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SPIE—The International Society for Optical Engineering

Expert Robots for Industrial Use

Ernest L. Hall
David P. Casasent
Kenneth J. Stout
Chairs/Editors

7–8 November 1988
Cambridge, Massachusetts

Sponsored by
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SPIE P PROCEEDINGS SERIES

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EXPERT ROBOTS FOR INDUSTRIAL USE

Volume 1008

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EXPERT ROBOTS FOR INDUSTRIAL USE

Volume 1008

INTRODUCTION

Intelligent machines, often creative combinations of industrial robots or manipulators, vision or other sensor system, and expert control computers, have made a new generation of expert robots available.

The papers assembled in this proceedings reflect the current work being conducted on prototype design, commercial products, and industrial applications of expert robots. Paper topics are as varied as the possibilities of these new experts: welding, automated assembly, material handling, machining, composite materials fabrication, forging, laser cutting, and advanced manufacturing, as well as theory and practice, or scientific foundations.

Ernest L. Hall
University of Cincinnati

David P. Casasent
Carnegie Mellon University

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SESSION 1

Vision

Chair

Rolf-Jürgen Ahlers
Fraunhofer-Institut für Produktionstechnik und Automatisierung (FRG)

Industrial Robots for Measurement and Inspection Purposes

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ABSTRACT

The use of industrial robots for measuring and testing is becoming increasingly significant as a component of flexible production.

In the early stages of their development robots were used mainly for monotonous and repetitive tasks such as handling and spot welding.

Thanks to improvements in the precision with which they work and also in control and regulation technologies, it is possible today to employ robots as flexible, sensor-assisted and even "intellligent" tools for measuring and testing. As a result, however, much higher accuracy is demanded of the robots used for such purposes. In addition, robot measurement and acceptance test requirements have become more exacting.

The present paper is based on recommendations that have been developed by cooperative work of the Association of German-Engineers (VDI/GMA). The appropriate working group is entitled "Industrial Robots -Measurement and Inspection". The author is the chairman of this working group.

Apart from the technical equipment involved, the use of industrial robots for measuring purposes also calls for the devising and programming of appropriate measuring strategies. In this context the planning and implementation of measuring projects have to be discussed along with software reliability and on-line/off-line programming strategies.

Four different utilizations of robots for measuring and testing are presented and illustrated by examples.

1. INTRODUCTION

Production today frequently involves medium or large series with numerous product variants and also a high degree of automation. In this situation industrial robots have had an increasingly important role to play and are already employed in many different areas, ranging form workpiece handling, automated assembly and painting to use also underwater and in space [1 - 3].

Most of these applications are developed either for reasons of economy or else because no viable alternative is available (e.g. in nuclear technology, clean rooms or in space). With the continuous improvement and innovation in periphery -sensor systems for workpiece recognition or to support machining or assembly processes - the capabilities and application potential of industrial robots become ever greater.

Measuring and testing is one such field which has opened up to robot utilization, helped by improvements in the accuracy of movement sequences as well as the upgrading of control and regulating techniques which today make flexible and sensor-assisted application a reality. Free programming in space and the integration of up to six axes in the control system enable poorly accessible workpiece geometries to be scanned without collision, an operation which was difficult to perform with coordinate measuring units.

This freedom of movement also means that the same location can be approached in a variety of different ways. Depending on the axes involved in the movement, the speed and direction, differing degrees of positioning and track accuracy with varying orientations towards the target point can also be achieved (Fig. 1). In these circumstances it is hardly surprising that the call for comparable performance variables, acceptance conditions and uniform measuring methods is becoming more and more strident.

The following article describes developments in the use of industrial robots for measuring and testing, as seen in the context of work of the VDI/GMA guidelines committee 7.12, a body which was formed to provide useoriented suggestions and corresponding guidelines to assist in the practical selection and integration of robots for measuring and testing. The paper covers the initial findings in this area and is intended not only to document the current state which the work has reached but also to provoke discussion.

