

## INTELLIGENT ATTRIBUTE CONTROL CHART SYSTEM ESTABLISHING FUZZY IMAGE PROCESSING TECHNIQUE

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### ABSTRACT

Currently, quality of product is an important business strategy in competitive global market. Moreover, improving tools for monitoring operation process has become inevitable. To reduce human error effect in inspection process, the objective of this study is to integrate image processing approach and fuzzy set technique for classifying quality of product and create attribute control chart. Image processing system was employed to assess quality of product through verifying size, shape, and position. Subsequently, the fuzzy set system was used to reduce ambiguous problems and identify abnormal conditions in the production process, then create an attribute control chart using MATLAB function. The results represented that the proposed system was an accurate approach to verify quality of product. Furthermore, the system was an effective tool to construct attribute control chart to monitor process stability and improve production process effectiveness.

**KEYWORDS:** Attribute control chart, image processing system, fuzzy set system

### 1. Introduction

Nowadays the increased customers' requirement 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 to enhance production capability and achieve in customer's satisfaction [1]. With regarding process of quality control and product inspection currently, automatic quality control systems are utilized to monitor product quality and replace traditional human inspectors' quality control because performances of a human inspector are highly influenced by emotional, physical and environmental distractions. Moreover, manual quality inspection

becomes expensive and time consuming [2, 3]. Consequently, the firm's managers have to create suitable tool and management system for increasing production line effectiveness. Based on previous literature, digital image processing approach was an efficient tool, which used to enhance reliability of production control processes and productivity [4-6]. Moreover, to eliminate the human inspector effect, many researchers employed fuzzy set theory to reduce the ambiguity problem that affects the decision making process [6-8].

The objective of this study is to establish the attribute control charts by integrating both approach fuzzy set and image processing technique (FIP). 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. Thus, we developed FIP to enhance the efficiency of quality management, and reduce human error in the production process.

The rest of this study is organized as follows. Section 2 explains regarding the literature of digital image processing and a relationship between fuzzy set theory and attribute control chart. Section 3 presents research methodology. Section 4 illustrates the results of fuzzy image processing. Finally, section 5 conclusions.

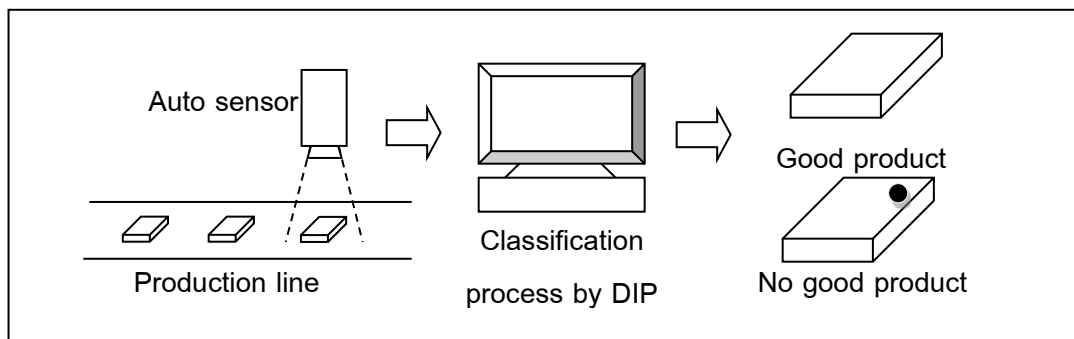
## **2. Literature review**

### **2.1 Digital image processing: DIP**

Quality management is growing rapidly in industrial development and operation production management. Moreover, quality assurance is also an important approach to increase customer satisfactions, which means that firm's manager have to concentrate production process and endeavour to detect defeat product and meet customer's requirement. DIP is the best technique that employed to support automated product testing and increase the production effectiveness. DIP consists of two processes as shown in figure 1.

According to figure 1, DIP input process through using an auto sensor to capture product image. Subsequently, the captured photo is transferred to the classification process which consists of preparing image process and classification process. The preparing image process is a process that provides a suitable photo to analysis data using image processing functions. Finally, classification process or DIP output, the suitable image analysed a quality of product by matching with standard product based on research objective such as DIP for measuring

product quality by size, shape, and surface, which good product is the captured image fit for standard product. Recently, DIP approach has been employed to study on quality management. Adem, Orhan, & Hekim [9] and Phan and Baird [10] created DIP system to perform the quality control of impermeable seams in multi-layered aseptic packages. Brosnan and Sun [11] used DIP technique for food products of high quality and safety standard. Perlo et al. [12] established DIP approach to analyse polymer and rubber materials of extruded rubber profiles for process control MRI. Arroyo, Lima, and Leitaio [2] adapted Image processing for quality control in production lines, which the results demonstrate significant image quality enhancements and a valuable reliability improvement of the automated quality control procedures.



