The most Efficient Path Algorithm from Feeders to PCBs

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Abstract

SMT(Surface Mount Technology) machines are used to place electronic components onto a PCB(Printed Circuit Board).

This study proposes a method of identifying the fastest path for picked up components to pass by a camera without stopping before being placed onto PCBs. The proposed method enables the gantry, responsible for moving the heads, to pass by the camera in the least amount of time possible.

Among the 16 possible paths, this study examines and addresses existing problems for the commonly used path(sLb-pRd type).

Through simulations, we found that the Fly1-Motion method improved productivity by 15%, and the Fly2-Motion method by 22%.

Keywords: *SMT, Surface Mount Device, Optimal Path Search*

1. Introduction

SMT is a method of placing surface mount devices via reflow soldering, a process in which a solder paste is used to attach electronic components onto PCBs [1].

As shown in Figure 1, an SMT machine consists of feeders that supply electronic components, heads and nozzles that pick up and place electronic components, and a conveyor belt along which PCBs travel. Multiple tape feeders are installed to supply electronic components for placement. Heads and their nozzles for each axis use suction cups to pick up electronic components from tape feeders. To inspect the pick up location and alignment, the components are inspected before a vision camera, and then moved to PCBs waiting on the conveyor for placement [2].

For precise placement of electronic components onto PCBs, the head on the XY-Gantry picks up electronic components using suction and places them accurately onto desired positions.

Since the picked up components will be slightly disaligned, offset values must be obtained in the X, Y and R axes before placement [3].

Images of the components are captured via the vision camera, and analyzed to derive offset values in the X, Y, and R axes. For enhanced productivity, the components are passed by the vision camera without stopping [4].

This study proposes a method of identifying the fastest path for picked up components to pass by a camera without stopping before being placed onto PCBs. The proposed method enables the gantry, responsible for moving the heads, to pass by the camera in the least amount of time possible.
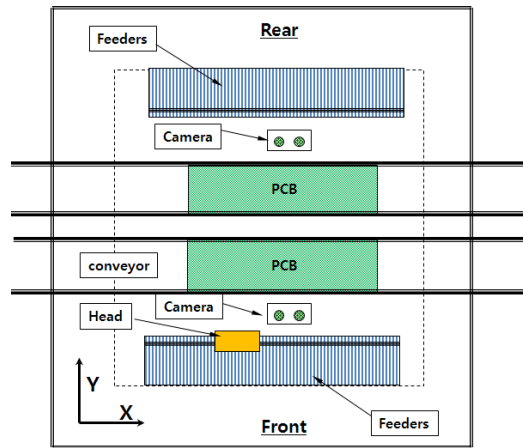
Figure 1. Typical Surface-Mount Machine Structure(Top view)

2. Related Work

2.1. Scope of Research

In SMT, productivity is expressed in terms of chips per hour (CPH), which is the amount of electronic components placed on PCBs in an hour. Many studies have attempted to improve the pick up speed, visual inspection speed, and placement speed of various SMT machines [5].

The SMT placement process is largely composed of the following.

① Pickup of electronic components

② Moving to camera position

③ Camera vision inspection

④ Moving to PCBs

⑤ Adjustment for offset values retrieved from vision inspection

⑥ Placement of electronic components

⑦ Moving to next pickup position

Existing methods of improving CPH carried out ④ and ⑤ to shorten the overall time. However, this study enhances CPH through simultaneous implementation of ②, ③, and ④.

In other words, the picked up components are not stopped before the camera for inspection, but inspected while passing by the camera on their way to the PCBs. The eliminated time for stopping thus enhances productivity.

Simultaneous implementation of ②, ③, and ④ requires the following technologies [6,7].

A) Moving technology for passing by the camera, B) camera technology for instantaneous recording of moving components, C) lighting control technology synchronized with the camera, and D) offset adjustment technology for enhanced precision

This study, which is focused on A) moving technology for passing by the camera, presents a method of moving picked up components to PCBs in the shortest possible time without stopping before a camera for visual inspection.

In an SMT machine, the XT-Gantry is often used for the movement shown in Figure 2 and the trajectory is determined based on a combination of movements in the X and Y axes.

