

## New Placement Technology for Rework Systems

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### Abstract

In the fast developing electronic industry the demands for production equipment are changing rapidly as well. The industry is looking for both, stable production processes and automated procedures in order to have full control of quality and costs.

This also affects the rework processes that are commonly still related to knowledge and skills of operators who are handling repair and touch-up of electronic assemblies.

To enable a rework system to carry out automated user independent rework the placement process needs to operate automatically. A new placement technology is introduced here that uses two cameras to identify the target area for component installation as well as the component pin structure. Image processing software calculates the correct placement position for the component out of the image information. A motorized four axes system is able to move the component to the target position without interaction of any operator. The procedure is based on an automatic pin detection algorithm along with a matching algorithm to find the correct position of the pin pattern in the target image. Several alignment procedures as well as camera corrections are implemented in order to reach the high demands of placement accuracy and repeatability.

The new placement technology relieves the user from exertive optical alignment and time consuming manual adjustment as well as guaranteeing a high repeatability in the positioning results. While the system is placing and installing the component the user can focus on preparative activities.

Besides automatic placement, the described rework technology allows automatic component flux and paste dipping as well as handling of paste printed components. Additionally soldering and desoldering processes are operated automatically.

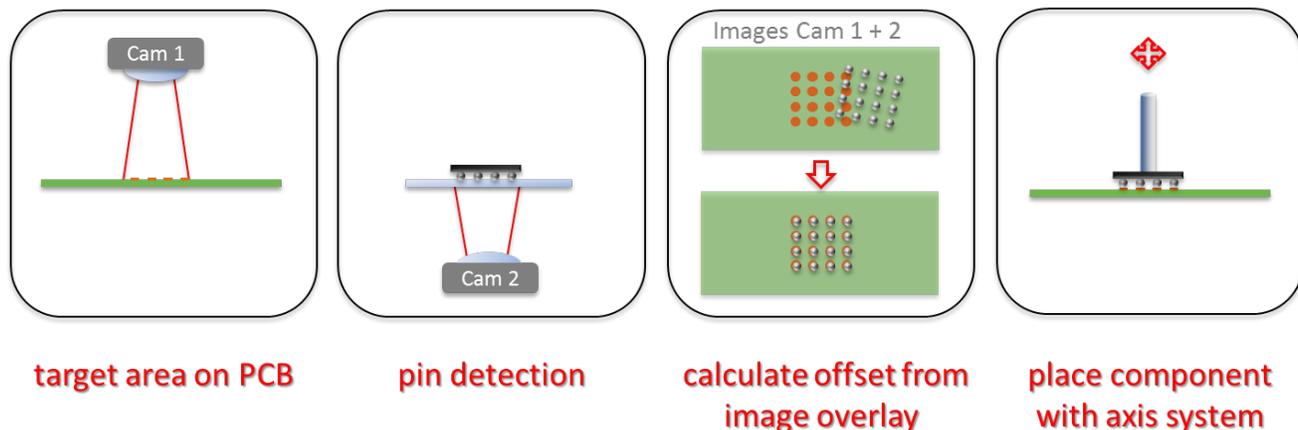


Figure 1 Schematic procedure of component placement with two cameras generating images

## **Introduction**

Rework in the electronics industry used to have a shadowy existence over the past 10 to 15 years. It was hard to accept that the zero failure production was and currently is a myth. Those in electronic production facing real life nevertheless know that production failures have been present and will continue to exist. They have tried to get faulty assemblies back to work. Many others did not ask how this had been done and how the quality of those doing rework could ever be controlled.

With the SMT process being standardized and widely understood, some experts started to look closer at the side processes. This includes touch-up and repair of assemblies. Moreover, the introduction of bottom terminated components, like BGAs created a push to general complexity of rework activities in the producing industry as well as for those who had to repair printed circuit boards, returning faulty from the field. Another driver was the lead-free introduction in Europe in 2006 – with formerly easy to handle rework activities struggling with smaller process windows and new materials. All in all the responsible personnel recognized these challenges and requested more stable and repeatable rework equipment from the suppliers. An intensive glance on the production costs made many of the customers ask for higher automated and fully controlled rework machines, prompting the development of new rework systems to satisfy such requirements. A detailed technical description of an example of this type of rework system follows.

