# Machine Intelligence

## An International Bibliography with Abstracts of Sensors in Automated Manufacturing

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# Introduction

In 1981 Robotics Bibliography was published containing over 1,800 references on industrial robot research and development, culled from the scientific literature over the previous 12 years. It was felt that sensors for use with industrial robots merited a section and accordingly just over 200 papers were included.

It is a sign of the increased research into sensors in production engineering that this bibliography on both the contact and non-contact forms has appeared less than three years after that first comprehensive collection of references appeared.

In a review in 1975 Professor Warnecke of IPA, Stuttgart drew attention to the lack of sensors for touch and vision. Since then research workers in various companies, universities and national laboratories in the USA, the UK, Italy, Germany and Japan have concentrated on improving sensor capabilities, particularly utilising vision, artificial intelligence and pattern recognition principles. As a result many research projects are on the brink of commercial exploitation and development. This bibliography brings together the documentation on that research and development, highlighting the advances made in vision systems, but not neglecting the development of tactile sensors of various types.

No bibliography can ever be comprehensive, but significant contributions from research workers and production engineers from the major industrialised countries over the last 12 years have been included.

Many major conferences and journals have been examined and selections made from the large number of papers available and, if the emphasis in the bibliography appears to be on vision sensors, this only reflects the predominant trend in research over the past 10 years.

As in the Robotics Bibliography, references included have been restricted where possible to those which are easily accessible through national document provision services such as the British Library Lending Division in the UK and the National Technical Information Service in the USA. Within any one section references are presented in chronological order.

In many cases it has been difficult to assess from the original papers whether or not the sensor designs described are actually in industrial operation. Where a decision has been difficult to make the tendency has been to include the design in an operational application section.

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Graduated as a mechanical engineer through London University and joined the English Electric Co. Ltd. as an information officer. After six years lecturing in information science at Leeds Polytechnic he is now Head of the Greater London Council Research Library. Previous publications include: "Thesaurafacet: A Classification and Thesaurus for Science and Technology", "Traffic Noise: A Review and Bibliography" and "Robotics Bibliography 1970–1981" compiled for IFS (Publications) Ltd. in 1981.

# Contents

# A

# General Literature on Sensors

## A.1. LITERATURE REVIEWS AND BIBLIOGRAPHIES

### A.1. (1) Robot manipulators: sensors and software.

1972-January 1983 (Citations from the International Aerospace Abstracts Data Base) (National Technical Information Service, Springfield, VA). Rept. for 1972-Jan 83, Jan 1983, 143pp. (Rept. No. PB83-859132, supersedes PB82-865577).

*Contains citations concerning research and development in computer software for mathematical modelling and synthesis, adaptive control of robotic manipulators, and optimal feedback control systems for industrial robotics. Sensory control of robots, including internal and external sensory devices, is also discussed. (This bibliography contains 147 citations.)*

### A.1. (2) Use of sensors in programmable automation.

Rosen, C. A. and Nitzan, D. (Stanford Research Institute, USA). Computer, Dec 1977, 10(12) pp. 12–23. Also National Science Foundation Report Apr 1976. 36pp (PB80–124142).

*Examines the need for sensors in visual inspection, finding parts and controlling manipulators. Describes both contact and non-contact sensors, including proximity types. Visual or electro-optical sensors are given some attention; there is also a useful bibliography of 59 references of research up to 1977.*

### A.1. (3) Industrial robots – a bibliography.

Berg, B. (Aeronautical Research Inst., Sweden). The Institute, 1974.

*700 references to the world literature. No abstracts. Complements this bibliography on pre-1974 research.*

### A.1. (4) Artificial intelligence (a bibliography with abstracts).

Grooms, D. W. NTIS/PS-78/0024/6GA, 177 pp. (January, 1978).

*Supersedes NTIS/PS-77/0044, 75/397, and COM-73-11714, covering natural language generation by computer, learning machines, question answering systems, theorem proving and speech understanding. Contains 172 abstracts and is a useful complement to NTIS/PS-78/0026/1GA which cover robots.*

### A.1. (5) Robots.

Roth, B. Applied Mechanics Reviews, November 1978, 31(11) pp. 1511–1519.

*A diagram divides a robot's structure into five functional elements: control, manipulation, locomotion, sensing and thinking. Although most robots do not contain all these functions, all robots have at least two and the more advanced ones have at least three. The author discusses all of these areas, from an applied mechanics point of view, the first four being the most important. The article emphasises the mechanics aspects of these. Those interested in details regarding specific hardware and software are referred to the bibliography and references. (74 refs.)*

### A.1. (6) Sensors for computer controlled mechanical assembly.

Wang, S. S. M. and Will, P. M. (IBM Thomas J. Watson Res. Cent., Yorktown Heights NY). Ind. Robot, 1 Mar 1978, 5(1) pp. 9–18.

