

Human-Computer Interaction Series

Editors-in-chief

John Karat
IBM Thomas J. Watson Research Center (USA)

Jean Vanderdonckt
Université catholique de Louvain (Belgium)

Editorial Board

Gaëlle Calvary, LIG-University of Grenoble 1, France

John Carroll, School of Information Sciences & Technology, Penn State University, USA

Gilbert Cockton, Northumbria University, UK

Larry Constantine, University of Madeira, Portugal, and Constantine & Lockwood Ltd,
Rowley, MA, USA

Steven Feiner, Columbia University, USA

Peter Forbrig, Universität Rostock, Germany

Elizabeth Furtado, University of Fortaleza, Brazil

Hans Gellersen, Lancaster University, UK

Robert Jacob, Tufts University, USA

Hilary Johnson, University of Bath, UK

Kumiyo Nakakoji, University of Tokyo, Japan

Philippe Palanque, Université Paul Sabatier, France

Oscar Pastor, University of Valencia, Spain

Fabio Pianesi, Bruno Kessler Foundation (FBK), Italy

Costin Pribeanu, National Institute for Research & Development in Informatics, Romania

Gerd Szwillus, Universität Paderborn, Germany

Manfred Tscheligi, University of Salzburg, Austria

Gerrit van der Veer, University of Twente, The Netherlands

Shumin Zhai, IBM Almaden Research Center, USA

Thomas Ziegert, SAP Research CEC Darmstadt, Germany

Human-Computer Interaction is a multidisciplinary field focused on human aspects of the development of computer technology. As computer-based technology becomes increasingly pervasive – not just in developed countries, but worldwide – the need to take a human-centered approach in the design and development of this technology becomes ever more important. For roughly 30 years now, researchers and practitioners in computational and behavioral sciences have worked to identify theory and practice that influences the direction of these technologies, and this diverse work makes up the field of human-computer interaction. Broadly speaking, it includes the study of what technology might be able to do for people and how people might interact with the technology.

In this series, we present work which advances the science and technology of developing systems which are both effective and satisfying for people in a wide variety of contexts. The human-computer interaction series will focus on theoretical perspectives (such as formal approaches drawn from a variety of behavioral sciences), practical approaches (such as the techniques for effectively integrating user needs in system development), and social issues (such as the determinants of utility, usability and acceptability).

For further volumes:

<http://www.springer.com/series/6033>

Emmanuel Dubois · Philip Gray · Laurence Nigay
Editors

The Engineering of Mixed Reality Systems

 Springer

Editors

Dr. Emmanuel Dubois
Université Toulouse III - Tarbes
Institut de Recherches en
Informatique de Toulouse (IRIT)
France

Philip Gray
University of Glasgow
Dept. Computing Science
UK

Pr. Laurence Nigay
Université Grenoble I
Labo. d'Informatique de
Grenoble (LIG)
France

ISSN 1571-5035

ISBN 978-1-84882-732-5

e-ISBN 978-1-84882-733-2

DOI 10.1007/978-1-84882-733-2

Springer London Dordrecht Heidelberg New York

British Library Cataloguing in Publication Data

A catalogue record for this book is available from the British Library

Library of Congress Control Number: 2009938036

© Springer-Verlag London Limited 2010

Apart from any fair dealing for the purposes of research or private study, or criticism or review, as permitted under the Copyright, Designs and Patents Act 1988, this publication may only be reproduced, stored or transmitted, in any form or by any means, with the prior permission in writing of the publishers, or in the case of reprographic reproduction in accordance with the terms of licenses issued by the Copyright Licensing Agency. Enquiries concerning reproduction outside those terms should be sent to the publishers.

The use of registered names, trademarks, etc., in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant laws and regulations and therefore free for general use.

The publisher makes no representation, express or implied, with regard to the accuracy of the information contained in this book and cannot accept any legal responsibility or liability for any errors or omissions that may be made.