**Figure 1 the entire digital image processing system**

## 2.2 A relationship between Fuzzy set and Attribute control chart.

Fuzzy set theory was established by Lotfi Zadeh, which is an approach that employed to reduce an uncertainly ambiguity in a complex problem. Moreover, it also can support a decision maker to forecast or evaluate the problem effect through using estimated conditions [7]. Fuzzy set theory has been applied in different areas such as quality management, which was used to inspect product quality and verify product quality characteristics [8, 13]. The fuzzy inference system consists of fuzzification interface, which created integrating between both processes crisp input and input membership functions, rule evaluation is a process to assess condition through transforming into the grade of membership function for linguistic terms of the system and finally defuzzification interface is a process to translate result/output from setting input, and simulation output.

A control chart is a tool in the quality management field that used in monitoring production process and ensuring process stability. In statistical control chart, the power of control charts lies in their ability to detect process shifts and indicate abnormal conditions in a production process [6]. P-control chart is a one type of attributed and verify nonconformity problems such as missing, product defect, incorrect colour etc. Therefore, to reduce human error when human subjectivity plays an important role in classifying the quality characteristics, the original control chart may not be suitable tools for monitoring production process. A contribution of fuzzy set theory are employed to reduce uncertain or vague, ambiguous or not well defined, and includes human subjectivity [14]. 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 subgroups, 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.

In this study, p-control chart is redesigned when the characteristics of product quality are defined as fuzzy set assessment. With regarding measurement process through employing triangular fuzzy numbers (TFNs). The calculation of control chart value can be transferred to the TFNs value as follows:

$$\bar{P} = \left[ \frac{\sum_{i=1}^n P_{a_i}}{n}, \frac{\sum_{i=1}^n P_{b_i}}{n}, \frac{\sum_{i=1}^n P_{c_i}}{n} \right] = TFN(T_1, T_2, T_3) \quad (5)$$

Where  $n$  is a subgroup's inspected number, and  $p$  value is a nonconforming product of each subgroup. Subsequently, a control limit values for creating p-control chart can be calculated as follows.

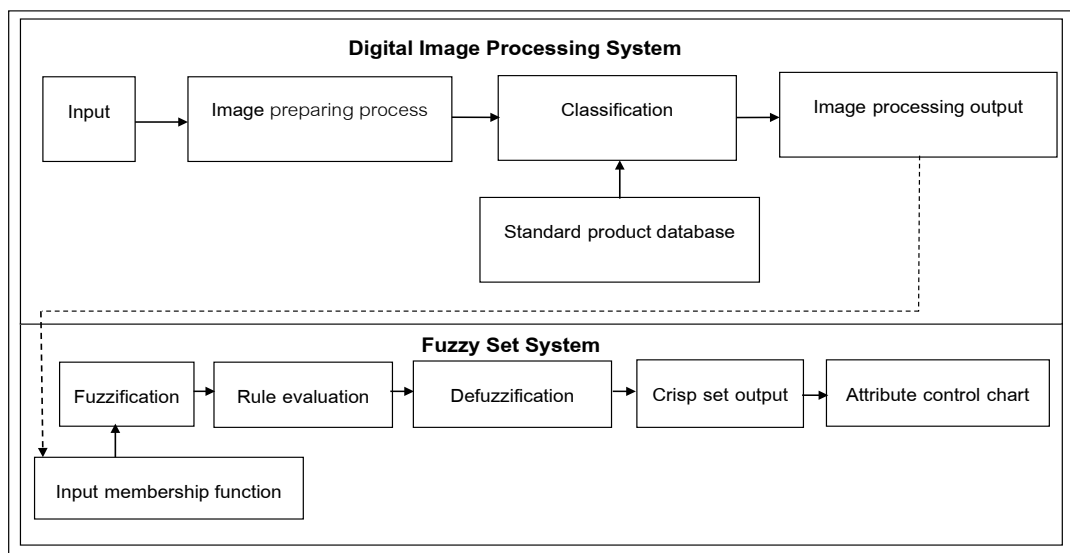
$$\begin{aligned} UCL_i &= \bar{P} + 3 \sqrt{\frac{\bar{P}(1 - \bar{P})}{n}} \\ &= \left[ \bar{P}_{a_i} + 3 \sqrt{\frac{\bar{P}_{a_i}(1 - \bar{P}_{a_i})}{n}}, \bar{P}_{b_i} + 3 \sqrt{\frac{\bar{P}_{b_i}(1 - \bar{P}_{b_i})}{n}}, \bar{P}_{c_i} + 3 \sqrt{\frac{\bar{P}_{c_i}(1 - \bar{P}_{c_i})}{n}} \right] \\ &= TFN(UCL_{a_i}, UCL_{b_i}, UCL_{c_i}) \end{aligned} \quad (6)$$

