

Construction of P-Control Chart Using Image Processing Technique

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Abstract. P-control chart is a graphical tool in statistical process control, which is widely used for monitoring and examining the activities of quality processes. Therefore, data accuracy and timely information are vital aspects that effect on production line efficiency. Thus, the aim of this study is to develop image processing technique to classify product quality and create p- control charts. Automated visual inspection is a key factor of image processing technique. The automated visual inspection section, digital camera was used to capture product image which is coming out of product line then transfer data to computer for further processing. Subsequently, the image processing was employed to compare and verify (i.e., size, shape, and position) manufactured product image with standard product and create p- control chart by using MATLAB software. The results indicated that digital image processing (DIP) technique was an accurate method to classify quality of product, and the system was also an effective approach to construct p – control chart for monitoring process stability. The findings of this study can be used to support managerial decision making when monitoring and improving effectiveness of manufacturing process.

Keywords: p-control chart, image processing, automated visual inspection

1. INTRODUCTION

The increased demands and quality of products for objectivity, consistency, and efficiency have forced manufacturers to increase the level of control in the production process and necessitated the introduction of accurate automated inspection systems (Sasso, Natalini, & Amodio, 2011). Traditional quality control and inspection performed by human inspectors have the potential to be replaced by computer systems because performances of a human inspector are highly influenced by emotional, physical and environmental distractions. Moreover, manual quality inspection becomes expensive and time consuming (Arroyo, Lima, & Leitao, 2013; Elbehiery, Hefnawy, & Elewa, 2007; Ibrahim, Zin, Nadzri, Shamsudin, & Zainudin, 2012; Park, Jin, Au, Luo, & Cui, 2009).

Consequently, the application of systems based on digital image processing technique is an effective tool, not only for increasing throughput, reliability of production control and also obtaining a large number of information that assist the

management of production processes (McAndrew, Wang, & Tseng, 2010; Park et al., 2009; Taylan, 2011).

In this study aim to establish the p-control charts by using DIP technique. We intend to justify that a computer can be able to solve problem and classify the quality of product by assisting of definitions from human eye. Hence, we developed DIP to increase the efficiency of quality control, and eliminate human error in the production process.

The rest of this study is organized as follows. Section 2 explains regarding the literature of DIP and p-control chart. Section 3 presents methods and system development process. Section 4 illustrates the results of DIP, product defect graph, and p-control chart. Finally, section 5 conclusions.

2. LITERATURE REVIEW

2.1 Digital image processing technique

DIP method stems from two principle application areas as

follows: 1) the improvement of pictorial information for human interpretation, and 2) processing of scan data for autonomous machine perception (Gonzalez & Woods, 1992; McAndrew et al., 2010). It is an area characterized by the need for extensive experimental to establish the viability of proposed solutions to a given problem which involves using a computer to change the native of a digital image (McAndrew, 2016).

In existing literature DIP approach has been widely employed almost every area of science and technology. For instance, Perlo et al. (2016) applied digital processing of image of extruded rubber profiles for process control MRI, Shen and Maa (2016) employed a camera and image processing system for floc size distributions of suspended particles, and Adem, Orhan, and Hekim (2015) developed DIP based quality control of the impermeable seams in multilayered aseptic packages, Yalman (2014) studied regarding histogram based perceptual quality assessment method for color images, Shirgahi and Danesh (2011) established a fuzzy system to determine berry product quality based on average color spectra by image processing, and Leiva, Mondragón, Mery, and Aguilera (2011) applied the automatic sorting using image processing improves postharvest blueberries storage quality.

We adopt MATLAB for DIP and image quality assessment, and p-control chart establishment. The reasons for applying MATLAB in this study are as follows: 1) MATLAB is a high performance language for technical computing. Moreover, it integrates computation, visualization, and programming in an easy to use environment, 2) the DIP toolbox is a collection of MATLAB functions, which extend the capability of the MATLAB environment for the solution of digital of DIP problems (Gonzalez, Woods, & Eddins, 2011).

2.2 P-Control Chart

Quality control charts are one type of the tools in quality management and vital aid to the quality control. Moreover, control charts are widely employed to monitor and ensure the process stability. The power of control charts lies in their ability to detect process shifts and identify abnormal conditions in the production process. However, they do have limitations, which one obvious limitation is that variable control charts cannot be used for quality characteristics that are attributed. Furthermore, nonconformities (i.e. missing, parts, incorrect color, product defect, and so on) are not measurable, and a variable control chart is not applicable. Consequently, p-control chart is used for attributes and nonconforming units.