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Contents

1 Introduction	1
Emmanuel Dubois, Phil Gray, and Laurence Nigay	
Part I Interaction Design	
2 An Integrating Framework for Mixed Systems	9
Céline Coutrix and Laurence Nigay	
3 A Holistic Approach to Design and Evaluation of Mixed Reality Systems	33
Susanna Nilsson, Björn Johansson, and Arne Jönsson	
4 Embedded Mixed Reality Environments	57
Holger Schnädelbach, Areti Galani, and Martin Flintham	
5 The Semantic Environment: Heuristics for a Cross-Context Human-Information Interaction Model	79
Andrea Resmini and Luca Rosati	
6 Tangible Interaction in Mixed Reality Systems	101
Nadine Couture, Guillaume Rivière, and Patrick Reuter	
7 Designing a Mixed Reality Intergenerational Entertainment System	121
Eng Tat Khoo, Tim Merritt, and Adrian David Cheok	
8 Auditory-Induced Presence in Mixed Reality Environments and Related Technology	143
Pontus Larsson, Aleksander Våljamäe, Daniel Västfjäll, Ana Tajadura-Jiménez, and Mendel Kleiner	
9 An Exploration of Exertion in Mixed Reality Systems via the “Table Tennis for Three” Game	165
Florian ‘Floyd’ Mueller, Martin R. Gibbs, and Frank Vetere	

10	Developing Mixed Interactive Systems: A Model-Based Process for Generating and Managing Design Solutions	183
	Guillaume Gauffre, Syrine Charfi, Christophe Bortolaso, Cédric Bach, and Emmanuel Dubois	
Part II Software Design and Implementation		
11	Designing Outdoor Mixed Reality Hardware Systems	211
	Benjamin Avery, Ross T. Smith, Wayne Piekarski, and Bruce H. Thomas	
12	Multimodal Excitatory Interfaces with Automatic Content Classification	233
	John Williamson and Roderick Murray-Smith	
13	Management of Tracking for Mixed and Augmented Reality Systems	251
	Peter Keitler, Daniel Pustka, Manuel Huber, Florian Echtler, and Gudrun Klinker	
14	Authoring Immersive Mixed Reality Experiences	275
	Jan M.V. Misker and Jelle van der Ster	
15	Fiiia: A Model-Based Approach to Engineering Collaborative Augmented Reality	293
	Christopher Wolfe, J. David Smith, W. Greg Phillips, and T.C. Nicholas Graham	
16	A Software Engineering Method for the Design of Mixed Reality Systems	313
	S. Dupuy-Chessa, G. Godet-Bar, J.-L. Pérez-Medina, D. Rieu, and D. Juras	
Part III Applications of Mixed Reality		
17	Enhancing Health-Care Services with Mixed Reality Systems . . .	337
	Vladimir Stantchev	
18	The eXperience Induction Machine: A New Paradigm for Mixed-Reality Interaction Design and Psychological Experimentation	357
	Ulysses Bernardet, Sergi Bermúdez i Badia, Armin Duff, Martin Inderbitzin, Sylvain Le Groux, Jónatas Manzolli, Zenon Mathews, Anna Mura, Aleksander Väljamäe, and Paul F.M.J Verschure	
19	MyCoach: In Situ User Evaluation of a Virtual and Physical Coach for Running	381
	Margit Biemans, Timber Haaker, and Ellen Szwajcer	

20 The RoboCup Mixed Reality League – A Case Study 399
Reinhard Gerndt, Matthias Bohnen, Rodrigo da Silva Guerra,
and Minoru Asada

21 Mixed-Reality Prototypes to Support Early Creative Design 419
Stéphane Safin, Vincent Delfosse, and Pierre Leclercq

Index 447

Contributors

Minoru Asada Graduate School of Engineering, Osaka University, Osaka, Japan, asada@ams.eng.osaka-u.ac.jp

Benjamin Avery Wearable Computer Laboratory, University of South Australia, Mawson Lakes, SA, Australia, 5095, ben@benavery.net

Cédric Bach University of Toulouse, IRIT, 118 route de Narbonne, 31062 Toulouse Cedex 9, France, Cedric.Bach@irit.fr

