

Editor-in-Chief

A. Joe Turner, Seneca, SC, USA

Editorial Board

Foundations of Computer Science

Mike Hinchey, Lero, Limerick, Ireland

Software: Theory and Practice

Bertrand Meyer, ETH Zurich, Switzerland

Education

Bernard Cornu, CNED-EIFAD, Poitiers, France

Information Technology Applications

Ronald Waxman, EDA Standards Consulting, Beachwood, OH, USA

Communication Systems

Guy Leduc, Université de Liège, Belgium

System Modeling and Optimization

Jacques Henry, Université de Bordeaux, France

Information Systems

Barbara Pernici, Politecnico di Milano, Italy

Relationship between Computers and Society

Chrisanthi Avgerou, London School of Economics, UK

Computer Systems Technology

Paolo Prinetto, Politecnico di Torino, Italy

Security and Privacy Protection in Information Processing Systems

Kai Rannenber, Goethe University Frankfurt, Germany

Artificial Intelligence

Max A. Bramer, University of Portsmouth, UK

Human-Computer Interaction

Annelise Mark Pejtersen, Center of Cognitive Systems Engineering, Denmark

Entertainment Computing

Ryohei Nakatsu, National University of Singapore

IFIP – The International Federation for Information Processing

IFIP was founded in 1960 under the auspices of UNESCO, following the First World Computer Congress held in Paris the previous year. An umbrella organization for societies working in information processing, IFIP's aim is two-fold: to support information processing within its member countries and to encourage technology transfer to developing nations. As its mission statement clearly states,

IFIP's mission is to be the leading, truly international, apolitical organization which encourages and assists in the development, exploitation and application of information technology for the benefit of all people.

IFIP is a non-profitmaking organization, run almost solely by 2500 volunteers. It operates through a number of technical committees, which organize events and publications. IFIP's events range from an international congress to local seminars, but the most important are:

- The IFIP World Computer Congress, held every second year;
- Open conferences;
- Working conferences.

The flagship event is the IFIP World Computer Congress, at which both invited and contributed papers are presented. Contributed papers are rigorously refereed and the rejection rate is high.

As with the Congress, participation in the open conferences is open to all and papers may be invited or submitted. Again, submitted papers are stringently refereed.

The working conferences are structured differently. They are usually run by a working group and attendance is small and by invitation only. Their purpose is to create an atmosphere conducive to innovation and development. Refereeing is less rigorous and papers are subjected to extensive group discussion.

Publications arising from IFIP events vary. The papers presented at the IFIP World Computer Congress and at open conferences are published as conference proceedings, while the results of the working conferences are often published as collections of selected and edited papers.

Any national society whose primary activity is in information may apply to become a full member of IFIP, although full membership is restricted to one society per country. Full members are entitled to vote at the annual General Assembly, National societies preferring a less committed involvement may apply for associate or corresponding membership. Associate members enjoy the same benefits as full members, but without voting rights. Corresponding members are not represented in IFIP bodies. Affiliated membership is open to non-national societies, and individual and honorary membership schemes are also offered.

Svetan Ratchev (Ed.)

Precision Assembly Technologies and Systems

5th IFIP WG 5.5

International Precision Assembly Seminar, IPAS 2010

Chamonix, France, February 14-17, 2010

Proceedings



Springer

Volume Editor

Svetan Ratchev
The University of Nottingham
Precision Manufacturing Centre
NG7 2RD Nottingham, UK
E-mail: svetan.ratchev@nottingham.ac.uk

Library of Congress Control Number: 2009943066

CR Subject Classification (1998): J.2, I.5, J.6, C.3, J.7

ISSN 1868-4238
ISBN-10 3-642-11597-7 Springer Berlin Heidelberg New York
ISBN-13 978-3-642-11597-4 Springer Berlin Heidelberg New York

This work is subject to copyright. All rights are reserved, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, re-use of illustrations, recitation, broadcasting, reproduction on microfilms or in any other way, and storage in data banks. Duplication of this publication or parts thereof is permitted only under the provisions of the German Copyright Law of September 9, 1965, in its current version, and permission for use must always be obtained from Springer. Violations are liable to prosecution under the German Copyright Law.

springer.com

© IFIP International Federation for Information Processing 2010
Printed in Germany

Typesetting: Camera-ready by author, data conversion by Scientific Publishing Services, Chennai, India
Printed on acid-free paper SPIN: 12844609 06/3180 5 4 3 2 1 0

