Lecture Notes in Computer Science 6515

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

Computers and Games

7th International Conference, CG 2010
Kanazawa, Japan, September 24-26, 2010
Revised Selected Papers

Springer

Volume Editors

H. Jaap van den Herik
Aske Plaat
Tilburg University
Tilburg Center for Cognition and Communication (TiCC)
P.O. Box 90153, 5000LE Tilburg, The Netherlands
E-mail: {h.j.vdnherik,a.plaat}@uvt.nl

Hiroyuki Iida
Japan Advanced Institute of Science and Technology
Research Unit for Computers and Games
1-1, Asahidai, Nomi, Ishikawa, 923-1292, Japan
E-mail: iida@jaist.ac.jp

Library of Congress Control Number: 2010941277

CR Subject Classification (1998): I.2, F.1, C.2, F.2, H.4, G.2

LNCS Sublibrary: SL 1 – Theoretical Computer Science and General Issues

ISSN 0302-9743
ISBN-10 3-642-17927-4 Springer Berlin Heidelberg New York
ISBN-13 978-3-642-17927-3 Springer Berlin Heidelberg New York

springer.com

Printed in Germany

Typesetting: Camera-ready by author, data conversion by Scientific Publishing Services, Chennai, India
Printed on acid-free paper 06/3180

Preface

This book contains the papers of the 7th Computer and Games Conference (CG 2010) held in Kanazawa, Japan. The conference took place during September 24–26, 2010 in conjunction with the 15^{th} Computer Olympiad and the 17^{th} World Computer Chess Championship.

The Computer and Games conference series is a major international forum for researchers and developers interested in all aspects of artificial intelligence and computer game playing. The contributions to the Kanazawa conference showed considerable progress in the development and implementation of new ideas. Without any doubt, the quality of the papers of this conference coincides with the increase of playing strength as appeared in many games. Earlier conferences took place in Tsukuba, Japan (1998), Hamamatsu, Japan (2000), Edmonton, Canada (2002), Ramat-Gan, Israel (2004), Turin, Italy (2006), and Beijing, China (2008).

The Program Committee (PC) was pleased to see that many submissions focused on the development of new ideas and tools to increase the playing strength. The ideas that supported this aim led to high-quality papers (e.g., for Go, Hex, and Connect6). Each paper was sent to three referees. If conflicting views on a paper were reported, the referees themselves arrived at a proper decision for the papers. With the help of many referees (see after the preface), the PC accepted 24 papers for presentation at the conference and publication in these proceedings.

The above-mentioned set of 24 papers covers a wide range of topics and a wide range of computer games. For the topics, we mention: Monte-Carlo Tree Search, Proof-Number Search, UCT Algorithm, Scalability, Parallelization, Opening Books, Knowledge Abstraction, Solving Games, Consultation of Players, Multi-Player Games, Extraversion, and Combinatorial Game Theory.

The number of games is also large owing to the fact that some papers discussed more than one game. In total 15 different games are dealt with. Twelve of them are played in practice by human players, namely, Chinese Checkers, Chinese Chess, Connect6, Go 9x9, Go 13x13, and Go 19x19, Havannah, Lines of Action, Pickomino, Shogi, Surakarta, and Yahtzee. Moreover, there are specialties, such as a computer puzzle with human assessment, Maze Design; two theoretical games, Synchronized Domineering and Focus; and one video game. Next to these games the topic of Multi-Player Game is investigated.

We hope that the readers will enjoy the research efforts performed by the authors. Below we provide a brief explanation of the order in which the 24 contributions are published. It is followed by a brief characterization of each contribution. Our brief explanation for the order chosen is as follows. We start with two single-issued contributions that provide an excellent insight into the intricacies in the domains involved: Hex and Connect6. The authors of "Solving

Hex: Beyond Humans" received the Best Paper Award of CG2010. Then, in connection to Connect6, we elaborate on Proof Number Search and offer applications of Evaluation-Function-based Proof Number Search in the games Lines of Action and Surakarta. Thereafter we focus on UCT, MCTS, and RAVE (eight contributions). Two contributions on opening books follow the MCTS approaches. Subsequently, three papers focus on consultation algorithms for Shogi, Go 9x9, and Go 19x19. As a sequel, four papers on different aspects of game research provide magnificent insight into the richness of our community's investigations. The current development toward multi-player games is exhibited by three contributions. The book is completed by a cognitive science paper on extraversion.

