

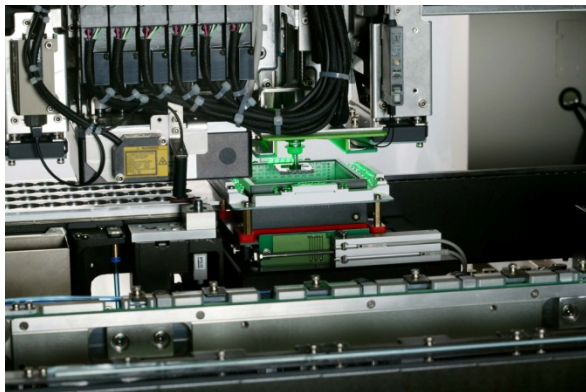
SMT Placement for ICs, Connectors and Odd-Shaped Components

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Accurate component placement is a basic requirement for any pick and place machine. The first step towards accurate placement is accurate centering, or measurement of the component's position on the placement head. One of the most widely used centering methods for ICs, connectors, and odd-shaped components are a camera based system that measures the component position relative to a known point. Camera based centering systems include three main elements: lighting, camera, and software. Each of these elements are critical to obtaining an accurate measurement of the component and ultimately for accurate component placement on the PCB. As the old adage goes, the system is only as strong as its weakest link.

Lighting

Good lighting is the first step towards accurate component placement. The wide variety of components that today's SMT systems need to place poses a great challenge to good lighting. Twenty years ago, a QFP was about as exotic as it got, but today we have QFPs, BGAs, LGAs, CSPs, die, flip chips, connectors, and many other devices with a variety of features, reflectivity, and shape. The camera and software cannot completely make up for a poorly lit component. For comparison, consider normal photographs taken in poor light. Photo processing software can be used to try to improve the brightness or contrast, but the final picture will never be as clear as if the light was good to start with. Lighting can be broken down into two sub-categories: direction and color. The design of the light applied to an object will dramatically influence the ability to center odd components and the accuracy of all components.



Caption: Back light recognition is ideal for odd-shaped components

Direction

SMT components fall into four main groups based on the types of features or elements they have: leads, balls or spheres, lands or flat pads, and edges or outline. The shape and location of the four different element types dictates the ideal lighting direction. Camera based centering relies on contrast to determine what features are important in calculating the component position. Ideally the camera should “see” only the elements to be used for centering with all other features and elements as “invisible” as possible. To the camera, this means the greatest contrast between the centering elements and all other features.

Bottom lighting, sometimes called “on axis lighting”, meaning the light source is located near the camera itself, is ideal for leaded components because the leads will reflect the light well while the plastic package typically will not. By lighting from the bottom, any other features on the bottom of the component will also be illuminated, but on a QFP, TSOP, etc, this is not typically a problem since the molding is black and not very reflective. White bodied connectors can pose some challenge for bottom lighting, but this can be accounted for through software. Some companies use backlighting for leaded devices, but this is not ideal since the entire component, including the body, is the same “dark” color and the background is light. With bottom lighting, only the leads, which are the most important part, are a different brightness.

BGAs often have traces, pads, or even missing balls that would also reflect the light if bottom lighting were used. Some CSPs and flip chips have a reflective bottom side that would create poor contrast between the important and background elements. This is why bottom lighting is not ideal for any component with balls. Side lighting, or lighting coming nearly horizontal to the plane of the balls, is better suited to these components. By illuminating a ball component from the side, it is much clearer when a ball is missing or present. When lit from the side, there is no ball to reflect light down to the camera and the difference between a missing and present ball is much more distinct. Bottom lighting of a missing ball would create a reflection that is similar in size to a ball that is present. This creates a bigger challenge for the software that has to determine if the ball is truly missing or not. Side lighting also does not illuminate unwanted features on the bottom of the component as much as bottom lighting would, making it less likely the software will mistakenly include these features in centering.

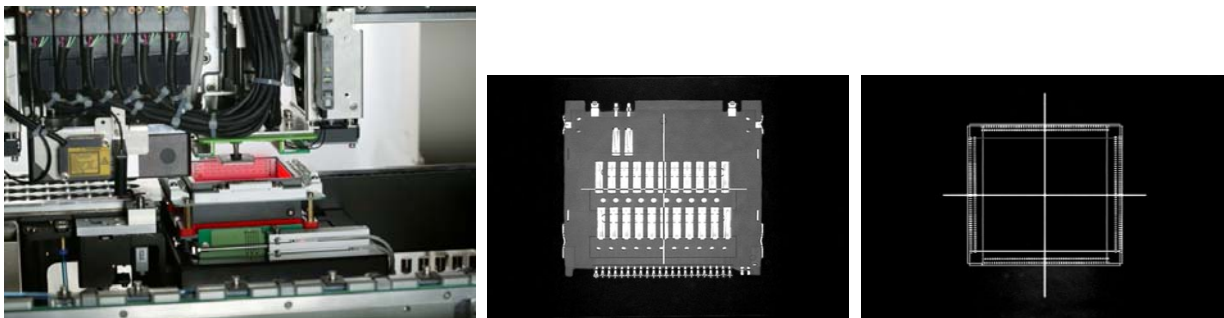
Outline and center-of-mass recognition of odd-shaped components with no leads or balls is the final challenge. Since these shapes can be fairly irregular and they can be shiny or dull, the best situation is to create a silhouette of the component. This means back lighting, light coming from top of the component and aimed towards the camera, is best. Back lighting creates a high-contrast silhouette regardless of the shape or reflectivity of the component.