## **Current technologies**

The time for using a hot air gun for BGA repair have been announced to be over – in reality they are still in the drawer. Since more than 20 years the suppliers of professional rework equipment have been presenting a battalion of different systems in order to remove and install bottom terminated components and other SMDs. Whereas in the section of energy transmission for the soldering and desoldering process the territory was split up into “hot gas” and “infrared radiation”, the means for component placement stayed the same. There was very little innovation in terms of alignment and placement of components onto the substrates.

The current component placement technologies can be divided into three major groups:

1. Placement with optical beam splitter
2. Placement with alignment tool
3. Vision placement

Other than in pick and place machines, during rework mostly only one component needs to be relocated onto a specific position on the PCB. CAD – or Gerber – data is often not available and most systems are not yet capable to handle such kind of electronic information. In order to achieve a precise component handling and component placement all above mentioned methods do require active work of the operator. This is a disadvantage for at least two reasons: repeatability of component placement and the pure necessity to let an operator do the alignment.

### **Placement with optical beam splitter**

Beam splitters allow to use one camera to visualize the PCB surface and component terminals in one image. This technology is commonly used but reaches its limits in resolution and illumination as the pitch gets smaller and smaller. Aligning the component to its target position is a tiresome process for the operator if for example the light color of component pins (bottom) and PCB pads (top) is the same.

### **Placement with alignment tool**

Another working principle is the usage of a special tool that is aligned to the PCB pattern and later moves the desired electronic component onto the previously identified position. Due to lack of magnification and possibly poor visibility this technology is restricted to a certain number of package types. The quality of the alignment strongly depends on the user’s abilities and skills.

### **Vision placement**

Finally the most promising method for component handling uses camera images and corner positions of the device and the target region. A computer aided method calculates the offset and aligns virtual rectangular structures to each other. If the operator is identifying the fiducial marks in high precision, the component placement will always be satisfactory. Some of the units providing this technology range high in price and may not meet the cost expectations of many customers.

## **A new placement technology for rework systems**

To combine and implement a new placement technology into a rework system with an acceptable market price is a challenging task: digital cameras for image generation, image processing software and a precise gantry system are the baseline in order to establish this placement technology in the world of repair. USB cameras supply image information; image processing algorithms evaluate the data and do the necessary calculations to identify the correct position for a component. The stepper motor axis system is used to handle the device and locate it to the target position. Movements in x-, y- and z-directions are carried out with tolerances in the micrometer range and also the rotation of the component can precisely be executed.

### **Digital cameras and image processing**

Crucial for a successful solution is the correct combination of the above mentioned elements. The cameras need to generate images in acceptable resolution. Numerous algorithms need to restructure the data and the calculated pixel offset needs to be perfectly converted into steps and micrometers to match the component to its target position. For the cameras and lenses – e.g. some corrections have to be implemented in order to attain one coordinate system for both cameras. Here the individual distortions of each camera and lens combination need to be corrected previous to any further operation.



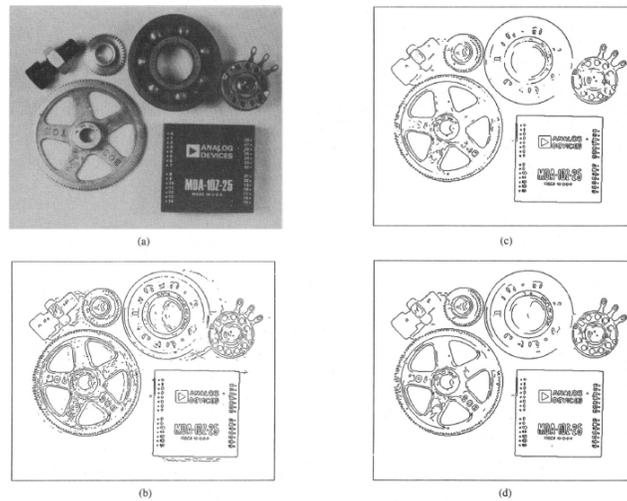
**Figure 2: distorted image (left) and corrected image (right) – source: MVTEC [1]**

Another process to adjust the unit before any repair takes place is to calibrate the individual light conditions. As anyone will understand, an open unit with cameras on board is influenced by environmental light conditions. These can be recognized and calibrated. An extreme change in the surrounding light can be compensated and the built-in LED illumination is adapted to the new light situation. By doing this, the rework system can generate best contrast images and precise placement results in nearly any environment.