2. THE NEED FOR EVALUATIONG INDUSTRIAL ROBOTS

When a robot is to be selected for use in industry, it is necessary first of all to confront the apparently insoluble task of comparing the relevant information. Manufacturers' descriptions are usually limited to a few (random) characteristics, and a comparison of the data provided by these manufacturers quickly shows that the same designation is often given to completely different characteristics. This dilemma causes particular problems for planning engineers. The industrial robot catalogues available [4] provide some assistance, but here too the question of uniform measuring procedures and assessment criteria is still unsolved [5 - 19].

Guidelines are in existence to define the performance characteristics and measuring tasks to be carried out [20 - 22]. These may be sub-divided as follows:

- geometric values
- load values
- kinematic values
- static/dynamic accuracy values

A variety of measuring procedures have been used, e.g. measuring heads with contactless or contacting sensors [9].

It is possible to define values in terms of reference blocks or by suitable arrangement of measuring system reference points, surfaces or volumes [5, 24].

Mechanical measuring systems usually consist of several linear and rotary axes and are coupled directly to the gripper or toll flange. There are thus similarities with the kinematics of an industrial robot, which informs the mechnical measuring system of its movements, enabling a measurement to be made by means of appropriate position measuring devices. The sphere coordinate measuring unit [15] provides a good example of this procedure.

Optical measuring systems offer the advantage of contactless measuring and are therefore practically non-interacting. Several different principles present themselves, with recent developments concentrating particularly on:

- theodolite measurement
- laser measurement
- image-processing

A summary is provided in [5].

3. THE NEED FOR MEASURING AND TESTING WITH INDUSTRIAL ROBOTS

Cartesian coordinate measuring systems are employed extensively in production engineering. They are mostly used for laboratory measurement and difficulties can arise when they are integrated in production processes or employed for measuring complicated and poorly accessible components. Thanks to their construction, industrial robots prove to be much more mobile and can be used for tasks which are difficult if not impossible to solve with coordinate measuring systems.

Unofficial terms such as "testing robots" or "measuring robots" have now gradually entered the language. Such descripions are misleading as the systems they are applied to are frequently nothing more than coordinate measuring systems "in disguise".

Generally speaking, the robots are not specially developed for measuring and testing purposes; it is more a case of existing systems (industrial robots, measuring devices) being combined to form new configurations which include these tasks [23].

The degree of sophistication possible is shown by the "flexible testing cell" in Figure 2 which enables testing and measuring tasks to be linked. The industrial robot covers a wide working range and testing and measuring is carried out by an image-processing system.

Thereafter the coordinates can be linked or the robot corrected in accordance with the readings, etc. [23, 25].

Conversely, it is also possible to manipulate objects for measurement, insert them in a measuring system and measure them. In principle, four different cases may be distinguished, as will be described in the next section.

4. VDI/GMA COMMITTEE 7.12

Industrial robots are all-purpose moving devices with several axes. The movement sequences, paths and angles can be programmed or guided by sensors. To enable them to carry out handling or production tasks they are equipped with grippers, tools and production or measuring devices.

The programmability of the robots sets them apart from simple insertion devices. The ability to carry out handling and/or production tasks also distinguishes them from machine tools [26].

When industrial robots are used for measuring and testing, the distinction between coordinate measuring devices and robots with Cartesian coordinates becomes more difficult to draw. This conflict led the VDI/GMA committee to exclude robots with Cartesian coordinates from its considerations and to group them rather with coordinate measuring devices [27].

Testing or measuring applications can be basically defined in terms of the following four principles:

Case 1:

The measuring instruments are manipulated by industrial robots with the position of the robot not being included in the reading.

Case 2:

The robot has measuring axes and can thus carry out measuring and testing tasks in conjunction, for example, with a zero sensor.

Case 3:

A combination robot with measuring axes and measuring instruments.

Case 4:

This case describes the possibility of an industrial robot with measuring axes manipulating the object to be measured and inserting it in a paticular orientation. The coordinates of all devices involved in the measurement are linked and combine to provide the reading.

This categorization shows that robots used for measuring and testing have a new quality, particualarly when, as "measuring" or "testing robots", the characteristics of the measuring device are also integrated as sub-sets (Fig 3).

This factor is also reflected in the current developments by industrial robot manufacturers.

The manufacturers of measuring appliances have also recongnized the great potential, and measuring devices with robot guidance are now used to automate the measuring process and make it more flexible at the same time, as in Case 1 above.

