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An Automatic Teaching Method by Vision Information for A Robotic Assembly System

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Abstract

In this study, an off-line automatic teaching method using vision information for robotic assembly task is proposed. Many of industrial robots are still taught and programmed by a teaching pendant. The robot is guided by a human operator to the desired application locations. These motions are recorded and are later edited, within the robotic language using in the robot controller, and played back repetitively to perform the robot task. This conventional teaching method is time-consuming and somewhat dangerous. In the proposed method, the operator teaches the desired locations on the image acquired through CCD camera mounted on the robot hand. The robotic language program is automatically generated and transferred to the robot controller. This teaching process is implemented through an off-line programming(OLP) software. The OLP is developed for the robotic assembly system used in this study. In order to transform the location on image coordinates into robot coordinates, a calibration process is established. The proposed teaching method is implemented and evaluated on the assembly system for soldering electronic parts on a circuit board. A six-axis articulated robot executes assembly task according to the off-line automatic teaching.

1. Introduction

The use of robots in the industry is universalized in order to increase productivity. Many robots are used for the electronic part assembly task. In order to teach the robot, a human operator usually guides the robot with teaching pendant to the desired location. This procedure is on-line teaching method. Recently, the product life cycle is becoming shorter, and the change of assembly task occurs frequently. Thus, a more flexible teaching method is demanded, which can rapidly adapt a robot to the change of circumstances.

In order to cope with this demands, modern automation trends have increasingly placed an emphasis on sensor-guided robots and off-line programming [1][2]. In the first, vision sensors such as CCD camera are often employed to detect differences between actual and desired part locations. And the robot motion commands are generated off-line from pre-modeled virtual robot system of OLP. The programmed task, in such a case, can be greatly simplified with the aid of interactive computer graphics, to simulate the effects of the planned motions, without actually running the robot[3][4][5].

In this study, an off-line automatic teaching method is proposed for teaching a robot task using OLP with the calibration function by vision information. This

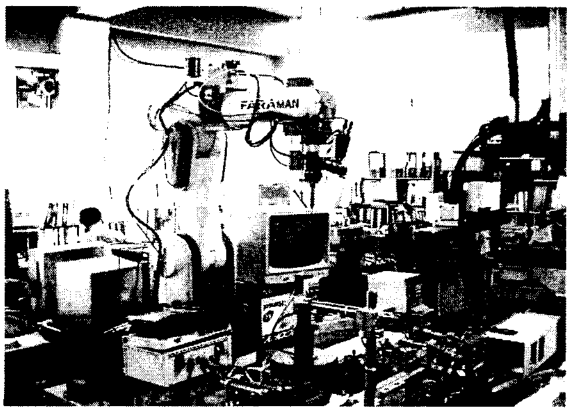

Fig. 1 Robotic system for assembly task

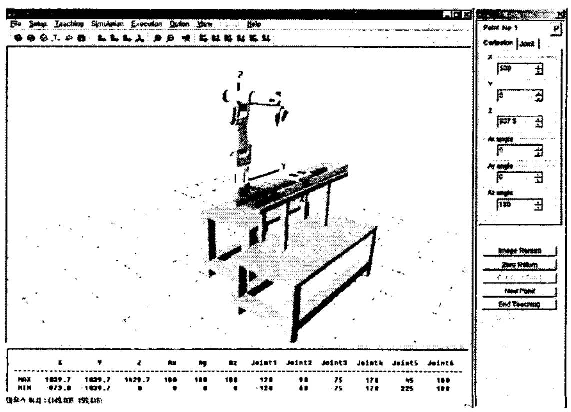

Fig. 2 Virtual robot system in OLP

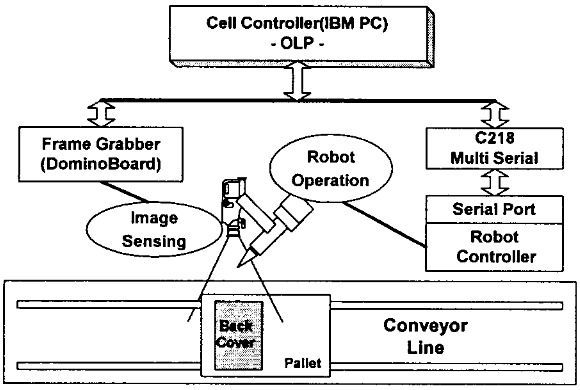

Fig. 3 System configuration for automatic teaching

assembly system used in the industrial field. The method is applied to the robot in the electronic part performance of the proposed method is evaluated experimentally.