To find individual structures in images – like pins of a Quad flat pack (QFP), a typical image processing procedure is “edge detection” – a method developed by John Canny, an Australian scientist who developed his “Canny edge detector” algorithm in 1986.

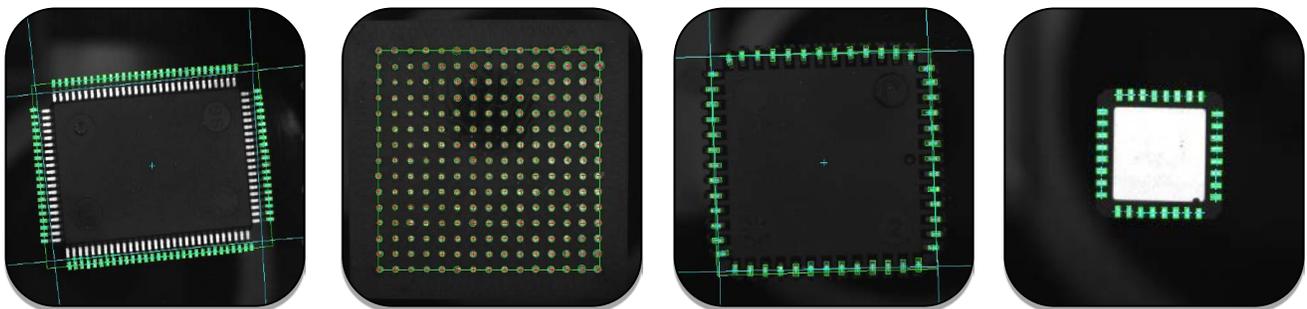
The computer is used to find changes of brightness in an image and interpret them as edges. Along with the information as to what type of component is currently analyzed, the mathematics will identify for example regions in the images that represent the rectangular shaped pins of a QFP component.

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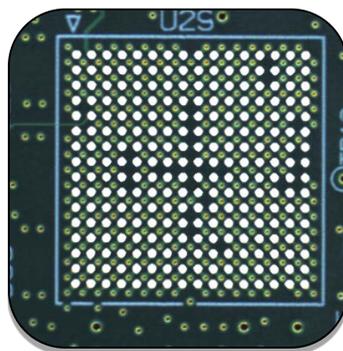
**Figure 3** Parts image and “Canny edge detector” results with different thresholds – source: Wikipedia.org [2]

Some similar procedures have to be used and implemented, to identify the pins of individual SMD components, like BGA, QFP, QFN (BTC) and PLCC components and others. The benefit for the user is that they do not have to deal with any component related data sets but simply place the component onto a region above the camera and the software will find the pins of the component by itself.



**Figure 4** Pin detection algorithm identifies terminals of QFP, BGA, PLCC and QFN (BTC) components (left to right)

When the component terminals are completely identified, the key function is to find the pin pattern in the image of the PCB. A number of other mathematical calculations lead to a virtual overlay of the detected pin structure and the initially detected target area. The best result of this matching procedure can be presented to the operator for final approval or manual correction. The calculated offset between the current component location and the desired target position is used to place the part. In the automatic mode the machine processes the entire sequence by itself.



**Figure 5** Target image with virtual pin overlay of the BGA component

In order to optimize the alignment accuracy for QFP components another algorithm is used to ideally match the pads and the pins. The pad row analysis compares the signals of the pad pattern and the pin pattern and readjusts the images until the best result has been detected.

### Additional benefits of the gantry system

The matching result is usually calculated within some seconds and if the PCB to rework is only one out of a batch, the placement and following soldering procedure can be fully automated. In this case the gantry system will move the BGA to the target position, the heating head will move there in the next step and the preselected thermal process of soldering is begun.

As the rework machine is equipped with a precise gantry system, other beneficial aspects can be achieved with none to little additional effort:

Treating more than one component automatically (for desoldering or placement and soldering) will be an easy task for such a system. Handling the component automatically and having cameras on board allows using the system for quality assurance aspects, by generating and evaluating images. E.g. a component could be inspected if all pins are in order, previous to its treatment. It is possible to apply flux or solder paste onto the component with comparatively simple means in very precise portions, by the dipping method.

