Developing an Automated Carousel System for the Inspection of Printed Circuit Boards (PCBs)

A. Mashayekhi, A. Rosinski, and H. Jackson
Department of Manufacturing Engineering Technology
Northern Illinois University
DeKalb, IL, 60115

***Abstract*— The inspection process is often overlooked when considering the development of a product. In order to reach market, companies spend vast resources solely on searching for faulty products to remove before being shipped out. Two main drawbacks of inspection processes are the time it takes for an operator to manually inspect a product as well as the presence of human error. Given its clear importance, we found a way to improve the procedure by using automation and image processing. We created a method inspired by current automated optical inspection (AOI) systems that inspects printed circuit boards (PCBs) to determine if and where part defects exist.**

Keywords-automation, inspection, image processing, computer vision, time standards, suface mount technology

I. Introduction

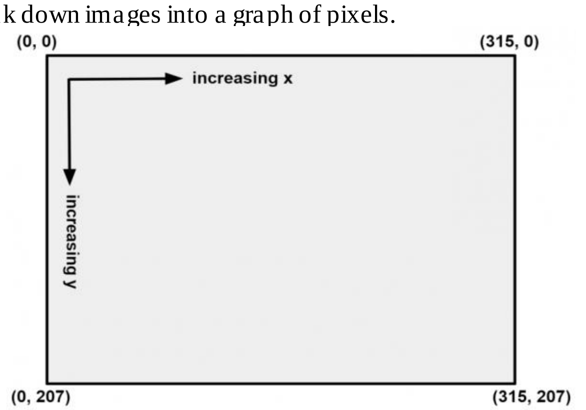
The demand for PCBs continues to grow rapidly with a market value of $63.1 billion in 2017 and is expected to reach $76.9 billion by 2024. [1] With such high demand for PCBs, modern manufacturers have turned to surface-mount technology (SMT) to place small electronic components onto boards quicker than a human by using rapid-moving feeding machines. SMT allows companies to make their boards more functional and complex with the ability to place a larger volume of components onto each board, but there is still a margin of error when operating with a high number of parts in a small space.

Without a proper inspection system at place, these examination processes usually end up being the bottleneck of an assembly line as it can force idle time. [3] Companies turn to AOI systems integrated in their assembly lines to substitute human-based inspection, which are proven more efficient and precise. A typical AOI can inspect roughly 30 sq. in. of PCB per second while roughly detecting 1.5 million components per hour. It also has an incredibly accurate inspection output, with an error rating of 500 parts per million (PPM), or a 0.05% typical error. [4]

Our objective is to design a system based on an AOI's concept while addressing its drawbacks: having a large footprint and being expensive, as some can reach over $90,000 in costs. [4] We will use image processing and computer vision to achieve the inspection aspect, create a portable and cost-effective system, have it accessible to operators, and make it interchangeable so companies can use it with various PCB operations. We will also create a sample PCB with 10 parts to test if our system is capable of finding missing or defected components on it.

II. Theory

The peripheral aspect of our system utilizes computer vision (CV), which is the study of how digital images and video allow computers to gain a higher understanding than simple binary code. We will use an image sensor and CV to break down images into a graph of pixels.



Each pixel coordinate (x, y) contains 3 values ranging for intensities of 0 to 255 (8-bit)
- Red - Green - Blue

Figure 1: pixel intensity graph

Once the image is acquired, it is broken down into pixel and then channel. Each pixel contains three channels that each make up a color: red, green, and blue. The mixture of different intensities per channel give us the full color spectrum. [2] With the use of image processing, we can essentially train our system to break down the image it receives into pixels and compare the pixel's intensities with arbitrary values derived from an image of a perfect PCB with no components missing. A change in intensity compared to our desired product can help us find defects on the PCB, specified as locations shown on the pixel intensity graph as a coordinate system for accessibility.

Rather than accessing each pixel, our system will focus on pixel clusters, or region of images (ROI) to inspect component areas. Not only does this alleviate strain on our CV analyzing each pixel, but it also allows imperfect parts to still pass if they are making adequate electronic connections via margin of error. Our system will then convert ROI areas into specific component numbers for an operator to easily read and determine which part is defected on the PCB.

Using a coding language and specific application programming interface for our chosen image sensor, the camera can act as the computer 's eyesight; the use of image processing is then used to break down each image gathered for more information regarding our sample PCB.

III. MATERIALS AND METHODS

A. *Carousel Design*

The design of our carousel comprises of three main parts: mechanical, electrical, and programming components.

For the mechanical aspect, we are using a circular tray and found it to fit up to eight PCBs with ease. It was decided to 3D print the tray for interchangeability as it could be offered to companies that run various PCB operations with different sizing. The tray is then directly mounted onto the motor with a flange mount for a lower center of mass.

The electrical side consists of three components: image sensor, stepper motor with drive, and microcontroller. We selected an image sensor based on requirements such as pixel sensitivity, frame refresh rate, and dedicated processing speed. Our stepper motor requirements were less strict as our operation does not require much torque.

