Lecture Notes in Artificial Intelligence 1454

Subseries of Lecture Notes in Computer Science
Edited by J. G. Carbonell and J. Siekmann

Lecture Notes in Computer Science
Edited by G. Goos, J. Hartmanis and J. van Leeuwen

Ian Smith (Ed.)

Artificial Intelligence in Structural Engineering

Information Technology for Design, Collaboration, Maintenance, and Monitoring

Springer

Series Editors
Jaime G. Carbonell, Carnegie Mellon University, Pittsburgh, PA, USA
Jörg Siekmann, University of Saarland, Saarbrücken, Germany

Volume Editor

Ian Smith
Structural Engineering and Mechanics(IMAG-DGC)
EPFL–Federal Institute of Technology
CH-1015 Lausanne, Switzerland
E-mail: Ian.Smith@epfl.ch

Cataloging-in-Publication Data applied for

Die Deutsche Bibliothek - CIP-Einheitsaufnahme

Artificial intelligence in structural engineering : information technology for design, collaboration, maintenance, and monitoring / Ian Smith (ed.). - Berlin ; Heidelberg ; New York ; Barcelona ; Budapest ; Hong Kong ; London ; Milan ; Paris ; Singapore ; Tokyo : Springer, 1998
(Lecture notes in computer science ; 1454 : Lecture notes in artificial intelligence)
ISBN 3-540-64806-2

CR Subject Classification (1991): I.2, D.2, J.2, J.6, H.5

ISBN 3-540-64806-2 Springer-Verlag Berlin Heidelberg New York

Printed in Germany

Typesetting: Camera ready by author
SPIN 10638211 06/3142 – 5 4 3 2 1 0 Printed on acid-free paper

Preface

Information technology applications in structural engineering are hindered by factors such as holistic knowledge, interdependent tasks, incomplete information and constantly changing contexts. Lower hardware costs, Internet communication, advances in product and process modelling, improved human-computer interfaces, faster computation and other advances in the information sciences have now created favourable conditions for increasing the number of useful applications. However, this is not enough for many important tasks.

Deductive tasks such as structural analyses have been successfully supported for several decades. However, applications to tasks such as design and diagnosis have not provided practising engineers with equivalent levels of assistance. Nevertheless, when engineers perform design and diagnosis tasks, they often add much more value to a project than when structural analysis tasks are carried out. Part of the difficulty originates in the nature of the task. Design and diagnosis tasks require abductive inference; engineers must reverse cause-effect and structure-behaviour relationships to satisfy multiple goals. To be reliable, black-box abductive inference requires complete domain models and this is impossible in structural engineering. Contextual parameters such as politics, economics and local conditions are nearly always important.

In addition to design and diagnosis, computer support for collaboration between multiple actors has much potential for improving the effectiveness of structural engineers. Project delays, excessive costs and even accidents are almost invariably linked to bad collaboration, especially when many changes have been necessary. Since a primary function of computing is to store and transmit data, support for collaboration seems easy. However, this is not the case in structural engineering. Structural engineers must work in parallel with architects, tradespeople, contractors and fabricators. Nearly every actor views construction projects differently and there are many competing goals. As a result, support for collaboration has required much more research than originally thought necessary.

One issue is common to all of these tasks. Representation, manipulation and use of structural engineering knowledge is inevitably a major challenge for each and every application. Since such aspects of knowledge have been the subject of study in artificial intelligence (AI) research since the late 1950s, it is understandable that researchers are looking to this field for inspiration. However, simple reuse of AI algorithms and representational frameworks is not possible. Most structural engineering tasks are complex, changing, long and poorly defined. Structures must be safe, serviceable, environmentally correct, useful, aesthetically pleasing, easy to build and long lasting. Therefore, structural engineering is one of AI's most difficult application fields.

The papers in this volume present the state of the art of AI in structural engineering. Not all contributions deal directly with structural engineering issues since much excellent and applicable research is underway in other areas. This work describes key advances that are becoming catalysts for fully exploiting the current favourable conditions which were mentioned above for increasing the number of useful applications.

I would like to thank all of the authors and particularly, every member of the IAB (International Advisory Board – see list overleaf) for contributing papers to this volume. The quality of the papers is a direct result of the work of reviewers who unselfishly provided constructive criticism so that authors could improve their papers. I would thus like to thank the members of the Programme Committee, the Organising Committee and the IAB for ensuring that each paper received at least three reviews. I am also grateful to K. Shea, B. Raphael and R. Stalker for additionally helping with review organisation, paper management and many administrative tasks. Finally, H. Flühler and C. Stamm of the Centro Stefano Franscini and ETHZ provided much advice and support.

Lausanne, May 1998 Ian F.C. Smith

Organisation

These papers were presented at a conference organised by the European Group for Structural Engineering Applications of Artificial Intelligence (EG-SEA-AI).
http://www.strath.ac.uk/Departments/Civeng/egseaai/
The conference was made possible through a generous grant from the Centro Stefano Franscini, Monte Verità, Ascona, Switzerland.

