IDP

Fixed-Point Matrix Multiplication

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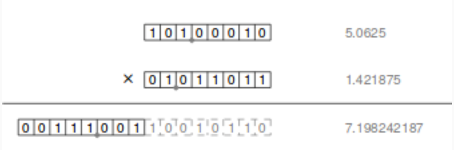
Introduction

Fixed Point Matrix Multiplication

The main idea of fixed point arithematic is to interpret bit words as integers coupled with a scale factor: $\frac{z}{2^n}$

Multiplication: The product of a $Q_{a,b}$ variable by a $Q_{c,d}$ yields a $Q_{a+b,c+d}$ variable.



Fixed Point Matrix Multiplication

Table 1: Fixed-Point Examples

Binary	Hex	Integer	Floating Point Fraction	Fixed-Point Fraction	Actual
0100000000000000	4000	16384	0.50000000	0.50000000	1/2
0010000000000000	2000	8192	0.25000000	0.25000000	1/4
0001000000000000	1000	4096	0.12500000	0.12500000	1/8
0000100000000000	0800	2048	0.06250000	0.06250000	1/16
0000010000000000	0400	1024	0.03125000	0.03125000	1/32
0000001000000000	0200	512	0.01562500	0.01562500	1/64
0000000100000000	0100	256	0.00781250	0.00781250	1/128
0000000010000000	0080	128	0.00390625	0.00390625	1/256
0000000001000000	0040	64	0.00195312	0.00195312	1/512
0000000000100000	0020	32	0.00097656	0.00097656	1/1024
0000000000010000	0010	16	0.00048828	0.00048828	1/2048
0000000000001000	0008	8	0.00024414	0.00024414	1/4096
0000000000000100	0004	4	0.00012207	0.00012207	1/8192
0000000000000010	0002	2	0.00006104	0.00006104	1/16384
0000000000000001	0001	1	0.00003052	0.00003052	1/32768
0010101010101011	2AAB	10923	0.33333000	0.33334351	0.33333
0101101001111111	5A7F	23167	0.70700000	0.70700073	0.707
0000000000001010	000A	10	0.0003141592	0.00030518	0.0003141592
0000000000000011	0003	3	0.000086476908	0.00009155	0.000086476908

Fixed Point Matrix Multiplication

It is similar to a normal matrix multiplication. Let us recall that inner product between two vectors.

$$\begin{bmatrix} A_x & A_y & A_z \end{bmatrix}\begin{bmatrix} B_x \\ B_y \\ B_z \end{bmatrix} = A_xB_x + A_yB_y + A_zB_z = \vec{A}\cdot\vec{B}$$

From the figure it is clear that C_{ij} = inner-product of i^{th} row of matrix A and j^{th} column of matrix B.

$$c_{11} = a_{11}b_{11} + a_{12}b_{21} + a_{13}b_{31} + a_{14}b_{41}$$

$$\underset{2 \times 4}{\begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \end{bmatrix}} \underset{4 \times 3}{\begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \\ b_{41} & b_{42} & b_{43} \end{bmatrix}} = \underset{2 \times 3}{\begin{bmatrix} c_{11} & c_{12} & c_{13} \\ c_{21} & c_{22} & c_{23} \end{bmatrix}}$$

$$c_{22} = a_{21}b_{12} + a_{22}b_{22} + a_{23}b_{32} + a_{24}b_{42}$$

$$\begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \end{bmatrix} \begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \\ b_{41} & b_{42} & b_{43} \end{bmatrix} = \begin{bmatrix} c_{11} & c_{12} & c_{13} \\ c_{21} & c_{22} & c_{23} \end{bmatrix}$$

Problem Statement

Problem Statement

- The input is sent through Arduino and then transmitted to the icoboard whenever the clock is triggered to positive.
- In order to flash verilog file in icoboard type make v_fname = mat_mul in terminal of RaspberryPi.
- Icoboard is flashed with verilog code which includes fixed point matrix multiplication logic.
- After executing the matrix multiplication, Icoboard outputs the matrix value to another Arduino where output is displayed.

Implementation Strategy

Implementation Strategy

- Arduino is used to input the matrix values. (i.e. matrix A and matrix B)
- Arduino converts floating point input to fixed point output.
- Ico board receives input from Arduino where matrix multiplication is programmed.
- The Project will be implemented for $(n \times n)$ matrix. And 8-bit fixed-point numbers will be used (n must be edited in the Arduino and verilog codes).
- For ease of demo, the implementation will be done for (2×2) matrix.
- Ico board sends the output after the multiplication process to another Arduino.
- The output matrix can be displayed in Arduino serial monitor after floating point conversion.

Implementation Strategy

- whenever the input is provided at the serial monitor of the input Arduino, then a clock signal is triggered to positive edge.
- every time the verilog code reads positive edge from the signal coming from the Arduino, the value of the input is stored in the registers.
- after all the required inputs have been provided, the code stops taking inputs from Arduino. and triggers a signal for Arduino to start the matrix multiplication logic.
- After the matrix multiplication is over, the values are stored in the registers.
- Later, when outputs are stored in registers, the code triggers another signal to the Arduino to start printing the output matrix.
- the output Arduino will trigger a signal for taking outputs stored in the registers at every clock signal.

References

References

1. download and setup RaspberryPi from: https://www.raspberrypi.org/downloads/raspbian/
2. get Arduino setup from: https://www.arduino.cc/en/Main/Software
3. Prorject codes are available in: https://github.com/BhargavasRamus/IDP_FPGA_Spring19/tree/master/codes

THANK YOU