"Solving Hex: Beyond Humans" is authored by Broderick Arneson, Ryan Hayward, and Philip Henderson. This contribution discusses improvements made to their Hex solver, which now surpasses humans in strength. Significant features include pruning new kinds of inferior moves, adding captured-cell reasoning to the connection detector, and using Focussed Depth First Proof Number Search, a new DFPNS variant. FDFPNS uses an evaluation function to restrict the search to a gradually opening window of moves. With a time limit of 25 days per position, the solver can solve more than half of the 81 9×9 openings. With a time limit of 1 minute, the solver can solve most 40-stone 11×11 positions.

The contribution received the Best Paper Award of CG2010. In the series of CG conferences, it was the first time that such an award was assigned.

"Job-Level Proof-Number Search for Connect6" by I-Chen Wu, Hung-Hsuan Lin, Ping-Hung Lin, Der-Johng Sun, Yi-Chih Chan, and Bo-Ting Chen presents a new idea, in which the PN search tree is maintained by a process (the client), and the search-tree nodes are evaluated or expanded by heavy-weight jobs, which can be executed remotely in a parallel system. NCTU6 and NCTU6-Verifier are used as the heavy-weight jobs. JL-PN search is used to solve several Connect6 positions including opening positions on desktop grids. For some of these openings (such as the Mickey Mouse Opening and the Straight Opening), so far no human expert had been able to find a winning strategy. The experiments show that speedups for solving the test positions are roughly linear, fluctuating from sublinear to superlinear.

"Evaluation-Function-Based Proof-Number Search" is introduced by Mark Winands and Maarten Schadd as a new framework for initializing the proof and disproof numbers of a leaf node by a heuristic evaluation function. They also discuss the second-level variant EF-PN^2. Experiments in Lines of Action and Surakarta show that compared to PN and PN^2 (which use mobility to initialize the proof and disproof number), EF-PN and EF-PN^2 take between 45% and 85% less time for solving positions. The authors conclude that EF-PN and EF-PN^2 reduce the search space considerably.

"On the Scalability of Parallel UCT" is written by Richard Segal. The paper investigates the limits of parallel MCTS in order to understand why distributed parallelism has proven so difficult. It attempts to prove the way toward future distributed algorithms with better scaling. The limitation of the existing algorithms became evident in the 2009 Computer Olympiad where Zen using a single four-core machine defeated both Fuego with ten eight-core machines, and MoGo with 20 32-core machines. The author first analyzes the single-threaded scaling of Fuego and finds that there is an upper bound on the play-quality improvements which can come from additional search. Then he analyzes the scaling of an idealized N-core shared memory machine to determine the maximum amount of parallelism supported by MCTS. He shows that parallel speedup critically depends on how much time is given to each player. This relationship is used to predict parallel scaling for time scales beyond what can be empirically evaluated due to the immense computation required. The results show that MCTS can scale nearly perfectly to at least 64 threads when combined with virtual loss, but without virtual loss scaling is limited to just eight threads. Interesting is Segal's final finding that for competition time controls scaling to thousands of threads is impossible, not necessarily due to MCTS not scaling, but because high levels of parallelism can start to bump up against the upper performance bound of Fuego itself.

"Scalability and Parallelization of Monte-Carlo Tree Search" by Amine Bourki, Guillaume Chaslot, Matthieu Coulm, Vincent Danjean, Hassen Doghmen, Jean-Baptiste Hoock, Thomas Hérault, Arpad Rimmel, Fabien Teytaud, Olivier Teytaud, Paul Vayssière, and Ziqin Yu focuses on the Go program MoGo and the Havannah program Shakti. The authors analyze its scalability, and in particular its limitations and the implications, in terms of parallelization. They use multicore machines and message-passing machines. The scalability of MCTS has often been emphasized as a strength of these methods. However, it is shown that when the computation time is huge, doubling it has a smaller effect than when it is small. The results given concur with those by Hideki Kato. Several parallelizations of MCTS on clusters have been proposed. As a case in point the authors mention that slow tree parallelization wins with a probability of 94% against very slow root parallelization in 19x19 Go. Many more interesting comparisons are given. The state of the art is well described.

