

ROBOTICA

Volume 9 Part 2

ROBOTICA

International
Journal of
Information,
Education and
Research in
Robotics and
Artificial
Intelligence

Cambridge University Press

ROBOTICA

INTERNATIONAL JOURNAL OF INFORMATION, EDUCATION & RESEARCH
IN ROBOTICS & ARTIFICIAL INTELLIGENCE

EDITOR:

Professor J. Rose, Honorary Director of the World
Organisation of Systems and Cybernetics.
ATM Visiting Professor, Lancashire Polytechnic (UK).
5 Margate Road
St Annes-on-Sea, Lancs. FY8 3EG England

DEPUTY EDITORS:

Dr E.W. Kent, Philips Laboratories, 345 Scarborough
Road, Briarcliff Manor, NY 10510, USA

Prof. R.A. Jarvis,
Dept. of Electrical Engineering, Monash University,
Clayton, Victoria 3168, Australia

Professor Y. Umetani, Dept. of Physical Engineering,
Tokyo Institute of Technology, Ookayama, Meguro-ku,
Tokyo, Japan

Dr P. Coiffet, C.R.I.I.F., BP 340,
75229 Paris Cedex 05, France.

EDITOR, ROBOTICS REPORTS AND SURVEYS:

Mr B.H. Rudall, School of Mathematics and Computer
Science, University College of North Wales, Bangor,
Gwynedd LL57 2UW, UK

EDITORIAL BOARD

I. Aleksander, UK
A.M. Andrew, UK
C.W. Burckhardt,
Switzerland
K. Desoyer, Austria
M.J. Dunne, USA
J.F. Harris, UK
K.H. Hunt, Australia
M. Ito, Japan
C.H. Kahng, USA
M. Kassler, Australia
A. Kusiak, Canada
T.K. Lien, Norway
K.L. McRoberts, USA
A. Mohri, Japan
V. Nicolo, Italy

T. Owen, UK
P.G. Ranky, USA
R. Reddy, USA
H. Rosenbrock, F.R.S.
UK
B.M. Sallot, USA
G.N. Sandor, USA
A. Siegler, Hungary
W.K. Taylor, UK
M.W. Thring, UK
S. Tsuji, Japan
C. Vibet, France
P. Vidal, France
H.-J. Warnecke, FRG
Wu Wei-Tsong, China

Robotica aims to endow robotics with an authoritative, competent and dedicated journal to serve industry, research and education. It will provide an international forum for the multidisciplinary subject of robotics and help to encourage developments in this important field of automation. It will cover the many aspects of robotics, including sensory perception, software (in the widest sense), particularly in regard to programming languages and links with master computers and CAD/CAM systems, control devices, the study of kinematics and dynamics involved in robot design, design of effectors and ancillary manipulators, problem solving, world model representation, development of relevant educational courses, training methods, analysis of managerial and social policy, economic and cost problems, and items of theoretical and practical interest. As well as original papers, the journal will publish research notes, book reviews, conference reports and letters to the editor.

© Cambridge University Press 1991

Subscriptions: *Robotica* (ISSN 0263-5747) is published quarterly in January, April, July and October. The subscription price (which includes postage) of Volume 9, 1991 is £95 net UK, £99 elsewhere (US \$179 in USA and Canada) for institutions and £45 (US \$79 in USA and Canada) for individuals certifying that the Journal is for their personal use. Single parts, cost £25 net (US \$46 in USA and Canada) plus postage. Four parts form a volume. Orders, which must be accompanied by payment, may be sent to a bookseller, subscription agent or direct to the publishers: Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge CB2 2RU (UK). Orders from the USA or Canada should be sent to Cambridge University Press, Journals Department, 40 West 20th Street, New York, NY 10011-4211, USA. Copies of the Journal for subscribers in the USA and Canada are sent by air to New York to arrive with minimum delay. Second class postage paid at New York, NY and additional mailing offices. POSTMASTER: send address changes in USA and Canada to *Robotica*, Cambridge University Press, 110 Midland Avenue, Port Chester, New York, NY 10573-9864.

Copying: This journal is registered with the Copyright Clearance Center, 27 Congress St., Salem, Mass. 01970. Organizations in the USA who are also registered with CCC may therefore copy material (beyond the limits permitted by sections 107 and 108 of US copyright law) subject to payment to CCC of the per-copy fee of \$05.00. This consent does not extend to multiple copying for promotional or commercial purposes. Code 0263-5747/91/\$5.00 + .00.

ISI Tear Sheet Service, 3501 Market Street, Philadelphia, Pennsylvania 19104, USA, is authorised to supply single copies of separate articles for private use only.

For all other use, permission should be sought from Cambridge or the American Branch of Cambridge University Press.