

ANALYSIS PROCEDURE OF ROBOT'S LOADING PERFORMANCE BY USING ACTUAL DATA

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The usage of robots in manufacturing systems is increase. For material handling, the robot loads and unloads a workpiece on and from the given position of a machine, respectively. A robot without a closed control system may fail in such a performance. In order to analyze the stochastic property of the robot's loading performance, playback accuracy on a given position is measured under given experimental conditions and then a statistical procedure on the measured data is described. Run test is used to determine whether the loading failure of any one cycle is random or not. Proposed method using real data of 400 consecutive cycles can be applied to build an analytical model on a manufacturing system using robots as material handling equipment.

Key Words : Loading Performance, Playback Accuracy, Stochastic Property, Bernoulli Process

1. INTRODUCTION

Robots in a manufacturing system are used frequently to load and unload a workpiece. When the workpiece is located outside the boundary of a jig or fixture, the loading fails. Also, when the size of the workpiece exceeds a maximum allowable size, the loading fails even if the robot locates the workpiece properly. So, the loading performance depends not only on the robot's positioning capability but also on the actual size of the workpiece, its orientation, etc. However, in order to keep the analysis simple, it is assumed in this study that the workpieces have the same size and orientation. Also, the size of jig or fixture is assumed to be constant and not to wear with time. Only the robot's positioning capability is considered while analyzing its loading performance.

In this study, an experiment to collect data on the positioning capability of the robot is described. Also a statistical procedure is developed to make inferences on the stochastic nature of the robot's loading performance by using the experimental data.

2. POSITIONING ACCURACY

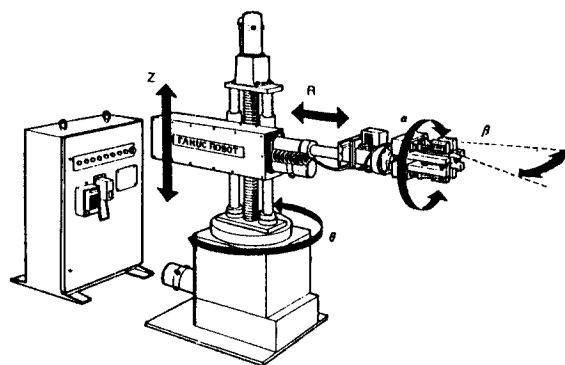
There are three basic components in a robot: manipulator, power supply and controller. Although all the three components affect the positioning performance, the position

of the manipulator determines the final position. There is no generalized method to measure the positioning accuracy specifying what to measure under what conditions. The National Bureau of Standards of USA(1981) explains the positioning capability of a robot in terms of its three properties: accuracy, repeatability, and play back accuracy as follows.

(a) Accuracy is the degree to which an actual position corresponds to the desired or commanded position.

(b) Repeatability is the closeness of agreement of repeated position movements to the same location, under the same condition.

(c) Playback accuracy is the difference between an actual position response of an automated control system during a



Axis	Option class	Basic option	Control method	Motion	Motion range	Max.motion speed
z	Basic axes		Servo control	Z axis up/down	500mm	500mm/sec
θ		Integrated type	Servo control	θ axis rotation	210°	60°/sec
		Separated type	Servo control	θ axis rotation	300°	70°/sec
R		R axis S R axis L	Servo control Servo control	R axis in/outR axis in/out	800mm 1100mm	1,000mm/sec 1,000mm/sec
α	Basic option	Wrist B	On/off control	α axis rotation	0°/90°or 0°/180°	60°/sec
		Wrist C	Continuous control	α axis rotaion	-90°~ +180°	60°/sec
β		Wrist B	Mechanically adjustable only	β axis bending	-3.5°~ +3.5°	—
		Wrist C	On/off control	β axis bending	-3.5°~ +3.5°	30°sec

Fig. 1 Motion and control axis of FANUC Robot-Model 1

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programming or teaching run and the corresponding response in a subsequent run.

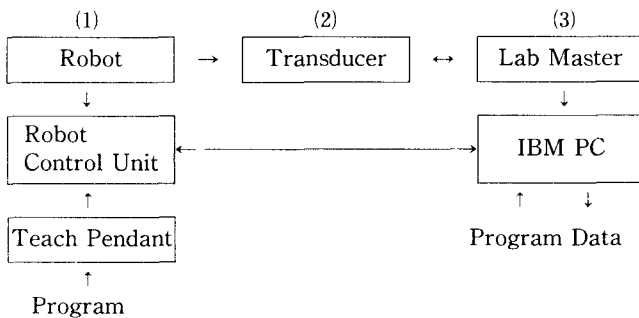
Causes of the positioning error of a robot were first studied from the point of view of mechanical system. Birk(1976) identified the following three factors as the causes of the positioning error: inaccurate measurement, arm servo inaccuracy, and bending in arm links. Krisztinicz and Elek(1976) experimented on the positioning problems of pneumatic robots by analyzing the interrelationships between load, motion speed, drive system design, and positioning accuracy. Morgan(1980) concluded that no robot maintained constant accuracy over its working volume because bearings needed space and beams were bent and twisted under different loading conditions. Internal control systems were another cause of positioning error because it often had analog to digital (and vice versa) conversion devices that use approximation techniques. Warnecke, et al. (1980) investigated the effect of the robot's thermal behavior on positioning accuracy. While electrically actuated robots were not remarkably influenced by temperature, robots with hydraulic actuators did not show stabilization until after a certain amount of warm-up time.