*The paper describes several sensors which are applicable to the requirements of computer controlled assembly and manufacturing processes. Various new types of sensors are presented including a multi-degree of freedom force sensor using interchangeable modules, a pneumatic retractable whisker, an ultrasonic probe, and various tactile and optical image sensors. (30 refs.)*

### A.1. (7) Application of robotic sensors: a survey and assessment.

Boykin, W. H. and Diaz, R. G. (Florida Univ. Gainsville, USA). (In, Advances in Computer Technology, Int. Computer Technology Conf., ASME Century 2 Emerging Technology Conf., Vol. 1, pp. 160–165, San Francisco, USA, 12–15 Aug. 1980).

*Sensors applicable to robotic manipulators were surveyed and assessed. The assessment classified the sensors according to the basic wave length or physical spectrum. Includes photoreceptors, mechanoreceptors,* *chemoreceptors, thermoreceptors and electromagnetic receptors. (48 refs.)*

**A.1. (8) Industrial robots and teleoperators June 1970–June 1980 (citations from the Engineering Index Data Case).**

Sassi, W. V. (New England Res. Applic. Center, Storrs, USA). NERACEI NT0477, August 1980, 162 pp. (PB80-851132).

*Contains 200 references on design, construction, performance and economic effectiveness of robots. Various applications including welding, painting and assembly are also covered.*

**A.1. (9) Assessment of robotic sensors.**

Nitzan, D. (SRI International, Calif.). (In, Proc. 1st International Conference on Robot Vision and Sensory Controls, 1–3 April, 1981, Stratford-upon-Avon, UK, organised by IFS (Conferences) Ltd., pp. 1–11). Bedford, IFS (Publications) Ltd., 1981, 347 pp.

*Review of the various types of robot sensor with a useful bibliography covering image processing, tactile sensors, range and force/torque sensors and computer vision. (37 refs.)*

**A.1. (10) Industrial robotics: bibliography.**

Lane, D. and Acland, J. Institution of Electrical Engineers, 1981. Unpaged.

*Contains 226 references dealing with practical and general aspects of robots and their controls. In two sections, the first dealing with general issues, introductions to robotics and reviews, and the second with specific aspects and applications. Author and subject keyword indexes are included. A number of references cover sensor technology.*

**A.1. (11) Robotics bibliography.**

Comersall, A. and Farmer, P. (Greater London Council). Bedford, IFS (Publications) Ltd., 1981. 190 pp.

*Includes over 1,800 abstracted reports, conference papers, books and journal articles covering the development of industrial robots since 1970. Design and performance of robots and their components including sensors of all types are covered. A large section includes papers on applications in assembly, inspection, production engineering, welding and in the aircraft, nuclear and marine industries.*

**A.1. (12) Robots.**

1964–March 1982 (Citations from the NTIS Data Base) (National Technical Information Service). Rept. No. PB82-808395 May 1982, 250 pp. Supersedes PB81-803215, and PB80-803836.

*Cites research on the design and application of robots. It includes studies on software development, memory models, and manipulation control algorithms. Also included are the many applications of robots and space exploration applications. (This updated bibliography contains 243 citations.)*

**A.1. (13) Computer vision for automatic assembly and inspection.**

1970–July 1982 (Citations from the Engineering Index Data Base). National Technical Information Service, Springfield, VA. Rept. for 1970-Jul. 82, Jul. 1982, 61pp. Rept. No. PB82-870254.

*Contains citations concerning studies and design of equipment and techniques for automatic assembly and inspection in which computer vision plays an integral role. Computer vision in automated visual inspection can be performed even on high speed production lines and enables an automated assembly system, such as the manipulators of an industrial robot, to orient the part and to locate the position of the assembly item. The citations cover both the hardware and software components of the computer vision systems. A few citations refer to some specialized applications as computer vision for security systems, mapping, and retrieval of parts from stock bins. (Contains 61 citations.)*

**A.1. (14) Artificial intelligence.**

1970–March 1983 (Citations from the Engineering Index Data Base). (National Technical Information Service, Springfield, VA). Rept. for 1970–Mar. 1983, Mar. 1983, 300 pp. PB83-861583; Supersedes PB82-871129.

*Contains citations concerning artificial intelligence. Topics include pattern recognition, theory and algorithms, image processing, automatic word processing, computer aids in pattern recognition, talking and answering systems, systems for the medical profession, and robotics. Applications in the aerospace industry are also included. (Contains 350 citations.)*

**A.1. (15) Anatomy of industrial robots and their controls.**

Luh, J. Y. S. IEEE Trans. Automatic Control, Feb. 1983 AC-28 (2), pp. 133–153.

*Broad review which includes an account of sensory devices, compliance, vision, command languages etc. Useful for its 106 accurate references which include many papers on artificial intelligence, pattern recognition, feedback, imaging, etc.*

**A.1. (16) Artificial intelligence.**

1972–March 1983 (Citations from the International Aerospace Abstracts Data Base). (National Technical Information Service, Springfield, VA). Rept. No. PB83-861575 for 1972–Mar. 1983, Mar. 1983, 263 pp. Supersedes PB82-871161.