The p-control chart data consists of the proportion of number of occurrences of an event to the total number of occurrences. It is used in quality to report the fraction or percent nonconforming in a product, quality characteristic or group of quality characteristics (Besterfield, 2013). Consequently, to calculate the trial central line, upper control

limit (UCL), and lower control limit (LCL), the formula is given as follows:

$$UCL = \bar{P} + 3 \sqrt{\frac{\bar{P}(1 - \bar{P})}{n}} \quad (1)$$

$$CL = \bar{P} \quad (2)$$

$$LCL = \bar{P} - 3 \sqrt{\frac{\bar{P}(1 - \bar{P})}{n}} \quad (3)$$

where \bar{P} is average proportion nonconforming for many subgroup, and n is a number inspected in a subgroup. The average proportion nonconforming or central line, which \bar{P} is obtained by the formula as follows:

$$\bar{P} = (\sum np)/(\sum n) \quad (4)$$

Depending on the value of P and n sometimes the value of LCL is less than 0, in this case, we customarily set LCL=0 and assume that the control chart only has an upper control limit.

2.2.1 Interpreting the p-control chart (Gupta & Walker, 2007)

2.2.1.1 If any point or points exceed the upper or lower control limit, we conclude that the process is not stable or some special causes are present in the process.

2.2.1.2 The presence of special causes, which may be favorable or unfavorable, must be investigated, and appropriate action should be taken.

2.2.1.3 A point above the UCL is generally an indication as follows: 1) the control limit or the plotted point is in error, 2) the process performance has deteriorated or is deteriorating, and 3) the measurement system has changed.

2.2.1.4 A point below the LCL is generally an indication as follows: 1) the control limit or the plotted point is in error, 2) the process performance has improved or is improving, and 3) the measurement system has changed.

2.2.1.5 If \bar{P} is moderately high ($n\bar{P} \geq 5$), then an approximately equal number of points should fall on either side of the CL. Therefore, either of the following conditions could indicate that the process has shifted or a trend of a shift has started.

2.2.1.6 The run is above or below the CL generally implies as follows: 1) the process performance has deteriorated and may still be deteriorating, and 2) the measurement system has changed.

3. METHODOLOGY

The main purpose of this study was to develop p-control charts using DIP technique. An overview of the system in this

study as shown in Figure 1. A digital camera and auto sensor were employed to capture product images that coming out of the product line. Subsequently, the captured image information was transferred to the computer for further processing. DIP approach was used to classify and verify the quality of product. The image required from the camera was analyzed by using the MATLAB image processing toolbox to check the product's quality by number, size, and position. Furthermore, we created command to calculate the central line, the upper control limit value, and the lower control limit value from classified data then establish graph and p-control chart.

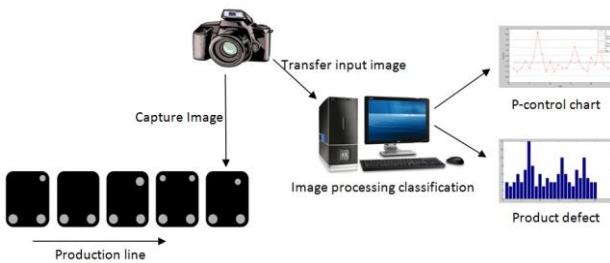


Figure 1: The overview of proposed systems

3.1 Digital Image Processing Procedure

In this study, the complete process flow as shown in Figure 2. We first created standard product image database for using in matching process, which match was estimated based on the intensity value pixel by pixel of both image and standard image. Subsequently, image processing task, the captured images from digital camera transferring were converted to a grayscale image by eliminating the hue and saturation information, and then converted this grayscale image to binary image by thresholding. A binary image is suitable image form for analyzing edge detection of DIP, which the output of binary image has values of 1 (white color) for replacing all pixels in the input image with luminance greater than level and 0 (black color) for all other pixels. After that, noise removal process, we used morphological operations to reduce noise of image through the shrink operation to remove pixels and fill a small hole for sharpening and smoothing image. The example of product's image after these processes as shown in Figure 3 where the product's image color consists of black and white color only.

The product's inspection process, the classification of quality of the product was done by testing a hole number, a hole shape, and a hole position. If the image fits accurately with standard product in database, the product will be considered as a good product. To carry out quality testing becomes automated production line, increased productivity, and reduced human errors.

