Editorial

The vision systems in placement machines play a critical role for their placement accuracy and therefore for their overall productivity. Determining the position of boards and components and evaluating the quality of each component are the vision system’s primary tasks. The vision system also makes sure that defective components can be properly discarded. Optical systems perform both tasks without having to physically touch anything.

In addition, vision systems in placement machines can be used for many other jobs such as reading barcodes, classifying ink dots or calibrating the machine.

The steadily rising speeds of placement machines and the increasing diversity of components place ever higher demands on the camera systems and their algorithms.

Leading makers of placement machines meet these requirements by accumulating vision competence in-house. SIPLACE has recognized this from the start and has counted on the expertise of its experienced SIPLACE vision experts for twenty years.

In this “Vision Technology” issue of SIPLACE SMT-Insights, the SIPLACE team wants to share this experience with you and give you valuable tips on which factors you should consider in your investment decision when the time comes to purchase new equipment.

If you have any questions regarding vision technology, please don’t hesitate to contact our SIPLACE vision experts directly.

Your SIPLACE Team
To realize the importance of the vision system’s role in the placement process, imagine the results if you had to manually place the components on the board while blind-folded. Simply impossible.

The vision system, on the other hand, can not only “see” the shape and the alignment of a component like a human being and place it correctly, it can also determine whether a component falls within preprogrammed tolerances and discard it if it doesn’t.

Thanks to the vision system, the component can be placed in a specific alignment and position. At the same time, the vision system checks a multitude of factors that have a direct impact on the desired placement quality and ultimately on the product quality. Since “vision” in this context is a measuring system for lengths, positions and angles, it can also be used for corresponding calibration tasks with the appropriate software to make sure that the machine’s axial systems can hit the programmed positions with minute accuracy before the machine actually places the component on the board.

The vision system is therefore the placement machine’s “central sensor” that can indicate whether a specific task can be executed correctly. Naturally, there are a lot more sensors in such a highly complex system, but no other system has such a critical impact on so many quality-related factors for the PCB as the vision system. If you compare the placement process with, say, the solder printing process, you will quickly realize that thanks to the vision system many more corrective actions are possible during the placement process’s execution than during the printing process.

The vision system’s role in the placement process

![Graph showing the relationship between DPM-Rate and Vision/Quality/Performance](image-url)
With their cameras, vision systems are responsible for the internal control of machine movements and the component pickup process. SIPLACE placement machines use head-mounted or stationary cameras as well as a PCB camera that is mounted on the placement head and looks at the PCB.

As a rule, SIPLACE vision systems determine the position of the PCB in the machine and inspect the components as well as their position. Only by determining this information is the machine able to ensure that the placement process will be performed with maximum precision. Vision systems have many other advantages over mechanical centering. For example, they don’t put any mechanical stress on the components and are able to identify the type of component and recognize bent leads.

Core tasks of vision systems

One of the core tasks of the vision systems involves detecting a PCB’s position and determining whether it is skewed or warped based on special markers or fiducials on the PCB. It determines the exact position of the PCB within the placement machine in order to make the necessary corrections when the machine places the components. The vision system is also able to calibrate the machine’s positioning system by measuring a highly accurate glass board. Another core task involves the detection of the component position and rotation during the placement process, i.e. the optical centering of components and the inspection of their connections.

Additional tasks

In addition, the vision system is able to perform tasks like these:

- Recognizing local reference markers (fiducials) for fine-pitch components
- Checking component tolerances
- Checking nozzles for contaminants
- Recognizing bad-board indicators in multiple-cluster applications
- Measuring the coplanarity for fine-pitch components
- Analyzing ink dots that indicate whether or not a circuit is to be populated.
Components of the SIPLACE vision system

Vision systems in placement machines are highly specialized units. They have special shapes, optics and sensors. They also operate with highly efficient image recognition algorithms for the simple reason that they must record and process the image information much more quickly than regular cameras. From the camera (sensor and lens) and lighting (angles and colors) to the (digital) image signal transmission and the image processing (algorithm/software and processor) – all components of the vision system must be coordinated with exceptional accuracy in order to achieve the highest possible level of inspection quality.

Example: Perfect interaction between placement head and vision system

Because it is perfectly coordinated with the placement head, the SIPLACE vision system can record and analyze each component individually. Only this type of individual inspection provides the level of robustness and accuracy that’s required in modern electronics production. Since many of the workflows occur simultaneously, the SIPLACE vision system can execute these individual inspections at the high level of speed with which modern machines operate.