The way in which these developments have already progressed and reflected is described in [27].

5. SUMMARY

New developments with industrial robots, while themselves in many cases dictated by demand, have led to wider applications.

The demand for industrial use of programmable measuring and testing systems with extremely flexible movement capabilities and precise sensory capacities has stimulated developments to a large extent and the first examples of this new robot application are already evident. Unforeseen eventualities are likely to continue to influence further progress in this direction.

Future "measuring and testing robots" will have to comply with certain specific requirements, including an increase in the absolute positioning and track precision, the possibiltiy of simple mechanical and program integration of sensors (e.g. measuring aids) and the capability of complete on-line and off-line programming.

The VDI/GMA committee on "industrial robots for measuring and testing" is concerned to assess the degreee to which these requirements need to be fulfilled. Its reports are designed to stimulate dialogue between users, manufacturers, developers and members of the committtee. The designs and ideas presented provide the basis for furhter discussion but are to be regarded at the same time as flexible and capable of adaption to developments and requirements of the industrial environment.

"Measuring and testing with industrial robots" is an ambitious target but on which we must set our sights on.

We still have a long way to go until robots can be used for a wide spectrum of applications but the first steps in this direction have already been made.

6. FIGURES

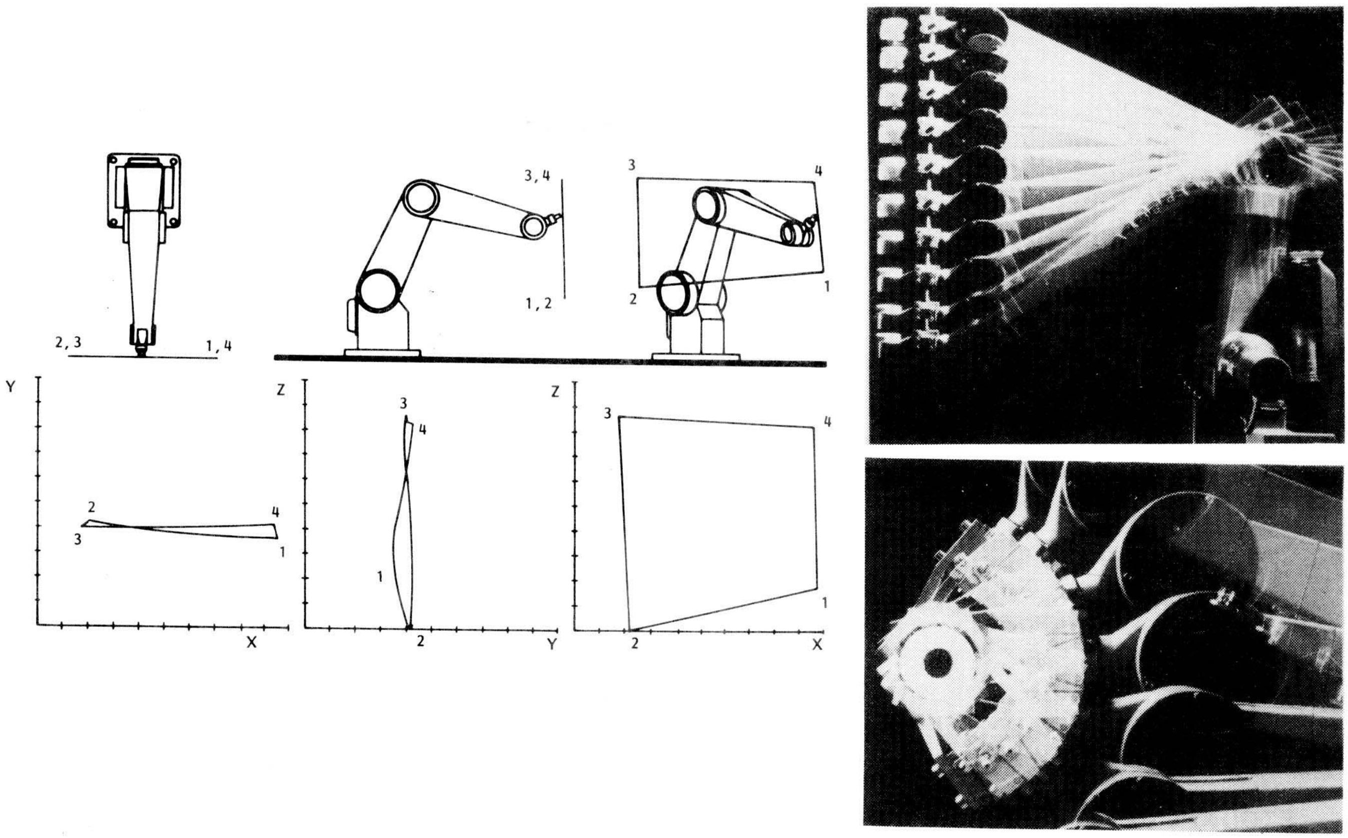
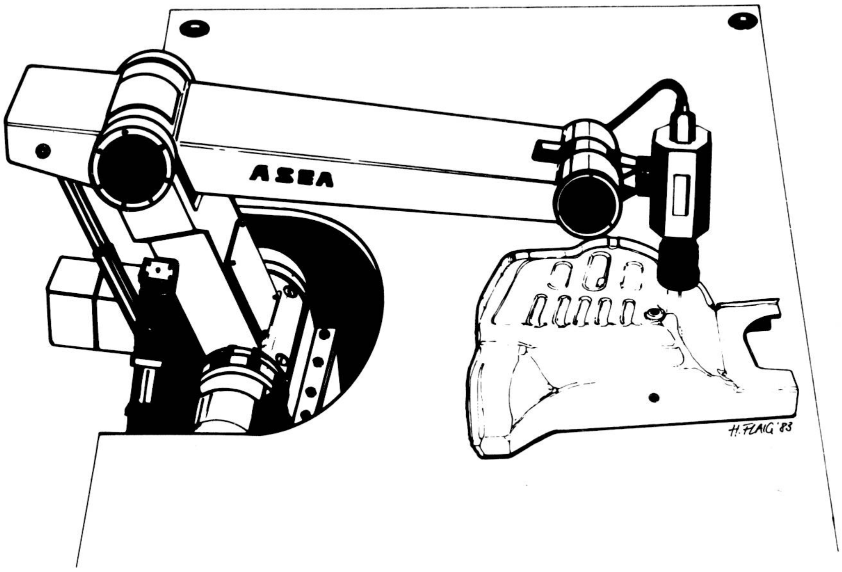


