



Universiteit
Leiden
The Netherlands

Estimation and Optimization of the Performance of Polyhedral Process Networks

Haastregt, S. van

Citation

Haastregt, S. van. (2013, December 17). *Estimation and Optimization of the Performance of Polyhedral Process Networks*. Retrieved from <https://hdl.handle.net/1887/22911>

Version: Corrected Publisher's Version

License: [Licence agreement concerning inclusion of doctoral thesis in the Institutional Repository of the University of Leiden](#)

Downloaded from: <https://hdl.handle.net/1887/22911>

Note: To cite this publication please use the final published version (if applicable).

Cover Page



Universiteit Leiden



The handle <http://hdl.handle.net/1887/22911> holds various files of this Leiden University dissertation.

Author: Haastrecht, Sven Joseph Johannes van

Title: Estimation and optimization of the performance of polyhedral process networks

Issue Date: 2013-12-17

Estimation and Optimization of the Performance of Polyhedral Process Networks

Sven van Haastregt

Estimation and Optimization of the Performance of Polyhedral Process Networks

Proefschrift

ter verkrijging van
de graad van Doctor aan de Universiteit Leiden,
op gezag van Rector Magnificus prof.mr. C.J.J.M. Stolker,
volgens besluit van het College voor Promoties
te verdedigen op dinsdag 17 december 2013
klokke 12:30 uur

door

Sven van Haastregt
geboren te Rijpwetering
in 1985

Samenstelling promotiecommissie:

promotor Prof.dr. Ed Deprettere
co-promotor Dr. Bart Kienhuis

overige leden: Prof.dr. Joost Kok
 Prof.dr. Harry Wijshoff
 Prof.dr. Koen Bertels Technische Universiteit Delft
 Dr. Hristo Nikolov

This manuscript was edited by the author using Vim, and typeset using L^AT_EX 2_&, BIBL^ETEX, and *MakeIndex* in a process automated using GNU Make. Graphics were produced mostly using Inkscape, and occasionally using Xfig or gnuplot. Git over ssh was used for revision tracking, synchronization, and backup purposes.

Cover design by Marcel IJssennagger.

Estimation and Optimization of the Performance of Polyhedral Process Networks

Sven van Haastregt. -

Thesis Universiteit Leiden. - With index, ref. - With summary in Dutch

190 pages, 47988 words, 176 index entries, 162 references.

ISBN 978-94-6182-383-0

Copyright ©2013 by Sven van Haastregt, Leiden, The Netherlands.

All rights reserved. No part of the material protected by this copyright notice may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying, recording or by any information storage and retrieval system, without permission from the author.

Printed in the Netherlands.

CONTENTS

Contents	vii
Notation	xi
1 Introduction	1
1.1 Problem Context	1
1.2 Problem Statement	4
1.3 Related Work	7
1.3.1 High-Level Synthesis	8
1.3.2 Electronic System-Level Synthesis	10
1.4 Contributions and Outline	12
2 Background	15
2.1 Polyhedral Model	15
2.2 Models of Computation	21
2.2.1 Homogeneous Synchronous Dataflow	22
2.2.2 Synchronous Dataflow	23
2.2.3 Cyclo-Static Dataflow	25
2.2.4 Polyhedral Process Networks	27
2.3 Derivation of PPNs from Sequential Programs	30
2.3.1 Channel Type Determination	31
2.3.2 Buffer Size Computation	32
2.4 Code Generation	33
2.4.1 Integrating Dedicated IP Cores	34
3 Synthesizing PPNs	37
3.1 Motivation & Contributions	37
3.2 IP Core Characterization	38
3.2.1 IP Core Integration	39

3.3	Data Reuse	40
3.4	Sticky FIFOs	42
3.5	Evaluation Logic Optimizations	43
3.5.1	Pipelined Evaluation Logic	44
3.5.2	ROM-Based Evaluation Logic	44
3.5.3	Related Work	47
3.6	Out-of-Order Communication	48
3.7	Conclusion and Summary	52
4	Performance Estimation	53
4.1	Motivation	53
4.2	Definitions	55
4.3	RTL Simulation	57
4.4	SystemC Simulation	57
4.4.1	Cycle-Accurate Timed SystemC Simulation	58
4.4.2	Light-weight Timed SystemC Simulation	60
4.5	Maximum Cycle Mean Analysis	61
4.5.1	Related Work	61
4.5.2	Maximum Cycle Mean Analysis	63
4.5.3	Derivation of PPN Modeling Graphs	64
4.5.4	Case Studies	72
4.6	Sequential Code Profiling	75
4.6.1	Related Work	76
4.6.2	Sequential Code Instrumentation of Static Programs	77
4.6.3	Maximum Degree of Parallelism	84
4.6.4	Absolute Throughput Estimation	85
4.6.5	Case Study	85
4.6.6	Transformation Performance Estimation	90
4.6.7	Instrumentation Overhead	92
4.7	Comparison	94
4.8	Experimental Results	96
4.8.1	Accuracy	97
4.8.2	Running Time	98
4.9	Conclusion and Summary	99
5	Application Transformation	101
5.1	Transformations	101
5.1.1	Splitting	101
5.1.2	Merging	105

5.1.3	Stream Multiplexing	106
5.1.4	Scheduling	109
5.2	Transformation Efficacy Analysis	116
5.2.1	Splitting	116
5.2.2	Merging	120
5.2.3	Stream Multiplexing	121
5.2.4	Scheduling	124
5.3	Conclusion and Summary	127
6	Industrial Case Study	129
6.1	Sphere Decoding	129
6.2	Reference Implementation	131
6.3	AutoESL	132
6.3.1	Design Flow	133
6.3.2	Design Entry	134
6.3.3	Design Productivity	138
6.4	Daedalus	140
6.4.1	Design Entry	141
6.4.2	Synthesis	147
6.5	Comparison	148
6.6	Conclusion and Summary	149
7	Conclusions	151
Samenvatting		155
Curriculum Vitae		157
Acknowledgments		159
Bibliography		161
Index		175

NOTATION

$ \cdot $	Cardinality: $ \mathcal{S} \equiv$ the number of elements in \mathcal{S} , page 20.
$[\cdot, \cdot)$	Interval: $[a, b) = \{x \in \mathbb{Z} \mid a \leq x < b\}$.
$\lceil \cdot \rceil$	Least integer: $\lceil x \rceil = n \Leftrightarrow n \in \mathbb{N} \wedge n - 1 < x \leq n$.
$\cdot \prec \cdot$	Lexicographical order, page 18.
D_p	Iteration domain of process p , page 27.
$d(e)$	Number of initial tokens on edge e , page 22.
δ_c	Process reading from channel c , page 27.
\mathcal{E}	The set of channels of a PPN, page 27.
II_F	Initiation interval of function F , page 38.
IPD_i^k	k -th Input Port Domain of process i , page 27.
Λ_F	Latency (input-to-output delay) of function F , page 38.
M_c	Channel relation of channel c , page 27.
\mathbb{N}	The set of natural numbers, including 0.
\mathbb{N}^+	The set of positive natural numbers, excluding 0.
OPD_i^k	k -th Output Port Domain of process i , page 27.
\mathcal{P}	The set of processes of a PPN, page 27.
\mathbb{Q}	The set of rational numbers.
σ_c	Process writing to channel c , page 27.
T_p	Period of a process p , page 55.
$t(a)$	Execution time of data flow node a , page 22.
τ_p	Throughput of a process p , page 55.
$\theta(\mathbf{i})$	Application of schedule θ to iteration vector \mathbf{i} , pages 111, 112.
\mathbb{Z}	The set of integers.

