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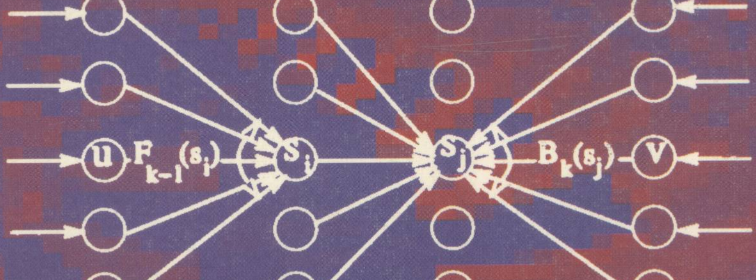
Ayumi Shinohara (Eds.)

State-of-the-Art Survey

LNAI 2281

# Progress in Discovery Science

## Final Report of the Japanese Discovery Science Project

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# Preface

This volume contains the research reports of the Discovery Science project in Japan (No. 10143106), in which more than 60 scientists participated. It was a three-year project sponsored by Grant-in-Aid for Scientific Research on Priority Areas from the Ministry of Education, Culture, Sports, Science, and Technology (MEXT) of Japan. This project mainly aimed to (1) develop new methods for knowledge discovery, (2) install network environments for knowledge discovery, and (3) establish Discovery Science as a new area of study in Computer Science / Artificial Intelligence.

In order to attain these aims we set up five groups for studying the following research areas:

**(A)** Logic for/of Knowledge Discovery
**(B)** Knowledge Discovery by Inference/Reasoning
**(C)** Knowledge Discovery Based on Computational Learning Theory
**(D)** Knowledge Discovery in Huge Databases and Data Mining
**(E)** Knowledge Discovery in Network Environments

These research areas and related topics can be regarded as a preliminary definition of Discovery Science by enumeration. Thus Discovery Science ranges over philosophy, logic, reasoning, computational learning, and system developments.

In addition to these five research groups we organized a steering group for planning, adjustment, and evaluation of the project. The steering group, chaired by the principal investigator of the project, consists of leaders of the five research groups and their subgroups as well as advisors from outside of the project. We invited three scientists to consider Discovery Science and the five above mentioned research areas from viewpoints of knowledge science, natural language processing, and image processing, respectively.

Group A studied discovery from a very broad perspective, taking account of historical and social aspects, and computational and logical aspects of discovery. Group B focused on the role of inference/reasoning in knowledge discovery, and obtained many results on both theory and practice in statistical abduction, inductive logic programming, and inductive inference. Group C aimed to propose and develop computational models and methodologies for knowledge discovery mainly based on computational learning theory. This group obtained some deep theoretical results on the boosting of learning algorithms and the minimax strategy for Gaussian density estimation, and also methodologies specialized to concrete problems such as algorithms for finding best subsequence patterns, biological sequence compression algorithms, text categorization, and MDL-based compression. Group D aimed to create computational strategies for speeding up the discovery process in total. For this purpose, group D was made up of researchers from other scientific domains and researchers from computer science so that real issues in the discovery process could be exposed and practical computational techniques could be devised and tested for solving these real issues. This group handled many kinds of data: data from national projects such as genomic data and satellite observations, data generated from laboratory experiments, data collected from personal interests such as literature and medical records, data collected in business and marketing areas, and data for proving the efficiency of algorithms such as the UCI repository. So many theoretical and practical results were obtained on such a variety of data. Group E aimed to develop a unified media system for knowledge discovery and network agents for knowledge discovery. This group obtained practical results on a new virtual materialization of DB records and scientific computations to help scientists make a scientific discovery, a convenient visualization interface that treats web data, and an efficient algorithm that extracts important information from semi-structured data in the web space.

We would like to express our immense gratitude to the members of the Discovery Science project, listed on the subsequent pages. The papers submitted to this volume were reviewed both by peers and external referees. We would like to express our sincere gratitude to the following external referees:

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September 2001

Setsuo Arikawa
Ayumi Shinohara

# Organization

## Steering Group

In addition to the five groups listed below we had a steering group (Soukatsu-han in Japanese) for planning, adjustment, and evaluation of the project, consisting of the following members:

Setsuo Arikawa (Chair, Kyushu University)
Masahiko Sato (Leader of Group A, Kyoto University)
Taisuke Sato (Leader of Group B, Tokyo Institute of Technology)
Akira Maruoka (Leader of Group C, Tohoku University)
Satoru Miyano (Leader of Group D, University of Tokyo)
Yasumasa Kanada (Leader of Group E, University of Tokyo)
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# Searching for Mutual Exclusion Algorithms Using BDDs

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**Abstract.** The impact of verification technologies would be much greater if they could not only verify existing information systems, but also synthesize or discover new ones. In our previous study, we tried to discover new algorithms that satisfy a given specification, by first defining a space of algorithms, and then checking each algorithm in the space against the specification, using an automatic verifier, i.e., model checker. Needless to say, the most serious problem of this approach is in search space explosion. In this paper, we describe case studies in which we employed symbolic model checking using BDD and searched for synchronization algorithms. By employing symbolic model checking, we could speed up enumeration and verification of algorithms. We also discuss the use of approximation for reducing the search space.

## 1 Introduction

Verification technologies have been successfully applied to guarantee the correctness of various kinds of information systems, ranging from abstract algorithms to hardware circuits. Among them is that of model checking, which checks the correctness of a state transition system by traversing its state space [2]. The success of model checking is mainly due to its ability to automatically verify a state transition system without human intervention.

However, the impact of verification technologies would be much greater if they could not only verify existing systems, but also synthesize or discover new ones.

In our previous study [6, 7], we tried to discover new algorithms that satisfy a given specification, by first defining a space of algorithms, and then checking each algorithm in the space against the specification, using a verifier, i.e., model checker. Note that this approach is possible only if the employed verifier is fully automatic. By the approach, we discovered new variants of the existing algorithms for concurrent garbage collection, and a new algorithm for mutual exclusion under some restrictions on parallel execution.

Perrig and Song have also taken a similar approach in the field of protocol verification [10]. They enumerated protocols for asynchronous and synchronous

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