FIGURE 1: Industrial-Robots: Structures, Workspaces, and Features



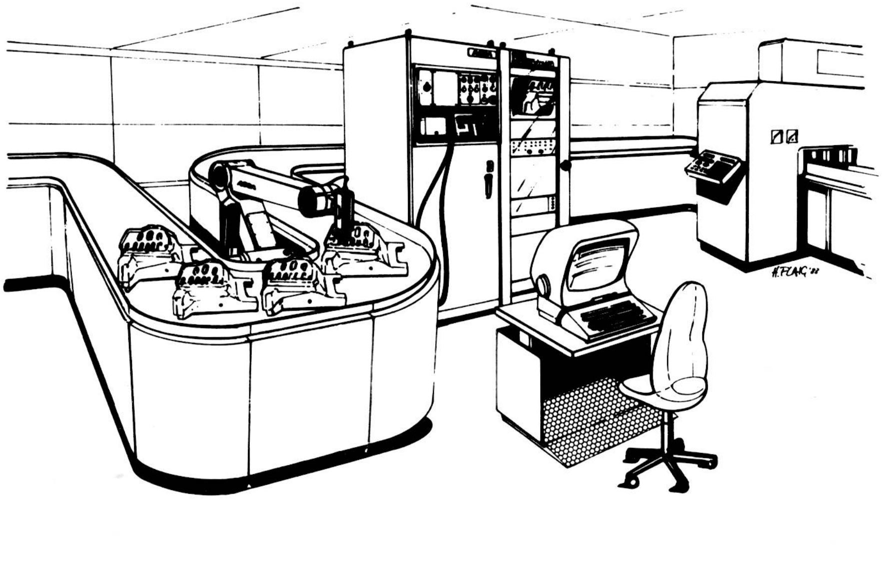


FIGURE 2: "Flexible Inspection Cell"

