

STREAM PROCESSOR ARCHITECTURE – STREAMING MEMORY SYSTEM

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*Specially to my beloved father and mother
Brothers and all my friends
for their inspiration, support and encouragement
throughout my adventure of educations*

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ABSTRACT

Streaming memory system in this project is defined as a process of an stream processor that need to be able to stream whole chunk of data from/to external memory with real time performance. Real-time implementation of Convolution Neural Network (CNN) application are taking large amount of CPU cycle to fetch and write data from/to external memory are popular issues in the field of media processing. So, a new FPGA-based streaming memory system was designed in order to allow the media processing application to execute multiple streaming operators. It would be a challenging task as computational capability would be increased. The hierarchy of streaming memory system consists of a memory system, stream register file (SRF) and arithmetic units. The memory system and SRF are the key part of the functional architecture of this project. This hierarchy can be used to exploit the parallelism and locality of streaming media applications. The main idea of three storage hierarchy is to allow the ALUs to operate efficiently in parallel. It is impractical to provide data on every cycle to ALU clusters using off-chip DRAM because peak bandwidth of memory system could not effectively support ALU clusters to achieve the computation rate. Moreover, the reason of creating streaming memory system is to fulfill the computational capability in media application that consists of multiple arithmetic operator. Two study case was tested which is RGB to YUV Cluster and 2D convolution cluster, and it was successfully to read or write a particular chunk of data in real time.

ABSTRAK

Sistem memori streaming dalam project ini adalah ditakrifkan sebagai proses di mana satu pemproses aliran yang dapat strim keseluruhan data dari/ke memori luaran dengan prestasi masa nyata. Implementasi masa nyata untuk aplikasi Konvolusi Rangkaian Neural (CNN) memerlukan jumlah kitaran CPU yang besar untuk mendapat dan menulis data dari/ke memori luaran merupakan isu yang popular dalam bidang pemprosesan media. Oleh itu, sistem memori streaming berdasar FPGA yang baru telah direka supaya membolehkan aplikasi pemprosesan imej untuk melaksanakan pelbagai pengendali streaming. Ia merupakan satu cabaran kerana keupayaan komputasi akan dipertingkatkan. Hierarki sistem memori streaming terdiri daripada sistem memori, fail daftar aliran (SRF) dan unit aritmetik. Sistem memori dan SRF merupakan bahagian penting dalam arkitek fungsi projek ini. Hierarki tersebut boleh digunakan untuk mengeksploitasi keselarian dan aplikasi media streaming tempatan. Idea utama dalam tiga penyimpanan hierarki adalah untuk membolehkan ALUs beroperasi dengan cekap secara selari. Ia adalah tidak praktikal untuk membekalkan data pada setiap kitaran kepada kelompok ALU dengan menggunakan luar-pemproses DRAM kerana puncak lebar jalur sistem memori tidak dapat menyokong kelompok ALU dengan cekap untuk mencapai kadar komputasi. Bukan itu sahaja, faktor untuk mewujudkan sistem memori streaming adalah untuk memenuhi keupayaan komputasi dalam aplikasi media yang terdiri daripada pelbagai pengendali aritmetik. Dua kes kajian telah diuji di mana RGB ke kelompok YUV dan 2D kelompok konvolusi, dan ia berjaya membaca atau menulis sebahagian data tertentu dalam masa nyata.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	DECLARATION	ii
	DEDICATION	iii
	ACKNOWLEDGEMENTS	iv
	ABSTRACT	v
	ABSTRAK	vi
	TABLE OF CONTENTS	vii
	LIST OF TABLES	x
	LIST OF FIGURES	xi
	LIST OF ABBREVIATIONS	xiii
	LIST OF APPENDICES	xiv
1	INTRODUCTION	
	1.1 Background of study	1
	1.2 Problem Statement	3
	1.3 Objective	4
	1.4 Scope	4
	1.5 Project Achievement	5
2	LITERATURE REVIEW	
	2.1 Stream Processor Architecture	6
	2.2 Stream Register File	7
	2.3 Streaming Memory System	9
	2.4 Bandwidth Hierarchy	10
	2.5 Instruction Set Architecture	11