"Biasing Monte-Carlo Simulations Through RAVE Values" by Arpad Rimmel, Fabien Teytaud, and Olivier Teytaud emphasizes that the MCTS performance heavily depends on the Monte-Carlo part. The authors propose a generic way of improving the Monte-Carlo simulation by using RAVE values, which already strongly improved the tree part of the algorithm. They substantially prove the generality and efficiency in practice by showing improvements for two different applications: the game of Havannah and the game of Go. Finally, they voice that the next step in improving the MCTS algorithm is finding an efficient way of modifying Monte-Carlo simulations depending on the context.

"Computational Experiments with the RAVE Heuristic" by David Tom and Martin Müller focuses on situations where the RAVE (Rapid Action Value Estimation) heuristic misleads the search. In such cases pure UCT search can find the correct solutions. However, sometimes a move has to be played as a first move in a series of moves, and when this does not happen, it is disastrous.

The behavior of the RAVE heuristic is studied in two games, SOS (Sum of Switches) and 9x9 Go. The authors show that there are great differences between SOS and Go. In SOS, they achieved some practical results by introducing false RAVE updates, but this method fails at Go. Other methods applied to Go do not achieve suitable results. Yet, the attempts are sufficiently interesting to encourage other researchers to find better ways of dealing with RAVE exceptions.

"Monte-Carlo Simulation Balancing in Practice" by Shih-Chieh Huang, Rémi Coulom, and Shun-Shii Lin describes a new technique to tune parameters of a playout policy for a Monte-Carlo game-playing program. A state-of-the-art program, Erica, learned an improved playout policy on the 9x9 board, without requiring any external expert to provide position evaluations. The evaluations were collected by letting the program analyze positions by itself. The results demonstrate that Simulation Balancing (SB) gives the program an improved playing strength when compared to the program Erica with the minorization-maximization algorithm. SB improved the winning rate from 69% to 78% against Fuego 0.4. Many improvements seem possible. For instance, to improve the quality of evaluations by cross-checking values with a variety of different programs, or by incorporating positions evaluated by a human expert.

"Score-Bounded Monte-Carlo Tree Search" is written by Tristan Cazenave and Abdallah Saffidine. The authors aim at improving the MCTS solver for cases in which a game had more than two outcomes (e.g., win, loss, draw). Bounds on the possible scores of a node are taken into account in order to select the node to be explored. The integration of score bounds (pessimistic and optimistic) is first introduced by Hans Berliner in his B* algorithm. The authors use the bounds for guiding the node value bias. They apply the new approach on Seki and Semeai positions which are notoriously hard for MCTS. The results of three slightly different algorithms are given. Moreover, the score-bounded MCTS is applied to Connect Four. Small boards could be solved easily with the new approach.

"Improving Monte-Carlo Tree Search in Havannah" is authored by Richard Lorentz. Five techniques are investigated to improve the basic MCTS algorithm: (1) improve the random playouts, (2) recognize forced wins, losses, and draws, (3) initialize total playout count and win count adequately, (4) improve progressive widening, and (5) improve the killer RAVE heuristic. The author demonstrates that at normal time controls of approximately 30 seconds per move Wanderer can make quite strong moves on boards with a basis size of four and five, and play a reasonable game on boards with a basis size of six or seven. At larger time controls these performances are considerably improved.

"Node Expansion Operators for the UCT Algorithm" by Takayuki Yajima, Tsuyoshi Hashimoto, Toshiki Matsui, Junichi Hashimoto, and Kristian Spoerer investigates the advantages of postponing node expansions. The authors show that delaying expansion according to the number of the siblings delivers a gain of more than 92% when compared to normal expansions. The well-known expansion operators are: (1) all ends, (2) visit count, and (3) siblings2. In the paper, three new operators are proposed: (4) transition probability, (5) salient winning rate, and (6) visit count estimate. Experimental results show that all advanced operators significantly improve the UCT performance when compared to the basic delaying expansion operators.

