

Contents

1	Introduction	1
1.1	Background	1
1.2	Problem Statement and Research Questions	3
1.3	Research Methodology	4
1.4	Structure of the Thesis	4
2	Solving Game Positions and Search Indicators	5
2.1	Solving Game Positions	5
2.1.1	AND/OR Tree	6
2.1.2	Basic Search Algorithms	8
2.2	AND/OR Tree Search using Proof Numbers	9
2.2.1	Proof Number Search	9
2.2.2	Related Algorithms	10
2.2.3	Depth-First Proof-Number Search	13
2.2.4	Derivation of Depth-First Proof-Number Search	14
2.3	New Perspective of Conspiracy Numbers	17
2.3.1	Conspiracy Numbers	18
2.3.2	Conspiracy Number Search	20
2.3.3	Analyzing Games with CNS	22
2.4	Concluding Remarks	25
3	Deep Proof-Number Search	27
3.1	The Seesaw Effect	28
3.2	Deep PN	30
3.2.1	The Basic Idea of DeepPN	30
3.2.2	Performance with Othello	33
3.2.3	Performance with Hex	35
3.2.4	Discussion	37
3.2.5	Focusing on the Depth and R	38
3.2.6	Seesaw Effect and R	39
3.3	Conclusion and Future works	42
4	Aesthetics and Search Indicators	43
4.1	Aesthetic of Mating Problems	44
4.1.1	Mating Problems and Assessment Factors	44
4.1.2	Experiments using Kanju-Award Problems	45
4.1.3	Experiments using Tsume-shogi Competition	46
4.1.4	Comparison with Previous Works	50

4.1.5	Discussion	52
4.2	Concluding Remarks	53
5	Conclusion	55
5.1	Summary	55
5.2	Answers to RQ1 and RQ2	56
5.3	Answer to Problem Statement	56
5.4	Future Work	56
A	Additional Experiments with DeepPN	67
A.1	Othello Experiments using WZebra	67
A.2	DeepPN with Previous Works	68