ROBOTICS AND FLEXIBLE MANUFACTURING TECHNOLOGIES

Assessment, Impacts and Forecast

Robert U. Ayres and Steven M. Miller

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Foreword

A critical assessment of current robotics and flexible manufacturing technologies, their impacts on the industrial base, and a forecast of future functional capabilities and emerging applications areas are presented in this book

Nearly three times as many robots were installed in industry in 1984 as in 1979, and the prospects for the future can only increase, probably by orders of magnitude. This valuable up to-date and critical assessment indicates that robotics and flexible manufacturing technologies will be a major driving force in the industrial world

Part I of the book reviews the role of tools, machines and controls in our society, the extensions of capabilities of commercially available robots, integration of sensory information processing with robotic devices, and the integration of robots, machine tools, parts handling and transport devices and computers into flexible manufacturing systems (FMSs). Analyses are given on changes in unit costs and production labor requirements which will accompany the more widespread use of industrial robots and FMSs.

Part II reviews key worldwide R&D activities and discusses the principal thrusts and trends in robotics development. It provides a technological forecast addressing future directions of robotics producers and end-users.

The information in this book is from

> *An Exploratory Assessment of Second Generation Robotics and Sensor-Based Systems* prepared by Robert U. Ayres and Steven M. Miller of the Department of Engineering and Public Policy, Carnegie-Mellon University for the National Science Foundation, September 1984

Robotic Technology An Assessment and Forecast prepared by James Just, Keith King, Michael Osheroff, George Berke, Peter Spidaliere and Tran Ngoc of DHR, Incorporated for the Aerospace Industrial Modernization Office of the Air Force Systems Command, July 1984

The table of contents is organized in such a way as to serve as a subject index and provides easy access to the information contained in the book

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PART I

CARNEGIE-MELLON ASSESSMENT

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1. Introduction

The first systematic assessment of the potential impacts of robots on employment and productivity was the report, "Technology Assessment: The Impact of Robots," submitted to the National Science Foundation by the Eikonix Corporation in 1979. The assessment primarily focused on robots in manufacturing, but gave some attention to household applications and to applications in the nuclear industry. The technology assessment was a useful examination of what was then known about the technology, what could be surmised about its future, and the implications for society, for industry, and for the government.

The Eikonix report stated that robot capabilities were, and would remain for at least ten to fifteen years, much too limited for the needs of most manufacturers; and that as a result, diffusion of the technology would be slow and gradual. The assessment concluded that "it is highly unlikely that diffusion of robotics will be rapid. . .The technical constraints against a vast change in the scope of robotic capabilities is one reason for the slow diffusion rate. . . there is just no evidence to suggest that the impacts will be anything but very minor, at least up to the turn of the century."[1]

NSF has sponsored this new assessment for three reasons. First, progress in the development of robotics technology has accelerated since 1979, particularly in the areas of sensory information processing. Second, the earlier study did not give much attention to parallel and concurrent developments in manufacturing technology such as flexible manufacturing systems and design for automated fabrication and assembly. Third, the U.S. now has con-

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[1] page 231.

siderably more experience with robotic use and impacts. There are nearly three times as many robots installed in U.S. indústry in 1984 as in 1979.

This updated assessment is comprised of two major components. The first is a set of four papers by the principal investigators, Robert Ayres and Steven Miller. The first paper by Ayres is an overview concerned mainly with articulating a set of broad issues. The second paper, by Miller, is a survey of recent developments in flexible manufacturing technology and the specific role of robotics and sensory information processing. The third and fourth papers were adapted from Miller's recent (1983) Ph.D. thesis. They provide detailed background information and analysis of the coming impacts of robotics in the metalworking industries specifically.

The second major component is the "proceedings" of a computer conference held to review and expand upon the ideas in the four Ayres and Miller papers. The computer conference was organized by the Center for Social and Economic Issues of the Industrial Technology Institute, Ann Arbor, Michigan. Over a two month period, 18 researchers in the U.S. and one in Sweden discussed a variety of issues related to the social and economic impacts of flexible automation via the computer conference network. Abstracts of the four papers, and an outline of the proceedings of the computer conference follow.

The first paper "The Robotics Society" discusses the role of tools, machines and controls in human society, and the conditions under which humans as machine controllers can expect to be replaced in the future by computers linked to sensors. It concludes that, during the coming two or three decades, most "operative" jobs on the factory floor could well be eliminated. On the other hand, relatively few non-factory jobs will be taken over by robots.