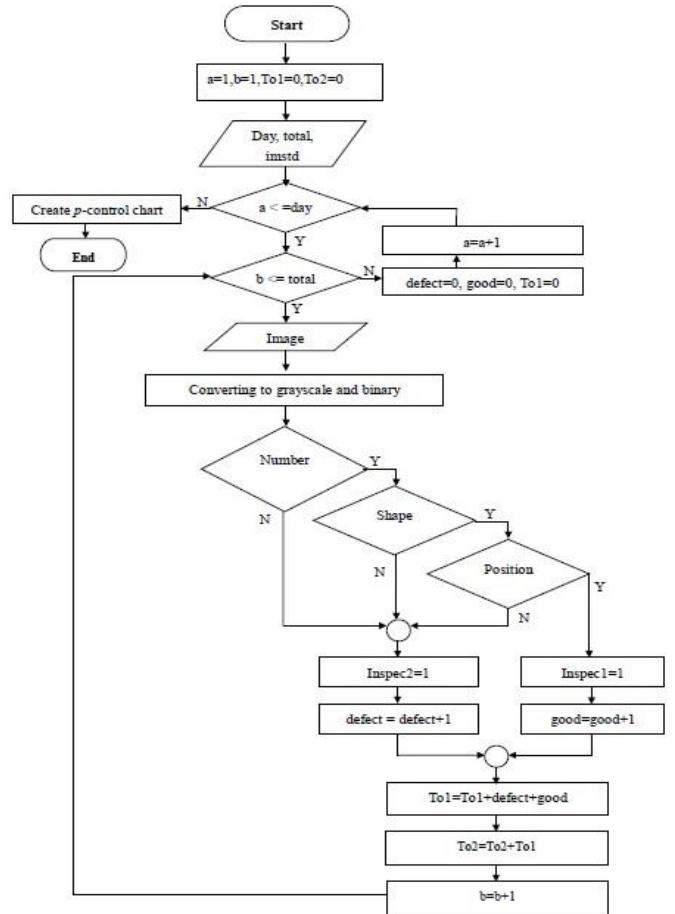


Figure 2: Digital image processing process systems

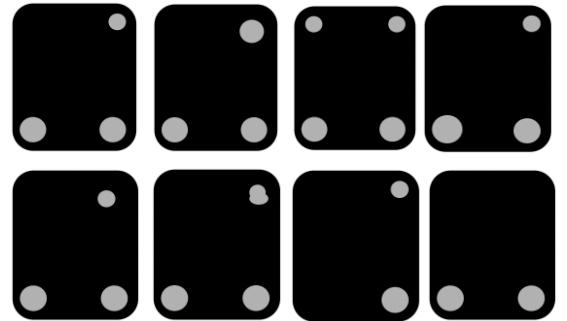


Figure 3: Images of product from morphological operation

3.2 P-Control Chart Process

For creating p-control chart, we used all only the product's classified as "not good product or faulty product" to calculate control chart values, create p-control chart, and establish defect product graph. The p-control chart and defect product graph code as follows.

Graph and p-control chart code:

```

chart
m=g;
d=f;
np=f;
ra=f1;
paverage=sum(np)/sum(m)
[r c]=size(imgCell);
b=1;
while b<=r;
    cl(b)=paverage;
    lcl(b)=paverage-3*((paverage*(1-paverage)/c)^(0.5));
    ucl(b)=paverage+3*((paverage*(1-paverage)/c)^(0.5));
    si1(b)=cl(b)+((ucl(b)-cl(b))/3);
    si2(b)=si1(b)+((ucl(b)-cl(b))/3);
    si3(b)=cl(b)-(cl(b)/3);
    si4(b)=si3(b)-(cl(b)/3);
    if lcl(b)<0;
        lcl(b)=0;
    end
    if f1(b)>ucl(b)
        plot(b,ra(b),'kO');
        hold on
    end
    b=b+1;
end
t=1:r;
plot(t,ucl,'k:',t,si1,'m:',t,si2,'g:',t,cl,'k-
',t,si3,'m:',t,si4,'g:',t,lcl,'k:',t,ra,'r*-');
hold on
legend('oc','ucl','1Sigma','2Sigma','cl','1Sigma','2Sigma','l
cl','defect')
xlabel('days')
ylabel('Propotion')
t=1:r;
figure,bar(t,f);
hold on
xlabel('days')
ylabel('defect')
hold off

```

4. RESULTS

To assess the quality of product in this study, we tested 25 days, 750 samples were selected into DIP system. The classification of product's quality has been done by employing the step that we mentioned in the previous sections. The result of the examination in mathematics by using image processing is provided in the table 1, in the table 1 represents the total products per day, defect products, good products, \bar{P} values, and classification percent values. The classification of product's quality has higher accuracy between 93 to 100 percent.