"Monte-Carlo Opening Books for Amazons" by Julien Kloetzer points to a remarkable discrepancy, namely, that Monte-Carlo Tree-Search programs cannot efficiently use opening books that are created by algorithms based on minimax. To overcome this issue, the author proposes an MCTS-based technique, Meta-MCTS, to create such opening books. The method requires additional tuning to arrive at the best opening book possible. All in all, promising results are reported for the game of Amazons. In the end, it appears that UCT is even better than Meta-MCTS, with an evaluation function that is more appropriate to create the best opening books for the MCTS-based Amazons program.

"A Principled Method for Exploiting Opening Books" by Romaric Gaudel, Jean-Baptiste Hoock, Julien Pérez, Nataliya Sokolovska, and Olivier Teytaud describes an improvement of generating and storing games for the construction of an opening book. However, their results are not very robust, as (1) opening books are definitely not transitive, making the non-regression testing extremely difficult, (2) different time settings lead to opposite conclusions, because a good opening for a game with 10s per move on a single-core machine is quite different from a good opening for a game with 30s per move on a 32-core machine, and (3) some very bad moves sometimes still occur. The authors formalize the optimization of an opening book as a matrix game, compute the Nash equilibrium, and conclude that a naturally randomized opening book provides optimal performance (in the sense of Nash equilibria). Moreover, the authors can choose a distribution on their opening books so that the constructed random opening book has a significantly better performance than each of the deterministic opening books.

"A Human – Computer Team Experiment for 9x9 Go" by Darren Cook considers the move selection under very long thinking times and no restrictions on the selection procedure. Two intriguing questions are: (1) how much stronger can a human become as a 9x9 GO player by using computers and taking a large amount of thinking time? and (2) what is the strongest opening move on a 9x9 board? The gathering of experimental evidence started in 2002. The experiment has been solely conducted on Little Golem. The research emphasis is on (1) opening book, (2) move selection and validation, and (3) unbalanced quiescence search. The test program is called "sm9." Since late 2008 it has been the strongest 9x9 Go player on the Little Golem site. It won the 17th, 19th, 20th, and 21st championships, with 2nd place in the 18th and 22nd. Moreover, the circumstantial evidence is that the 5-5 (tengen) opening is either the strongest opening or the joint strongest opening.

"Consultation Algorithm for Computer Shogi: Move Decisions by Majority" by Takuya Obata, Takuya Sugiyama, Kunihito Hoki, and Takeshi Ito describes an algorithm that consists of a combination of existing Shogi programs to investigate the winning rate of moves. The authors believe that the consultation algorithm has three remarkable advantages: (1) it can use a loosely coupled environment, (2) it is effective for many programs, and (3) it shows a clear improvement in the quality of searches. Two methods of using the consultation algorithm are reported: a consultation system and a council system. Both algorithms are successful. The consultation algorithm improves the performances of computer Shogi engines. The council system (consisting of three well-known Shogi programs) plays better games than any of the three programs individually.

"Optimistic Selection Rule better than Majority Voting System" by Takuya Sugiyama, Takuya Obata, Kunihito Hoki, and Takeshi Ito presents a new strategy of move selection based on the search values of a number of players. The move decision is made by selecting one player from all M players. Each move is selected by referring to the evaluation value of the tree search of each player. The authors show that the optimistic selection rule, which selects the player that yields the highest evaluation value, outperforms the majority voting system. Here, we remark that this paper has been written by the same authors as the previous one. The conclusion of this paper is that by grouping 16 or more computer players, the winning rates of the strongest Shogi programs increase from 50 to 60% or even higher.

"Knowledge Abstraction in Chinese Chess Endgame Databases" by Bo-Nian Chen, Pangfeng Liu, Shun-Chin Hsu, and Tsan-sheng Hsu deals with the size of the Chinese chess endgame databases. A novel knowledge abstraction strategy is proposed to compress the endgame databases. The goal is to obtain succinct knowledge for practical endgames. A specialized goal-oriented search method is described. It is applied on the KRKNMM endgame. The method focuses on finding the critical configurations for winnable positions. The obtained critical configurations can also act as an intelligent tutoring system that teaches human players how to draw and win an endgame.