A critical benefit of this new form of computer-integrated automation is that it will greatly increase the flexibility of large scale manufacturing and shift the basis for product competition away from price and towards quality and performance.[2] Potential socio-economic implications for the present generation of industrial workers, the industrial unions, and the specialized manufacturing communities, cannot be dismissed lightly. These impacts deserve further study in detail together with possible education and other responses from the public sector.[3]

In the longer run, the paper argues that specialized robots will find many other uses, but that a general purpose "Humanoid" robot is most unlikely to be developed. The reason is, briefly, that a generalized "human" appearance and capability could only be achieved by sacrificing the special skills that would give robots advantages in particular applications. Moreover, even without special skills, it is most unlikely that humans could design a truly general purpose machine that could closely approach the human level of physical performance, sensitivity and intelligence simultaneously across the whole range. Hence, the impact of robotics on human society in the next century will be mostly of an indirect kind; viz. through productivity and employment. The robotic society of the 21st century will in no way resemble the traditional science-fiction view. Robots are and will remain machines that extend human

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[2] See Ayres, Robert U., The Next Industrial Revolution Reviving Industry Through Innovation, Ballinger Publishing Co., Cambridge, MA, 1984.

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[3] See Ayres, Robert U and Steven M. Miller, Robotics Applications and Social Implications, Ballinger Publishing Co., MA, 1983. Also Ayres and Miller, Robotics and the Conservation of Human Resources, Technology and Society, Vol. 4(3), winter, 1982, pages 181-97 and Ayres and Miller, Robotic Realities Near-Term Prospects and Problems, Annals of the American Academy of Political and Social Sciences, Vol. 470, November, 1983, pages 28-55.

capabilities They will eventually serve people directly in some capacities, as they now serve other machines. In the long run, the major social benefit may be that it will no longer be necessary for a class of human workers to operate, load, unload, and watch over production machines, thus--in effect-- being paced by and "serving" the machines.

The second paper, "Recent Developments in Robotics and Flexible Manufacturing Systems," reviews some of the recent developments in robotics and flexible manufacturing technology. Attention is focused on three broad classes of developments:

1. Extensions of the capabilities of commercially available robots.
2. Integration of sensory information processing with robotic devices, and
3. Integration of robots, machine tools, parts handling and transport devices, parts feeders and assembly machines, "smart sensors" and computers into flexible manufacturing systems.

Topics covered that relate to the first class of development include increases in the number of robot models designed for precision placement and increases in the use of computer controlled robots. Topics that relate to the second class include capabilities and limitations of machine vision systems for controlling robot positioning and manipulation in parts acquisition, tool handling, and assembly. Topics relating to the third class include:

- The integration of multiple FMS for machining in one plant
- The use of FMS in manufacturing processes other than machining
- The addition of artificial intelligence and sensor-based systems to FMS

In the third paper, "Impacts of Robotic and Flexible Manufacturing Technologies on Manufacturing Costs and Employment," the issues considered include the extent to which unit costs and production labor requirements might be reduced if there is more widespread use for industrial robots and flexible manufacturing systems. These issues are analyzed from two different perspectives. The technological focus of the first perspective is narrowly confined to the use of robotic manipulators. It is assumed that robotic manipulators will be "retrofitted" into existing production facilities without making major changes in the organization of production within the factory, other than modifying individual work stations so that robots can replace one (or perhaps several) operators. The critical variable in this perspective is an estimate of the percent of the production worker jobs that will be replaced by robots. Reductions in unit cost are calculated by assuming that a given percentage of labor costs is reduced. The question of whether decreases in production labor requirements could be offset by an increase in demand stimulated by a reduction in price is also discussed.

The focus of the second perspective is much broader than the first, and is concerned with the impacts of integrating robots with other types of computer assisted manufacturing (CAM) technologies into flexible manufacturing systems. It is assumed that a factory using general purpose machines to produce specialized products in batches can be reorganized and integrated so the machines are fully utilized and used more efficiently. One critical variable in this perspective is an estimate of the potential increase in output that could be realized if all of the time in a year available for production were utilized. The other critical variable is an estimate of the unit cost and of the labor requirements in a fully utilized batch production plant. Based on an analysis of a cross section of metalworking industries, a relationship is specified between the level of output and the level of unit cost. Reductions in unit cost for a given increase in output are derived from this relationship. Reductions in unit labor requirements are calculated in a similar manner.