ABSTRACT
We propose an online quality control for ball grid array (BGA) inspection system in this paper. The automated BGA inspection using a machine vision technique is proposed. In addition, it establish the website to present real time information for production control. The inspectioning results are stored to database server. When users need to gain the inspection reports, they can link to the server and monitor the production process from website. Thus, users can effectively gather real time production information and they are able to control the manufacturing process. In further, it can prevent defective items be sent to the next process and avoid from failure inspection.

Keyword: ball grid array, control chart, machine vision, quality control.

INTRODUCTION
Most of the industrial inspections are made by human inspectors in traditionial. Human inspection has a low efficiency due to tiredness, personal skill, deconcentrate in working or maybe mood of the operators which may lead to instability of product examination and low accuracy in inspection. As the information technology growing rapidly, this traditional approach has been gradually replaced to automatic inspection. Machine vision inspection system, with high stability, high accuracy and long time working hour advantages, has been executed in industrial environment for years.

Machine vision inspection and image processing have been widely used in industry, for example in the textile industry, padlock manufacturing, ceramic tiles, color printing inspection, etc. Stojanovic et al. (2001) proposed an automatic vision-based system for quality control of web textile fabrics by using improved binary, textural and neural network algorithms for defect inspection. Hakulinen and Hakkarainen (1996) presented a neural network based visual quality control system for padlock manufacturing. Smith and Stamp (2000) developed a visual inspection system of textured ceramic tiles to analyze the complex surfaces and to control products quality. Zhang and Luo (2003) proposed an algorithm to automate the color prints inspection process, which incorporates color histogram-based techniques for color image processing and neural network for image classification.

There are a lot of methodology have been applied in the inspection of ball grid array (BGA). Lin and Lue (2001) indicated the development of automated measurement machine to deal with (BGA) type printed circuit boards (PCB). They proposed to automate the boundary scan and circularity estimation by introducing the idea of the least-square circle to find the center of the holes and pads. The vision system, then, can easily inspect the local deviation when positioning table locates the PCB on the image capturing point. Chen (2001) introduced new rules for defect detection by comparing results of different methods of image processing. He found out threshold value for image segmentation and a better sub-pixel edge detect operator that can upgrade the inspection. To improve inspection
efficiency, least square error cycle to approximate the shape of solder balls is applied. He, then, provided an improvement proposal for the compensation method of the moving angle deviation between BGA substrate and the charge-coupled device (CCD) camera during the image capture procedure.

The main purpose for inspection is to make sure the quality of the product. A lot of statistical method has been applied to assist product examination. Hong et al (1999) used statistical method to control the software defect detection process and further defect prevention analysis. Zhang (1996) pointed out the important of integrating automatic inspection systems within the context of computer integrated manufacturing. Integrating quality control can be realized through an integration of inspection systems with process quality control systems such as statistical process control (SPC). Malamas et al. (2003) presented the state of the art in machine vision inspection and a critical overview of real-world application. They reviewed the most contemporary software and hardware tools for developing industrial vision system. Moreover, they pointed out the important issues and future directions for designing and developing industrial vision systems.

Above studies have great contributions in machine inspection techniques. However, researches in this field are not technically full integrated with the quality control and the system itself is limited to the single-machine operations, which can not immediately transfer the results to other departments.

This paper proposes the design of an online statistical control chart. The inspection results are entering from the inspection. With the internet, the inspection data are saved to server. When the makers or officers in charge need to monitor the production process, they can easily obtain the statistical control chart.

![Flowchart of online statistical control chart system](image)

**Figure 1. The flowchart of online statistical control chart system**

**METHODOLOGY**

This paper purposes a BGA solder ball inspection, by developing an online electronic inspection system with the implementation of machine vision techniques. The flowchart of the system is shown in
Fig. 1. Image is captured by using CCD camera and inspected by our proposed machine vision inspection system. The inspection results will then be stored in server’s database. Whenever the clients need to acquire these results, they can obtain them by connecting to server.

A. Image Preprocessing

After image captured by CCD camera, a serial of image preprocessing methods is applied to obtain solder ball image segmentation and feature extraction. The first step is to lessen information flow in an image so the processing time may be faster. Gray scale is generally employed in this stage, because it can reduce information flow to one-third of original flow.

In consideration of captured image may contain much nuisance factors, which can disturb the processing and may lead to misjudge the results, suppress noise is essential to decrease these interferences. Median-pass filter is one of the effective tools and frequently been used for this purpose, since the distortion on image it brings is quite low. Binary threshold, then, is hold to distinguish solder ball from board image. It is an extreme approach to obviously obtain solder ball image for further feature extraction. Next, each solder ball in image is labeling, the same object is tagged with similar chromosome number. That is, each pixel in one solder ball will be assigned to the same number.

