VECTORAL IMAGING… THE NEW DIRECTION IN AUTOMATED OPTICAL INSPECTION

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ABSTRACT
Traditional methods of identifying and inspecting components during PCB assembly are giving way to geometric pattern matching using vectors to define component boundaries. Increased throughput and higher precision in machine vision analysis are the result.

Key words: AOI, Inspection, Template Matching, Vectoral Imaging, Synthetic Modeling, Vectors, Pixelization

BACKGROUND
As component sizes in electronics get smaller and board densities become more compact, the need for automatic inspection in electronic manufacturing is becoming a must. The mainstream use of 0402 components and the arrival of the 0201 components makes this requirement even more urgent as manufacturers are seeking ways of making sure not only that components are present, but that they have the correct polarity and value. Doing this repeatably and reliably on devices as small as 0201 components has become a real challenge. Due to the fact that reworking components such as these after reflow present other significant issues, the need to inspect prior to reflow is becoming the accepted solution. Many applications using these state of the art components are in the telecommunications sector, which have the added complication of using RF shields. These shields are placed by the fine pitch placement machine, making inspection just prior to reflow impossible. In cases such as these, inspection prior to fine pitch placement, and post Chip shooter, is the preferred solution. As an added precaution, incorporating inspection of the paste deposition prior to fine pitch placement may be an option. There are several methods of inspection available that utilize laser scanning and x-ray that can be implemented. The solution that is most widely accepted today is the Automatic Optical Inspection (AOI), which uses single, dual or multiple camera configurations. Laser Scanning is mainly being used for Solder paste deposition inspection, while X-Ray is being used as a diagnosis tool after In Circuit Test (ICT) or as a sampling method for detection of bad joints after reflow. With this in mind, we wish to take a closer look at the new technologies available for Automatic Optical Inspection in comparison to those that have been around for many years.

TRADITIONAL AOI TECHNOLOGY
Traditional methods of optical inspection using pixel-counting algorithms such as object recognition, blob analysis or template matching have been around for over 25 years. These methods are widely used in the industry for simple applications such as fiducial alignment and component alignment before placement. However, these methods have some major drawbacks when implemented in high-speed in-process inspection of populated circuit boards during production. This is due to the throughputs required and the environment in which they are being asked to work.

Method One: Object Recognition
This method of object recognition identifies image patterns corresponding to physical objects in a view. It compares the new image with an ideal image of the object and reports any differences that may occur. The appearance of an object may vary considerably depending on a number of factors. These variations in view include: illumination density and distribution, object surface characteristics, orientation in relation to the camera, position in relation to the pixel grid, optical and electronic characteristics of the hardware being used such as the camera, lens, lighting, focus, distortion and noise, scene clutter and occlusion as well as any acceptable manufacturing variations in size and shape.


P1

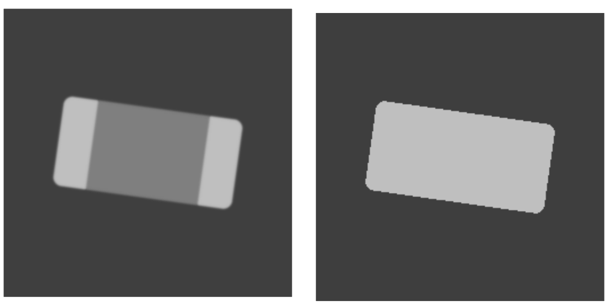

P2


P3

Figure 1. P1, P2 and P3 are examples of the effect of different lighting on the same object when rotated.

Method Two: Blob Analysis
Blob Analysis first requires separating the object from the background. Using a pixel-based image, the object pixels are grouped to form a blob. The geometry of the blob is then used to identify the object, locate and inspect.

The advantages of Blob Analysis are that it is a very simple method. It is fast and can handle changes in rotation and size. The disadvantages are that it is not as robust as other methods and that separating the object from the background for in-process inspection is often made difficult due to the environment of the printed circuit board, such as changes in color, board traces, pads and component densities.