2. Off-line teaching for the robot

The robotic system used in this study is the work cell that takes a section of line in which backcover of camera is manufactured. Fig. 1 shows the shape of the robotic system.

This cell carry out three tasks which are heat calking inspection, electronic circuit soldering, and solder inspection. The soldering task is done by 6 axis articulated robot, AC-1.5(Samsung Electronics Co.). The robot motion has been taught by on-line teaching pendant. Thus, in case of model change, it took much time to reprogram the robot motion. In order to reduce the time of reprograming, an OLP is used as an off-line tool for the automatic teaching with the help of vision information.

2.1 Off-line automatic teaching

The motion program of robot is generated by automatic teaching in OLP. Fig. 2 shows the virtual robot system in OLP, Fig. 3 shows the configuration of hardware system.

The automatic teaching process consists of four procedure which are acquisition of workpiece information, teaching locations of soldering points, generation of robot program, and downloading the program to robot controller.

In order to acquire information of workpiece, a CCD camera is attached to the hand of the robot. An interface module through which image data from camera is sent to OLP is installed in the developed OLP system. And a serial interface module through which the OLP operates the robot controller is installed. By doing so, the generated robot program in OLP can be directly downloaded to robot controller. Then the robot is controlled according to the motion program which is taught.

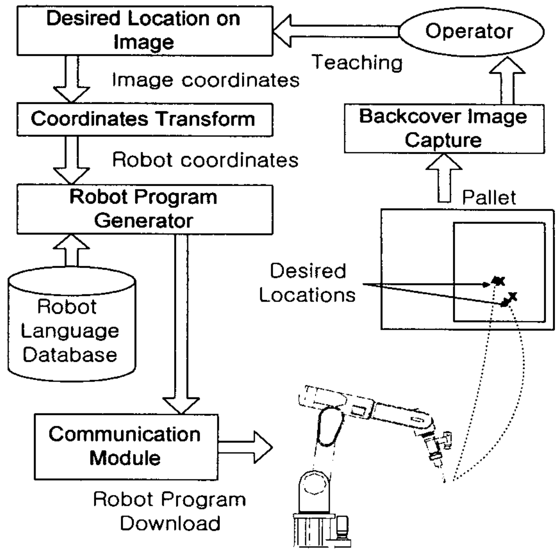

Fig. 4 Automatic teaching process

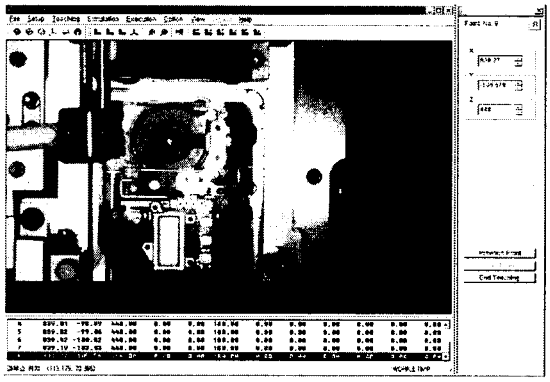

Fig. 5 Teaching through image in OLP

2.2 Teaching by vision information

The process of the proposed automatic teaching method is shown in Fig. 4. When automatic teaching menu in OLP is clicked, the robot moves to the position for taking a photograph of the workpiece. Then, the camera captures the image of workpiece, and it is displayed on the monitor in OLP as shown in Fig. 5. Then, an operator catches the image information of workpiece and determines the position to solder. Operator can teach the desired points to solder in workpiece by marking the locations of soldering points on that displayed image. In order to mark the teaching points, operator uses a mouse and moves the cross-shaped cursor on the image of workpiece to the desired position. The taught position is marked with red circle. The image coordinates of the location is automatically transformed to the robot coordinates by a transformation algorithm whose parameter is calculated through calibration process. Based on this robot coordinates, the robot program is automatically generated by referring to robot program database. Then, the generated program is downloaded to robot controller and the robot is operated according to the taught program for test.

