



MSCS

Mathematical Structures in Computer Science

*A journal in the applications of categorical, algebraic
and geometric methods in Computer Science*

SEPTEMBER 1993 VOLUME 3 NUMBER 3

Cambridge University Press

EDITOR-IN-CHIEF

Giuseppe Longo

Laboratoire d'Informatique (CNRS) et DMI, Ecole Normale Supérieure, 45, Rue D'Ulm, 75005 Paris (France), e-mail: longo@dm.ens.fr

ASSOCIATE EDITORS

P. L. Curien

LIENS, 45 rue d'Ulm, 75230 Paris, Cedex 05, France
e-mail:curien@dm.ens.fr

A. Pitts

University of Cambridge, Computer Laboratory, New Museums Site,
Pembroke Street, Cambridge CB2 3QG

EDITORIAL BOARD

S. Abramsky

Department of Computing, Imperial College of Science, Technology &
Medicine, University of London

M. Barr

Department of Mathematics, McGill University, Montreal, Quebec

G. Berry

Ecole des Mines, Valbonne, France

R. M. Burstall

Computer Science Department, University of Edinburgh

H. Ehrig

Technische Universität, Berlin

E. Engeler

Informatik, ETH-Zentrum, Zürich

P. J. Freyd

Department of Mathematics, University of Pennsylvania, Philadelphia

J. Y. Girard

UER de Math. Equipe de Logique Mathématique, Un. de Paris VII

J. Goguen

Computing Laboratory, Oxford University

J. W. Gray

Department of Mathematics, University of Illinois, Urbana

S. Hayashi

Department of Applied Mathematics & Informatics, Ryukoku University,
Shiga, Japan

C. A. R. Hoare

Computing Laboratory, Oxford University

R. J. M. Hughes

Department of Computer Sciences, Chalmers University of Technology,
Göteborg

M. Hyland

Department of Mathematics, University of Cambridge

J. Lambek

Department of Mathematics, McGill University, Montreal, Quebec

William F. Lawvere

State University of New York at Buffalo, New York

E. G. Manes

Department of Mathematics and Statistics, Amherst, Massachusetts

José Meseguer

SRI International, Menlo Park, California

R. Milner

Department of Computer Science, University of Edinburgh

G. Mints

Department of Philosophy, Stanford University, California

J. C. Mitchell

Computer Science Department, Stanford University, California

U. Montanari

Dipartimento de Informatica, Università di Pisa

A. Obtulowicz

Institute of Mathematics, Polish Academy of Sciences, Warsaw

G. D. Plotkin

Department of Computer Science, University of Edinburgh

Vaughan Pratt

Department of Computer Science, Stanford University, California

J. C. Reynolds

School of Computer Science, Carnegie Mellon University, Pittsburgh,
Pennsylvania

Vladimir Yu. Sazonov

Institute of Programmable Systems, AS, Russia

A. Sedrov

Department of Mathematics, University of Pennsylvania, Philadelphia

D. S. Scott

School of Computer Science, CMU, Pittsburgh, Pennsylvania

P. J. Scott

Department of Mathematics, University of Ottawa, Ontario

R. A. G. Seely

Department of Mathematics, John Abbott College, Montreal, Quebec

J. Tiuryn

Institute of Mathematics, University of Warsaw

E. G. Wagner

IBM T. J. Watson Research Center, Yorktown Heights, New York

Mitchell Wand

Computer Science Department, Northeastern University, Boston,
Massachusetts

C. Wells

Department of Mathematics and Statistics, Case Western Reserve University,
Cleveland, Ohio

G. Winskel

Computer Science Department, Aarhus University, Denmark

© CAMBRIDGE UNIVERSITY PRESS 1993

SUBSCRIPTIONS. *MSCS-Mathematical Structures in Computer Science* (ISSN: 0960-1295) is published four times a year in March, June, September and December. The subscription price of Volume 3, 1993, is £105 net (UK), (USA, Canada and Mexico US \$185) post free; single parts cost £27 net (USA, Canada and Mexico US \$50) plus postage. Four parts form a volume. Orders, which must be accompanied by payment, may be sent to any bookseller, subscription agent or to the publisher: Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge CB2 2RU, or in the USA, Canada and Mexico to Cambridge University Press, The Journals Department, 40 West 20th Street, New York, NY 10011-4211, USA. Copies of the journal for subscribers in the USA, Canada and Mexico are sent by air to New York to arrive with minimum delay. Japanese prices for institutions (including ASP delivery) are available from Kinokuniya Company Ltd, P.O. Box 55, Chitose, Tokyo. Second class postage is paid at New York, NY and at additional mailing offices.

POSTMASTER: send address changes in USA, Canada and Mexico to *MSCS-Mathematical Structures in Computer Science*, Cambridge University Press, 110 Midland Avenue, Port Chester, NY 10573-9864, USA.

Claims for missing issues should be made immediately on receipt of the subsequent issue.

COPYING. This journal is registered with the Copyright Clearance Center, 27 Congress Street, Salem, MA 01970. Organisations in the USA who are also registered with the C.C.C. may therefore copy material (beyond the limits permitted by sections 107 and 108 of the US copyright law) subject to payment to C.C.C. of the per-copy fee of \$5.00. This consent does not extend to multiple copying for promotional or commercial purposes. Code 0960-1295/93 \$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.

Organisations authorised by the Copyright Licensing Agency may also copy material subject to the usual conditions.

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