P4 P5

Figure 2. P4 represents a simplified image of a chip capacitor on a black background. P5 represents the resultant blob after the image of the chip is separated from the background.

Method Three: Template Matching with Normalized Gray Scale Correlation
In template matching we must first train the system by storing a “golden” pixelized image of the object or component. The product to be inspected, or the printed circuit board, is then scanned to find images that match the stored pixelized object. The most successful method uses normalized gray scale correlation as a measure of the match.

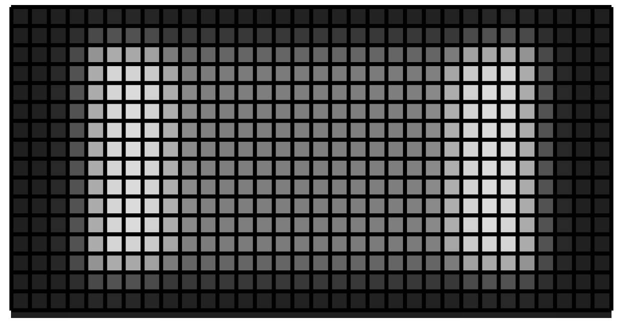


Figure 3. Above is a pixelized image of a chip capacitor used by gray scale correlation processing.

The advantage of this method is that it is much more accurate and more robust than the previous two methods. The added advantages are that it is relatively easy to train an object and that the object does not need to be separated from the background.

The disadvantages of such a method are that it cannot handle much variation in rotation and size and is adversely affected by non-uniform shading. In the application of in-process inspection, changes in rotation and size as well as non-uniform shading is the standard rather than the exception.

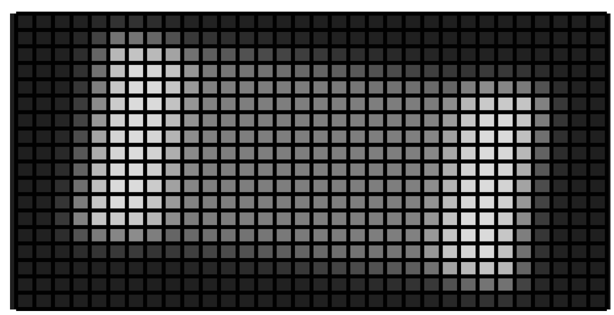


Figure 4. Above is an image of the same chip capacitor as in Figure 3 when rotated; which would fail when analyzed by normalized gray scale correlation processing.

For applications of in-process inspection on printed circuit boards, there are the effects of manufacturing variation and confusing backgrounds. Both of which add more complications and show us that this method has challenges, which lead to longer programming times and errors of repeatability with an object.

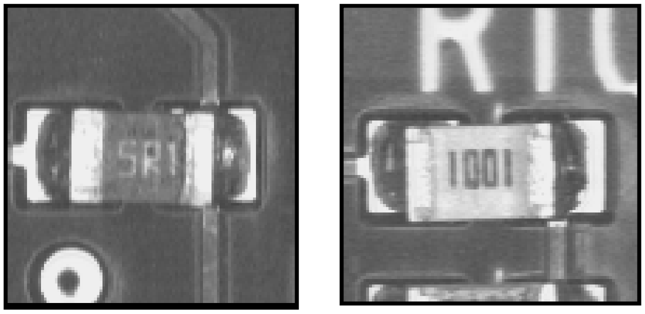


Figure 5. Two examples of chip resistors that would induce false failures due to variation in body color.

VECTORAL IMAGING TECHNOLOGY

After a detailed and extensive look into all of the different methods available, it was clear that for the application of in-process inspection of components on a printed circuit board, none of the existing methods would give the ease of use, repeatability and robustness required by the industry. Over the past two years, a new technology has emerged as a real solution to the requirement of inspecting populated printed circuit boards at speeds compatible with today's high-speed production lines. This new technology is Vectoral Imaging.

Locating Vectors compared to Counting Pixels

As we can see from the figure below, pixel based technology will try to recognize an object by counting pixels and comparing it to a stored image. This method is relatively slow and is adversely affected by changes in color, background, size and rotation.