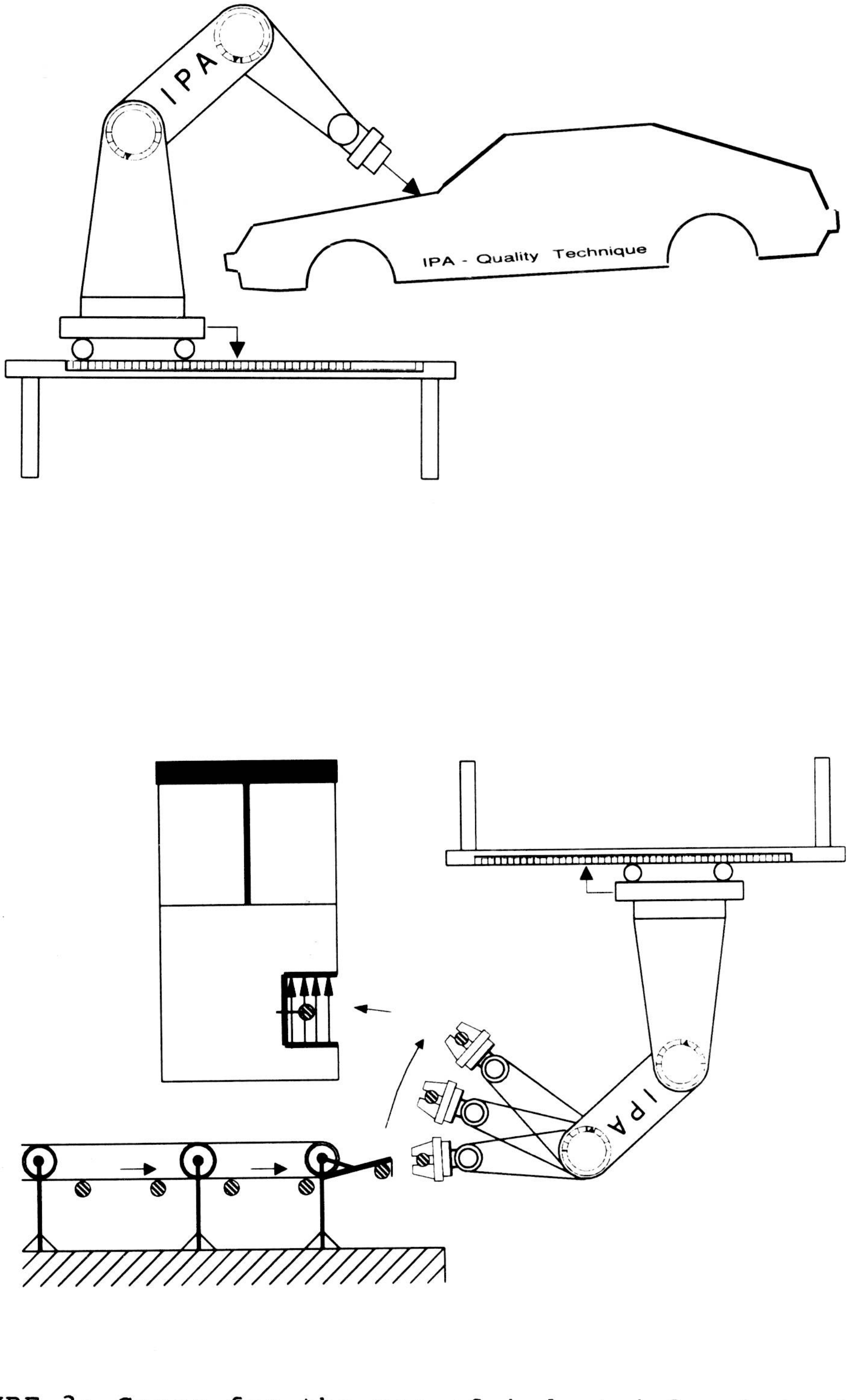


FIGURE 3: Cases for the use of industrial robots in conjunction with sensors

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