*Contains citations concerning artificial intelligence. Topics include pattern recognition theory and algorithms, image processing, automatic word processing, computer aids in pattern recognition, talking and answering systems, systems for the medical profession, and robotics. (Contains 284 citations.)*

**A.1. (17) Computer vision for automatic assembly and inspection.**

1975–February 1983 (Citations from the International Information Service for the Physics and Engineering Communities Data Base). (National Technical Information Service, Springfield, VA.) Rept. No. PB83-861112 for 1975–Feb. 83, Feb. 1983, 192 pp. (Supersedes PB82-870247.)

*Contains citations concerning studies and design of equipment and techniques for automatic assembly and inspection in which computer vision plays an integral role. Computer vision in automated visual inspection can be performed even on high speed production lines. Computer vision enables an automated assembly system, such as the manipulators of an industrial robot, to orient the part and to locate the position of the assembly item. The citations cover both the hardware and software components of the computer vision systems. Some citations refer to automatic image analysis systems which use computer vision to recognise specific patterns or textures for data collection purposes or for the sorting of parts. (Contains 187 citations.)*

## A.2. RESEARCH REVIEWS AND PROJECTIONS

### A.2. (1) The first 10 years of artificial intelligence research at Stanford.

(Stanford University, USA) Report No. AD776233, 1973, 119 pp.)

*Summarises accomplishments in computer vision and control of manipulators, speech recognition, heuristic programming, representation theory, mathematical theory of computation and modelling of organic chemical processes. Bibliographies are included in all research areas.*

### A.2. (2) Adaptable-programmable assembly systems: an information and control problem.

Nevins, J. L. and Whitney, D. E. (Charles Stark Draper Lab. Inc., USA). Proceedings 10th International Symposium Industrial Robots sponsored by Society Manufacturing Engineers & Robot Institute of America, pp. 387–406, 22–24 September, 1975. Dearborn, Society Manufacturing Engineers, 1975.

*It is assumed that technologically viable adaptable assembly systems will be quite limited, supplementing rather than replacing people. Such systems may be classified according to how much sensory information they receive from their working environment (the minimum being none) and how sophisticated are the control loops and strategies which use this feedback to accomplish assembly tasks. Systems of increasing control and information level can be expected to perform, with decreasing human involvement, increasingly complex tasks. Analytical and experimental work to investigate these ideas are described.*

### A.2. (3) Developments in programmable automation.

Rosen, C. A. and Nitzan, D. (Stanford Research Inst., USA). Manufacturing Engineering, September, 1975. 75(3), pp. 26–30.

*The authors indicate that robots previously limited to parts handling operations are growing in sophistication and suggest that the reason is the advent of artificial intelligence. They consider the limitations of existing hardware and software, training and computer constraints, sensor controlled manipulation, path control by co-ordinate transformation and training the manipulator system. Visual, tactile sensing and pattern recognition are included.*

### A.2. (4) Computer control of robots – a servo survey.

Snyder, W. E. (North Carolina State Univ., USA), SME Technical Paper No. MR76-617, 13 pp. (1976). Dearborn, Society Manufacturing Engineers, 1976.

*This paper covers recent past and state-of-the-art techniques in digital control of the servo systems utilised in general purpose manipulators. The topics mentioned include transducers for position and velocity information and how the choice of a transducer affects the choice of a servo technique; the nature of available control algorithms; and methods of implementation of these algorithms.*

*Several types of implementations are discussed, including the variation from hybrid to fully digital control. Types of end-point control including position control, trajectory control and resolved direction control. Strategies employed at some companies and recent work at several research centres are surveyed.*

### A.2. (5) Research activities at the Institute of Production and Automation in the field of robotics.

Warnecke, H. J. and Schraft, R. D. (Inst. Prod. & Automation, Stuttgart, West Germany). (In, Proc. 7th ISIR Sponsored by Soc. Biomechanics and Japan Industrial Robot Assoc. pp. 25–35. 19–21 October, 1977.) Tokyo, JIRA, 1977, 655 pp.

*A review of the research projects undertaken by IPA, Stuttgart University over the past ten years is presented in this paper. Amongst the projects investigated are market studies, test facilities, work-place analysis and sensor development. A useful assessment of early work by the authors and their Institute.*

### A.2. (6) Standards and control technology for industrial robots.

Evans, J. M., Barbera, A. J. and Albus, J. S. (National Bureau of Standards). (In, Proc. 7th International Symp. Industrial Robots, Tokyo, Japan, 19–21 October, 1977. Organised by Japan Industrial Robot Association, pp. 479–486). Tokyo, JIRA. 1977. 655 pp.

*Discusses NBS developments in dynamic sensors and computer control leading to a hierarchical control concept that provides a basis for robot classification for developing higher level languages for programming robots and for interface standards. (8 refs.)*

### A.2. (7) Industrial robots: looking forward to the third generation.

Ferretti, M. Nouvel Automat. November, 1978, (2) pp. 315–327. In French.

*Briefly surveys intelligent industrial robots provided with senses, such as sight and touch, controlled by microcomputers. Applications include control of assembly machine-tools.*

### A.2. (8) Industrial robots with sensors and object recognition systems. An overview.

Koehler, G. W. (Kernforschungszentrum, Karlsruhe, W. Germany. Abt. Reaktorbetrieb und Technik.) Rept. No. KFK 2571 Jan, 1978, 53 pp. (NTIS 79025561.) In German.