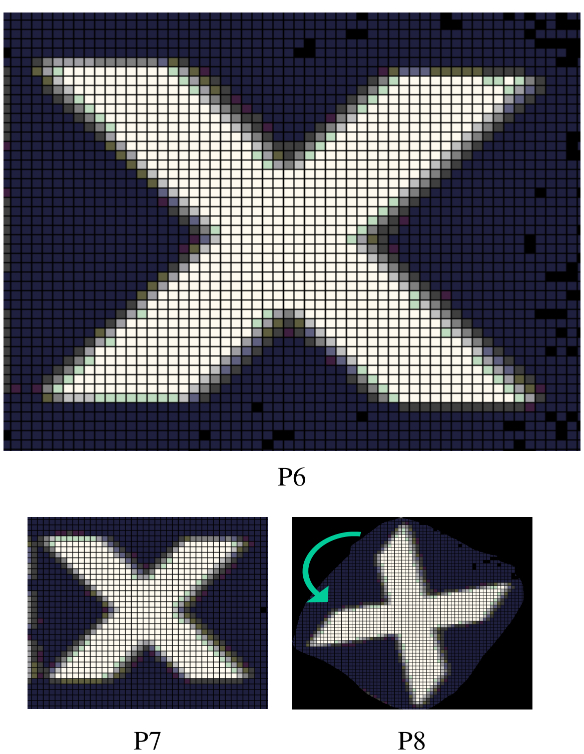


Figure 6. P6 is a pixelized image of an object. P7 is the same object reduced in scale. P8 is the same object reduced in scale and rotation.

Vectoral imaging approaches the problem with a completely different method in order to overcome the problems of grid based pattern analysis. Vectoral imaging converts the pixel grids provided by the image sensor into geometric features.

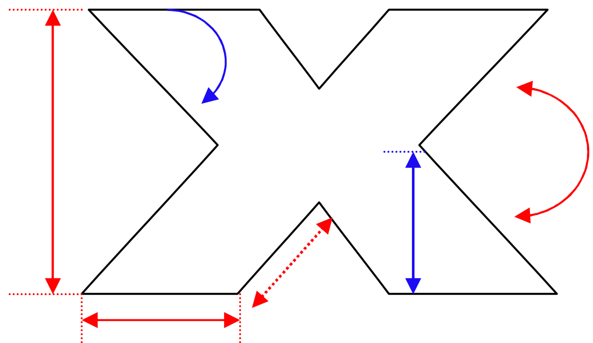
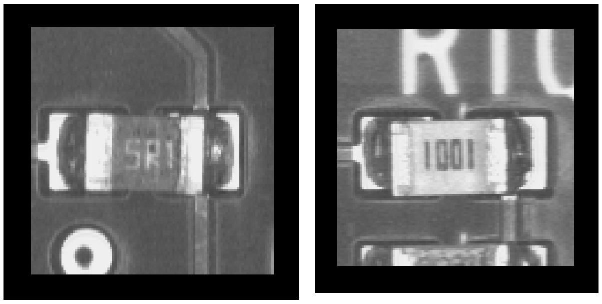


Figure 7. Vectoral analysis of the same object showing relationships between features. These relationships still exist regardless of scale or object position.

Vectoral Imaging is a pattern location search technology based on geometric feature extraction rather than absolute gray scale pixel values. Patterns are not dependent on the pixel grid. A feature is a contour that represents the boundary between dissimilar regions in an image. Features can be line segments, arcs, angles and open or closed geometric shapes.

By using geometric features, the image analysis is not affected by color changes or non-linear changes in size such as those found with components due to manufacturing variations. Jedec and IPC standards allow for changes in both the size and shape of components, which are acceptable to the industry. Any vision system used for this application has to take this into account as well as the changes in appearance due to vendor variations and different manufacturing processes.



Dark Bodied Component   Light Bodied Component

Figure 8. Examples of two chip resistors that maintain the same geometric shape regardless of body color.