Figure 2 shows the component pickup position (start position), camera position, and placement position. Visual inspection is conducted to ensure accurate

placement. While the existing method stops components before the camera to obtain images (Stop-Motion), the method proposed in this study considers the distance to be moved along the X and Y axes without stopping (Fly1-Motion).
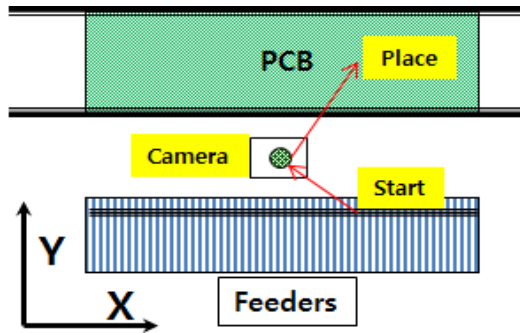
**Figure 2. Pickup-Camera-Place Structure(Top view)**

Taking into account the distance traveled in the X and Y axes, there are a total of 16 paths as shown in Figure 3 when the pickup and placement sections are each divided into four. The characteristics of each path are as follows.
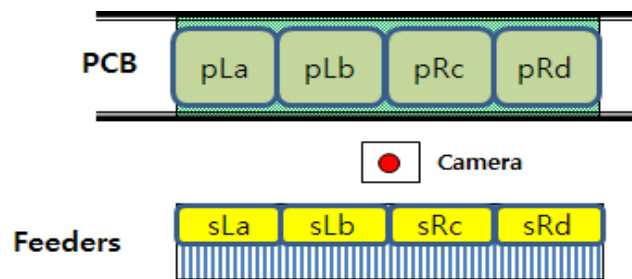
Figure 3. Section of Location

sLa: left side of pickup (distance comparison: x>y)
sLb: left side of pickup (distance comparison: x<y)
sRc: Right side of pickup (distance comparison: x<y)
sRd: Right side of pickup (distance comparison: x>y)
pLa: left side of placement (distance comparison: x>y)
pLb: left side of placement (distance comparison: x<y)
pRc: Right side of placement (distance comparison: x<y)
pRd: Right side of placement (distance comparison: x>y)

Among the 16 possible paths, this study examines and addresses existing problems for the commonly used path shown in Figure 4.
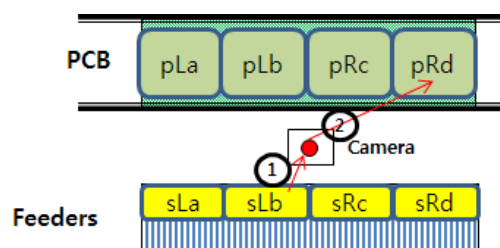
Figure 4. Moving Path

The conditions for maximum gantry speed, gantry acceleration, pickup position, camera position and placement position are outlined in Table 1.

Table 1. Input Conditions

| Item	X axis	Y axis	Unit
Max Velocity	2.0	2.0	m/sec
G Acceleration	2.0	2.0	g
G [M/Sec^2]	9.81	9.81	m/sec^2
Acceleration	19.6	19.6	m/sec^2
Pickup Position	-20	-150	mm
Camera Position	0	0	mm
Place Position	300	250	mm

2.2. Components Stopped Before Camera for Inspection (Stop-Motion)

Under this method, electronic components are stopped before the camera for inspection before moving to PCBs for placement [8].

The speed at the camera position is 0m/sec in both the X and Y axes. The given speed, acceleration, and distance of Table 1 result in the speed graph of Figure 5.

The long axis follows the given speed and acceleration, while the short axis has a speed and acceleration proportionate to the long axis. The speed graph and results for Stop-Motion are presented in Figure 6 and Table 2.
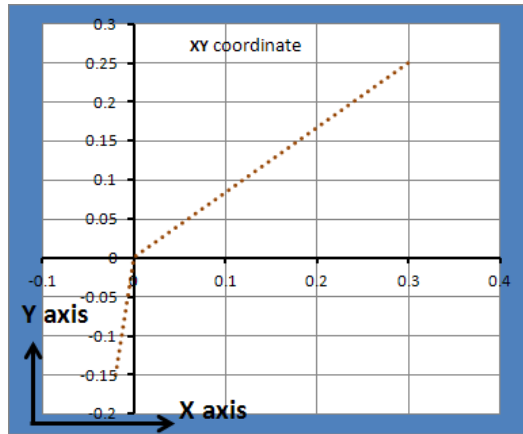
This method involves deceleration before stopping in front of the camera, followed by acceleration after stopping. The total simulation time was 427m/sec because of the long time consumed in acceleration and deceleration.
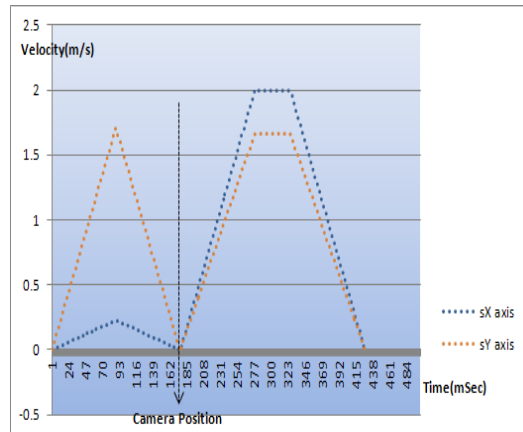
Figure 5. Stop-Motion Velocity Graph

Table 2. Result of Stop-motion

| Mode	Total Time(m/sec)	Velocity of Camera position	
		X	Y
Stop-Motion	427	0.0	0.0

Figure 6. Stop-Motion Moving Path

## 2.3. Components Passed by Camera Considering Distance in X and Y Axes (Fly1-Motion)

Under this method, electronic components are passed by the camera without stopping by taking into account the distance in the X and Y axes.