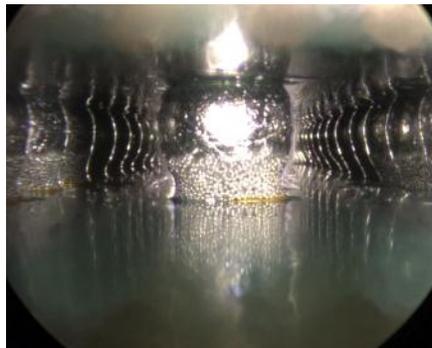


Figure 6 Side view image of a BGA ball, placed after the component was dipped into solder paste

The dipping method needs the precision of the gantry system in combination with a precise cavity allows the supply of accurate and small portions of solder paste to each individual solder ball (in the case of a BGA). The previously dipped component is aligned to the target position, placed and then is ready for soldering. The result of this rework process would be comparable to a soldering result created by a SMT production line.

### Outlook

As already mentioned, there will be obstacles in the way of this technology in terms of new and unknown components that cannot be handled by the system initially.

To address this question, there needs to be a deeper look into the methods of image processing. The key idea is to generate a learning system which will improve its own capability instead of being trained to new challenges by human programmers. There might be some questions to be answered, but if the human programmers concentrate on a learning system which is dealing with a flexible algorithm library instead of adapting a set of algorithms to new data, this vision might not be out of reach for the next generation of rework systems.

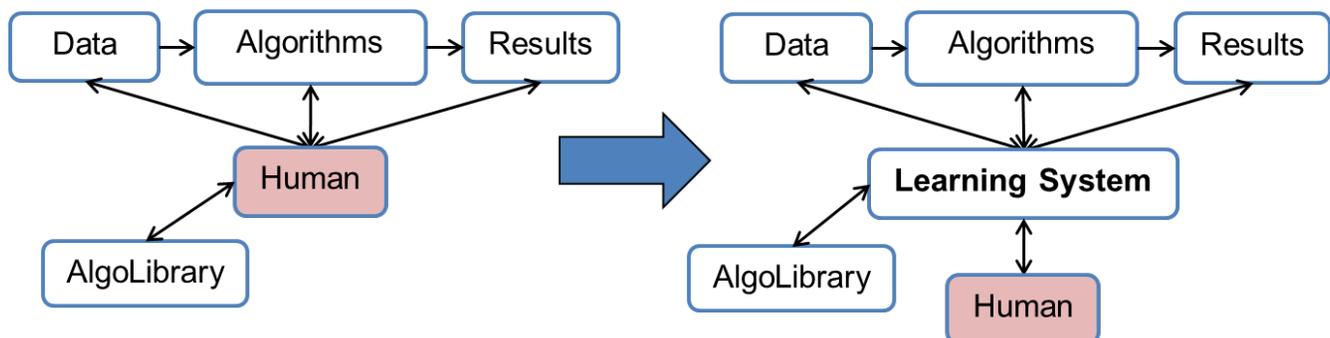


Figure 7 Method of learning system in image processing – source: Math & Tech Engineering GmbH [3]

### **Summary**

Compared to the existing methods of component placement and treatment, the new placement technology implemented in a rework system opens up a field to repair complex electronic assemblies. At the same time competitive cameras and stepper motor axes allow to introduce this technology on a more widely accepted price level.

Accuracy and repeatability of the procedures are increasing along with the higher degree of automation in the machine which can operate standard SMT components and bottom terminated components from 1 x 1 mm to 50 x 50 mm without any special tools for desoldering, soldering or placement. No component data needs to be supplied or evaluated; the operator can execute the rework process starting with the first assembly and the first component. The success rate can easily rise by more than 10 % compared to simple, non-automated repair procedures.

Automated processes can save up to 30 – 50 % of the operator's time. The alignment of components is done by the rework system and the operator can concentrate on other activities with operator generated alignment mistakes removed reducing defects during rework.

### **References**

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3. Workshop "Automatic Learning Systems in Image Processing", Math&Tech Engineering GmbH, 25.02.2013, p. 4