Sergi Bermúdez i Badia SPECS@IUA: Laboratory for Synthetic Perceptive, Emotive, and Cognitive Systems, Universitat Pompeu Fabra, Tànger 135, 08018 Barcelona, Spain

Ulysses Bernardet SPECS@IUA: Laboratory for Synthetic Perceptive, Emotive, and Cognitive Systems, Universitat Pompeu Fabra, Tànger 135, 08018 Barcelona, Spain, bernuly@gmail.com

Margit Biemans Novay, 7500 AN Enschede, The Netherlands, Margit.Biemans@novay.nl

Matthias Bohnen University Koblenz-Landau, Koblenz, Germany, mbohnen@uni-koblenz.de

Christophe Bortolaso University of Toulouse, IRIT, 118 route de Narbonne, 31062 Toulouse Cedex 9, France, Christophe.Bortolaso@irit.fr

Syrine Charfi University of Toulouse, IRIT, 118 route de Narbonne, 31062 Toulouse Cedex 9, France, Syrine.Charfi@irit.fr

Adrian David Cheok Mixed Reality Lab, 21 Lower Kent Ridge Rd, National University of Singapore, Singapore 119077, Singapore, adriancheok@mixedrealitylab.org

Céline Coutrix Grenoble Informatics Laboratory, 385 avenue de la Bibliothèque, Domaine Universitaire, B.P. 53, 38 041 Grenoble cedex 9, France, Celine.Coutrix@imag.fr

Nadine Couture ESTIA-RECHERCHE, Technopole Izarbel, 64210 Bidart, France; LaBRI, 351, cours de la Libération, 33405 Talence, France, n.couture@estia.fr

Vincent Delfosse LUCID-ULg: Lab for User Cognition and Innovative Design – University of Liège – Belgium, Vincent.Delfosse@ulg.ac.be

Emmanuel Dubois University of Toulouse – Tarbes, IRIT, 118 route de Narbonne, 31062 Toulouse Cedex 9, France, Emmanuel.Dubois@irit.fr

Armin Duff SPECS@IUA: Laboratory for Synthetic Perceptive, Emotive, and Cognitive Systems, Universitat Pompeu Fabra, Tànger 135, 08018 Barcelona, Spain

Sophie Dupuy-Chessa Laboratory of Informatics of Grenoble, Grenoble Université, 385 rue de la bibliothèque, B.P. 53, 38041 Grenoble Cedex 9, France, Sophie.Dupuy-Chessa@imag.fr

Florian Echtler Technische Universität München, München, Germany

Martin Flintham Mixed Reality Lab, Computer Science, University of Nottingham, Jubilee Campus, Nottingham, NG8 1BB, UK, mdf@cs.nott.ac.uk

Areti Galani International Centre for Cultural and Heritage Studies, Newcastle University, Bruce Building, Newcastle upon Tyne, NE1 7RU, UK, areti.galani@ncl.ac.uk

Guillaume Gauffre University of Toulouse, IRIT, 118 route de Narbonne, 31062 Toulouse Cedex 9, France, Guillaume.Gauffre@irit.fr

Reinhard Gerndt University of Applied Sciences Braunschweig/Wolfenbuettel, Wolfenbuettel, Germany, r.gernd@fh-wolfenbuettel.de

Martin R. Gibbs Interaction Design Group, Department of Information Systems, The University of Melbourne, Parkville, VIC, Australia, martin.gibbs@unimelb.edu.au

Guillaume Godet-Bar Laboratory of Informatics of Grenoble, Grenoble Université, 385 rue de la bibliothèque, B.P. 53, 38041 Grenoble Cedex 9, France, Guillaume.Godet-Bar@imag.fr

T.C. Nicholas Graham School of Computing, Queen’s University, Kingston, Canada K7L3N6, graham@cs.queensu.ca

Phil Gray University of Glasgow, DCS, Glasgow G12 8QQ, Scotland, UK, pdg@dcs.gla.ac.uk

Timber Haaker Novay, 7500 AN Enschede, The Netherlands, timber.haaker@telin.nl

Manuel Huber Technische Universität München, München, Germany, huberma@in.tum.de

Martin Inderbitzin SPECS@IUA: Laboratory for Synthetic Perceptive, Emotive, and Cognitive Systems, Universitat Pompeu Fabra, Tànger 135, 08018 Barcelona, Spain