Finally, our programming design intent mainly focuses on using a scripting language that can easily connect our image sensor and microcontroller to run the operation.

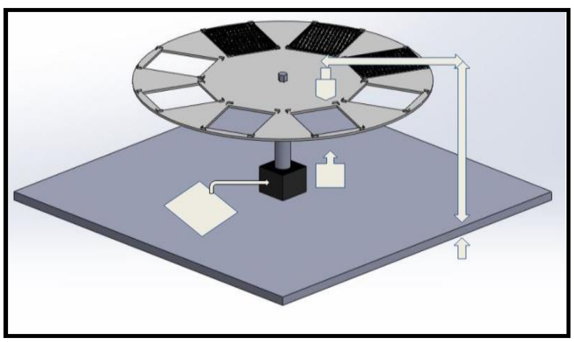


Figure 2: carousel system design

B. *System Requirements*

Because our system inspects PCBs, torque is negligible due to the low weight requirements of eight boards being inspected per cycle. To find torque (T), we first found the summation of each moment of inertia (I) through the entire carousel along with our desired angular acceleration (α).

$$T = I \cdot \alpha; \; I = \tfrac{1}{2} \cdot m \cdot r^2; \;\; \alpha = \theta / t^2 \qquad (1)$$

Based on our carousel's goals of completing the eight rotations at one second each and torque necessities, we calculated the following:

$$T = (7.59 \text{ x}10^{-3} \text{ kg} \cdot \text{m}^2) \cdot (0.785 \text{ rad/s}^2) \qquad (2)$$

We obtained a rated torque of roughly $5.96 \text{ x}10^{-3}$ N·m which helped us select a stepper motor for the system.

C. *Procedure*

1. Motor turns tray so PCB reaches inspection point
2. Sensor acquires PCB image, compares to original
3. If fails, system stops / sends error data to operator
4. If passes, motor turns to next station on carousel

IV. RESULTS

To formulate results and show that our system is more efficient than a human inspection process, we used a Predetermined Time Standard (PTS) to study the motion of both inspection procedures. Our time standard breaks down each basic motion into micromotion elements. [3]

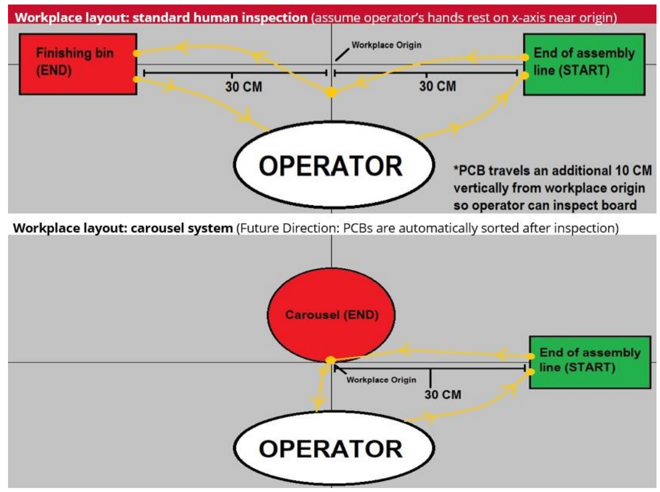


Figure 3: workstation assumption for each inspection process

Through time standards and workstation assumptions, it would take an operator 48.86 seconds to inspect eight boards, versus our system at 26.82 seconds per eight boards.

V. DISCUSSION

Based on the times for both inspection processes and assuming a workday with 7 hours of operation time, we determined that a human could inspect 3,752 PCBs per day versus our system inspecting 6,832 PCBs per day. The difference is 3,080 more PCBs inspected by our system.

VI. CONCLUSIONS

Our automated inspected system proves to inspect PCBs at a faster rate than a human. This is beneficial for a company because it saves time in the inspection process, which could be a potential bottleneck in the overall cycle time of a product. [3] Addressing this can save money in the long run through efficiency in manufacturing.

ACKNOWLEDGMENT

We would like to thank Dr. R. Kilaparti, Dr. S. Takai, Mr. N. Osorio, and Mr. A. Shansi of Indak Manufacturing.

REFERENCES

[1] Energias Market Research. 2018. "Global Printed Circuit Board (PCB) Market Outlook, Trend and Opportunity Analysis, Competitive Insights, Actionable Segmentation & Forecast 2024"

[2] Innat, M. 2018. "Basic Image Processing In Python - Part 1" Khulna University of Engineering & Technology (KUET), Bangladesh

[3] Meyers, F. E. & Stewart, J. R. 2002. "Motion and Time Study for Lean Manufacturing." 3rd Edition. Pearson Prentice-Hall. Upper Saddle River, NJ. Chapter 8

[4] Nordson YESTECH. FX-940 Automated Optical Inspection System Specifications and Datasheet