3. MEASUREMENT OF ROBOT'S REPEATED POSITIONS

In the experiments conducted to analyze the positioning error, the playback accuracy of the FANUC Robot-Model shown in Fig. 1, was measured using the following devices:

- Transducer system to convert measured distance to voltage, (noncontact and $200 \text{ mV/mil} \pm 4\%$)
- Laboratory master to convert back the voltage to distance, and
- IBM personal computer to control all components of the system and to record data of the distance.

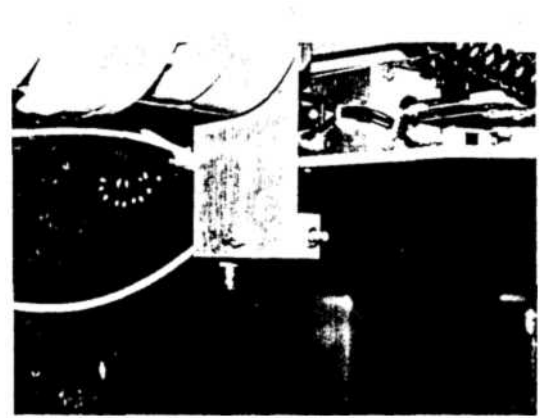
A schematic diagram of the experimental devices is shown in Fig. 2.



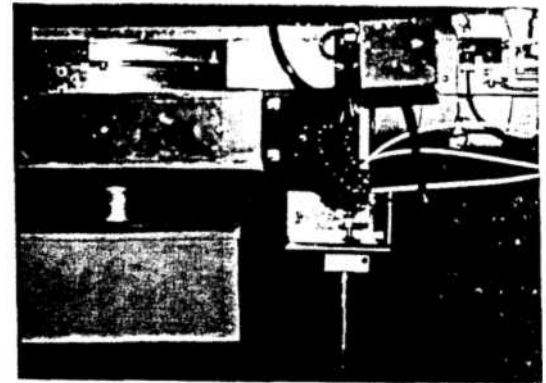
- (1) FANUC Robot Model 1
- (2) Bently Nevada Proximity Transducer
- (3) Tecmar PC-Mate Laboratory Master

Fig. 2 Schematic diagram of the experimental devices

Controlled by the IBM PC and the robot control unit, the robot movement of loading a workpiece from the buffer on the machine is simulated. Every time the robot's gripper reaches the loading position, its location with respect to three mutually perpendicular reference surfaces is measured by means of the transducers and recorded. Since the robot moves in a cylindrical coordinate, the location by the rotational movement is not linear. However, the variation of the final location in the rotational direction is so small that



(a) Transducers



(b) Three-sided reference surface

Fig. 3 Transducers and three-sided reference surface

it is assumed that the final location in the rotational direction is linear. Actually, the distances are measured as voltages. This voltage is changed to a digital signal through the laboratory master and is stored in a data files of the IBM PC. The robot moves for as many cycles as the program of the IBM PC commands. The transducers and the three sided reference surfaces are shown in Fig. 3.

The FANUC Robot-Model 1(1980) is a cylindrical coordinate type robot and has electronic servo control for body movement and pneumatic control for hand movement. The robot is taught to operate through a teach pendant by a program which is composed of a maximum of 300 addresses, each address consisting of positional data, speed, and S cod. The S codes are used to move the wrist and gripper to various points along the robot path. They also specify other functions which control the robot's movement. The robot is programmed to simulate the following operations in a cycle:

- to pick up a workpiece from an input buffer.
- to load it on the machine,
- to move back and wait for the machine to finish to operation,
- to return to the machine and unload the workpiece.
- to release the workpiece into an output buffer,
- to move back and wait for a while, and
- to return to the input buffer.

After several warm-up cycles, three initial positions along the three mutually perpendicular directions are defined as desired positions of reach, rotation, and height. When the robot rotates more than desired, the robot reaches closer to the reference surface vertical to the rotational transducer and the vertical reference surface becomes shorter than

desired. When the robot rotates less than desired, the distance becomes larger than desired. The other two distances of reach and height are measured in the same way. A program (Rho, 1985) is coded in BASIC to perform the following operations;

- (a) to decide the number of cycles required.
- (b) to control the robot's movement,
- (c) to obtain data on the repeated positions,
- (d) to calculate statistics on the drifts,

(e) to show the drifts on the screen of IBM PC, and
(f) to analyze the loading performance interactively.