"Rook Jumping Maze Design Considerations" by Todd Neller, Adrian Fisher, Munyaradzi Choga, Samir Lalvani, and Kyle McCarty defines several maze features to be considered and assessed. The paper starts by defining the Rook Jumping Maze, then provides a historical perspective, and subsequently describes a generation method for such mazes. When applying stochastic local search algorithms to maze design, most creative efforts concern the definition of an objective function that rates maze quality. The authors describe their own preferred design choices, make design process observations, and discuss the applicability of their consideration to variations of the Real Jumping Maze.

"A Markovian Process Modeling for Pickomino" by Stéphane Cardon, Nathalie Chetcuti-Sperandio, Fabien Delorme, and Sylvain Lagrue deals with a non-deterministic game based on dice rolls and on the "stop or continue" principle. Each player has to make decisions on (1) which dice to keep and on (2) continuing or stopping depending on the previous rolls and on the available resources. The formal framework is based on Markov Decision Processes (MDPs). Here the main problems are (1) to determine the set of states, and (2) to compute the transition probabilities. The authors propose original solutions to both problems: (1) a compact representation of states, and (2) a construction method to compute the probability distribution, based on the partitioning of the space of roll results depending on a set of marked values. Finally, they show the efficiency of the proposed method. The result is impressive, in particular when compared with the performances of previous programs.

"New Solutions for Synchronized Domineering" by Sahil Bahri and Clyde Kruskal describes a technique of analysis based on a first-player relaxation accompanied by a splitting strategy. The technique is applied to Synchronized Domineering, a game invented by Cincotti and Iida. The authors obtained complete results for the board sizes 3xn, 5xn, 7xn, and 9xn (for n sufficiently large), and partial results for board sizes 2xn, 4xn, and 6xn. The authors believe that a variant of their technique may confirm the existing results for Standard Domineering.

"The Lattice Structure of Three-Player Games" by Alessandro Cincotti contributes considerably to the few results known so far about the overall structure of three-player games. The author proves (1) that three-player games born by day d form a distribution lattice with respect to every partial order relation, but also proves (2) that the collection of all finite three-player games does not form a lattice.

"Enhancements for Multi-Player Monte-Carlo Tree Search" by Pim Nijssen and Mark Winands proposes two enhancements for MCTS in multi-player games: (1) Progressive History and (2) Multi-Player Monte-Carlo Tree Search Solver (MP-MCTS-Solver). The authors analyze the performance of the enhancements in two different multi-player games: Focus and Chinese Checkers. Based on the experimental results they conclude that Progressive History is a considerable improvement in both games, and the MP-MCTS-Solver, using the standard update rule, is a genuine improvement in Focus.

"Nearly Optimal Computer Play in Multi-Player Yahtzee" by Jakub Pawlewicz presents the first in-depth analysis of this game. For the single-player version, optimal computer strategies both for maximizing the expected average score and for maximizing the probability of beating a particular score are already known. The author proposes the implementation of an optimal strategy for the single-player version that significantly speed up the calculations. Moreover, it is shown that developing an optimal strategy for more players is not possible with the use of the current technology. For the two-player game the size of the resources needed to solve the game has been calculated. Subsequently, software has been created that is able to perform all calculations. To approximate the optimal strategy, a heuristic strategy $EMP(\cdot)$ has been constructed. It uses distributions, a notion which was introduced for the speedup of the single-player version. The most surprising discovery is that the $EMP(\cdot)$ strategy performs "almost" as well as the optimal strategy. A carefully executed series of experiments arrives at losing 2.34 games more per 1,000 games by using the EMP(1) strategy instead of the optimal strategy. The author's conclusion reads: Yahtzee is highly a game of chance, and advantage of the optimal strategy is insignificant.

"Extraversion in Games" by Giel van Lankveld, Sonny Schreurs, Pieter Spronck, and Jaap van den Herik examines the human tendency of being sensitive to rewards. This often results in humans seeking socially rewarding situations. Extraversion plays a prominent part in the in-game behavior of a player. The in-game behavior can be decomposed in 20 different in-game elements. Two experiments are performed. Variation in behavior caused by extraversion is seen in 12 of the 20 elements.

This book would not have been produced without the help of many persons. In particular, we would like to mention the authors and the referees for their help. Moreover, the organizers of the three events in Kanazawa (see the beginning of this preface) have contributed substantially by bringing the researchers together. Without much emphasis, we recognize the work by the committees as essential for this publication.