*The previous development and the present status of industrial robots equipped with sensors and object recognition systems are described. This type of equipment allows flexible automation of many work stations. A classification system facilitates an overview of the large number of technical solutions now available. The possibilities of application of this equipment* *are demonstrated by a number of examples. As a result of the present state of development of the components required, and in view also of economic reasons, there is a trend towards special designs for a small number of specific purposes and towards stripped-down object recognition systems with limited applications.*

### A.2. (9) Proceedings of NBS/RIA Robotics Research Workshop, Williamsburg, VA, 12–13 July 1977.

Evans, J. M., Barbera, A. J. and Albus, J. S. (eds.) Sponsored by National Bureau of Standards and Robotics Institute of America. Washington, NBS April 1978 (NBS Special Publ. 500-29), 34 pp. (PB-279334).

*Incorporating a Delphi forecast on the use of sensors in robot applications. Covers tactile, force, and vision systems. Participants at workshop were asked specific questions on future use and the answers tabulated.*

### A.2. (10) Robotics in 1984.

Engelberger, J. F. (Unimation Inc., USA). Industrial Robot, September 1979 6(3), pp. 115–119.

*An examination of past and future predictions for robot technology and how far they have already been realised including visual and tactile sensing and voice communication.*

### A.2. (11) Second generation robots have eye for industry.

Hart, D. E. Data Management, June, 1979, 17(6), pp. 13–14, 16–19.

*Describes research in General Motors Laboratories, concentrating on creating robots with vision through a device like a TV camera which acts as the robot's eye, and vision programs for data interpretation. The research is assisted by a GM second generation electronic digital camera – CONSIGHT.*

### A.2. (12) Advanced industrial robot control systems. Report No. 4. Jan–July, 1979.

Paul, R. P. and others (Purdue Univ., Lafayette, Ind. School of Electrical Engineering). National Science Foundation Sponsored Research. NSF Rept. No. NSF-APR77-14533; Rept. No. TR-EE-80-29; July, 1980. 90 pp. (PB 81-125288.) See also PB81-122517; July, 1980. 57 pp. NSF/RA-800228.

*An approach to robot programming and teaching has been developed based on homogeneous transformation equations. These equations allow the position-dependent structure of a task to be represented and utilized by the robot. The same equations are employed during teaching to interpret manipulator task positions and to solve any undefined task transformations. Teaching by an operator involves moving the robot through the task and recording the positions. Symbols inserted by the programmer in the task program indicate how each equation, defined by a task position, is to be used for solving the task transformations. Transformations representing objects are of secondary importance in this system as their only function is to hold together various object features, most importantly grasping positions. They are defined automatically with appropriate precision as a result of normal task execution during teaching.*

### A.2. (13) Assembly research.

Nevins, J. L. and Whitney, D. E. (Charles Stark Draper Lab. Inc., Cambridge, Mass.). (In, Factory Automation: Infotech state of the art report. Invited papers, pp. 137–175.) Maidenhead, Berks. Infotech Ltd., 1980. 387 pp. (Series 8, No. 6).

*Describes assembly research in the context of the need to increase manufacturing productivity. Includes comment on vision sensors and force sensing as one of the components of new automation systems. (24 refs.)*

### A.2. (14) Computer control for industrial robots.

Paul, R. P. (In, Proceedings of the 6th IFAC/IFIP Conference, on Digital Comput. Applications to Process Control; Dusseldorf, Germany, 14–17 October, 1980, pp. 55–62.) Oxford, Pergamon, 1980, 581 pp.

*The concept of a sensor controlled robot which will adapt to any task, assure product quality, and eliminate machine tending is discussed. Such robots will need computers to process their sensor data, transform it, and make decisions regarding task sensors, relying instead on precise position and orientation control of all aspects of the task. Describes various approaches to the development of sensor controlled robots, together with developments in the areas of task programming, sensor design and sensor data interpretation. (16 refs.)*

### A.2. (15) Development of robots in GDR and researches regarding the preparation of its application.

Mittag, G. and others. (Ingenieurhochschule Zwickau, Zwickau, Germany.) Fertigungstech. & Betr., 1980, 30(8). pp. 478–480. In German.

*Presents several industrial robots made in GDR. The authors refer to the development of sensors and they report on research regarding the development for applications of the robots. (7 refs.)*

### A.2. (16) The 1980 summer research fellowship program.

Darden, G. C. (Hampton Roads Sanitation District, Norfolk, USA). Rept. No. NASA-CR-159369; Oct. 1980, 31 pp.

*Describes the problem of incorporating visual input into robot systems; and analyses a computer operated mathematical symbolic manipulation system.*

### A.2. (17) Recent advances in robotics research.

Kelly, F. Society of Automotive Engineers Preprint No. 800383. Meeting 25–29 March, 1980, 5 pp.