	2.5.1	Stream-level ISA	11
	2.4.2	Stream Command ISA	12
	2.6	Stream Register File and Stream Controller Data Flow	15
	2.7	Data Stream on RGB_2_YUV Kernel	17
3		METHODOLOGY	
	3.1	Project Methodology	19
	3.2	Design Methodology	21
	3.3	Design Tools	21
	3.4	Streaming Memory System	23
	3.4.1	Overview	23
	3.4.2	Top-Level Design	
	3.4.3	Stream-Level Instruction Set (ISA)	
	3.4.4	Stream-Level ASM-Chart	25
	3.4.5	RTL Design	26
	3.4.6	Module Design	30
	3.4.6.1	Data Memory (SDRAM)	30
	3.4.6.2	Program Counter System	31
	3.4.6.3	Stream Register File (SRF)	31
	3.4.6.4	Stream Controller	32
	3.4.6.5	Kernel ISA	33
	3.4.6.6	Microcontroller	35
	3.5	Case Study 1: RGB to YUV ALU Cluster	37
	3.5.1	Algorithm	38
	3.5.2	Specification	38
	3.5.3	ASM Chart	39
	3.5.4	RTL Design	40
	3.5.5	Top-Level Design	42
	3.5.6	Datapath Unit (DU)	43
	3.5.7	Control Unit (CU)	46
	3.5.8	RGB to YUV Kernel	49
	3.6	Case Study 2: 2D Convolution Cluster	51

3.6.1	Algorithm	51
3.6.2	Data Flow Graph	52
3.6.3	ASM Chart	53
3.6.4	RTL Design	54
3.6.5	Top-Level Design	56
3.6.6	Datapath Unit (DU)	57
3.6.7	Control Unit (CU)	58
3.6.8	Convolution Kernel	61
3.7	Integration of Streaming Memory System and RGB to YUV Cluster	62
3.8	Integration of Streaming Memory System and 2D Convolution Cluster	63
3.9	Timeline of Instruction Execution	64
4	RESULTS AND DISCUSSIONS	
4.1	Streaming Memory System Result	66
4.1.1	Load Memory	66
4.1.2	Load SRF	68
4.1.3	Store SRF	69
4.1.4	Store Memory	71
4.2	Conversion of RGB to YUV Result	72
4.2.1	Matlab Simulation Result	73
4.2.2	Quartus Simulation Result	75
4.3	2D Convolution Result	80
4.3.1	Matlab Simulation Result	81
4.3.2	Quartus Simulation Result	82
5	CONCLUSION	
5.1	Conclusion	90
5.2	Future Work	91
	REFERENCES	92
	Appendices A - E	94 - 131

LIST OF TABLES

FIGURE NO.	TITLE	PAGE
2.1	Peak bandwidth	11
2.2	Imagine stream-level instruction set	12
2.3	Stream Command	14
3.1	Comparison between Different HDL Simulators	22
3.2	Stream-Level ISA	26
3.3	Control Vector of Kernel ISA	34
3.4	Control Vector	36
3.5	Control signal Table	37
3.6	Control Signal Table	47
3.7	Control Vector	48
3.8	Control Vector of RGB to YUV kernel	49
3.9	Control Signal Table	60
3.10	Control Vector	61
3.11	Control Vector of Convolution kernel	61
4.1	Load Memory Instruction	67
4.2	Load SRF Instruction	69
4.3	Store SRF Instruction	70
4.4	Store Memory Instruction	72
4.5	Execute Kernel Instruction	78
4.6	Quartus Simulation Result of Pixels	79
4.7	Execute Kernel Instruction	86
4.8	Quartus Simulation Result of Convolution	87

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
1.1	Stream Processor Block Diagram	2
1.2	ALU Cluster	3
2.1	Stream Processor Block Diagram	7
2.2	SRF Block Diagram	8
2.3	Streaming Memory System	9
2.4	Bandwidth Hierarchy	10
2.5	DPU architecture	14
2.6	Timeline of stream command execution	15
2.7	Flow Chart of the SRF	16
2.8	Flow Chart of the Stream Controller	17
2.9	RGB_2_YUV Kernel and Streams	18
2.10	Graphical Depiction of Kernel	18
3.1	The Project Methodology of Stream Processor Design	20
3.2	Design Methodology	21
3.3	Overview of Streaming Memory System	24
3.4	Top-Level Design of Streaming Memory System	25
3.5	ASM-Chart of Streaming Memory System	28
3.6	SDRAM	30

3.7	Program Counter System	31
3.8	SRF	32
3.9	Stream Controller	33
3.10	SIMD Instruction Set	33
3.11	Kernel ISA module	34
3.12	Microcontroller	35
3.13	ASM-Chart of RGB to YUV Cluster	40
3.14	Top Level Module of RGB to YUV Cluster	43
3.15	RGB to YUV DU Block Diagram	45
3.16	RGB to YUV CU Block Diagram	46
3.17	RGB to YUV Kernel	50
3.18	Data Flow Graph of Convolution Cluster	52
3.19	ASM-Chart of Convolution Cluster	54
3.20	Top_Level Module of Convolution Cluster	56
3.21	Convolution DU Block Diagram	58
3.22	Convolution CU Block Diagram	59
3.23	Convolution Kernel	62
3.24	Integration of Streaming Memory System and RGB to YUV Cluster	63
3.25	Integration of Stream Processor and Convolution Cluster	64
3.26	Timeline of Instruction Execution	65
4.1	Load Memory Instruction Result	67
4.2	Load SRF Instruction Result	68
4.3	Store SRF Instruction Result	70
4.4	Store Memory Instruction Result	71
4.5	RGB Pixels	73
4.6	Matlab Simulation Result of YUV Pixels	75
4.7	Execute Kernel Instruction	78
4.8	3x3 image and 3x3 Gaussian Filter	81
4.9	Matlab simulation result of Convolution	83
4.10	Quartus Simulation Result of Execute Kernel Instruction	85