We are grateful for the support by JAIST, ChessBase, Ishikawa Prefecture, TiCC (Tilburg University), Fujitsu, Komatsu, Hokkoku Bank, Gakken Education Publishing, I-O DATA, Tanaka & Shobundo Graphic Art, PFU, Matsusaki, NTTWEST and Foundation for JAIST, Hokuriku. They have made the events possible.

September 2010

H. Jaap van den Herik
Hiroyuki Iida
Aske Plaat

Organization

Executive Committee

Editors	H. Jaap van den Herik Hiroyuki Iida Aske Plaat
Program Co-chairs	H. Jaap van den Herik Hiroyuki Iida Aske Plaat

Organizing Committee

Hiroyuki Iida (Chair)
Setsuko Asakura
Johanna W. Hellemons
H. Jaap van den Herik
Aske Plaat

List of Sponsors

JAIST
ChessBase
Ishikawa Prefecture
TiCC, Tilburg University
Fujitsu
Komatsu
Hokkoku Bank
Gakken Education Publishing
I-O DATA
Tanaka & Shobundo Graphic Art
PFU
Matsusaki
NTTWEST
Foundation for JAIST, Hokuriku

Program Committee

The members of the Program Committee all acted as referees.

Ingo Althöfer
Yngvi Björnsson
Bruno Bouzy
Ivan Bratko
Tristan Cazenave
Guillaume Chaslot
Keh-Hsun Chen
Paolo Ciancarini
Rémi Coulom
Jeroen Donkers
Peter van Emde Boas
David Fotland
Aviezri Fraenkel
Reijer Grimbergen
Matej Guid
Michael Greenspan
Tsuyoshi Hashimoto
Guy Haworth
Ryan Hayward
Jaap van den Herik
Huang Hong
Tsan-Sheng Hsu
Hiroyuki Iida
Graham Kendall
Akihiro Kishimoto
Johan de Koning
Clyde Kruskal
Richard Lorentz
Ulf Lorenz
Martin Müller
Jakub Pawlewicz
Jacques Pitrat
Aske Plaat
Matthias Rauterberg
Aleksander Sadikov
Jonathan Schaeffer
Pieter Spronck
Nathan Sturtevant
Omid David Tabibi
Yoshimasa Tsuroka
Jos Uiterwijk
Erik van der Werf
Mark Winands
Xinhe Xu
Georgios Yannakakis
Jan van Zanten

The Computers and Games Books

The series of Computers and Games (CG) Conferences started in 1998as a complement to the well-known series of conferences in Advances in Computer Chess (ACC). Since 1998, seven CG conferences have been held. Below we list the conference places and dates together with the Springer publication (LNCS series no.).

Tsukuba, Japan (1998, November)
Proceedings of the First Computers and Games Conference (CG98)
Eds. H.J. van den Herik and H. Iida
LNCS 1558, 335 pages.

Hamamatsu, Japan (2000, October)
Proceedings of the Second Computers and Games Conference (CG2000)
Eds. T.A. Marsland and I. Frank
LNCS 2063, 442 pages.

Edmonton, Canada (2002, July)
Proceedings of the Third Computers and Games Conference (CG2002)
Eds. J. Schaeffer, M. Müller, and Y. Björnsson
LNCS 2883, 431 pages.

Ramat-Gan, Israel (2004, July)
Proceedings of the 4th Computers and Games Conference (CG2004)
Eds. H.J. van den Herik, Y. Björnsson, and N.S. Netanyahu
LNCS 3846, 404 pages.

Turin, Italy (2006, May)
Proceedings of the 5th Computers and Games Conference (CG2006)
Eds. H.J. van den Herik, P. Ciancarini, and H.H.L.M. Donkers
LNCS 4630, 283 pages.

Beijing, China (2008, September)
Proceedings of the 6th Computers and Games Conference (CG2008)
Eds. H. J. van den Herik, X. Xu, Z. Ma, and M.H.M. Winands
LNCS 5131, 275 pages.

Kanazawa, Japan (2010 September)
Proceedings of the 7th Computers and Games Conference (CG2010)
Eds. H. J. van den Herik, H. Iida, and A. Plaat
LNCS 6515, 279 pages.

Table of Contents