Preface

The development of new-generation micro-manufacturing technologies and systems has revolutionised the way products are designed and manufactured today with a significant impact in a number of key industrial sectors. Micro-manufacturing technologies are often described as disruptive, enabling and interdisciplinary leading to the creation of whole new classes of products that were previously not feasible to manufacture. While key processes for volume manufacture of micro-parts such as machining and moulding are becoming mature technologies, micro-assembly remains a key challenge for the cost-effective manufacture of complex micro-products. The ability to manufacture customizable micro-products that can be delivered in variable volumes within relatively short timescales is very much dependent on the level of development of the micro-assembly processes, positioning, alignment and measurement techniques, gripping and feeding approaches and devices.

Micro-assembly has developed rapidly over the last few years and all the predictions are that it will remain a critical technology for high-value products in a number of key sectors such as healthcare, communications, defence and aerospace. The key challenge is to match the significant technological developments with a new generation of micro-products that will establish firmly micro-assembly as a mature manufacturing process.

The book includes the set of papers presented at the 5th International Precision Assembly Seminar IPAS 2010 held in Chamonix, France from the 14th to the 17th February 2010. The International Precision Assembly Seminar was established in 2003 by the European Thematic Network Assembly-Net to provide a forum for discussing the latest research, new innovative technologies and industrial applications in the area of precision (mini and micro) assembly.

The published works have been grouped into four parts. Part 1 is dedicated to micro-product design with specific emphasis on design for micro-assembly (DF μ A) methods and solutions. Part 2 is focused on micro-assembly processes and includes contributions in process modelling, high-precision packaging and assembly techniques and specific examples of micro-assembly applications. Part 3 describes the latest developments in micro-gripping, micro-feeding and micro-metrology. Part 4 provides an overview of the recent developments in the design of micro-assembly production systems with specific emphasis on reconfigurable modular micro-assembly equipment solutions.

The seminar is sponsored by the International Federation of Information Processing (IFIP) WG5.5, the International Academy of Production Research (CIRP) and the European Factory Automation Committee (EFAC). The seminar is supported by a number of ongoing research initiatives and projects including the European sub-technology platform in Micro and Nano Manufacturing MINAM, the UK EPSRC Grand Challenge Project 3D Mintegration, the EU-funded coordinated action NanoCom and the EU-funded collaborative project FRAME.

The organisers should like to express their gratitude to the members of the International Advisory Committee for their support and guidance and to the authors of the papers for their original contributions. Our special thanks go to Luis Camarinha-Matos, Chair of the IFIP WG5.5, and Michael Hauschild, Chair of the STC A of CIRP, for their continuous support and encouragement. And finally our thanks go to Ruth Strickland and Rachel Watson from the Precision Manufacturing Centre at the University of Nottingham for handling the administrative aspects of the seminar, putting the proceedings together and managing the detailed liaison with the authors and the publishers.

February 2010

Svetan M. Ratchev

Organization

International Advisory Committee

T. Arai	University of Tokyo, Japan
H. Afsarmanesh	University of Amsterdam, The Netherlands
M. Björkman	Linköping Institute of Technology, Sweden
H. Bley	University of Saarland, Germany
C.R. Boer	ICIMSI-SUPSI, Switzerland
I. Boiadjiev	TU Sofia, Bulgaria
L.M. Camarinha Matos	University Nova, Portugal
D. Ceglarek	Warwick University, UK
A. Delchambre	ULB, Belgium
M. Desmulliez	Heriot-Watt University, UK
S. Dimov	University of Cardiff, UK
G. Dini	University of Pisa, Italy
S. Durante	DIAD, Italy
K. Ehmann	Northwestern University, USA
R. Fearing	University of California at Berkeley, USA
R.W. Grubbström	Linköping Institute of Technology, Sweden
C. Hensch	Festo AG & Co, Germany
T. Hasegawa	Kyushu University, Japan
J. Heilala	VTT, Finland
J. Jacot	EPFL, Switzerland
M. Krieger	CSEM, Switzerland
S. Koelemeijer	Jaeger-Lecoultré, Switzerland
P. Lambert	ULB, Belgium
R. Leach	National Physical Laboratory, UK
N. Lohse	University of Nottingham, UK
P. Lutz	LAB, France
H. Maekawa	Nat. Inst. of Adv. Industrial Science and Technology, Japan
B. Nelson	ETH, Switzerland
J. Ni	University of Michigan, USA
D. Pham	Cardiff University, UK
M. Pillet	Polytech Savoie, France
G. Putnik	University of Minho, Portugal
B. Raucent	UCL, Belgium
K. Ridgway	Sheffield University, UK
G. Seliger	TU Berlin, Germany
W. Shen	Nat. Research Council, Canada
M. Tichem	TU Delft, The Netherlands
R. Tuokko	TUT, Finland
E. Westkämper	Fraunhofer IPA, Germany
D. Williams	Loughborough University, UK