*Various aspects of robot research are discussed including kinematics, geometry, controls, locomotion,* *sensing, and artificial intelligence. It is sugge ·d in each of these areas there exist important research needs and opportunities. (45 refs.)*

### A.2. (18) Research needed to advance the state of knowledge in robotics, workshop held in Newport, Rhode Island on April 15–17, 1980.

Birk, J. and Kelley, R. B. (Rhode Island Univ., Kingston). Report Nos. PB81-132557; NSF/RA-800223. Apr. 1980, 254pp., Grant: NSF-ENG79-21587.

*The framework for identifying these basic research issues involved examining robotic systems in terms of intelligence and decisionmaking; control; manipulation; locomotion; sensing systems; and communication. Papers addressed these areas of knowledge, the demands that robotic systems place on scientific disciplines, existing research and research issues which require investigation. A valuable and extensive survey by two well known research workers in the field of sensor technology for robots.*

### A.2. (19) Sensors control and man-machine interface for advanced teleoperations.

Bejczy, A. K. Science, 20 June 1980, 208 (4450), pp. 1327–1335.

*Overall review of developments in sensor technology including vision, force/torque, introduction of computers, and other advanced teleoperation techniques. Includes references to work carried out at the Jet Propulsion Laboratory, California Institute of Technology. (35 refs.)*

### A.2. (20) NBS/RIA Robotics Research Workshop.

Proceedings of the NBS/RIA Workshop on Robotics Research, Gaithersburg, MD, USA, 13–15 Nov, 1979. Washington, National Bureau of Standards, 1981. Rept. No. NBS-SP-602.

*The workshop had two objectives: (1) to provide a forum for structured discussions between research workers in robotics and manufacturers and users of robot systems; and (2) to develop a consensus forecast of future developments in sensors and control systems for industrial robots. Researchers, manufacturers, and users came together to determine the needs and priorities for future research in sensor and control techniques for industrial robots. There were no formal papers; small group discussions and presentations and preparation of a Delphi Forecast were used to address research needs and priorities.*

### A.2. (21) Sensing tasks in manufacturing.

Warnecke, H. J. (Fraunhofer Inst. fur Produktionstech. und Automatisierung, Stuttgart, Germany.) Umsch. Wiss. & Tech., 1 March 1981, 81(5), pp. 139–143. In German.

*The state of the art and the problems encountered within the on-going development of tactile and optical sensors are described. (6 refs.)*

### A.2. (22) Sensory gripping system: the software and hardware aspects.

Taylor, P. M. and others. (Univ. of Hull, Hull, England.) Sensor Rev. (GB), Oct. 1981, 1(4), pp. 184–187.

*Describes research at Hull University where software has been developed which is common to all types of sensor and has been written using selected elements of a previously developed macro library. (13 refs.)*

### A.2. (23) Some critical areas in robotics research.

Holzer, A. J. (Dept. of Mech. Engng., Carnegie-Mellon Univ., Pittsburg, PA, USA). Comput. Ind. (Netherlands), Oct. 1981, 2(3), pp. 199–208.

*Reviews the general field of robotics with some attention to computer vision and compliance. Some comparisons between the various approaches to the vision question are made, and active and passive force measurement are contrasted. Finally some other important areas including hierarchical control, manipulators, grippers and fixtures are considered. It is concluded that significant developments in robotic technology, particularly as they apply to batch manufacturing, will be forthcoming in the near future. (40 refs.)*

### A.2. (24) Achieving flexibility in manufacturing cells.

Wright, P. K. and Cutkosky, M. R. (Carnegie-Mellon Univ., Pittsburgh, USA). (In, Robotics Research and Advanced Applications, sponsored by ASME, Dynamics Systems and Controls Division, New York, 1982. pp. 259–268.)

*Research on the effectiveness and capability of robot sensor systems to localise parts. Considers sensory feedback systems and end effectors in robots.*

### A.2. (25) A study of interactive control scheduling and economic assessment of robotic systems.

(Final Report) University of Southern California, Institute for Technoeconomic Systems. Report No. NASA-CR-168652, JPL-9950-645, 29 January 1982, 23 pp.

*A class of interactive control systems is derived by generalising interactive manipulator control systems. Tasks of interactive control systems can be represented as a network of a finite set of actions which have specific operational characteristics and specific resource requirements, and which are of limited duration. The performance benefits of sensor referenced and computer-aided control of manipulators in a complex environment is evaluated. The first phase of the CURV arm control system software development and the basics of the control algorithm and software implementation are presented. An optimal solution for a production scheduling problem is investigated.*

## A.3 CONFERENCES

### A.3. (1) Industrial robots.

Proceedings including papers and discussion of meeting sponsored by Swiss Institute of Technology, Lausanne, Oct. 1974. Burckhardt, C. W. (ed.). Basle, Switzerland, Birkhaueser Verlag, Interdisciplinary Systems Research, No. 4, 1975. 222 pp.

