An Energy-Efficient SIMD Accelerator for Visual Pattern Matching

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1. Motivation

• Object recognition and classification are currently some of the hot topics in computer vision with applications in image matching, robotics and panorama stitching

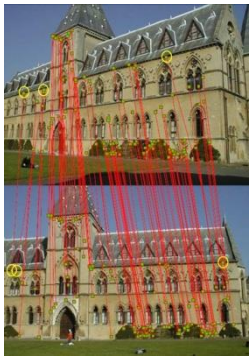
• When matching large databases against each-other, matching speed is an important performance metric, but power and energy plays a major role in the economy of the entire process.

2. Background

Image **matching** :
• query images
• search images
Purpose: find objects from query images in search images

Step1: Extract local features (keypoints) with an algorithm like SIFT (Scale Invariant Feature Transform)

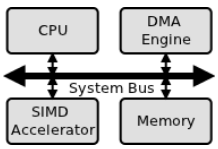
Step2: Find matching (D1/D2 distance) keypoints in both the query set and at least one search image



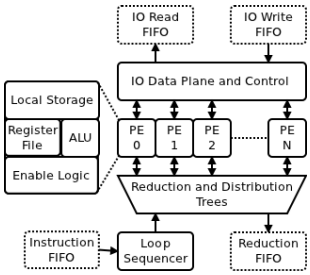
http://imaging.utk.edu/people/former/whao/whao.htm

3. Proposed Architecture

System



Accelerator



4. Case study

Accelerator instance
• 128 Processing Elements
• 16-bit operands
• 32 registers
• 2KB Local Storage

SIMD matching application:
• SSD (Sum of Squared Differences)= L2
• SAD (Sum of Absolute Differences) = L1

$$L_p = (\sum_{i=1}^{D} |X_i - Y_i|^p)^{\frac{1}{p}}$$

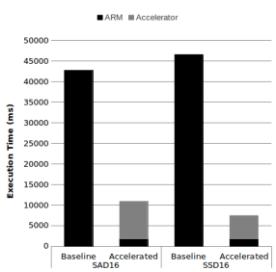
SAD computation

```
for(int j = 0; j < 28; j + +) {
    R30 = R[28]  - R[j ];
    R31 = R30 < R29;
    WHERE LT (R30 = R[j ] - R[28]; )
    REDUCE(R31);
}
```

SSD computation

```
for(int j = 0; j < 28; j + +) {
        R31 = R[28] - R[j ];
        R31 = R31 * R31;
        REDUCE(R31);
}
```

5. Results



Profiling of Execution Time

Energy Consumption per 100 MMatches

Platform	TDP[W]	SAD energy [J]	SSD energy [J]
Core i7 2600K	95	83.77	76.98
NVidia GTX680	195	24.23	24.37
NVidia 8800 Ultra	175	–	286.88
ARM Cortex A9	1.25	53.41	59.24
SIMD accelerator	1.2	13.01	8.95

SSD and SAD matching

Platform	ARM Cortex A9	SIMD Accelerator
Frequency [MHz]	667	100
SSD Rate [MM/s]	2.11	13.40
SSD Speedup	1	6.35
SAD Rate [MM/s]	2.34	9.22
SAD Speedup	1	3.94

6. Conclusions

• The SIMD accelerator implemented using a Zynq-7000 SOC is able to achieve 4-6x better SIFT descriptor matching throughput than a Cortex A9 processor, despite the FPGA implementation and 100 MHz operating frequency.

• Performance is delivered at about 3x less energy consumption and similar power consumption

• The accelerated system is 40% more energy effective than Intel Core i7 2600K and Nvidia GTX680 when executing SIFT matching benchmark