Table of Contents

Part I: Design of Micro Products

Chapter 1. Design for Micro-assembly

Analysis of the Applicability of Design for Microassembly Theory to Biomedical Devices	5
<i>Carsten Tietje, Daniel Smale, Steve Haley, and Svetan Ratchev</i>	
A Haptic Tele-operated System for Microassembly	13
<i>P. Estevez, S. Khan, P. Lambert, M. Porta, I. Polat, C. Scherer, M. Tichem, U. Staufer, H.H. Langen, and R. Munnig Schmidt</i>	
Neutral Interface for Assembly and Manufacturing Related Knowledge Exchange in Heterogeneous Design Environment	21
<i>Minna Lanz, Roberto Rodriguez, Pasi Luostarinen, and Reijo Tuokko</i>	

Chapter 2. Tolerancing for Micro-assembly

Defining Tolerances in Assembly Process with the Aid of Simulation	33
<i>H.-A. Crostack, R. Refflinghaus, and Jirapha Liangsiri</i>	
Assembly Analysis of Interference Fits in Elastic Materials	41
<i>Kannan Subramanian and Edward P. Morse</i>	
How Form Errors Impact on 2D Precision Assembly with Clearance?	50
<i>Pierre-Antoine Adragna, Serge Samper, and Hugues Favreliere</i>	

Part II: Micro-assembly Processes

Chapter 3. Development of Micro-joining Processes

Precision Assembling and Hybrid Bonding for Micro Fluidic Systems . . .	65
<i>Agathe Koller-Hodac, Manuel Altmeyer, and Silvio Walpen</i>	
Feasibility of Laser Induced Plasma Micro-machining (LIP-MM)	73
<i>Kumar Pallav and Kornel F. Ehmann</i>	

Focused Ion Beam Micro Machining and Micro Assembly 81
Hongyi Yang and Svetan Ratchev

Chapter 4. Innovative Assembly Processes

Hybrid Assembly for Ultra-Precise Manufacturing 89
Alexander Steinecker

Development of the Roll Type Incremental Micro Pattern Imprint System for Large Area Pattern Replication 97
Jung-Han Song, Hye-Jin Lee, Shuhuai Lan, Nak-Kyu Lee, Geun-An Lee, Tae-Jin Lee, Seogou Choi, and Sung-Min Bae

Utilisation of FIB/SEM Technology in the Assembly of an Innovative Micro-CMM Probe 105
Daniel Smale, Steve Haley, Joel Segal, Ronaldo Ronaldo, Svetan Ratchev, Richard K. Leach, and James D. Claverley

Chapter 5. Metrology and Control for Micro-assembly

Miniaturized Camera Systems for Microfactories 115
Timo Prusi, Petri Rokka, and Reijo Tuokko

Vision and Force Sensing to Decrease Assembly Uncertainty 123
R. John Ellwood, Annika Raatz, and Jürgen Hesselbach

Modelling the Interaction Forces between an Ideal Measurement Surface and the Stylus Tip of a Novel Vibrating Micro-scale CMM Probe 131
J.D. Claverley, A. Georgi, and R.K. Leach

Part III: Gripping and Feeding Solutions for Micro-assembly

Chapter 6. High Precision Positioning and Alignment Techniques

Alignment Procedures for Micro-optics 143
Matthias Mohaupt, Erik Beckert, Ramona Eberhardt, and Andreas Tünnermann