Conference Chair

I.F.C. Smith, EPFL, Switzerland

Program Committee

B. Kumar University of Strathclyde, UK, Chair
C. Moore University of Wales, Cardiff, UK
J. Bento IST, Lisbon, Portugal
P. Salvaneschi ISMES, Bergamo, Italy

Organising Committee

I.F.C. Smith, EPFL
S. Boulanger, EPFL
B. Raphael, EPFL
K. Shea, EPFL
R. Stalker, EPFL

International Advisory Board

M. Abe, University of Tokyo, Japan
J.W. Baugh, University of North Carolina, USA
S.J. Fenves, Carnegie Mellon University, USA
G. Fischer, University of Colorado, USA
M. Fischer, Stanford University, USA
R. Fruchter, Stanford University, USA
J.H. Garrett, Carnegie Mellon University, USA
J.S. Gero, University of Sydney, Australia
J.C. Kunz, Stanford University, USA
K.H. Law, Stanford University, USA
M.L. Maher, University of Sydney, Australia
W.J. Mitchell, MIT, USA
D.T. Ndumu, BT Labs, UK
F. Peña-Mora, MIT, USA
K. Roddis, University of Kansas, USA
R.J. Scherer, TU Dresden, Germany
G. Schmitt, ETHZ, Switzerland

Table of Contents

Long Papers

Structural monitoring of civil structures using vibration measurement – current practice and future ... 1
M. Abé

Object-oriented software patterns for engineering design standards processing ... 19
M.K. Badrah, I. MacLeod, B. Kumar

Design and verification of real-time systems ... 30
J.W. Baugh

Using knowledge nodes for knowledge discovery and collaboration ... 48
P. Christiansson

Heating system design support ... 60
P. Cichocki, M. Gil, J. Pokojski

Collaborative desktop engineering ... 69
E.L. Divita, J.C. Kunz, M.A. Fischer

Towards personalized structural engineering tools ... 86
S.J. Fenves

Complex systems: Why do they need to evolve and how can evolution be supported ... 92
G. Fischer

Formalizing product model transformations: Case Examples and applications ... 113
M. Fischer, F. Aalami, R. Akbas

Internet-based web-mediated collaborative design and learning environment 133
R. Fruchter

Wearable computers for field inspectors: Delivering data and knowledge-based support in the field ... 146
J.H. Garrett, A. Smailagic

Conceptual designing as a sequence of situated acts ... 165
J.S. Gero

Some personal experience in computer aided engineering research ... 178
K.H. Law

Knowledge discovery from multimedia case libraries 197
M.L. Maher, S.J. Simoff

Customisable knowledge bases for conceptual design 214
J.C. Miles, C.J. Moore, I. Bradley

Articulate design of free-form structures 223
W.J. Mitchell

Applying quantitative constraint satisfaction in preliminary design 235
C.J. Moore, J.C. Miles, J.V. Cadogan

Agents in computer-assisted collaborative design 249
D.T. Ndumu, J.M.H. Tah

A collaborative negotiation methodology for large scale civil engineering and architectural projects 271
F. Peña-Mora

An investigation into the integration of neural networks with the structured genetic algorithm to aid conceptual design 295
M.Y. Rafiq, C. Williams

Finding the right model for bridge diagnosis 308
B. Raphael, I. Smith

Knowledge-based assistants in collaborative engineering 320
W.M.K. Roddis

CAD modelling in multidisciplinary design domains 335
M.A. Rosenman, J.S. Gero

A family of software components to deliver solutions for the interpretation of monitoring data 348
P. Salvaneschi, M. Lazzari

AI methods in concurrent engineering 359
R.J. Scherer

A new collaborative design environment for engineers and architects 384
G. Schmitt

Intelligent Structures: A New Direction in Structural Control 398
K. Shea, I. Smith

Integration of expert systems in a structural design office 411
A. Cauvin, R. Passera and G. Stagnitto

Short Papers

Teaching knowledge engineering: Experiences 424
T. Anderson, S.C. Hartvig

Design support for viaducts 428
J. Corte-Real Andrade, J.Bento

Converting function into object 434
A. Borkowski, E. Grabska

Software agent techniques in design 440
S.C. Hartvig

Case-based design process facilitating collaboration and information evolution 444
P. Johansson, S. Popova

Shared experiences: Management of experiential knowledge in the building industry 449
E. Leijten, G. Maas, E. Vastert

Dam safety: Improving management 455
E.Alvez Portela, J. Bento

Integrating virtual reality and telepresence to remotely monitor construction sites: A ViRTUE project 459
A. Retik, G. Mair, R. Fryer, D. McGregor

Proposal for 4.5 dimensional design via product models and expert system 464
M. Salonen, J. Rautakorpi, M. Heinisuo

A product information system based on dynamic classification 469
S. Scheler

Structural Monitoring: Decision-Support through Multiple Data Interpretations 474
R. Stalker, I. Smith

Augmented Reality Applications to Structural Monitoring............... 479
R. Stalker, I. Smith

Analysis and design of the as-built model 484
W. Tizani

On theoretical backgrounds of CAD 490
Z. Turk

Author Index 497