Lecture Notes in Computer Science 748

Edited by G. Goos and J. Hartmanis

Advisory Board: W. Brauer   D. Gries   J. Stoer

Robert H. Halstead, Jr. Takayasu Ito (Eds.)

Parallel Symbolic Computing: Languages, Systems, and Applications

US/Japan Workshop
Cambridge, MA, USA, October 14-17, 1992
Proceedings

Springer-Verlag
Berlin Heidelberg New York
London Paris Tokyo
Hong Kong Barcelona
Budapest

Series Editors

Gerhard Goos
Universität Karlsruhe
Postfach 69 80
Vincenz-Priessnitz-Straße 1
D-76131 Karlsruhe, Germany

Juris Hartmanis
Cornell University
Department of Computer Science
4130 Upson Hall
Ithaca, NY 14853, USA

Volume Editors

Robert H. Halstead, Jr.
Cambridge Research Lab, Digital Equipment Corporation
One Kendall Square, Bldg. 700, Cambridge, MA 02139, USA

Takayasu Ito
Department of Computer and Mathematical Sciences
Graduate School of Information Sciences, Tohoku University
Sendai 980, Japan

Preface

Parallel and distributed computing are becoming increasingly important as cost-effective ways to achieve high computational performance. Symbolic computing is widespread in applications and hence parallel symbolic computing is important, but symbolic computations are notable for their use of irregular data structures (such as trees, lists, and graphs) and irregular, data-driven operations on them. As a result, parallel symbolic computing has its own distinctive set of technical challenges.

To explore these issues, a workshop was held at MIT in Cambridge, Massachusetts, on October 14–17, 1992. This workshop brought together researchers interested in parallel symbolic computing to identify:

- Important common theoretical and implementation problems.
- The important application areas for parallel symbolic computing.
- How to move parallelism into wider use for symbolic computing.
- Opportunities for research collaboration.

The past ten years have seen the development of several small-scale (mostly shared-memory) systems for parallel symbolic computing based on Lisp and Prolog. Many symbolic programs written for serial computers have been successfully transformed into parallel programs using these systems. More recently, we have seen massively parallel processing and distributed computing take on greater importance, but these systems are more challenging to use and both their hardware and software are still immature.

The overriding technical objective driving this workshop and this book is to identify the common and fundamental technical issues in massively parallel symbolic computing and hasten the widespread availability and use of high-performance parallel symbolic computing systems. Accordingly, the papers included in this book cover a wide range of areas:

- Speculative computation.
- Scheduling techniques.
- Program development tools and environments.
- Programming languages and systems.
- Models of concurrency and distribution.
- Parallel computer architecture.
- Symbolic applications.

The workshop began on Wednesday afternoon, October 14, and concluded early in the afternoon on Saturday, October 17. The program included 24 presentations grouped roughly into the topic areas listed above. In addition there were two panel discussions, "Massively Parallel Architectures and Symbolic Computation," and "Applications for Parallel Symbolic Computation," focusing special attention on two areas of key importance to the future of parallel symbolic computing.

Workshop participants submitted papers which were distributed at the workshop. Based on the presentations and discussions at the workshop, all but one

of the speakers revised their manuscripts and contributed them to this book. Contributions in this book are of two kinds: full papers and extended abstracts. Many participants contributed full papers based on their talks at the workshop; some participants contributed extended abstracts, because the work had already been published elsewhere or for other reasons. In addition, this book includes the questions for the panel discussions and position statements contributed by the panelists.

The papers and extended abstracts in this book are organized into groups by subject:

Part I: Speculative computation.
Part II: Implementation techniques.
Part III: Program development tools.
Part IV: Languages and conceptual models.
Part V: Systems.

Before the first group we include an overview of the papers. After the papers, we include the panel questions, position statements, and a list of the workshop participants.

The idea of having this workshop originated at an earlier workshop on parallel Lisp that was held in Sendai, Japan, in June, 1989. (The proceedings of that workshop were published in 1990 as *Lecture Notes in Computer Science* vol. 441 by Springer-Verlag.) Participants in that workshop felt it was a valuable experience that should be repeated in the future, so proposals were submitted to the U.S. National Science Foundation and the Japan Society for the Promotion of Science to have a follow-up workshop in 1992.

Although the 1989 workshop was exclusively a U.S./Japan meeting, the 1992 workshop also included participants from other countries (such as the U.K., France, and Canada). We hope the "new blood" thus brought into this workshop will expand our understanding of the opportunities and challenges of parallel symbolic computing and advance the ability of this computing discipline to contribute to solving real-world problems.

The workshop was held at the MIT Laboratory for Computer Science in Cambridge, Massachusetts, U.S.A., in a building where many ideas in symbolic computing originated—including Lisp, Macsyma, Actors, Scheme, Multilisp, and many artificial intelligence applications—and which has also seen many advances in parallel computing research. In addition to the formal workshop sessions, the workshop participants were hosted for lunch by the Mitsubishi Electric Research Lab in Cambridge, and enjoyed an evening reception *cum* panel discussion at the Cambridge Marriott Hotel. Following the formal portion of the workshop, a group of the participants traveled to Concord, Massachusetts, to explore a non-technical subject: the early history of the United States.

We are grateful for the support we received for this workshop from the Japan Society for the Promotion of Science, the National Science Foundation, the MIT Laboratory for Computer Science, Tohoku University, and the Mitsubishi Electric Research Lab. In addition, we are grateful to Anant Agarwal of MIT, who

co-organized the workshop with us, and to Michelle Gillespie and Anne Mc-Carthy, who handled many of the logistical details.

The papers in this proceedings represent active projects in parallel symbolic computing by a distinguished and active group of researchers. We are happy that we have been able to bring this group together and collect their work in the form of this proceedings. We are sincerely grateful to Alfred Hofmann and Hans Wössner of Springer-Verlag for their assistance in this book's publication, and we also thank all who helped organize the workshop, and participated in it, for their invaluable contributions.

Cambridge, Massachusetts
July 1993

Robert H. Halstead, Jr.
Takayasu Ito

Table of Contents

Part I: Speculative Computation

Part II: Implementation Techniques

Part III: Program Development Tools

Part IV: Languages and Conceptual Models

Part V: Systems

Part VI: Panel Discussions