Flow diagram of the program is shown in Fig. 4. This program can also identify the states of the loading positions as up or down, based on the interactively given permitted variations. That is, the stored loading positions for each cycle are compared with arbitrarily given permitted variations, so that the states of the loading positions can be determined.

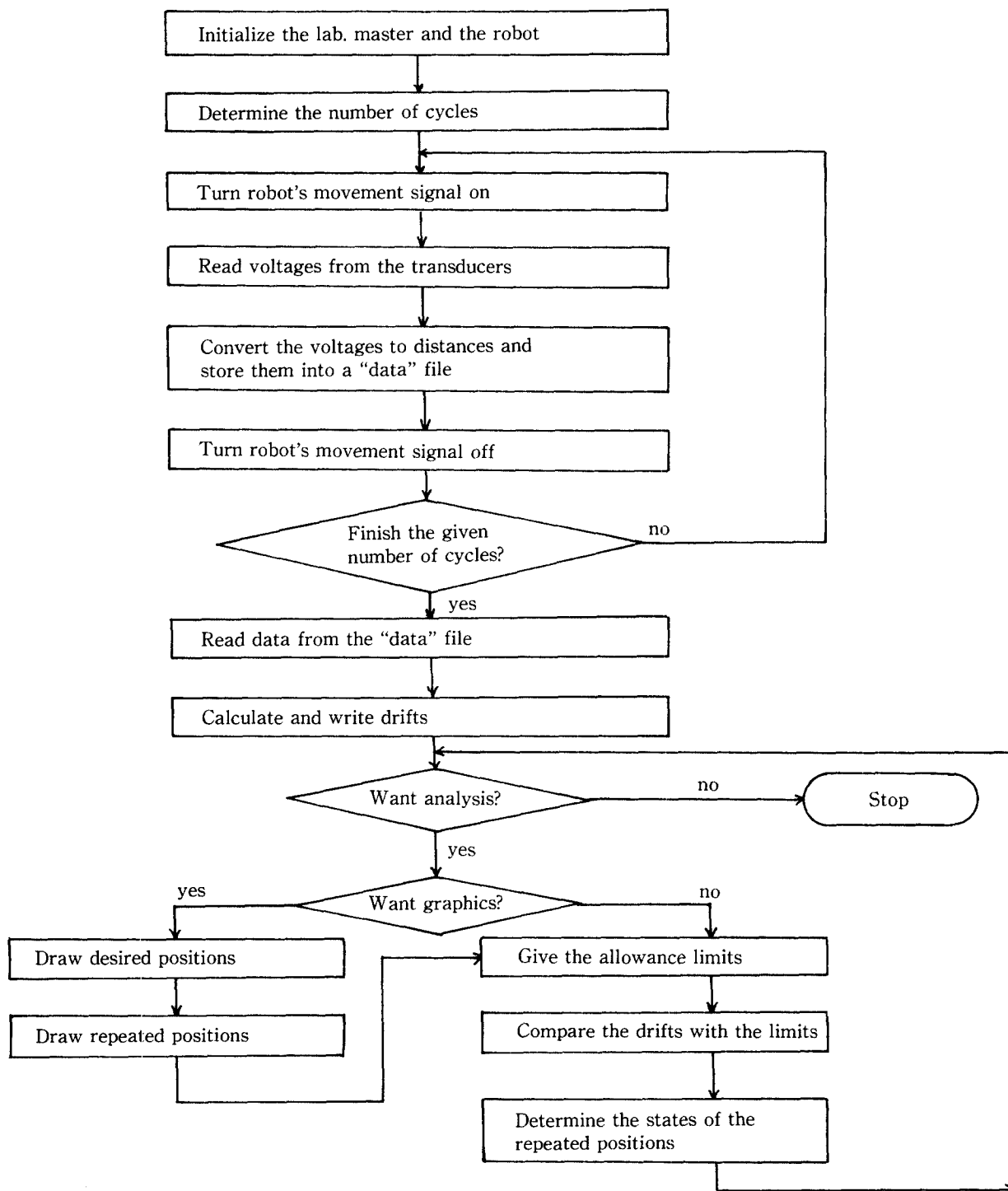


Fig. 4 Flow diagram of BASIC program to run the experimental devices from the analysis of the robot's positioning performance.

The above procedure can be used to validate an assumption about the robot's loading performance, which has to be made in order to build an analytical model on a manufacturing system using robots as material handling equipments (Rho, 1985). For more reliable conclusion, it is recommended that the above procedure is applied to data from more general experimental conditions.

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