Pneumatic Driven Positioning and Alignment System for the Assembly of Hybrid Microsystems	151
<i>Christian Brecher, Martin Freundt, and Christian Wenzel</i>	
Flexure-Based 6-Axis Alignment Module for Automated Laser Assembly	159
<i>Christian Brecher, Nicolas Pyschny, and Jan Behrens</i>	
Approach for the 3D-Alignment in Micro- and Nano-scale Assembly Processes	167
<i>Thomas Wich, Christian Stolle, Manuel Mikczinski, and Sergej Fatikow</i>	
Guidelines for Implementing Augmented Reality Procedures in Assisting Assembly Operations	174
<i>Viviana Chimienti, Salvatore Iliano, Michele Dassisi, Gino Dini, and Franco Failli</i>	
Monodirectional Positioning Using Dielectric Elastomers	180
<i>C. Pagano, M. Malosio, and I. Fassi</i>	
Chapter 7. Gripping and Handling Solutions	
Active Gripper for Hot Melt Joining of Micro Components	191
<i>Sven Rathmann, Annika Raatz, and Jürgen Hesselbach</i>	
Grasping and Interaction Force Feedback in Microassembly	199
<i>Marcello Porta and Marcel Tichem</i>	
Low Voltage Thermo-mechanically Driven Monolithic Microgripper with Piezoresistive Feedback	207
<i>Vladimir Stavrov, Emil Tomerov, Chavdar Hardalov, Daniel Danchev, Kostadin Kostadinov, Galina Stavreva, Evstati Apostolov, Assen Shulev, Anna Andonova, and Mohammed Al-Wahab</i>	
Improvement of Robotic Micromanipulations Using Chemical Functionalisations	215
<i>Jérôme Dejeu, Patrick Rougeot, Michaël Gauthier, and Wilfrid Boireau</i>	
Positioning, Structuring and Controlling with Nanoprecision	222
<i>Regine Hedderich, Tobias Heiler, Roland Gröger, Thomas Schimmel and Stefan Walheim</i>	
Challenges of Precision Assembly with a Miniaturized Robot	227
<i>Arne Burisch, Annika Raatz, and Jürgen Hesselbach</i>	

Part IV: Development of Micro-assembly Production Systems

Chapter 8. Modular Reconfigurable Assembly Systems

Application of a Reconfiguration Methodology for Multiple Assembly System Reconfigurations	239
<i>D. Smale and S. Ratchev</i>	
Multi-agent Architecture for Reconfiguration of Precision Modular Assembly Systems	247
<i>Pedro Ferreira, Niels Lohse, and Svetan Ratchev</i>	
Reconfigurable Self-optimising Handling System	255
<i>Rainer Müller, Martin Riedel, Matthias Vette, Burkhard Corves, Martin Esser, and Mathias Hüsing</i>	
Modular and Generic Control Software System for Scalable Automation	263
<i>Christian Brecher, Martin Freundt, and Daniel Schöllhorn</i>	
Agile Multi-parallel Micro Manufacturing Using a Grid of Equiplets	271
<i>Erik Puik and Leo van Moergestel</i>	
Development of a Reconfigurable Fixture for the Automated Assembly and Disassembly of High Pressure Rotors for Rolls-Royce Aero Engines	283
<i>Thomas Papastathis, Marco Ryll, Stuart Bone, and Svetan Ratchev</i>	

Chapter 9. Micro-Factory

Architectures and Interfaces for a Micro Factory Concept	293
<i>Niko Siltala, Riku Heikkilä, Asser Vuola, and Reijo Tuokko</i>	
Desktop Micro Forming System for Micro Pattern on the Metal Substrate	301
<i>Hye-Jin Lee, Jung-Han Song, Sol-Kil Oh, Kyoung-Tae Kim, Nak-Kyu Lee, Geun-An Lee, Hyoung-Wook Lee, and Andy Chu</i>	
Miniaturization of Flexible Screwing Cell	309
<i>Asser Vuola, Riku Heikkilä, Timo Prusi, Mikko Remes, Petri Rokka, Niko Siltala, and Reijo Tuokko</i>	

Chapter 10. Micro-assembly Technology Studies

A Cooperation Model and Demand-Oriented ICT Infrastructure for SME Development and Production Networks in the Field of Microsystem Technology	319
<i>Markus Dickerhof</i>	
A Methodology for Evaluating the Technological Maturity of Micro and Nano Fabrication Processes.....	329
<i>Emmanuel Brousseau, Richard Barton, Stefan Dimov, and Samuel Bigot</i>	
Function and Length Scale Integration Study in Emerging MST-Based Products	337
<i>Samuel Bigot, Stefan Dimov, and Roussi Minev</i>	
Author Index	343