*Proceedings includes 13 papers on the current and future technology of industrial robots. Starting from the social and economic background, a technical description of industrial robots and some of their applications is given. Some research problems in this field are then discussed, particularly those of control and programming. Furthermore, problems of artificial intelligence are dealt with in connection with automatic assembly. The future of industrial robots is outlined in two papers and in general discussion. In French, German, and English.*

### A.3. (2) 3rd Milwaukee Symposium on Automation Computing and Control.

Proceedings and Papers, Milwaukee, Wis, Apr. 18–19, 1975. West Period Co., North Hollywood, Calif., 1975. 460 pp.

*Proceedings includes 58 papers including some on artificial intelligence, control theory, software engineering, clustering, robotics, pattern recognition, signal processing, microprocessor applications, parallel processing and operating systems, industrial control systems, and image processing.*

### A.3. (3) Proceedings of the 1st CISM/IFTOMM Symposium on Theory and Practice of Robots and Manipulators (RO MAN SY), 1975.

Morecki, A. and Kedzior, K. (eds.) (Tech. Univ. of Warsaw, Inst. of Aircr. Eng. and Appl. Mech., Pol.) CISM (Int. Cent. for the Mech. Sci.) – IFTOMM Prepr., Warsaw, Pol., Sep. 14–17, 1975. Publ. by PWN-Pol. Sci. Publ., Warsaw, 1976, 530 pp.

*Proceedings includes 44 papers dealing with the state-of-the-art of industrial robots and manipulators. The following topics are included: synthesis and design, sensors, artificial intelligence, man-machine systems, and applied robotics.*

### A.3. (4) Proceedings of 2nd Symposium on Theory and Practice of Robots and Manipulators.

Sponsored by CISM-IFTOMM, 14–17 Oct. 1976, edited by Morecki, A., New York, Elsevier and Warsaw PWN – Pol. Sci. Publ. 1977, 500 pp.

*The proceedings contains 48 pages and these include presentations on sensors, artificial intelligence, and applied robotics.*

### A.3. (5) 2nd IEEE Milwaukee Symposium on Automation Computing and Control (MSAC**2 76), Apr. 22–24 1976.

IEEE (Cat. No. 76CH 1091-9 SMC), New York, NY, 1976. 468 pp.

*Proceedings includes 86 papers, including some on robotics, operating systems, control systems, human-machine interfaces, artificial intelligence, medical applications of pattern recognition, computer architecture, trainable manipulators, nonlinear control systems, pattern recognition in remote sensing, industrial and computer control systems, signature analysis, scene analysis, distributed systems in process control, estimation and control, microprocessor and microcomputer applications.*

### A.3. (6) 14th Annual Conference on Manual Control, Southern University, California.

Sponsored by NASA 25–27 April, 1978; N79-155588/3GA, Report No. NASA-CP12060; A-7615, 692 pp. (November, 1978).

*Includes papers on manipulators and their use in space exploration, mathematical logic of their control mechanisms, optical control, perception, and sensory-motor performance.*

### A.3. (7) CAM-1. Proceedings of 1979 International Spring Meeting, held in New Orleans, USA.

April 10–12, 1979, Smith, B. D. (ed.) Arlington, Texas. Computer Aided Manufacturing International Ltd., 1979, 240 pp.

*Includes 18 papers covering materials handling, metal joining, quality control and inspection and robotics. The latter section includes eight papers on sensor based robots, part-mating, programmable assembly software and hardware, and computer control.*

### A.3. (8) IJCAI-79, Proceedings of the 6th International Joint Conference on Artificial Intelligence, 20–23 Aug. 1979, Tokyo, Japan.

Sponsored by International Joint Conference on Artificial Intelligence Inc. Publ. by Int. Jt. Conf. on Artif. Intell., 1979. Available from Stanford Univ., Comput. Sci. Dep., Calif., 2 Vols., 1146 pp.

*This conference proceedings contains 231 papers. The topics covered include: vision; applied artificial intelligence; natural language processing; program synthesis; theorem proving; image analysis; data bases; robotics; distributed AI; deductive methods; and program understanding.*

### A.3. (9) 9th International Symposium on Industrial Robots, 13–15 Mar. 1979, Washington, DC.

Sponsored by Society of Manufacturing Engineers. Dearborn, Mich., SME, 1979, 733 pp.

*This conference proceedings contains 51 papers. Topics covered include; application of the robot; robot assembly; robot vision; robot control; simulating robot performance; shape discrimination; distance sensors; manipulators; and, adaptivity.*

**A.3. (10) Proceedings of the 1st International Conference on Assembly Automation, 1980, 25–27 Mar., 1980, Brighton.**

Sponsored by IFS (Conferences) Ltd. Bedford, IFS (Publications) Ltd., 1980, 506 pp.

*Contains 40 papers. The subject matter is primarily concerned with the design, operation and control of automatic systems used for assembly of various components. Computer applications are described, as well as robotics. Several papers on sensor technology are entered in their relevant sections in this bibliography.*

**A.3. (11) Proceedings of the 10th International Symposium on Industrial Robots/5th International Conference on Industrial Robot Technology, 5–7 Mar. 1980, Milan, Italy.**

Sponsored by IFS (Conferences) Ltd. and Italian Society for Industrial Robots (SIRI). Bedford, IFS (Publications) Ltd., 1980, 686 pp.