Color

While the direction of the light is important, so is the color of the light. Unlike lighting direction, it is not the shape or location of the centering elements that creates the need for different color lighting. It is

usually the body of the component or the area around the centering elements. Just like the “secret message” toys where a word is written in a colored background and can only be viewed with a red filter, the goal of colored lighting is to filter out items that might confuse the camera and make it hard to “read” the component position.

There is no standard for what color works best with different component types. Determining the best color lighting is more of a process of trial and error. The best colors are simply ones that work better with typical colors of SMT components. Ball components are usually the biggest challenge, due to the wide variety of packaging methods used. Many BGAs have traces or via holes visible on the bottom. While side lighting will filter out much of this, applying blue lighting to the gold traces or via holes will further improve the contrast between balls and unwanted elements. In the case of silhouette images, green is a more ideal color. The use of multi-colored lighting gives added flexibility for centering a wide variety of components.



Caption: Multi-colored lighting gives added flexibility for centering a wide variety of components

Camera

Once the component is lit well, the next step is for the camera to capture the image of the component on the nozzle. There are a huge variety of cameras used in component centering and most are “off-the-shelf” varieties. There are analog and digital cameras and several different communication types (CameraLink, USB, Firewire (IEEE1394), and GigE. While these differences are important to the designers for cost and speed reasons, the main issue to consider for the end user is the resolution. The general rule of thumb is that the camera should have a resolution of ten times the required accuracy.

Cameras need to take a picture with enough detail to accurately measure the component’s position. More lines or pixels in a given space produce a more detailed image, but it is not enough to consider just the pixel count as is common in today’s consumer digital camera market. The field of view (FOV) is the area a camera can see. A camera with a high pixel count, but large field of view may not produce sufficiently detailed images. The number of pixels per millimeter is a more important measurement of the camera’s resolution than how many megapixels it has.

Using a camera with insufficient resolution is similar to trying to accurately measure the length of a room with just an unmarked yard stick. Unless the room is precisely a whole number of yards, it would

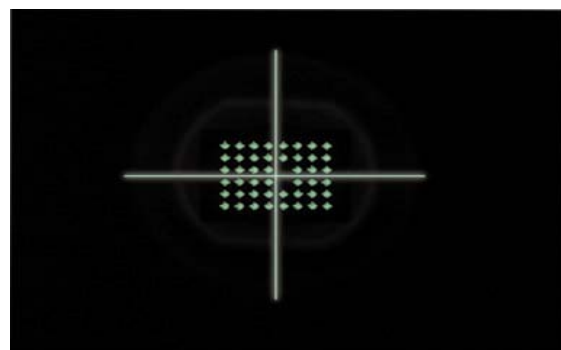
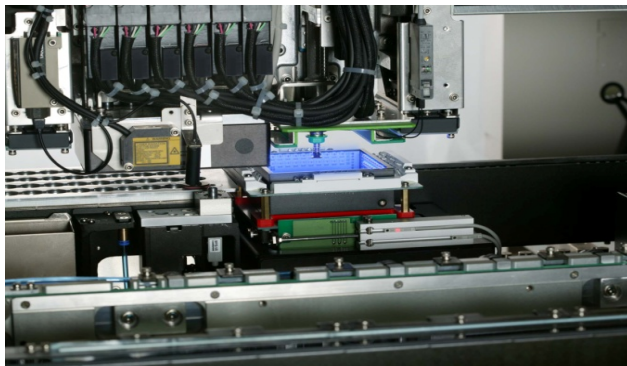
be necessary to estimate some fraction of a yard for the length. If, by contrast, a tape measure with markings down to 1mm were used, a more accurate length can be determined. The same applies to component centering. Higher resolution (more pixels per millimeter) is equivalent to finer measurement markings. The finer those “markings” are, the more accurately the camera can measure the component position.

The challenge to equipment designers is to select the best compromise between resolution and FOV because if the FOV is small, the maximum component size is also small. On the other hand, if the resolution (pixels per mm) is low, the centering accuracy is low. Since SMT parts come in such a wide range of dimensions, element sizes, and pitches, it is sometimes necessary to use two different cameras to handle the full range of possible components.

Software

Software is used to analyze the image and determine the component location in the final step of the centering process. The software must be able to determine which features in the image will be used for centering, what the exact location is, and then calculate the center of the component. Position calculation is typically done by edge based algorithms that precisely locate each of the centering elements. In some cases, the algorithms apply pattern matching to enhance the system’s ability to ignore unimportant features captured by the camera. “Sub-pixel accuracy”, which is the effective splitting of a pixel into two or more pixels, is also used to enhance the effective resolution of the camera. Most software used for vision processing is proprietary and often considered trade secrets.

Interactive and flexible user interface software will give the operator the ability to easily define most complex element patterns. While most leaded devices and simple BGAs have elements arranged in very simple patterns that are equally simple to define, more and more component designers are using designs that are very complex and often times nearly random. This is especially true for BGAs. However, there are also leaded components, especially connectors that have leads of varying width and/or length that are also in irregular locations. These components can be difficult for the operator to define by simple coordinate entry. Advanced vision systems allow the operator to automatically “learn” the ball or lead pattern. This method is faster and more accurate than manual data entry.



Caption: Advanced vision systems allow the operator to automatically “learn” the ball or lead pattern

Finally, the vision system should have programmable light direction, color, and intensity to handle components that do not work well with standard lighting or work better with custom lighting patterns. In these cases, it is critical that the software gives the user detailed control vision parameters while reporting accurate centering results.

Conclusion

There are a wide variety of camera based centering systems used in the SMT market. It is important when evaluating these systems to consider the total package and not just a single feature. Does the lighting handle a wide range of parts? Does the camera have sufficient resolution for the task? Does the software allow the operator to easily define complex or irregular components? In many cases the best way to evaluate this is to test the most unusual components available and then check the placement accuracy. A good, complete, "vision system" can handle this.

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