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H. Jaap van den Herik   Hiroyuki Iida (Eds.)

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Series Editors

Gerhard Goos, Karlsruhe University, Germany
Juris Hartmanis, Cornell University, NY, USA
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Volume Editors

H. Jaap van den Herik
Department of Computer Science, University of Maastricht
Maastricht, The Netherlands
E-mail: herik@cs.unimaas.nl

Hiroyuki Iida
Department of Computer Science, Shizuoka University
Hamamatsu, Japan
E-mail: iida@cs.inf.shizuoka.ac.jp

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Preface

This book contains the papers presented at the First International Conference on Computers and Games (CG'98) held at the Electrotechnical Laboratory (ETL), in Tsukuba, Japan, on November 11-12, 1998.

The CG'98 focuses on all aspects of research related to computers and games. Relevant topics include, but are not limited to, the current state of game-playing programs. The book contains new theoretical developments in game-related research, general scientific contributions produced by the study of games, social aspects of computer games, mathematical games, cognitive research of how humans play games, and so on. As this volume shows, CG'98 is an international conference, with participants from many different countries who have different backgrounds and hence exhibit different views on computers and games.

The Conference was the first one in a series of conferences on this topic. It was a direct follow-up of many successful computer-games-related events held in Japan, such as the series of four Game Programming Workshops (GPW'94 to GPW'97) and the IJCAI-97 Workshop on Computer Games.

The technical program consisted of a keynote lecture, titled: *Predictions* (by H.J. van den Herik), and 21 presentations of accepted papers. The conference was preceded by an informal Workshop on November 10, 1998. The Program Committee (PC) received 35 submissions. Each paper was sent to three referees, who were selected on the basis of their expert knowledge. Twelve papers were accepted immediately, 12 papers were not accepted, and 11 papers were returned to the authors with the request to improve them, and with the statement that they would be refereed again. Finally, with the help of many referees (see the end of this preface), the PC accepted 21 papers for presentation and publication.

Originally, we tried to sequence the contributions in some logical order, such as: from mathematical games via computer science to cognitive sciences, but we failed. Neither did the listing of the contents as mentioned above solve the problem of ordering the papers. In a way it is a fortunate coincidence that such an order could not be established, since it shows that the topic of computers and games has an interdisciplinary nature. Nevertheless, to structure the book to some extent we distinguish, somewhat arbitrarily, between four sections: (1) Search and Strategies, (2) Learning and Pattern Acquisition, (3) Theory, and (4) Go, Tsume Shogi, and Heian Shogi.

Search and Strategies

In the proceedings of this conference, the first set of six contributions deals with search and strategies. The editors believe that search is an important factor when trying to solve simple games or to play complex games. Although this is disputable for the game of Go, it certainly is true for chess-like games. Moreover, any strategy defined as a combination of straightforward movement, indirect approaches, and prophylaxis, is based on search and knowledge. The nature of a game determines which factor is predominant.

The first paper by Junghanns and Schaeffer, titled: *Relevance Cuts: Localizing the Search*, deals with single-agent search. The authors apply their new pruning technique on Sokoban. The idea is to use the influence of a move as a measure of relevance. Hence, they distinguish between local (relevant) moves and non-local (not relevant) moves, with respect to the sequence of moves leading to the current state. The new pruning technique uses the m previous moves to decide if a move is relevant in the current context; if not, the move must be cut off. The application of the technique on a 90-problem test set using search, limited to 20 million nodes, leads to 44 solutions. So, much more research is needed to solve all 90 problems.

The contribution by Björnsson and Marsland, titled: *Multi-Cut Pruning in Alpha-Beta Search*, examines the benefits of investing additional search effort at cut-nodes by expanding other move alternatives as well. Their results when applied to the game of chess show a strong correlation between the number of promising move alternatives at cut-nodes and an emerging new principal variation. This correlation can also be exploited otherwise. Hence, there is still a great deal of research to be done on other innovative methods based on investigating other move options.

Breuker, Van den Herik, Uiterwijk, and Allis treat the well-known graph-history-interaction (GHI) problem. Their contribution, titled: *A Solution to the GHI Problem for Best-First Search*, introduces the notion of twin nodes, which makes it possible to distinguish nodes according to their history. The implementation of this idea, called BTA (Base-Twin Algorithm), is performed to proof-number search. Experimental results in the field of computer chess confirm the claim that the GHI problem has been solved for best-first search.

Under the heading: *Optimal Play against Best Defence: Complexity and Heuristics*, Frank and Basin investigate the best defence model of an imperfect information game. They prove that finding optimal strategies for such a model is NP-complete in the size of the game tree. The introduction of two new heuristics, viz. beta-reduction and iterative biasing, appears to work well. The general idea is that there is a reduction of non-locality due to the introduction of mutual relationship between the various choices at MAX nodes. The heuristics are applied to a Bridge problem set and actually outperform the human experts who produced the model solutions.

