

Contents

Foreword	xvii
Acknowledgement	xix
Abstract	xxi
1 Introduction	1
1.1 Motivation	2
1.2 Scope and Orientation	3
1.3 Contributions	3
1.4 Thesis Structure	6
1.5 Abbreviations	6
I Background	9
2 Constraint Satisfaction	11
2.1 What is a Constraint Satisfaction Problem?	11
2.2 Examples of <i>CSPs</i>	12
2.2.1 N-queens Problem	13
2.2.2 Graph-coloring Problem	13
2.3 Algorithms for Solving <i>CSPs</i>	14
2.3.1 Complete Search	15
2.3.2 Incomplete Search	18
2.3.3 Inference Algorithms	20
2.4 Summary	24
3 Distributed Constraint Satisfaction	25
3.1 What is a Distributed Constraint Satisfaction Problem?	25
3.2 Example of <i>DisCSPs</i>	26
3.2.1 Distributed n-queens Problem	27
3.2.2 Distributed n-pieces m-chessboard Problem	27
3.2.3 Distributed Sensor-Mobile Problem	27
3.3 Algorithms for Solving <i>DisCSP</i>	29
3.3.1 Synchronous Search	30

3.3.2	Asynchronous Search	31
3.4	Comparing Algorithmic Performance	35
3.4.1	Random Binary <i>DisCSP</i>	35
3.5	Simulator	36
3.6	Summary	37
II	Approaches	39
4	Synchronous Backtracking	41
4.1	Synchronous Backtracking	41
4.2	Synchronous <i>CBJ</i>	42
4.3	Heuristics for Dynamic Variable and Value Ordering	43
4.4	Experimental Results	44
4.4.1	Distributed n -queens Problem	44
4.4.2	Random Binary <i>DisCSP</i>	46
4.5	Summary	46
5	Asynchronous Backtracking	47
5.1	Asynchronous Backtracking Algorithm	47
5.2	The Unifying Kernel	49
5.2.1	The <i>ABT_{kernel}</i> algorithm	50
5.2.2	Theoretical Results	52
5.3	The <i>ABT</i> Family	54
5.3.1	<i>ABT_{all}</i> : Adding links as preprocessing	55
5.3.2	<i>ABT</i> : Adding links during search	55
5.3.3	<i>ABT_{temp}</i> : Adding temporary links	57
5.3.4	<i>ABT_{not}</i> : No links any more	57
5.3.5	Discussion	58
5.4	Implementation Details	58
5.4.1	Selecting the Best Nogood	59
5.5	Experimental Results	60
5.6	Summary	62
6	Synchronous versus Asynchronous Backtracking	63
6.1	Asynchrony in <i>ABT</i>	64
6.2	The <i>ABT</i> Hybrid Algorithm	64
6.3	<i>ABT_{hyb}</i> : Theoretical Results	66
6.3.1	Correctness, Completeness and Termination	66
6.3.2	Comparison with <i>ABT</i>	68
6.4	Processing Messages by Packets	71
6.5	Experimental Results	72
6.5.1	Distributed n -queens Problem	72
6.5.2	Random Binary <i>DisCSP</i>	75
6.6	Related Work	76
6.7	Summary	76

7 Non-binary <i>DisCSP</i>	79
7.1 Related Work	79
7.2 Asynchronous Backtracking	80
7.2.1 Non-binary <i>ABT</i>	80
7.2.2 Non-binary <i>ABT_{not}</i>	81
7.2.3 Adding Constraints Projections	81
7.2.4 Example	82
7.3 Synchronous Backtracking	84
7.3.1 Non-binary <i>SCBJ</i>	84
7.3.2 Non-binary <i>SCBJ</i> with Projections	84
7.4 Experimental Results	85
7.5 Summary	89
III Privacy	91
8 Privacy in <i>DisCSP</i>	93
8.1 Domain Privacy	94
8.2 Assignment Privacy	95
8.2.1 Distributed Forward Checking	95
8.2.2 <i>DisFC</i> : Theoretical Results	97
8.3 Constraint Privacy	98
8.3.1 Partially Known Constraint Model	99
8.3.2 Two-Phase Strategy for <i>PKC</i>	100
8.3.3 Single Phase Strategy for <i>PKC</i>	103
8.3.4 <i>DisFC₂</i> / <i>DisFC₁</i> : Theoretical Results	106
8.3.5 An Example	108
8.3.6 Evaluating Privacy Loss of Constraints	109
8.4 Experimental Results	112
8.4.1 <i>ABT</i> , <i>ABT₂</i> and <i>ABT₁</i>	113
8.4.2 <i>DisFC₂</i> and <i>DisFC₁</i>	115
8.5 Summary	117
9 Enhancing Privacy with Lies	119
9.1 The Strategy of False Domains in <i>DisFC₁</i> / <i>DisFC₂</i>	120
9.2 The <i>DisFC_{lies}</i> Algorithm	120
9.3 Theoretical Results	122
9.4 Privacy Improvements of <i>DisFC_{lies}</i>	123
9.5 Experimental Results	124
9.6 Summary	126
IV Applications	127
10 Distributed Meeting Scheduling	129
10.1 What is the Meeting Scheduling Problem?	130

10.1.1	The Distributed Meeting Scheduling Problem	130
10.2	Privacy on <i>DisMS</i> Algorithms	132
10.2.1	The <i>RR</i> Algorithm	133
10.2.2	<i>SCBJ</i>	135
10.2.3	<i>ABT</i>	135
10.3	Experimental Results	136
10.4	Related Work	140
10.5	Summary	141
11	Distributed Stable Matching Problems	143
11.1	What is the Stable Marriage Problem?	144
11.2	A Constraint Formulation	146
11.3	Generalizations of the Stable Marriage	147
11.4	The Distributed Stable Marriage Problem	149
11.4.1	From Centralized to Distributed Algorithms	150
11.4.2	Distributed Constraint Formulation	151
11.5	The Stable Roommates Problem	156
11.5.1	Algorithms for a Distributed Setting	156
11.6	Experimental Results	159
11.7	Summary	161
V	Conclusions and Appendixes	163
12	Conclusions	165
12.1	Conclusions	165
12.2	Further Research	168
A	Specialized Algorithms for Stable Matching Problems	169