Automated Cell Design to Implement Solder Paste and PCB Assembly

Advanced Manufacturing Processes

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Abstract

This paper describes the design, programming and implementation of an assembly cell for paste tin application and assembly of SMD electronic components. A mechatronic system based on a board feeding system was designed and built. Likewise, a KUKA R900 robot was programmed for the assembly of electronic components. Along with this, a Siemens S7 1200 PLC control command was programmed and implemented. Five assembly sequences were developed and programmed, from which it was concluded that the optimal one was a series of linear and Point-to-Point movements, creating an optimal trajectory lasting 16 seconds in the assembly of the electronic components.

Introduction

Over time, most technological implementations have evolved towards the integration of automated industrial robots. This necessary evolution came from the requirements of fast-paced mass manufacturing processes that require precision and repetitive activities. Therefore, industrial robots have been around since the 1970's, having some predecessors in development, such as the Unimation robots, which initiated the transition to an automated industry. These machines have been one of the major innovations in the industrial sector, creating a configuration that has excellent reliability and efficiency in its performance during manufacturing activities.

This extends to the high demand for precise fabrication and assembly of PCBs and electronic components. The most complex process in this area is the assembly of components, since, if assembled manually, a large amount of time is spent on this operation. There are other machines such as Pick & Place that allow movements. However, these machines are not accessible due to their high cost. There are other alternatives, such as using industrial robots and PLCs to perform this type of tasks in collaboration with the operator.

In addition, robotic arms allow complex movements over a specific space and can handle many electronic components depending on the tool that is implemented. This paper describes a new way to integrate a robotic arm to accomplish a variety of tasks with a single process. Also, the use of these processes can reduce risks in the work area, as well as create a more efficient workflow with a variety of products to be manufactured.

Materials and methods

The materials implemented for the entire assembly cell were mainly: 30 mm x 30 mm aluminum structural profile, ATmega328P microcontroller, KUKA R900 with its CR4 controller, Siemens S7 1200 PLC and a PLC control panel. For the construction of the automatic card feeder, a NEMA 17 motor, 8 mm trapezoidal 4-wire spindles, 20 mm x 20 mm aluminum structural profile and a stepper motor driver were used. Parts designed in 3D were printed, as well as the development of an electronic connection board. The assembly cell was designed with Solidworks® and Autodesk Inventor ® software, in addition to a virtual simulation to verify the assembly of the cell and its operation, which can be seen in Figures 1 and 2. For the correct process of paste application and assembly of components on the PCB, it was necessary to divide the program logic into three areas as shown in Fig. 3:

Figure 1 CAD Cell Design

Figure 2 CAD Design Side View

Figure 3 Process Diagram

- **Communication with Integrated Project**: As shown in Fig. 3, to control and follow the process, communication was established between the PLC, the microcontroller of the plate feeder and the KUKA R900.
- **Solder paste application**: The R900 must spread the solder paste efficiently while the board feeder aligns the PCB to meet the requirements of the soldering activity. This is done through a stencil that rests on the base. The solder paste application must meet the correct quality standards to ensure component position.
- **Component Placement Application**: The Pick & Place task must be performed in a timely manner to meet the time standard for the entire activity. In addition, this application was repeatable and had constant motion throughout the component placement.

Design and program an efficient sequence of paste application and the assembly of its electronic components for an SMD board using a KUKA R900 robot which is controlled by a Siemens PLC.

Having programmed the KUKA robot and the PCB dispenser, the process control link is carried out by the PLC. Also, as shown in Fig. 4, the communication is coupled with a graphical interface to monitor the process in real time with an HMI, which provides useful data to document the performance of the system.

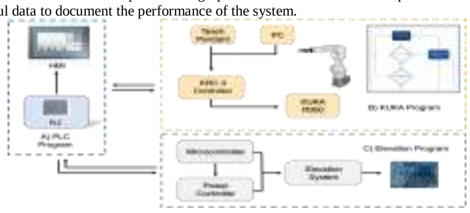

Figure 4 Communication Diagram of the System

Results

Fig. 5 shows the plate before the assembly process in the cell. As can be seen in Fig. 6, the application of the paste corresponds to the correct location of each track, allowing a perfect adhesion on each component. In addition, each of the components was correctly placed on the tracks with a very small gap between the components with smaller size. To have an optimal result, 5 programs were developed on the KUKA robot, which consist of: Point-to-Point, Linear, Circular, SPTP-LIN and SLIN-CIRC movements.

Figure 5 Pasta-Free Plate

Figure 6 Paste Application Result

Figure 7 Final Result of Paste Application and Component Assembly

The routine that was chosen as optimal was in program 5, reducing component placement time to 19.8 seconds at 30% of full speed, dropping to 16.25 seconds using 50% of robot speed without compromising quality or motion. In terms of the difference in the gap spacing in each test, the smallest deviation of the TCP from the center of the component was minimal, ranging from 0.3 mm to as small as 0.13 mm. Fig. 7 shows the result of the complete component assembly process and its paste application, showing the efficiency of the process. Fig. 8 shows the final physical assembly of the complete assembly cell together with the R900, and Fig. 9 shows the PLC control panel with its respective tools. Along with this, the graphical interface of the HMI implemented in the plate production control is visualized in Fig. 10.

Figure 8 Final Assembly Cell and KUKA R900

Figure 9 Siemens S7 1200 PLC, Control Panel, HMI and Connections

Figure 10 User Interface, Control for Production Inventory

Conclusions

According to the tests and results obtained, the design and programming of the PCB feeding system describes precise alignments and movements, since the repeatability of the solder paste application and assembly of the components on the PCB depends on it.

The integration of a KUKA robot, PLC and mechatronic systems generates an important tool for students of engineering in computational robotics and embedded systems to develop in the areas of programming, design and analysis of systems of programming, design and analysis in assembly and manufacturing systems.

Future of research

The integration of a vision system would improve the task of plate alignment within the cell, which would make the process more efficient and reliable in repeatability over a large number of batches. Many machine vision systems currently exist that generate new coordinates from the centroids of the components being manipulated, such as KUKA.VisionTech, which allows users to automatically generate code based on the KUKA's own image recognition applications. For future applications, the recommended criteria would be to use a smaller diameter nozzle and the ability to have an interchangeable system, either by magnetic bonding, threading mechanism or even having a rotating tool spindle in the TCP of the KUKA R900.

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