

Contents

Abstract	xi
Resumen	xiii
Resum	xv
1 Introduction	1
1.1 Background	2
1.1.1 Superscalar Processors	2
1.1.2 Multithreaded Processors	4
1.1.3 Multicore Processors	5
1.2 Motivation and Challenges	6
1.2.1 Challenges in Superscalar Processors	7
1.2.2 Challenges in Multithreaded Processors	7
1.2.3 Challenges in Multicore Processors	8
1.3 Objectives of the Thesis	9
1.4 Contributions of the Thesis	9
1.5 Thesis Outline	11
2 The Multi2Sim Simulation Framework	13
2.1 Overview	14
2.1.1 Existing Simulation Tools	14
2.1.2 The Multi2Sim Project	15
2.2 The Superscalar Pipeline Model	16
2.2.1 Branch Prediction	16
2.2.2 Register Renaming	19
2.2.3 Pipeline Stages	21
2.3 Support for Parallel Architectures	24
2.3.1 Multithreading	26
2.3.2 Multicore Architectures	27
2.4 The Memory Hierarchy	27

2.4.1	Memory Hierarchy Configuration	27
2.4.2	Cache Coherence	30
2.5	Experimental Environment	31
2.5.1	Multi2Sim Extensions	31
2.5.2	Benchmarks and Methodology	32
2.5.3	Performance Metrics	34
2.6	Summary	35
3	The Superscalar Validation Buffer Architecture	37
3.1	Proposed Architecture	38
3.1.1	Register Reclamation	40
3.1.2	Recovery Mechanism	42
3.1.3	Uniprocessor Memory Model	43
3.1.4	Potential Benefits in Performance	44
3.2	Working Example	44
3.3	Performance Evaluation	46
3.3.1	Quantifying the Performance Potential	46
3.3.2	Exploring the Behavior in a Modern Microprocessor	49
3.3.3	Impact on Performance of Memory Latencies	51
3.3.4	Supporting Precise Floating-Point Exceptions	52
3.4	Hardware Complexity	53
3.4.1	Size of the Major Processor Components	53
3.4.2	Impact of the Pipeline Width	54
3.5	Summary	55
4	The Multithreaded Validation Buffer Architecture	57
4.1	Out-of-Order Retirement Multithreaded Architecture	58
4.1.1	Execution of Multiple Contexts	58
4.1.2	Resources Sharing	59
4.1.3	Resource Allocation Policies	60
4.1.4	Using Out-of-Order Retirement	61
4.2	Performance Evaluation	62
4.2.1	Sharing Strategies of Hardware Structures	63
4.2.2	Comparison of Multithreading Paradigms	64
4.2.3	Impact of the Number of Hardware Threads	65
4.2.4	Impact of Resource Allocation Policies on SMT processors .	66
4.2.5	Resources Occupancy in SMT Designs	67
4.3	Summary	69

5 The Multicore Validation Buffer Architecture	71
5.1 Dealing with Sequential Consistency	72
5.2 Out-of-Order Retirement Multiprocessor Architecture	74
5.2.1 Architecture Description	74
5.2.2 Hardware Support	75
5.2.3 Working Example	76
5.3 Analysis of Single-Thread Performance	78
5.3.1 Enhanced Register Usage	78
5.3.2 Extended Instruction Window	79
5.4 Performance Evaluation	81
5.4.1 Out-of-Order Retirement and Memory Consistency Model .	81
5.4.2 Performance Bottlenecks	83
5.4.3 Impact of Delayed Writebacks	84
5.4.4 Impact of the Resources Size	85
5.4.5 Main Memory Latency	87
5.5 Hardware Complexity	88
5.5.1 Size of the Major Processor Components	88
5.5.2 Impact of the Pipeline Width	89
5.6 Summary	90
6 Related Work	93
6.1 Proposals Based on Uniprocessors	94
6.1.1 Speculative Out-of-Order Retirement with Checkpoints . .	94
6.1.2 Non-Speculative Out-of-Order Retirement Without Check- points	95
6.1.3 Enlargement of the Major Processor Structures	95
6.2 Proposals Based on Multiprocessors	96
6.2.1 Sequential Consistency Implementations	96
6.2.2 Out-of-Order Retirement in Multiprocessors	97
6.3 Summary	98
7 Conclusions	99
7.1 Contributions	100
7.2 Future Work	101
7.3 Publications Related with This Work	102
References	105