The given speed, acceleration, and distance of Table 1 result in the speed graph of Figure 7. The longer axis is subject to the given speed and acceleration of Table 1 and the components are passed by the camera at maximum speed. For the shorter axis, the components are passed by the camera at a slower speed according to the moving time of the longer axis.
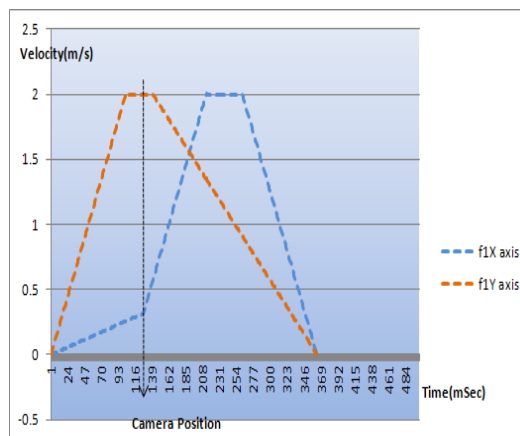
Figure 7. Fly1-Motion Velocity Graph

For the conditions given in Table 1, the components pass the camera at 2m/sec in the Y axis, and 0.318m/sec in the X axis. As shown in Figure 8, the X axis follows the speed and acceleration of Table 1 after passing by the camera, and the Y axis decelerates accordingly.
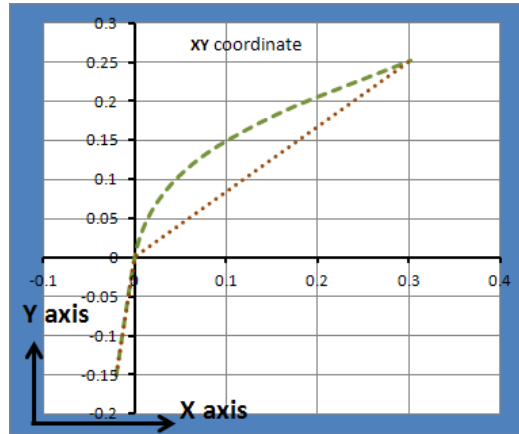
Figure 8. Fly1-Motion and Stop-Motion Moving Path

This method does not require deceleration in the longer Y axis, along which a speed of 2m/sec is maintained. The total simulation time was 363m/sec, an improvement over the Stop-Motion method by 64m/sec. However, this method does not reduce time significantly due to the slower speed in the X axis.

This study presents a method of rapidly passing by the camera position even for the shorter X axis, and verifies through a simulation that productivity is enhanced.

Table 3. Result of Fly1-Motion

| Mode	Total Time (m/sec)	Difference (m/sec)	%	Velocity of Camera position	
				X	Y
Stop-Motion	427	-	-	0.0	0.0
Fly-Motion	363	64	15	0.3	2.0

3. Fly2-Motion Method

Under the conditions given in Table 1, the proposed Fly2-Motion method involves moving 150mm in the Y axis, and 20mm in the X axis. The Y axis follows the given acceleration and passes by the camera at 2m/sec. The speed to the camera is 126m/sec for the X and Y axes. Since the distance to be traveled in the X axis is 20mm, the speed at which components pass by the camera is 0.318m/sec. The X axis follows the given acceleration after passing by the camera and moves for 237m/sec.

This study proposes a method of optimizing speed in the X axis when picked up components are passed by the camera for inspection, thus shortening the overall moving time of the gantry.

The faster the speed at which components pass by the camera, the shorter the time required to reach the PCBs.

