Contents

1 Introduction 1

1.1 Motivation 1

1.2 Contributions of This Thesis 2

1.3 Thesis Structure 4

2 Background and Related Work 5

2.1 The Game of Go 5

2.1.1 Rules and Terms 5

2.1.2 Complexity 11

2.2 Game Tree Search 12

2.2.1 Terminology 13

2.2.2 Traditional Game Tree Search Algorithms 14

2.3 Computer Go 16

2.3.1 History 16

2.3.2 Computer Go as Fertile Ground for Monte Carlo Tree Search 17

3 Monte-Carlo Tree Search 19

3.1 Terminology 19

3.2 Basic Algorithmic Framework 21

3.2.1 Bandit Based In-Tree Policy π_{UCT} 23

3.2.2 First Play Policy 26

3.2.3 Handling of Transpositions 27

3.3 Enhancements to Basic MCTS 28

3.3.1 RAVE: Rapid Action Value Estimate 28

3.3.2 PB: Progressive Bias 30

3.3.3 PW: Progressive Widening 31

3.4 Playout Policies π_p 31

3.4.1 Random Policies 32

3.4.2 Handcrafted Policies 33

3.4.3 Machine Learning Based Policy Design 33

Bibliografische Informationen
http://d-nb.info/1053529392

digitalisiert durch DEUTSCHE NATIONAL BIBLIOTHEK

4 Parallel Monte-Carlo Tree Search 35
4.1 Related Work 36
4.1.1 Parallelization for Shared and Distributed Memory 37
4.1.2 Parallelization for Accelerator Hardware 40
4.1.3 General Techniques for Scalability Improvements 41
4.2 Proposed Parallelization: Distributed-Tree-Parallelization 42
4.2.1 Distributed Simulations 43
4.2.2 Tree Node Duplication and Synchronization 44
4.2.3 Distributed Transposition Table 46
4.2.4 Implementation Details 49
4.2.5 Load Balancing 51
4.2.6 Broadcast Nodes 53
4.3 Experimental Results 56
4.3.1 Setup 56
4.3.2 Performance and Scalability 57
4.3.3 Overhead Distributions 68
4.3.4 Effect of Parameters 71
4.3.5 Discussion of the Comparison of MCTS Parallelizations . . 73
4.4 Chapter Conclusion 74

5 Move Prediction in Computer Go 77
5.1 Background 78
5.1.1 Terminology 78
5.1.2 Probability Models for Paired Comparison 79
5.1.3 Bayes Theorem 80
5.1.4 State-Action Abstraction with Patterns in Computer Go . 81
5.2 Bayesian Move Prediction Systems 83
5.2.1 Minorization-Maximization 85
5.2.2 Bayesian Ranking Model 86
5.2.3 Bayesian Approximation Ranking 88
5.2.4 Probabilistic Ranking 89
5.3 Experimental Results 91
5.3.1 Setup 91
5.3.2 Results 91
5.4 Chapter Conclusion 97

6 MCTS Driven Position Analysis 99
6.1 Motivation 99
6.2 Background and Related Work 100
6.3 MC-Criticality Based Semeai Detection 104
6.3.1 Notations 104
6.3.2 Clustering 105

6.3.3 Player-wise, Intersection-wise and Cluster-wise MC-Criticality 109
6.3.4 Detecting and Identifying Local Fights 112
6.3.5 Experiments 113
6.4 Chapter Conclusion 118

7 Summary and Outlook 119
7.1 Contributions 119
7.2 Conclusions and Lessons Learned 120
7.3 Future Directions 122

Bibliography 125