Gao, Iida, Uiterwijk, and Van den Herik present a generalization of OM search, called (D, d)-OM search. Their paper, titled: *A Speculative Strategy*, investigates whether it is worthwhile to deviate from the objectively best path when knowing that the opponent only searches to a depth d, whereas the player (e.g., the program) searches to a depth $D > d$. It is shown that a difference in search depth can be exploited by deliberately chosing a suboptimal move in order to gain a larger advantage than when playing the optimal move. Some experiments in the domain of Othello confirm the effectiveness of the proposed strategy.

In their paper: *An Adversarial Planning Approach to Go*, Willmott, Richardson, Bundy, and Levine propose an alternative to the usual procedure of searching a tree of possible move sequences combined with an evaluation function. They model the goals of the players and their strategies for achieving these goals. It implies searching the space of possible goal expansions, which is typically much smaller than the space of move sequences. They describe how adversarial hierarchical task network planning can provide a framework for goal-directed game playing. The program GOBI has been successfully tested on two test sets of Go problems taken from Yoshinori's four-volume series. It was observed that strengthening GOBI's defensive knowledge led to an improvement in attacking plans, and vice versa. This reflects the fact that the better opponent model is more likely to find refutations for poor attacking plans.

Learning and Pattern Acquisition

The second set of five contributions deals with learning and pattern acquisition. The techniques described are applied to the following games: Shogi, Othello, Tsume Go (twice), and Checkers.

The first paper of this set, by Beal and Smith, attempts to determine whether sensible values for Shogi pieces can be obtained in the same manner as for western chess pieces. Under the heading: *First Results from using Temporal Difference Learning in Shogi*, the authors arrive at values that perform well in matches against programs with handcrafted values. They stress the fact that the Shogi piece values were learnt from self-play without any domain-specific knowledge being supplied. It is remarkable to note that Shogi experts are traditionally reluctant to assign values to the pieces. The authors claim that the method is also applicable to learning an appropriate weight for positional evaluation terms in Shogi.

Even more advanced is the topic of learning features to be used in evaluation functions. This topic is treated by Buro in his paper *From Simple Features to Sophisticated Evaluation Functions*. He discusses a practical framework for the semi-automatic construction of evaluation functions for games. Based on a structured evaluation-function representation, a procedure for exploring the feature space is presented. So, new features are discovered in a computationally feasible way. Convincing experimental results for Othello are given and several theoretical issues are discussed.

In their paper: *A Two-Step Model of Pattern Acquisition: Application to Tsume-Go*, Kojima and Yoshikawa carry out a cognitive study. The first step is the pattern acquisition step, which uses only positive examples. The second step, the pattern refinement step, uses both positive and negative examples. The combination of positive and negative examples leads to precise conditions and also to a way of conflict resolution. Three distinct algorithms are introduced for the first step, and two for the second one. The domain of application is Tsume-Go (life and death problems). The performances of six conditions are compared. The best performance is achieved by a condition which gives 31% of the answers correctly. This result equals the achievement of a one-dan human player.

Sasaki, Sawada, and Yoshimura focus on Tsume-Go problems positioned on a 9×9 board which has a unique solution. Under the heading: *A Neural Network Program of Tsume-Go*, they describe a network with 543 neurons dealing with Kurosen-Shiroshi problems. The backpropagation method is applied and the performance of the network is roughly equivalent to a one-dan human player. The authors claim that their neural network can be used as a component of the strong Tsume-Go and Go programs.

Although the Checkers program CHINOOK (by Schaeffer *et al.*) has been crowned as the champion of man-machine contests, the game has not lost any of its attractiveness as a research domain. In their paper: *Distributed Decision Making in Checkers*, Giráldez and Borrajo use the game as a testing ground for techniques for distributed decision making and learning by Multi-Agent DEcision Systems (MADES). They propose a new architecture for knowledge-based systems dedicated to Checkers playing. MADES should learn how to combine individual decisions, in such a way that it outperforms programs without a priori knowledge of the quality of each model.

Theory

Theory is an outstanding tool for the verification of ideas. We admit that good ideas in the context of computers and games must be implementable, but if the implemented ideas contain unexpected errors, they give computers a bad reputation. So, the theoretical contributions constitute an important part of this book. We arranged five papers under this heading. They deal with solution trees, heap games, impartial games, complexity, and thermography.

Pijls and De Bruin show in their contribution: *Game Tree Algorithms and Solution Trees*, that the concept of solution tree is the basic idea underlying the minimax principle. They distinguish between two types of solution trees: max trees and min trees. Subsequently, they formulate a cut-off criterion in terms of solution trees, which eliminates nodes from the search without affecting the result. Moreover, they show that any algorithm actually constructs a superposition of a max and a min solution tree. At the end of their paper they discuss solution trees in relation to alphabeta, SSS*, and MT-SSS.

Fraenkel and Zusman analyse an extension of Wythoff's game and provide a polynomial-time strategy. Their contribution titled: *A New Heap Game*, deals with k heaps of tokens ($k \geq 3$). It is a two-player game with the following rules: a move is either taking a positive number of tokens from at most $k-1$ heaps, or removing the same positive number of tokens from all the k heaps. The authors remark that the Sprague-Grundy function g of a game provides a strategy for the sum of several games. They express their interest in computing the g-function for this new heap game, but state that they are unaware of the complexity of the problem.