Background: Digital vision systems achieve their best resolution when the object takes up as much sensor space as possible. If the image contains multiple objects, the resolution per object (i.e. the number of pixels) suffers.

With the latter arrangement, the system must also find a lighting compromise for the different components. In this case, some components or parts thereof will not be evenly lit, which leads to recognition problems. The SIPLACE vision system minimizes such problems by checking each component individually.
Lighting makes the difference

One of the prerequisites for high measurement accuracy is optimally coordinated lighting. Only if all the relevant features are recorded completely and with lots of contrast will the system be able to measure and inspect them with a high degree of accuracy.

Many vision systems continue to operate with backlighting, a technique that places the object to be measured between the light source and the sensor chip. Unfortunately, this means that the sensor can only detect the object’s contours, not the details within these contours. This has serious disadvantages. On the one hand, it does not measure the connectors which have to be placed in precise positions on the PCB. On the other hand, this technique interferes with quality related inspection tasks which modern vision systems should be able to perform. Components with connectors on the bottom of the package such as ball grid arrays (BGAs) or plastic leaded chip carriers (PLCCs) cannot be fully inspected with backlight systems.

That’s why SIPLACE vision systems operate with frontal light where the light source and the sensor chip are on the same side of the object. The vision system is thus able to detect all structures facing the sensor chip, including those that are inside the component, and inspect all connectors.

To accomplish this, several individually selectable lighting levels are available that illuminate the object from different angles. The intensity of each lighting level can be varied as well. But combining different lighting levels and intensities, the system is thus able to illuminate all connector types perfectly.

**Fully automatic**

Based on the component, the vision system automatically picks a light setting that matches the object. Of course, the user can manually modify this setting for each component.
In addition to generating images, the vision system must also analyze them. The related algorithms must meet the following requirements:

- **Robustness**: The algorithm must recognize as many damaged components as possible while avoiding as many false positives as possible.

- **Accuracy**: The placement accuracy is a key parameter for placement machines. The component position must therefore be determined as precisely as possible. SIPLACE vision systems compute the position of many components with an accuracy of much less than one pixel.

- **Speed**: The component measurement and vision analysis should not slow down the placement speed. This means that only a limited amount of time is available to perform each analysis. For example, the SIPLACE vision system analyzes most components within 30 milliseconds, i.e. without slowing down the placement performance.

Powerful vision systems should meet all requirements as much as possible. This requires perfectly coordinated analytical algorithms. The SIPLACE vision system accomplishes this with a three-step process:

- In the first step, the system determines possible connector positions by using so-called geometric filters. Although they are simply structured, they nevertheless conform well to the connectors' outlines.

- Next, these position candidates are matched to the component model. The system determines which candidate matches which connector. During this step, the system also computes the component’s position.

- Once the position is known, all connectors can be inspected.

The analysis algorithm gets its data from a geometrical model of the component. Compared to creating the model based on a sample image, this keeps small inaccuracies from negatively affecting the measurement results.
SIPLACE Vision Teaching Station and robustness

To maximize productivity in electronics manufacturing, you want to reduce non-productive machine time to a minimum. This is particularly important for processes involving new product introductions (NPIs). The SIPLACE vision system supports this approach with a unique level of excellence. The automatic setting of lighting levels and algorithm parameters alone produces ideal values for almost all components. Only the geometric information must be supplied manually.

These settings can also be made offline at the SIPLACE Vision Teaching Station. This station is a standalone system that includes all components of the vision system found in SIPLACE placement machines (camera, interface card and PC with vision software) together with a data management and system configuration application. With the SIPLACE Vision Teaching Station, users can determine all vision settings and adjustments before a product changeover offline, i.e. without having to take valuable time away from the actual production machine in the line. The SIPLACE Vision Teaching Station offers the following features:

▪ Creation and modification of component descriptions consisting of the geometric description, lighting parameters and algorithm parameters.

▪ Remote link to any SIPLACE Pro system (SIPLACE Pro 5.0 or higher) for easy data transfers between the Teaching Station and the production system.

▪ Component measurement using the Teaching Station’s camera. Descriptions can be easily tested and retested after modifications.

▪ Analysis of measurement contexts.

