Software Programming for Performance

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Assignment 1

Know your Computer

CPU Specifications

Specification	Value
CPU	AMD Ryzen 7
Model	4800H
Frequency Range	2.9GHz - 4.2GHz
Number of physical cores	8
Hyperthreading	Yes
SIMD ISA	AVX2
Cache	512 KiB, 4 MiB, 8 MiB
Memory Bandwidth	68.27 GB/s

Theoretical FLOPS

Whetstone benchmark

Running the whetstone benchmark with \(10^6\) loops gives a total of 6.25 GIPS.

```
Loops: 1000000, Iterations: 1, Duration: 16 sec.
C Converted Double Precision Whetstones: 6250.0 MIPS
```

Compiling the whetstone benchmark with the flag `-03` we get the following result

```
Loops: 1000000, Iterations: 1, Duration: 4 sec.
C Converted Double Precision Whetstones: 25000.0 MIPS
```

Using the `icc` compiler instead of `gcc` gives us 10000 MIPS even with the `-03` flag

My benchmark

My benchmark has been able to achieve 400 GFLOPS.

Memory Specifications

Specification	Value
Memory size	32 GiB
Type	DDR4
Maximum Memory Bandwidth	34.13 GB/s

My memory benchmark has been able to achieve a total of 33.5 GB/s.