LIST OF ABBREVIATIONS

ALU	-	Arithmetic Logical Unit
SRF	-	Stream Register File
VLIW	-	Very Long Instruction Word
LRF	-	Local Register File
SP	-	Scratch Pad
CNN	-	Convolution Neural Network
CPU	-	Central Processing Unit
FPGA	-	Field-Programmable Gate Array
HDL	-	Hardware Description Language
RISC	-	Reduced Instruction Set Computing
ASIC	-	Application-Specific Integrated Circuit
DRAM	-	Dynamic Random-Access Memory
SDRAM	-	Synchronous Dynamic Random-Access Memory
DPU	-	Data Path Unit
DSP	-	Digital Signal Processing
MIPS	-	Microprocessor without Interlocked Pipeline Stages
PE	-	Processing Element
FSM	-	Finite State Machine
VCS	-	Verilog Compiled code Simulator
ISA	-	Instruction Set Architecture
ASM	-	Algorithm State Machine

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	FYP Gantt Chart 1	94
B	FYP Gantt Chart 2	95
C	System Verilog Code of Streaming Memory System and Testbench	96
D	System Verilog Code of RGB to YUV Cluster and Testbench	109
E	System Verilog Code of Convolution Cluster and Testbench	124

CHAPTER 1

INTRODUCTION

1.1 Background Study

Stream processors are fully programmable processors that exploit the compute intensity, parallelism, and producer-consumer locality in media applications to provide performance efficiencies comparable to special-purpose processors [1]. Stream processors are computing engines that perform calculations on an input stream with high efficiency, while an output stream is produced to be used by other stream processors and ALU clusters. Stream processors can be grouped in close proximity, and in large numbers, to provide immense parallel processing power.

The stream processor architecture effectively exploits the preferable application characteristic exposed by the stream model. The stream processor meets the bandwidth demand and computation of image processing application by directly processing the chunk of naturally arising data streams within the application [2]. Figure 1.1 shows a block diagram of stream processor architecture. The function of stream controller is to sequence the instruction from host the stream processor. The stream register file (SRF), which is a large on-chip storage for streams effectively isolates the ALU clusters from the memory system. The microcontroller is a very long instruction words (VLIW) control engine, issues instruction to arithmetic cluster. As

shown in Figure 1.2, each ALU cluster consists of 3 adders, 2 multipliers, 1 divider, 1 scratch pad, 1 communication units. The ALUs are fed by two local register files (LRFs) each, external ports for accessing the SRF. In addition, there is a scratchpad (SP) unit, used for small indexed addressing operations within a cluster, and an intercluster communication (COMM) unit, used to exchange data between clusters.

