean difference of row vector obtain in

previous processing step. This operator is use by the MATLAB® software command `mean(diff())`. The result obtain from this step will show the exact difference of sample image and input image. By the sufficient retraining of these processing steps we obtain a particular difference which is set as a limit for the acceptance of the product which is manufactured.

9.6 RESULTS OBTAIN FROM IMAGE PROCESSING ALGORITHM

The difference between the sample image and input image is described the deviation in the quality of the product. The high value of difference represents the maximum deviation in the product. As retrain the AVI system obtain a certain value from the image processing algorithm. Above this value the product is rejected. The following given table show the results obtain from the Image Processing Algorithm:

Table 1: Results obtain from the image processing algorithm for product is acceptable or not

Sample & Input Image Pair	Mean Difference	Numerical Value	Result
A1A2	$1.2545e^{-005}$	0.00845275	OK
A1A3	$1.3092e^{-019}$	0.00000001	OK
A1A4	$2.5023e^{-019}$	0.01686036	OK
A1B1	$2.1555e^{-004}$	0.03947935	NOT OK
A1B2	$2.1555e^{-004}$	0.03947935	NOT OK
A1B3	$2.1555e^{-004}$	0.03947935	NOT OK

By the above table we see that a particular value is fixed for accepted product. When final mean difference is less than a certain value then this image or product is accepted or else the product is rejected. By the help of above table that value is fixed to the mean difference value (0.01686036).

10. CONCLUSION

The use of an Image Processing Algorithm in Automated Visual inspection system can improve the quality inspection process. By the use of software assisted inspection process the flexibility of AVI

system improve rapidly. The main advantage of the threshold based system is that it is simple.

The most important finding of this research article is advantage of example based learning to train AVI system. Example based learning give quick result. If this approach is used for inspection process the chance of success and a trouble free system can be developed. The strong result of the threshold-based system is also suggested that this may be an approach for future development.

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