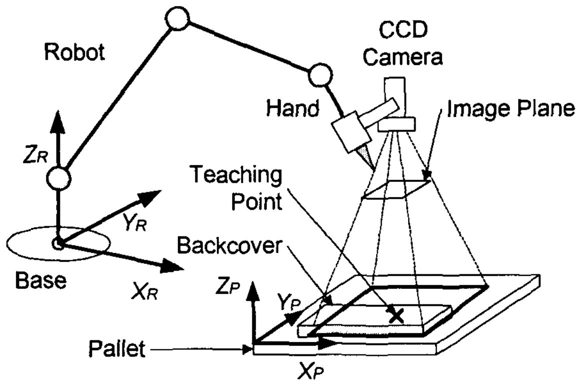

Fig. 6 Hand-eye system for automatic teaching

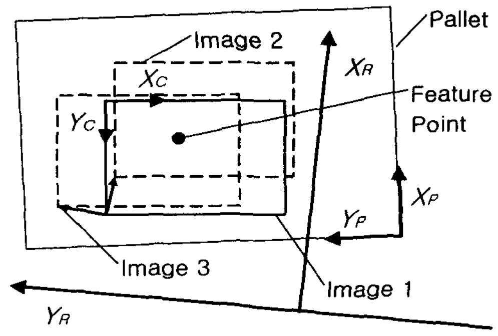

Fig. 7 Calibration between image coordinates and robot coordinates

3. Coordinates calibration

In teaching automation by image information, the taught location is represented in two coordinate systems. The first is image coordinate system through which the desired location is taught on image in OLP. The second is robot coordinate system which is world coordinate system of the robot controller. In order to exactly transform image coordinates to robot coordinates, a calibration should be performed [2][6][7].

Fig. 6 shows the configuration of the system to be calibrated. In this configuration, the soldering task is executed on the plane of workpiece which is parallel to the robot base plane. The world coordinates of 6-axis articulated robot are represented as x, y, z, α, β, γ. The x, y, z represent the 3D position of standard point of robot hand, and α, β, γ represent the orientation of hand [8]. The soldering task is supposed to be executed only on one plane, thus calibration process is needed for two dimensional coordinates, x, y. The z, α, β, γ coordinates of robot hand where the image of the workpiece is captured are chosen and fixed so that image plane is parallel to pallet plane.

The calibration process to acquire the exact transformation algorithm consists of two steps. First step is to find two dimensional transformation between image coordinates and robot coordinates. Second is to find the tip position of soldering iron on the base of image coordinates.

3.1 Transformation algorithm

In order to find the displacement of image coordinates according to that of robot coordinates, three images are captured at other positions as shown in Fig. 7. 1st image includes feature point on pallet. 2nd image is captured at the position where the robot is Δx_{RT} distant from the position of 1st image. And 3rd image is captured at the position where the robot is Δy_{RT} distant from the position of 1st image. Comparing 1st image with 2nd image, the displacement of image coordinates, Δx_{CX}, Δy_{CX} are acquired and comparing 1st Image with 3rd Image, displacement of image coordinates, Δx_{CY}, Δy_{CY} are acquired. Then

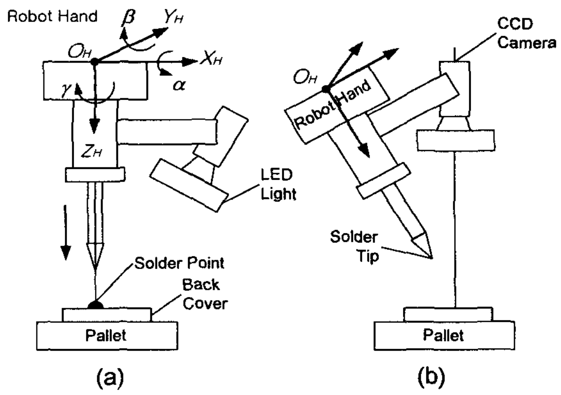

Fig. 8 (a) Orientation for soldering
(b) Orientation for image capture

transformation matrix T is acquired as eq. (1).