$$CL_i = \bar{P} = (\bar{P}_{a_i}, \bar{P}_{b_i}, \bar{P}_{c_i}) = TFN(CL_{a_i}, CL_{b_i}, CL_{c_i}) \quad (7)$$

$$\begin{aligned} LCL_i &= \bar{P} - 3 \sqrt{\frac{\bar{P}(1 - \bar{P})}{n}} \\ &= \left[ \bar{P}_{a_i} - 3 \sqrt{\frac{\bar{P}_{a_i}(1 - \bar{P}_{a_i})}{n}}, \bar{P}_{b_i} - 3 \sqrt{\frac{\bar{P}_{b_i}(1 - \bar{P}_{b_i})}{n}}, \bar{P}_{c_i} - 3 \sqrt{\frac{\bar{P}_{c_i}(1 - \bar{P}_{c_i})}{n}} \right] \\ &= TFN(LCL_{a_i}, LCL_{b_i}, LCL_{c_i}) \end{aligned} \quad (8)$$

### 3. Research methodology

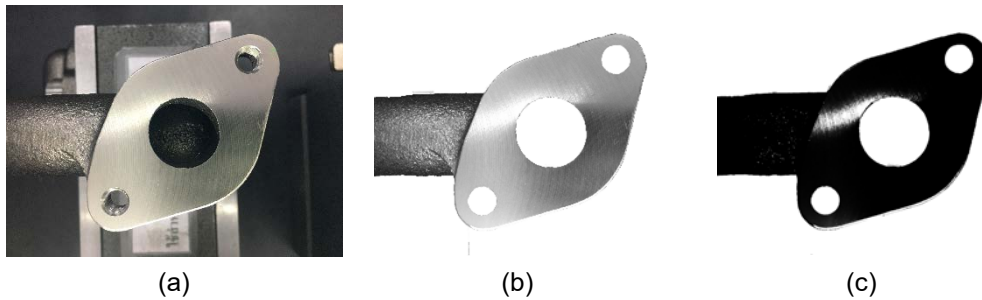
The objective of this study was to establish attribute p-control charts integrating fuzzy set theory and DIP technique. Nakhon Ratchasima's auto parts company was selected to investigate in this study and product image in Figure 3. An overview of the system in this study as shown in Figure 2.



**Figure 2 the overview of fuzzy image processing system**

### 3.1 Image Processing Process

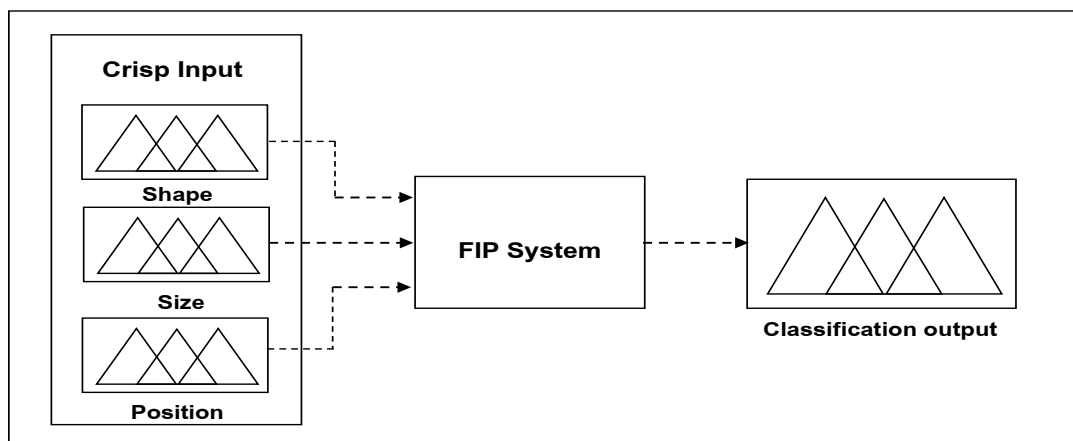
With regard input DIP system process, firstly auto sensor was used to capture a product's image that coming out of the production line process, then the captured image was transferred to the classification process by using the MATLAB image processing toolbox to create image processing system. Second process, DIP approach was employed to verify and classify quality of product. Preparing image process, the captured image (Figure 3 (a)) from auto sensor transferring was converted to grayscale image format to reduce hue and saturation of images (Figure 3 (b)) then converted to binary mode using thresholding technique as shown in Figure 3 (c). Binary form is a suitable mode for the DIP system to analyse edge and shape detection, while the binary form consists of both values 0 and 1. White color represents by "1" for replacing all pixels in the input. Image with luminance greater than level and "0" value black color (for other pixels). Subsequently, with regarding preparing suitable image process for DIP analysis, morphological operation approach was used to reduce noise image through sharpening and smoothing image. Finally, inspection process, the completed image was transferred to classify quality of produce by comparing with standard product, which verify by shape, position, and number. If the image fits accurately with standard product and customer's requirement, the product will be considered as a good product.