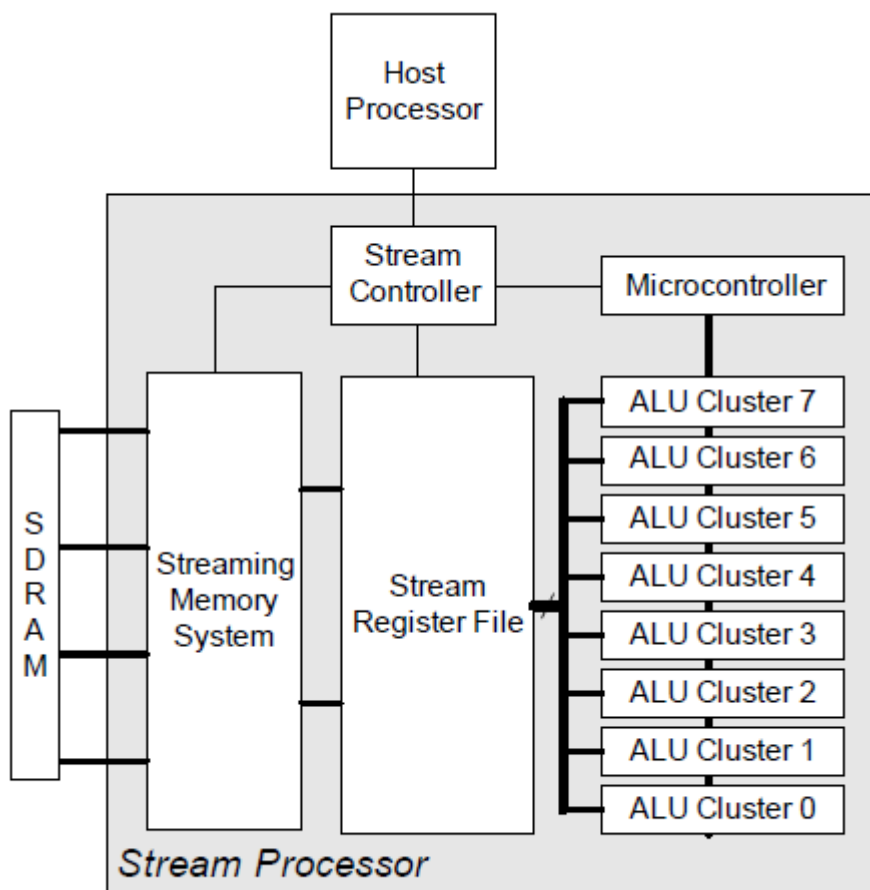


Figure 1.1: Stream Processor Block Diagram

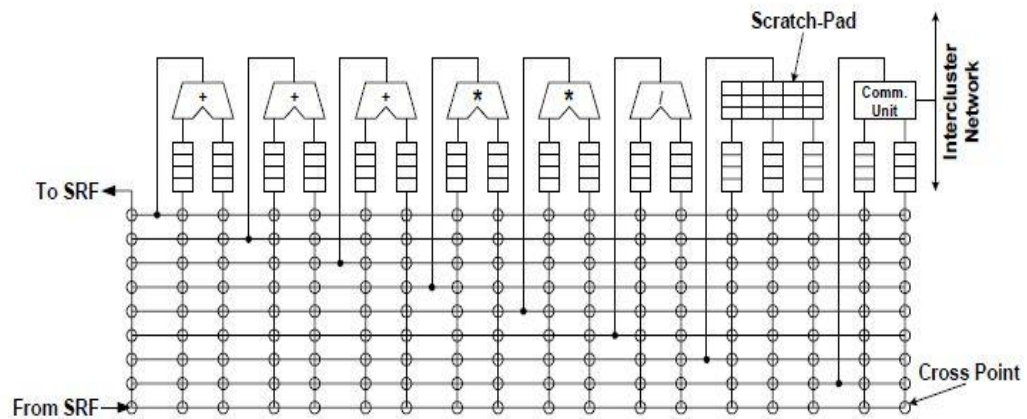


Figure 1.2: ALU Cluster

1.2 Problem Statement

The motivation behind this project is driven by some reason in the previous performance on stream memory system. Most of the real-time implementation of Convolution Neural Network (CNN) application like face recognition needs a very high speed streaming memory system to fetch and write data from/to external memory. The hardware data-path with multiple arithmetic operators and the execution of multiple streaming operators impose the challenge to increase in computational capability with increase in performance.

Moreover, a conventional load/store CPU or more commonly known as general purpose CPU is also capable of processing media applications, a dedicated stream media processor offer greater performance of throughput versus cost. Other than high CPU cycle, the biggest challenge of processing media with conventional CPU is the frequent memory access and continuous cache miss which makes the cache totally useless in this application.

1.3 Objective

There are two main objectives in designing streaming memory system which are:

1. To develop a FPGA-based streaming memory system for real-time performance CNN application with large number of ALU.
2. To develop a streaming memory system with three-tiered storage bandwidth hierarchy.
3. To develop a streaming memory system which has better memory efficiency for media processing compared to a conventional load/store processor.

1.4 Scope

The scope of the project is to focus on FPGA-based streaming memory system which are:

1. The project of streaming memory system include memory system, Stream Register File (SRF) and stream controller using System Verilog HDL in a parameterized and configurable design way, that provide flexibility to alter the parameters like bandwidth of the SRF and stream buffer.
2. The ALU cluster and microcontroller will not be part of the project. However, two dedicated ALU design which are RGB to YUV conversion and convolution will be used as test case in this project.
3. Test-bench will be created to perform functionality check for each configuration.

1.5 Project Achievement

The design of streaming memory system contribute a few achievement in the project which are:

1. The design of streaming memory system is state of the art in stream processor. This can be a new model in designing of future stream processor.
2. The new architecture return in the design is more efficient and configurable compare to a simple RISC processor.
3. The project is successfully target to FPGA design although IMAGINE return the design in ASIC. A new design methodology has been return in the project.

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