Because the distance to be traveled in the X axis is 20mm under the Fly1Motion method, the speed becomes 0.318m/sec. A greater distance is acquired by moving in the direction opposite to the X axis before accelerating, thus reaching a higher speed at the camera position.
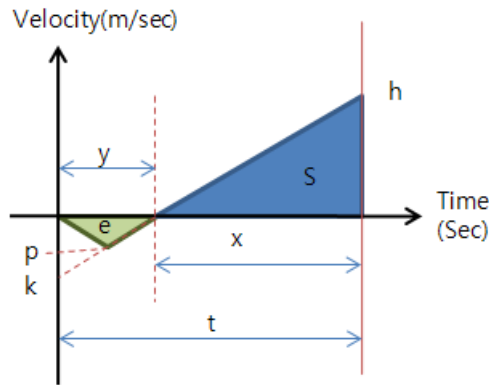
Figure 9. h Velocity Graph

Input conditions in Figure9:
d = Distance moved
 t = moving time
j = acceleration
s: distance moved during x (+direction)
e: distance moved during y (-direction)
h: final speed
d = s-e: when defined as the total distance moved

$$t = x + y, \; j = h / x, \; d = s - e, \; s = xh / 2 \tag{1}$$

$$p = k / 2 = hy / 2x \quad (k = hy / x) \tag{2}$$

$$e = py / 2 = hy^2 / 4x = h(t - x)^2 = (ht^2 - 2htx + hx^2) / 4x \tag{3}$$

$$\therefore \; d = xh / 2 - hy^2 / 4x \quad (h = j\,x) \tag{4}$$

$$jx^2 + 2jtx - jt^2 - 4d = 0 \tag{5}$$

$$x = (-jt \pm \sqrt{(2j^2t^2 + 4jd)}) / j \; (0 < x \leq t) \tag{6}$$

$$\therefore \; h = -jt \pm \sqrt{(2j^2t^2 + 4jd)} \tag{7}$$

When the components are moved as shown in Figure 9 under the conditions of Table 1, a speed of 1.241m/sec in the X axis (h) can be achieved at the camera position by moving a distance of e (-20mm) in the opposite direction for a time of y (62m/sec), and a distance of s(+40mm) for a time of x(64m/sec).
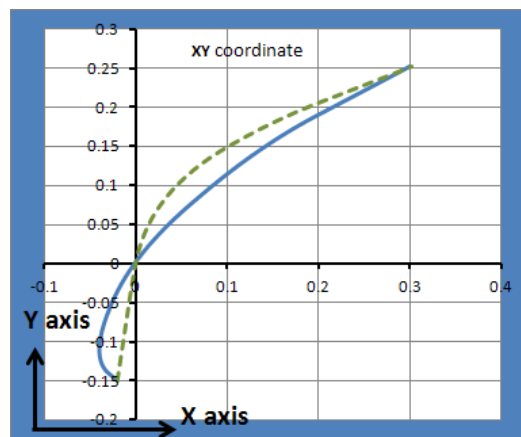
4. Comparison of Three Methods

For the Fly1-Motion method, the X axis speed at which components pass the camera is 0.318m/sec. This means that the time from the camera to the PCBs is 237m/sec. The method proposed in this study allows components to pass the camera at an X axis speed of 1.241m/sec. The time taken to move from the camera to PCBs is 208m/sec, an improvement over the Fly1-motion method by 29m/sec.

The speed graph under the proposed method is given in Figure 10, and the trajectory in Figure 11.
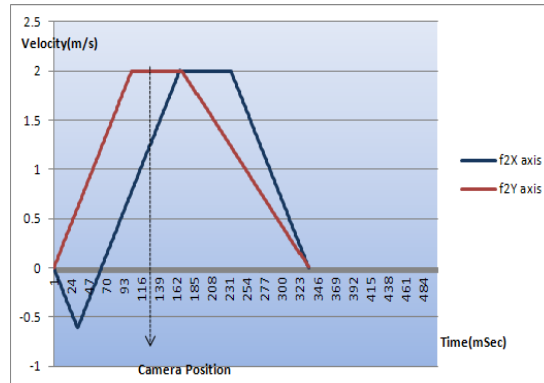
Figure 10. Fly2-Motion Velocity Graph

Figure 11. Fly2-Motion and Fly1-Motion Moving Path

Table 4 compares the moving time of the three methods: Stop-Motion, Fly1-Motion, and the proposed Fly2-Motion.

Table 4. Result of Fly2-Motion

Mode	Total Time (m/sec)	Difference (m/sec)	%	Velocity of Camera position	
				X	Y
Stop-Motion	427	-	-	0.0	0.0
Fly1-Motion	363	64	15	0.3	2.0
Fly2-Motion	334	93	22	1.2	1.2

5. Conclusion and Future Work

This study tested three methods of passing by a vision camera for a gantry style SMT machine. The Fly1-Motion method involved less time compared to the Stop-Motion method, which requires components to stop in front of the camera. Through simulations, we found that the Fly1-Motion method improved productivity by 15%, and the Fly2-Motion method by 22%.

As future work, the proposed method can be applied to surface mount devices to improve CPH. Vibration and heating of the motor are problems that must be addressed.

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