*Contains 64 papers. Topics covered include: robot use in various manufacturing processes; robots on the assembly line; robot programming; control systems; microcomputer applications; error detection in robots; grippers; prehension systems; manipulators; robot design; vision; and, trends in robot development. Many papers are abstracted in their relevant sections in this bibliography.*

**A.3. (12) Robotics Support Project for the Air Force ICAM Program.**

Wheatley, T. E., Albus, J. S. and Nagel, R. N. (eds.). (NBS, Washington, DC, USA.) (In, Proceedings AUTOFACT West, V 1: CAD/CAM 8, Anaheim, Calif., USA, Nov. 17–20, 1980, Dearborn, Mich., Soc. Manufacturing Engrs., 1980, pp. 673–725).

*Attendees were assigned to one or more of five separate working areas: the Sensor interface between simple peripheral devices and a robot control system; the Wrist interface, between the robot wrist and the end effector; the Complex Sensor interface that covers vision, complex touch, and other such sensors; the Common Robot Control interface, providing robot independent trajectory descriptions; and Future Guidelines towards interfaces, covering data base, offline programming, and system integration interfaces.*

**A.3. (13) 4th CISM-IFTOMM Symposium on Theory and Practice of Robots and Manipulators, RO MAN SY.**

(CISM (Cent. Int. des. Sci. Mec.), Udine, Italy.) Prepr. of 4th CISM-IFTOMM Symp. on Theory and Pract. of Robots and Manipulators, RO MAN SY, Zaborow, Pol., Sept. 8–12, 1981, Udine, Italy, CISM 1981, 506 pp. (Centre Internat. des Sciences Mecaniques.)

*Proceedings include 46 papers. The theory and applications of robotic devices and manipulators are emphasized. Topics considered include; grippers, computer simulation, kinematics, adaptive and optimal controls, mechanical arms and legs, the use of microcomputers, sensors and remote sensing, and the use of robots in arc welding.*

**A.3. (14) NSF Grantees 8th Conference on Production Research and Technology, Stanford, California, 27–29 January, 1981.**

Binford, T. O. (Stanford University, Dept. Computer-Science). Report No. NSF/MEA-8001; PB81-183964; 1981, 174 pp.

*Conference covers tool wear sensing via acoustic emission analysis, stochastic modelling of electro-discharge machining with a view to off-line optimisation, design and control of adaptable programmable assembly systems. Also included are presentations on a triangular laser-based scanning rangefinder, progress in mathematical methods for manufacturing systems, and design and analysis of computerised manufacturing systems for small parts with emphasis on non-palletised parts of rotation. Further discussions concerned modelling and analysis of material handling systems, optimal planning of computerised manufacturing systems, discrete product flow models, computer-aided design for castings, computer-aided injection moulding systems, feedback in robotics for assembly and manufacturing, parts mating theory for compliant parts, and advanced industrial robot control systems.*

**A.3. (15) Proceedings of COMPSAC 81. IEEE Computer Society's 5th International Computer Software & Applications Conference, Chicago, USA, 16–20 Nov., 1981.**

IEEE, New York, USA, 1981.

*Includes papers on text processing and speech synthesis, robotic technology and sensing and applications.*

**A.3. (16) Proceedings of the 1st International Conference on Robot Vision and Sensory Controls, 1–3 April, 1981, Stratford-upon-Avon, UK.**

Bedford, IFS (Publications) Ltd., 1981, 347 pp.

*Includes 34 papers covering the latest developments on vision and control for robots and manipulators, including both theoretical analyses and applications to welding and automated assembly. Many include references not found elsewhere in this bibliography. Selected papers are included in relevant sections in the bibliography.*

**A.3. (17) Proceedings of the 4th British Robot Association Annual Conference, Brighton, UK, 18–21 May, 1981.**

British Robot Assoc., Kempston, Beds., England, 1981, 254 pp. IFS (Publications) Ltd.

*25 papers including presentations on employment and automation; installation and maintenance; safety; automobile industry; casting; programming; assembly; vision systems; metallisation; polishing; injection moulding; machine tools; flexible manufacture; sensing systems; and arc welding.*

**A.3. (18) Proceedings of the 2nd International Conference on Assembly Automation, Brighton, UK, 18–21 May 1981.**

Sponsored by IFS (Conferences) Ltd. IFS (Publications) Ltd., Kempston, Bedford, England, 1981.

*29 papers including presentation on economics and investment; management aspects; integrated factory; electronic control; user requirements; drives; handling systems; product design; maintenance; part feeding; visual recognition; programmable techniques; industrial robots; and station modules.*

**A.3. (19) IEEE 1982 Proceedings of the International Conference on Cybernetics and Society. Seattle, WA, USA, 28-30 Oct., 1982.**

IEEE. New York, USA, 1982, 698 pp.

*Includes the following topics: human information processing; adaptive and learning systems; mathematical programming; robotics; decision support systems; analysis, design and validation of models; computer vision; systems science; pattern recognition; and artificial intelligence.*

**A.3. (20) Robot Sensor Signal Processing: Colloquium sponsored by Institution of Electrical Engineers, London, 11th Nov., 1982.**

London I.E.E., 1982, various pagination (IEE Colloquium Digest No. 1982/75).