$$T = \begin{bmatrix} \dfrac{\Delta x_{CX}}{\Delta x_{RT}} & \dfrac{\Delta x_{CY}}{\Delta y_{RT}} \\ \dfrac{\Delta y_{CX}}{\Delta x_{RT}} & \dfrac{\Delta y_{CY}}{\Delta y_{RT}} \end{bmatrix} \tag{1}$$

The robot displacement, Δx_R, Δy_R to capture new image which is Δx_C, Δy_C distant from original image can be calculated by eq.(2).

$$\begin{bmatrix} \Delta x_R \\ \Delta y_R \end{bmatrix} = T^{-1} \begin{bmatrix} \Delta x_C \\ \Delta y_C \end{bmatrix} \tag{2}$$

3.2 Calibration to find tip position

In order to locate the tip of soldering iron at the position taught on the image, the image coordinates of the tip position should be calibrated. The orientation of hand for soldering is chosen and fixed as shown in Fig. 8(a) and Fig. 8(b) shows that for taking a photograph.

The second step of calibration process is to find the virtual image coordinates of the tip in the orientation of soldering. When the robot at the position, x_{RS}, y_{RS} and at the orientation of Fig. 8(a) locates the tip of soldering iron at some point on the pallet, the contact

Table 1. Comparison of teaching time

Comparison item	Teaching by teaching pendant	Automatic teaching
Set up (calibration & database edit)	0	1 ~ 2 hour
Teaching time (4 point)	30 min	30 sec
Program edit	30 min	1 sec

point is marked. The marked point is shown at the position, x_{Cmark}, y_{Cmark} in the image which is captured by camera of robot hand, when the robot position is x_{Rmark}, y_{Rmark}. The image coordinates, x_{CS}, y_{CS}, which represent the virtual position of the soldering iron tip on the image, are calculated by eq.(3).

$$\begin{bmatrix} x_{CS} \\ y_{CS} \end{bmatrix} = T \begin{bmatrix} x_{RS} - x_{Rmark} \\ y_{RS} - y_{Rmark} \end{bmatrix} + \begin{bmatrix} x_{Cmark} \\ y_{Cmark} \end{bmatrix} \quad (3)$$

3.3 Transformation of the taught location

The desired location is taught by the operator on the image of workpiece which is captured at robot position, x_{Rpic}, y_{Rpic}. The image coordinates of the taught location is x_{Cteach}, y_{Cteach}. This location is transformed to the robot coordinates, x_{Rteach}, y_{Rteach} by eq.(4).

$$\begin{bmatrix} x_{Rteach} \\ y_{Rteach} \end{bmatrix} = T^{-1} \begin{bmatrix} x_{CS} - x_{Cteach} \\ y_{CS} - y_{Cteach} \end{bmatrix} + \begin{bmatrix} x_{Rpic} \\ y_{Rpic} \end{bmatrix} \quad (4)$$

As long as the position of camera relative to robot hand does not change, eq.(4) is available. The calibration process is done when the CCD camera is set up on the robot hand. The z coordinates of robot is determined by operator.

3.4 Experiment

The proposed automatic teaching method is evaluated experimentally. The desired location is taught as shown in Fig. 5, and the robot location for soldering is calculated by the transformation algorithm which is obtained through pre-performed calibration. The error between the real robot location and the desired location is less than 0.5 mm. The soldering task by this method was done successfully in the experiment.

Table 1 shows the comparison of the time consumed in teaching process between the on-line teaching by teaching pendant and the proposed off-line automatic teaching. The proposed method consumes some time on set-up, but after once setting-up, the off-line teaching takes quite less time than on-line teaching by teaching pendant.

4. Conclusions

In this study, the off-line automatic teaching method using vision information was proposed. The information of workpiece for teaching is supplied to an operator by the image from the camera attached to the robot hand and the operator can teach the desired locations on the image directly in OLP. Thus, teaching time is reduced and a non-skilled operator can teach the motion of the robot for assembly task, easily and safely. When there are frequent demand for reprogramming of the robot task, the proposed teaching method may be efficient and increase the productivity.

Acknowledgement

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