Björn Johansson Department of Computer and Information Science, Linköping University, SaabSecurity, Santa Anna IT Research Institute AB, Linköping, Sweden, bjorn.j.e.johansson@saabgroup.com

Arne Jönsson Department of Computer and Information Science, Linköping University, SaabSecurity, Santa Anna IT Research Institute AB, Linköping, Sweden, arnjo@ida.liu.se

David Juras Laboratory of Informatics of Grenoble, Grenoble Université, 385 rue de la bibliothèque, B.P. 53, 38041 Grenoble Cedex 9, France, David.Juras@imag.fr

Peter Keitler Technische Universität München, München, Germany, keitler@in.tum.de

Eng Tat Khoo Mixed Reality Lab, 21 Lower Kent Ridge Rd, National University of Singapore, Singapore 119077, Singapore, khooet@mixedrealitylab.org

Mendel Kleiner Department of Applied Acoustics, Chalmers University of Technology, SE-412 96, Göteborg, Sweden, mendel.kleiner@chalmers.se

Gudrun Klinker Technische Universität München, München, Germany, klinker@in.tum.de

Pontus Larsson Department of Applied Acoustics, Chalmers University of Technology, SE-412 96, Göteborg, Sweden; Volvo Technology Corporation, SE-405 08 Göteborg, Sweden, pontus.larsson@chalmers.se

Pierre Leclercq LUCID-ULg: Lab for User Cognition and Innovative Design – University of Liège – Belgium, Pierre.Leclercq@ulg.ac.be

Sylvain Le Groux SPECS@IUA: Laboratory for Synthetic Perceptive, Emotive, and Cognitive Systems, Universitat Pompeu Fabra, Tànger 135, 08018 Barcelona, Spain

Jônatas Manzolli Interdisciplinary Nucleus for Sound Communications (NICS), State University of Campinas, Rua da Reitoria, 165 – Cidade Universitária "Zeferino Vaz" Campinas, São Paulo, Brasil

Zenon Mathews SPECS@IUA: Laboratory for Synthetic Perceptive, Emotive, and Cognitive Systems, Universitat Pompeu Fabra, Tànger 135, 08018 Barcelona, Spain

Tim Merritt Mixed Reality Lab, 21 Lower Kent Ridge Rd, National University of Singapore, Singapore 119077, Singapore, tim@mixedrealitylab.org

Jan M.V. Misker V2_ Institute for the Unstable Media, Eendrachtstraat 10, 3012 XL, Rotterdam, The Netherlands, jan@v2.nl

Florian ‘Floyd’ Mueller Interaction Design Group, Department of Information Systems, The University of Melbourne, Parkville, VIC, Australia, floyd@floydmueller.com

Anna Mura SPECS@IUA: Laboratory for Synthetic Perceptive, Emotive, and Cognitive Systems, Universitat Pompeu Fabra, Tànger 135, 08018 Barcelona, Spain

Roderick Murray-Smith University of Glasgow, Glasgow, UK, rod@dcs.gla.ac.uk

Laurence Nigay Grenoble Informatics Laboratory, 385 avenue de la Bibliothèque, Domaine Universitaire, B.P. 53, 38 041 Grenoble cedex 9, France, Laurence.Nigay@imag.fr

Susanna Nilsson Department of Computer and Information Science, Linköping University, SaabSecurity, Santa Anna IT Research Institute AB, Linköping, Sweden, susni@ida.liu.se

J.-L. Pérez-Medina Laboratory of Informatics of Grenoble, Grenoble Université, 385 rue de la bibliothèque, B.P. 53, 38041 Grenoble Cedex 9, France, Jorge-Luis.Perez-Medina@imag.fr

W. Greg Phillips Department of Electrical and Computer Engineering, Royal Military College of Canada, Kingston, Canada K7K7B4, greg.phillips@rmc.ca

Wayne Piekarski Wearable Computer Laboratory, University of South Australia, Mawson Lakes, SA 5095, Australia, wayne@tinmith.net