Another major advantage with Vectoral Imaging is the elimination of background features that may cause false failures. When inspecting the same component on different printed circuit boards, the board layout changes dramatically due to circuitry and density. This can induce false failures when using grayscale correlation techniques.

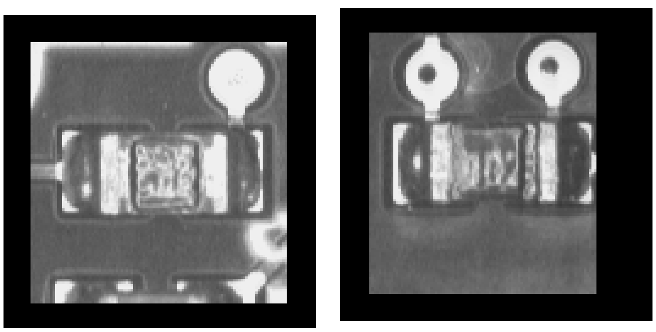


Figure 9. Background vias ignored by vectoral analysis.

Vectoral Imaging is also able to tolerate changes in rotation and scale and to measure them with increased accuracy and speed.

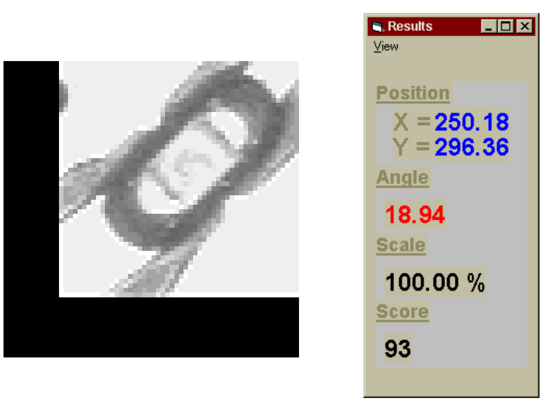
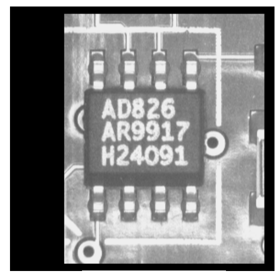


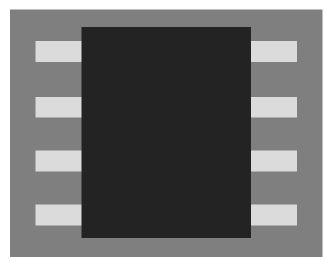
Figure 10. Geometric features are trained once and can be used to inspect components at any angle and scale.

Synthetic Models

Because Vectoral Imaging uses geometric features and mathematics to represent an actual image model, it is also possible to generate purely mathematical models, or "synthetic models," of the pattern to be located. The use of these synthetic models minimizes the effects of variations of lighting and background, as the model is not connected to the environment. The models can be generated by using the data from IPC or JEDEC component specification sheets; or from actual component images taken by the equipment.



P9



P10

Figure 11. P9 represents an actual S08 package and P10 is a synthetic model of an S08 package.

This allows the user to have a very robust library of Synthetic Models for each component, which can be modified easily on site or downloaded from the Internet. The greatest advantage of the Synthetic Models is the transportability and the capability to be used universally. A user with several machines will have the capability to use the same library of synthetic models on every machine. The library can be stored on a network at a central location and models downloaded as required.

CONCLUSION

Vectoral Imaging will dramatically change the way inspection is used in the electronics industry by supplying a method, which is easy to program, reliable and adapted to the difficult environment of printed circuit board assembly.

Advantages of Vectoral Imaging

- Represents an object as a geometric shape
- Image is not tied to a pixel grid
- Independent of shading and non-linear lighting
- Tolerates and measures variations in angle and size
- Improves accuracy by up to 10X over grid matching and maintains that accuracy despite changes in the run-time image
- Provides defect and positional data for Statistical Process Control (SPC)
- Is able to use Synthetic Models for the component library
- Transportability of the synthetic images and the library

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