**Figure 3** product images for image processing analysis

### 3.2 Fuzzy set process

Firstly, with regarding fuzzification process of fuzzy set system, DIP results and customer's acceptable values were integrated to set a suitable membership function, which its structure represented three input variables (i.e., area, centroid, and hold number) and one output variable in the system combined by the fuzzy control functions as shown in Figure 4. Subsequently, the fuzzy rules were defined into the system through expert's suggestion who have experiences and knowledge in production process such as a head of production department and head of quality control department. Defuzzification process, this step was used to translate crisp set input to evaluate crisp set output. Finally, for creating p-control chart, we employed all only the product's classified as "not good product or faulty product" to establish control chart values.



**Figure 4** fuzzy set system

#### 4. Results

To assess the quality of product in this study, we tested 25 days, 30 products per day, and total 750 samples were selected into fuzzy image processing (FIP) system. The classification of product's quality has been done by employing the step that mentioned in the previous sections. The result of the examination in mathematics by creating the FIP system is provided in the table 1.

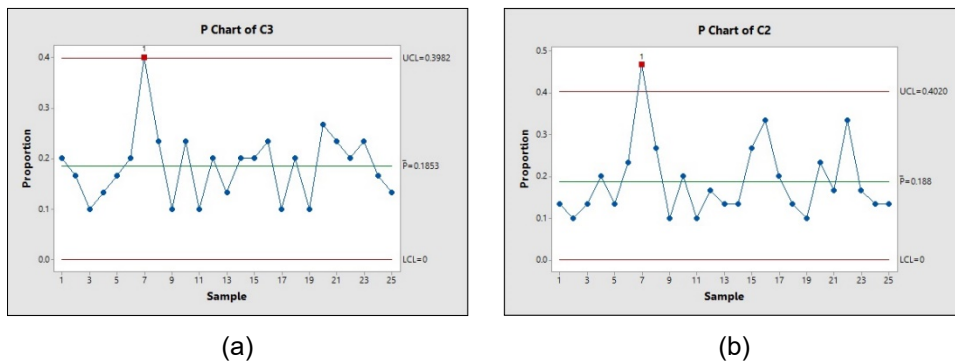
**Table 1 a comparison results between human inspection and FIP inspection**

Weeks	Human Inspection			FIP Inspection		
	Total	Defect products	Classification (%)	Total	Defect products	Classification (%)
1	210	41	85.71	210	42	100
2	210	36	85.79	210	33	100
3	210	40	70.14	210	43	100
4	120	22	73.75	120	23	100

In the table 1 represents a comparison results between human inspection and FIP inspection by the total products, defect products, and classification (%). The classification performance of proposed system has higher accuracy and effectiveness 100 percent, whereas human inspection's classification results around 70.14 to 85.79 percent. For the second week, the defect product of the FIP approach is 33 pieces and lower than human inspection, which the reasons were new employee problem and measurement error. With regarding P- control chart results are provided in Figure 5, which Figure 5 (a) is p-control chart of human inspection and Figure 5 (b) is p-control chart of FIP inspection.

Figure 5 represents p-control chart of both approaches (i.e., human inspection approach and the FIP approach) for 25 days and collected 30 products per day. The defect product graph that the sample 7 is highly defect product (14 defect products and 16 good products) and out of control. 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.





**Figure 5 p-control chart results**

## 5. Conclusion

This study addresses the enhancement of the adaptable system for monitoring product quality and reduce human error in the production process. Therefore, the objective of this study is to create attribute control chart (p- control chart) especially integrating fuzzy set approach and DIP technique through utilization of MATLAB software. DIP approach was created to input product image and classify the product quality by number, shape, and position. Subsequently, DIP results are transferred to assess whether product quality meets standard value and customer's acceptable value using fuzzy set evaluation. Finally, ensuring process stability and monitoring by calculating p- control chart values consist of LCL, CL, and UCL to construct p-control chart. Based on the experimental results, the proposed systems have been able to classify the quality of product with performance accuracy and effectiveness. Future research, firm's manager may be able to adopt such proposed technique to support firm's automatic quality management field, reduce waste of human error, and increase customer satisfaction.

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