The contribution: *Infinite Cyclic Impartial Games*, by Fraenkel and Rahat, treats the family of locally path-bounded digraphs, which is a class of infinite digraphs. The authors show that it is relatively easy to compute an optimal strategy for a combinatorial game on this particular class of graphs. Whenever possible, they achieve a win in a finite number of moves. This is done by proving that the Generalised Sprague-Grundy function is unique and has finite values on this class of graphs.

On the Complexity of Tsume-Go is the title of Crâşmaru's contribution. With the game of Go as a starting point, the author embarks upon an analysis of the concept of alive vs. dead, for which he proposes a mathematical model. Tsume-Go problems are investigated and it is shown that this kind of problem is NP-complete.

In *Extended Thermography for Multiple Kos in Go*, Spight discusses the concept thermography. Many Go positions give rise to combinatorial games. The mean value of the game corresponds to the count, and its temperature to the value of the play. Thermography determines the mean value and the temperature of a combinatorial game. Moreover, thermography has been generalized to include positions containing a single ko. Spight extends the notion of thermography even further, namely to include positions with multiple kos. He also introduces a method for pruning redundant branches of the game tree.

Go, Tsume Shogi, and Heian Shogi

The last set of five contributions deals with Go, Tsume Shogi, and Heian Shogi. All five papers provide relevant information on the games and put them in perspective.

Although the interest in Go research has increased considerably in the last decade, the playing strength of Go programs is still mediocre. Among the Go researchers, a feeling has emerged that developments in the world of chess also may crop up in the world of Go.

As a first step, Müller contributes to this feeling in his contribution: *Computer Go: a Research Agenda*. The author suggests that the obstacles to progress are posed by the current structure of the Go community and are at least as serious as the purely technical challenges. He introduces three proposals for large-scale Go projects, viz. (1) form teams funded by a large company (such as DEEP BLUE), (2) make public-domain source code available (such as GNU CHESS and CRAFTY), and (3) initiate as many university projects as possible. His main concern is to overcome the lack of critical human resources. Having seen the enthusiasm of the Go researchers at the CG'98, the editors believe that Go research has a bright future.

In Go, the position evaluation is very important, but also very complex. So far, no good evaluation functions have been developed. One of the major factors for the evaluation of a position is the strength of a group. Tajima and Sanechika describe a new method for estimating the strength of a group, in their paper: *Estimating the Possible Omission Number for Groups in Go by the Number of n-th Dame*. The authors have developed a simple method for making a rough estimation. They define a PON (Possible Omission Number) as a precise measure for the strength of groups. Using PON, their method calculates n-th dame (liberties). Experiments support the claim of the effectiveness of the method.

The way of using Go terms while playing Go depends on the player's skill. Not every player uses the same notion to indicate a certain board characteristic. Yoshikawa, Kojima, and Saito have performed extensive cognitive research in this area. They report on their research in the paper: *Relations between Skill and the Use of Terms - An Analysis of Protocols of the Game of Go.* Three experiments are described in full detail. Starting with a profound analysis of their results, the authors developed a hypothesis, which they call the iceberg model, implying that the bulk of knowledge is not known to human players. Since it is crucial to make the knowledge of how to evaluate a Go position explicitly available for computer programs, protocol analyses and the modelling of thought processes remain an important issue for future research.

Grimbergen provides a very readable overview of Tsume-Shogi programs, titled: *A Survey of Tsume-Shogi Programs using Variable-Depth Search.* Tsume-Shogi is the name for mating problems in Japanese chess. He discusses six different Tsume-Shogi programs. Difficult Tsume-Shogi problems have solution sequences which are longer than 20 plies. Hence, all programs have a variable search depth and use hashing techniques. The combination of transposition, domination, and simulation leads to strong programs that outperform human experts. The best program is able to solve Microcosmos, a Tsume-shogi problem with a solution sequence of 1525 plies.

Finally, in the contribution: *Retrograde Analysis of the KGK Endgame in Shogi: Its Implications for Ancient Heian Shogi*, Iida, Yoshimura, Morita, and Uiterwijk examine the evolutionary changes that have occurred in the game of Shogi. They go back to the ancient game of Heian Shogi and investigate the game results of the KGK endgame (King and Gold vs. King) on $N \times N$ boards. Since Heian Shogi is only briefly described in the literature, the authors must guess which rules were applicable under which circumstances. The paper focuses on a logical interpretation of the change of rules at the time that the 8×8 board was replaced by a 9×9 board. Moreover, the authors demonstrate that the 10×10 board is the largest $N \times N$ board on which the KGK endgame is a deterministic win (of course, with the exception of trivially drawn cases in which the Gold can be captured). Future research will focus on the relation between the given analysis of the KGK endgames and the reuse rule of captured pieces in modern Shogi.

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H. Jaap van den Herik
Maastricht, The Netherlands

Hiroyuki Iida
Hamamatsu, Japan

December 1, 1998

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CG'98 is organized by many persons and organizations. Below we have listed them by function and by support.

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