*Several short papers cover smart sensors; a microprocessor controlled solid state camera; first level processing of signals from a solid state camera; an adaptable robot multi-sensor system; high speed signal processing architecture for robot sensory systems; and tactile sensor arrays for flexible assembly automation. Six papers were presented.*

## A.4. GENERAL PAPERS, REVIEWS, BOOKS, REPORTS

### A.4. (1) Design studies on industrial robots.

Thring, M. W. (Queen Mary College, University of London). Paper presented at Symposium on Theory and Practice of Robots and Manipulators, Udine, Italy. 20 pp. incl. 10 figs. (5–8 September, 1973).

*The robot (a machine pre-programmed to do any one of a range of complex manipulative tasks) is in a very early stage of development because those in industry have no sensory adaptability and cannot do tasks involving moving themselves about the factory. Most of the work on giving them touch, force and visual senses requires a large computer to enable them to adapt their movements to sense impressions in the pre-instructed way. Work is described on developing sensory systems which can be readily adapted to different complex situations using only small digital or analogue computers or devices like selector switches.*

### A.4. (2) Robotics.

Young, J. F. New York, John Wiley, 1973, 303 pp.

*Covers all aspects of robotics with the exception of the controlling brain. The characteristics of human sense organs are reviewed as an introduction to robot methods of perception and control. Robot actuations, such as pneumatic, electrical, etc., are compared and practical industrial robots such as Unimate and the Versatran are described. The information covers the theory and practice of robotics and will be of interest to all those working in or entering this new field. The extensive bibliographies given at the end of each chapter are useful for those starting work in robotic technology.*

### A.4. (3) Sensory devices for industrial manipulators and tools.

Parks, J. R. (National Physical Laboratory). Paper presented at Symposium on Theory and Practice of Robots and Manipulators, Udine, Italy (5–8 September, 1973). 18 pp. incl. 4 figs. (Also in, Proceedings of 1st Conference on Industrial Robot Technology, Nottingham, 1973. Bedford, IFS (Publications) Ltd., 1973.)

*With the gradually increasing application of industrial manipulators and robots the need is emerging for sensory devices capable of providing these devices with a considerable degree of contact with their environments. Existing use of simple contacts and photo-electric detectors are limited to detection of limit stop conditions or obstruction. The several advanced robot projects are aimed at producing almost human sensory capabilities and are too slow and expensive for industrial application.*

*The paper discusses briefly some tactile and visual image approaches to sensory systems. An approach to machine monitoring through machine reaction is discussed.*

### A.4. (4) Automatic manipulation using a simple sensory system.

Madayoshi, K. (University of Tokyo, Japan), Third Symposium on Industrial Robots, organised by Chubu Automation Society, Japan, Paper B2, 6 pp. (14–15 February, 1974). In Japanese.

### A.4. (5) Framework for robotic design.

Weinstein, M. (Calif. Inst. of Technol., Pasadena). In, 2nd USA–Jpn. Computer Conf. Proceedings, Tokyo, Jpn., 26–28 Aug. 1975, pp. 276–280. Montvale, AFIPS, 1975.

*Restricted to robotic systems based on symbol manipulation, identifies and classifies the functional characteristics of the processes involved in robotic activity, and introduces a conceptual model for sensory robotic systems. The functional configuration of robotic systems provides a convenient basis for the classification of a variety of systems that are generally considered as robots. Finally, the introduction of the concept of a virtual robot provides a framework for robotic design and developments. (24 refs.)*

### A.4. (6) Industrial robots in Japan.

Kettner, H. and others. Technische Universitat Hanover, Lehrrstuhl duer Arbeitsmaschinen und Fabrikanlagen. BMFT-FB-T-75-39. In German, English summary.

*Report of a technical visit to Japan in 1974 sponsored by Bundesamt, Fuer Forsch und Technol. Gripper hands, locomotion, tactile discrimination and television cameras as part of control systems for robots were investigated.*

### A.4. (7) Problems of creating sensitised robots.

Kobrinsky, A. Y. 4th World Congress on the Theory of Mach. and Mech. Univ. of Newcastle upon Tyne (8–12 September, 1975), pp. 423–428. London, Mech. Engng. Publ. Ltd. In Russian.

*Discusses the state of the art and presents a new information system for robots which is based on utilising sensitised surfaces. (7 refs.)*

### A.4. (8) A scientific approach to the design of computer controlled manipulators.

Nevins, J. L. and others. Charles Stark Draper Lab. Inc., Cambridge, Mass. Gov. Rep. No. AD-A007582/OGA Co. Report No. R-837, 1975.

*Develops a technology for the design of computer controlled manipulator systems which could be selected for small manipulators. Relationships between tasks, task scale and performance requirements for actuators and sensors in the manipulators are determined.*

### A.4. (9) Putting it all together – with robots.

Pond, J. Iron Age, 13 December, 1976. 218 (24) pp. 47–56.