Table 1: The Classification of product's quality by using DIP

Days	Total products	Defect products	Good products	\bar{P}	Classification (%)
1	30	4	26	0.13	100
2	30	3	27	0.10	100
3	30	4	26	0.13	100
4	30	6	24	0.20	97
5	30	4	26	0.13	100
6	30	7	23	0.23	100
7	30	14	16	0.46	93
8	30	8	22	0.26	100
9	30	3	27	0.10	100
10	30	6	24	0.20	100
11	30	3	27	0.10	93
12	30	5	25	0.16	100
13	30	4	26	0.13	97
14	30	4	26	0.13	100
15	30	8	22	0.26	97
16	30	10	20	0.33	97
17	30	6	24	0.20	100
18	30	4	26	0.13	100
19	30	3	27	0.10	100
20	30	7	23	0.23	97
21	30	5	25	0.16	100
22	30	10	20	0.33	93
23	30	5	25	0.10	100
24	30	4	26	0.13	100
25	30	4	26	0.13	100
Total	750	141	609	0.18	

Figure 4 represents the defect product graph that the sample 7 is high and out of control, for which the sample size is 30, 14 defect products, 16 good products. In the p-control chart graph, the central line illustrates the nonconforming items. Therefore, the central line, upper control limit, and lower control limit for p-control chart is as follows. CL=0.1880, UCL=0.4020, and LCL= 0, respectively. The p-control chart for the 25 samples is shown in Figure 5.

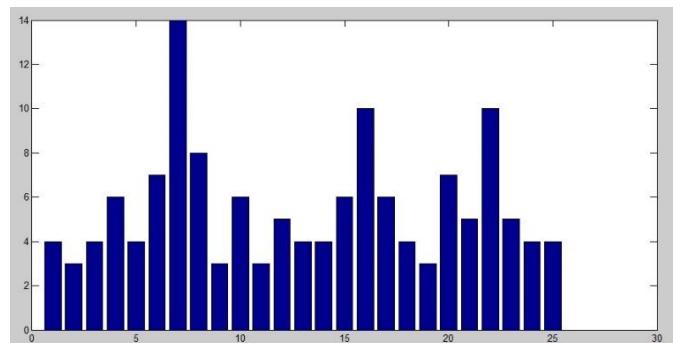


Figure 4: Defect products

As it can be seen from Figure 5, only the sample 7 is out

of control, it means that some special cause was happened in the process. The sample 16 and 22 fall in warning area, which the quality inspector should check and take appropriate action.

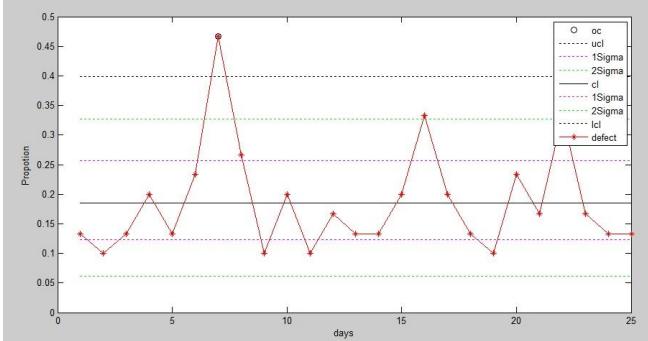


Figure 5: A p-controlchartst to represent the trial central line and control limits for 25 samples

5. CONCLUSION

This study addresses the enhancement of adaptable system for monitoring product's quality in production process. Hence, the objective in this study is to construct P-control chart by using DIP technique through utilization of MATLAB software with image processing tools. DIP technique was employed to classify the quality of product by number, shape, and position. Subsequently, we calculate control chart values (i.e., LCL, CL, and UCL) and created defect product graph and p-control chart by using MATLAB function. Based on the experimental results, the proposed systems have been able to classify the quality of product with performance accuracy and effectiveness. Future research may be able to adopt such methods to quality management field such as quality control, quality assurance.

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