Storage Specifications

1. **SSD**

Specification	Value
Size	256 GiB
Read	2400 MB/s
Write	950 MB/s

2. **HDD**

Specification	Value
Size	1 TiB
Read	160 MB/s
Write	40 MB/s

Know your Cluster

1. ADA peak FLOPS : 70.66 TFLOPS
2. Abacus Peak FLOPS : 14 TFLOPS

BLAS Problems

3.1 BLAS Level 1

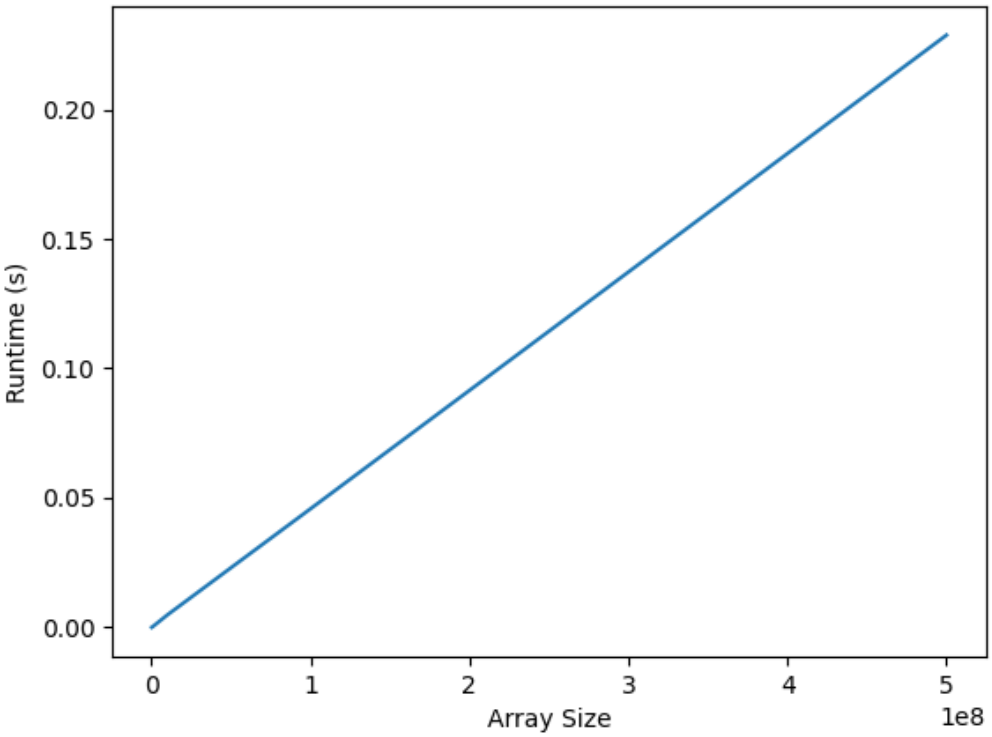
xSCAL

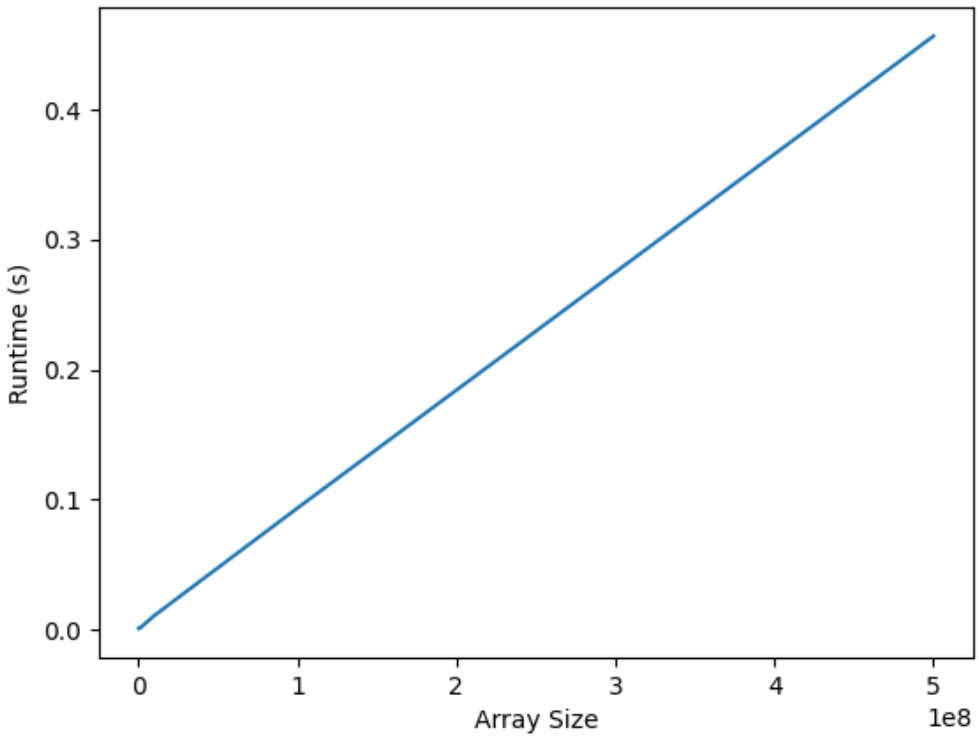
- Operational Intensity : 0.25 FLOP/Byte for `float`, 0.125 FLOP/Byte for `double`
- Execution times (input size : $1e^8$)

```
sscal with gcc : 50ms
dscal with gcc : 100ms

sscal with icc : 55ms
dscal with icc : 110ms
```

- Baseline execution time : 400ms
  Best execution time : 50ms
- Speedup : 8×
- Baseline GFLOPS : 0.25
  Best GFLOPS : 2.0
- Optimization strategies : Vectorization
- Memory bandwidth : 8 GB/s
- The problem is CPU bound!