The SIPLACE Teaching Station is supplemented by another useful feature. With the help of the so-called robustness analysis, users will be able to determine quickly whether a component description will produce stable and robust measurement results under actual production conditions. To do this, the analysis performs repeated component measurements under typical variations of the conditions, such as lot fluctuations or different component angles. A clear visual representation of the results facilitates an intuitive assessment of the robustness.

Robustness analysis is a function where a single image of the component is used to simulate (modify) the real tolerances of its parts (such as leads) as well as its rotation and reflective behavior within a preset range. In production applications, this results in stable measurements, although the components’ individual characteristics may vary slightly from batch to batch.
Vision measurement contexts make fault analysis easy

A modern vision system must also make it easy to analyze defects or errors. In SIPLACE placement machines, this is implemented by logging so-called measurement contexts. For each measurement during which the component is not correctly recognized, the system logs input parameters such as the component model, the camera image, the pickup position, etc. in a file. With the help of this file, a technician can subsequently repeat and analyze the measurement.

This concept provides several benefits:

- The clear display of all stored measurement contexts provides a quick overview of the current component measurement status. It shows relevant data such as the component name, track, gantry, etc. that makes it easy to recognize, analyze and fix problems like small pickup rates, for example.

- Since the measurement contexts can also be analyzed offline at the Vision Teaching Station, components can be optimized without interfering with the production flow.

- The measurement contexts provide excellent information about the quality of the components. If the quality is inferior, the stored images provide informative and powerful documentation for a claim against the supplier.

- In case of problems, the measurement context files can be easily transmitted to the SIPLACE Support. By being able to reconstruct the logged measurements, the SIPLACE experts can provide quick and competent feedback and help.

These sample images are from measurement contexts stored during production. All components shown were recognized as faulty by the vision system. The examples show production problems such as “tombstoned” components as well as defective components such as resistors where the metal coating on one connector is missing. The images demonstrate the outstanding inspection quality of the vision system.
SIPLACE 3D Coplanarity Module: Another step towards zero-defect production

To detect special defects, additional visual sensor technologies can be used. One such example is the coplanarity measurement of components, because even the most minute deformation of component leads or balls can significantly reduce the quality of PCBs being populated by the placement machine.

**Example:** With larger BGAs or QFPs, their transportation or storage or manufacturing problems by the supplier can lead to bent leads. As a result, the component will no longer sit flush on the solder paste, and the open connection causes a defect. While the vision inspection in the placement machine will check the connectors' presence and position and even recognize missing balls, it will rarely categorize non-planar components as defective. As a result, the defect has serious consequences, because it will not be detected until a function check is performed. By then, it can only be fixed at great expense or not at all.

**Reliable selection prior to the placement process**

The SIPLACE 3D Coplanarity Module recognizes deformed BGAs or QFPs before they are placed on the PCB so that they can be safely discarded. Expensive defects are thus prevented at an early stage in the production process. The SIPLACE 3D Coplanarity Module scans the components with a laser and uses triangulation to compute the profile of the components' underside. Based on this data, the system is able to determine the planarity of components up to 50 mm by 50 mm large. All this is done at impressive speed. For example, the system requires only 500 milliseconds to inspect QFP-100 components. If the measured value exceeds the component's specific tolerance, it is discarded.

If a component is faulty, the system stores its measurements along with all other specific information. It shows the component's profile graphically and marks the faulty connector to make the subsequent analysis as easy as possible and document the supplier's quality.
The vision system with its respective camera is responsible for measuring the lengths, positions and angles of objects in SIPLACE placement machines. The geometrical information is used to determine the PCB position, to inspect and accurately place the components and to calibrate the system.

Most of the units making up the vision systems in SIPLACE machines were developed by SIPLACE itself. SIPLACE vision systems achieve their exceptional accuracy and speed thanks to the efficient interaction of their components. Camera, lighting, signal transmission and the image processing software work together perfectly.

The SIPLACE vision system also improves the efficiency of new product introductions significantly. Automatic settings as well as the offline configuration at the Vision Teaching Station reduce machine downtimes during NPIs to a minimum. Additional features like the logging of measurement contexts or the coplanarity measurement of components also help users to reduce costs and improve the quality and efficiency of their electronics production.

Our mission as the industry’s innovation leader:
As the market leader for SMT placement machines, the SIPLACE team has made it its mission to research and develop new technologies and processes in cooperation with other technologically leading equipment manufacturers. This expert knowledge we would like to pass on to you.
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