B. Machine Vision Inspection

After a serial of image preprocessing approach is executed, the features of the image can be extracted. Before the system was well prepared to be active, the examination training, which aimed to develop solder ball specification rules, was enforced. Hence, defect detection is made by comparing the feature extraction and specification rules. Two main performances to measure flaws of BGA are area and roundness. Area is the calculation of solder ball pixels and roundness is the difference value between the shorter line from centroid to perimeter and ball’s radius divided by radius of solder ball. The inspection results are then displayed in the inspection post machine and concurrently be saved in database. The complete figure of machine vision inspection is shown in Fig. 2.
The aim of this study is to provide an online inspection system; to gather the output results for quality analysis, therefore, it is necessary to link to the database in order to store inspection’s outputs. Database utilized here is Microsoft Access which included two data files. One is data file to record the outputs of solder ball’s area and roundness. Another is data file to account the frequency flaws like missing, overlap, undersize or oversize of balls on each batch of inspections. These inspection results, then, can be seen on the website by using active server pages (ASP) as its connection.

This study uses Internet Information Server as its platform. Since ASP is simple to learn and it connects to database easily. Hence, it is one of the famous interactive language programming. Our paper utilized ASP to connect to database, interpret the inspection results to a control chart, and website is set to be automatically updated. Whenever a new inspection results is stored in database, the website will directly be modified. So without time and space limitations, one can realize the processing update status. The development of website is shown in Fig. 3.

Figure 2. Machine vision inspection system

C. Development of WebSite

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D. Quality Control Chart

Automatic inspection system can smoothly gathered production process status, consequently, users can monitor output results whenever he needs to attain the processing situations. SPC is frequently been used to control process quality. Setting the upper control limit (UCL), lower control limit (LCL) and central Line (CL) from the sample size, then, these distribution sample size is transformed to control chart. Users can learn, by using our proposed system, whether there are anomalies symptoms, such as the unstable output results like decrease or increase continuously for more than seven times.

This study applied SPC with X-s chart to analyze solder balls’ inspection process. X is the sample mean and s is the standard deviation of sample population. The formula of UCL, CL and LCL of X chart and s chart are described as follows (Montgomery, 2001):

**EXPERIMENTAL RESULTS**

With the concept of object oriented programming (OOP), it establishes each processing function as an independent module. Users can use this system directly by choosing the suitable procedure desired. Median-pass filter, binary threshold, project segmentation, feature extraction area and roundness inspection procedure are employed for solder ball shape detection, to compute each solder ball’s area and roundness value. The inspection results, then, are stored to database using sort query language (SQL) provided by ASP. Figure 4 shows the interface of BGA inspection system. It used median-pass filter to suppress the noise, binary threshold to enhance the image, project segmentation to divide each solder ball, then extract its calculation area and roundness value, to, finally, dispatch the information to database.
Figure 4. The Module of BGA inspection system.

Table 1. $\bar{X}$-s chart

<table>
<thead>
<tr>
<th></th>
<th>Area</th>
<th>Roundness</th>
</tr>
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<tbody>
<tr>
<td>$\bar{X}$ Chart</td>
<td>UCL 81.32</td>
<td>0.310</td>
</tr>
<tr>
<td></td>
<td>CL 76.50</td>
<td>0.239</td>
</tr>
<tr>
<td></td>
<td>LCL 71.12</td>
<td>0.000</td>
</tr>
<tr>
<td>S Chart</td>
<td>UCL 8.15</td>
<td>0.110</td>
</tr>
<tr>
<td></td>
<td>CL 4.14</td>
<td>0.056</td>
</tr>
<tr>
<td></td>
<td>LCL 0.12</td>
<td>0.002</td>
</tr>
</tbody>
</table>

The $\bar{X}$-s statistical control chart is suitable applied for sample size larger than 20–25, with 4–6 samples number on each, thus, this paper took 25 cards of BGA, and randomly selected 6 solder balls on each card as its sample. After the inspection, sample mean and standard deviation of area and roundness can be determined and expressed in the statistical control chart. Table 1 shows the UCL, CL and LCL of area and roundness value in $\bar{X}$-s chart. In this study, the roundness is expected to be minimal, which means that the lower limit should be zero. Solder ball is supposed to be completely round, therefore, the LCL of $\bar{X}$ chart is 0.

The $\bar{X}$-s control chart, users can observe the distribution of each sample size of $\bar{X}$ and s. Monitoring upper and lower control limit to judge whether the process has anomalies symptoms, for example the output distribution area of $\bar{X}$ chart (see Fig. 5).

Figure 5. The output distribution area of $\bar{X}$ chart
The website provides two categories information for enquiries, one is data output of inspection results, another is control chart of inspection sampling. The website will be automatically update to collect new inspection data output from database, and display the latest update inspection output through web-browser. Whenever user connects to system’s website, he needs to login or to request for authorization before entering the system to make sure the security of the system.

CONCLUSIONS
This paper proposes a BGA automatic inspection system by using machine vision and image processing techniques. Most of the previous studies provide automatic inspection system to be executed on the single machine only. This paper offers an online statistical control inspection system. By using client-server framework, developed a webservice to store data in database, through ASP as its gateway between client and server/database. The inspection results are presented in the SPC control chart, which enable the users to get real time information in more convenience way, without time and space limitations.

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