Daniel Pustka Technische Universität München, München, Germany

Andrea Resmini University of Bologna, Via Carboni 2, 43100 Parma, Italy, root@resmini.net

Patrick Reuter LaBRI, 351, cours de la Libération, 33405 Talence, France; INRIA Bordeaux – Sud Ouest, 351, cours de la Libération, 33405 Talence France; Université Bordeaux 2, 146 rue Léo Saignat, 33076 Bordeaux, France, preuter@labri.fr

Dominique Rieu Laboratory of Informatics of Grenoble, Grenoble Université, 385 rue de la bibliothèque, B.P. 53, 38041 Grenoble Cedex 9, France, Dominique.Rieu@imag.fr

Guillaume Rivière ESTIA-RECHERCHE, Technopole Izarbel, 64210 Bidart, France; LaBRI, 351, cours de la Libération, 33405 Talence, France, g.riviere@estia.fr

Luca Rosati University for Foreigners of Perugia, via XX settembre 25, 06124 Perugia, Italy, luca@lucarosati.it

Stéphane Safin LUCID-ULg: Lab for User Cognition and Innovative Design – University of Liège – Liège, Belgium, Stephane.Safin@ulg.ac.be

Holger Schnädelbach Mixed Reality Lab, Computer Science, University of Nottingham, Jubilee Campus, Nottingham, NG8 1BB, UK, hms@cs.nott.ac.uk

Rodrigo da Silva Guerra Graduate School of Engineering, Osaka University, Osaka, Japan, rodrigo.guerra@ams.eng.osaka-u.ac.jp

J. David Smith School of Computing, Queen's University, Kingston, Canada K7L3N6, smith@cs.queensu.ca

Ross T. Smith Wearable Computer Laboratory, University of South Australia, Mawson Lakes, SA 5095, Australia, ross@r-smith.net

Vladimir Stantchev Public Services and SOA Research Group, Berlin Institute of Technology and Fachhochschule für Ökonomie und Management, Berlin, Germany, vstantch@cs.tu-berlin.de

Jelle van der Ster V2_ Institute for the Unstable Media, Eendrachtstraat 10, 3012 XL, Rotterdam, The Netherlands, jelle@v2.nl

Ellen Szwajcer Novay, 7500 AN Enschede, The Netherlands, Ellen.Szwajcer@telin.nl

Ana Tajadura-Jiménez Department of Applied Acoustics, Chalmers University of Technology, SE-412 96, Göteborg, Sweden, ana.tajadura@gmail.com

Bruce H. Thomas Wearable Computer Laboratory, University of South Australia, Mawson Lakes, SA 5095, Australia, bruce.thomas@unisa.edu.au

Aleksander Väljamäe Department of Applied Acoustics, Chalmers University of Technology, SE-412 96 Göteborg, Sweden; Research Laboratory for Synthetic Perceptive, Emotive and Cognitive Systems (SPECS), Institute of Audiovisual Studies, Universitat Pompeu Fabra, Barcelona, Spain, aleksander.valjamae@iaa.upf.edu

Daniel Västfjäll Department of Applied Acoustics, Chalmers University of Technology, SE-412 96, Göteborg, Sweden; Department of Psychology, Göteborg University, Göteborg, Sweden, daniel@ta.chalmers.se

Paul F.M.J. Verschure SPECS@IUA: Laboratory for Synthetic Perceptive, Emotive, and Cognitive Systems, Universitat Pompeu Fabra, Tànger 135, 08018 Barcelona, Spain; ICREA, Technology Department, Universitat Pompeu Fabra, Tànger 135, 08018 Barcelona, Spain, paul.verschure@iaa.upf.edu

Frank Vetere Interaction Design Group, Department of Information Systems, The University of Melbourne, Parkville, VIC, Australia, fv@unimelb.edu.au

John Williamson University of Glasgow, Glasgow, UK, jhw@dcs.gla.ac.uk

Christopher Wolfe School of Computing, Queen's University, Kingston, Canada K7L3N6, wolfe@cs.queensu.ca