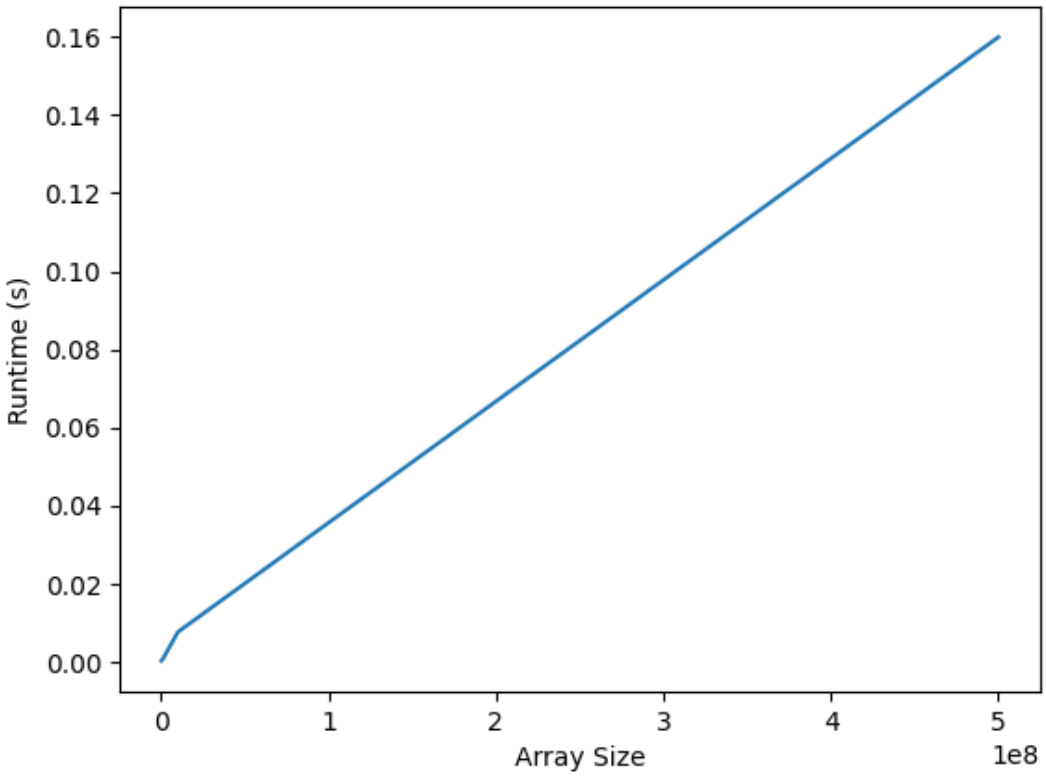
xDOT

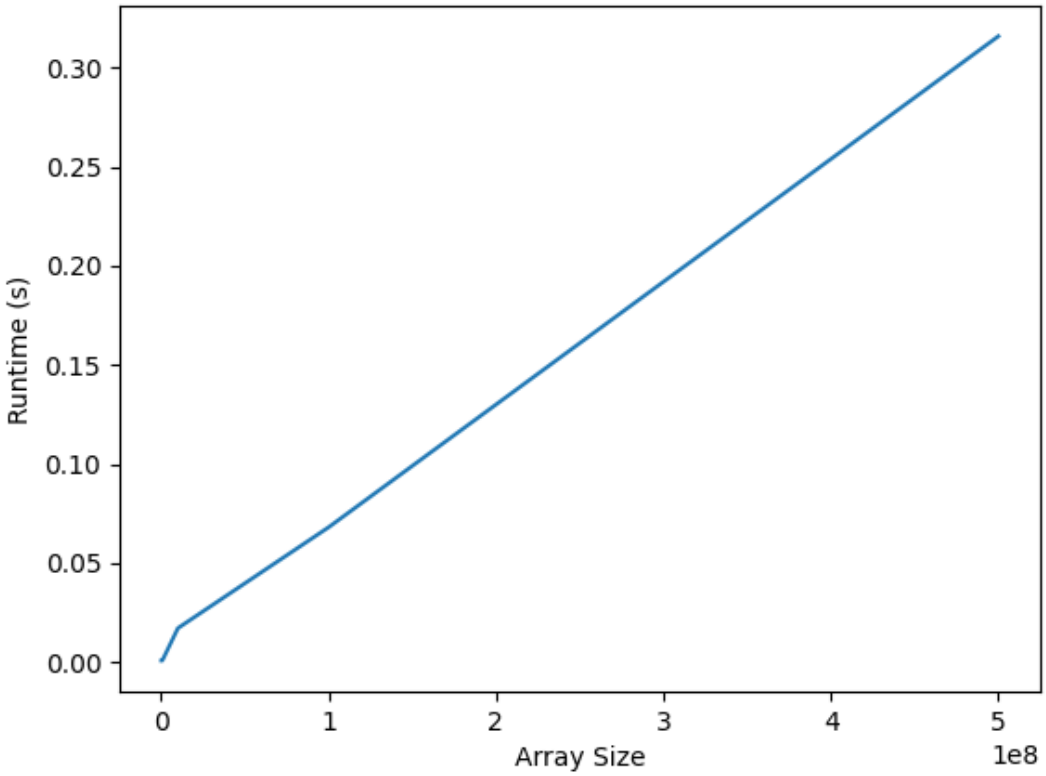
- Operational Intensity : 0.25 FLOP/Byte for float and 0.125 FLOP/Byte for double
- Execution times (Input size $1e^8$)

```
sdot with gcc : 40ms
sdot with icc : 55ms

ddot with gcc : 75ms
ddot with icc : 80ms
```

- Baseline execution time : 700ms
  Best execution time : 40ms
- Speedup : $14\times$
- Baseline GFLOPS : 0.3
  Best GFLOPS : 4
- Optimization strategies : O3 and vectorization
- Memory bandwidth : 16 GB/s
- Problem is memory bound





xAXPY

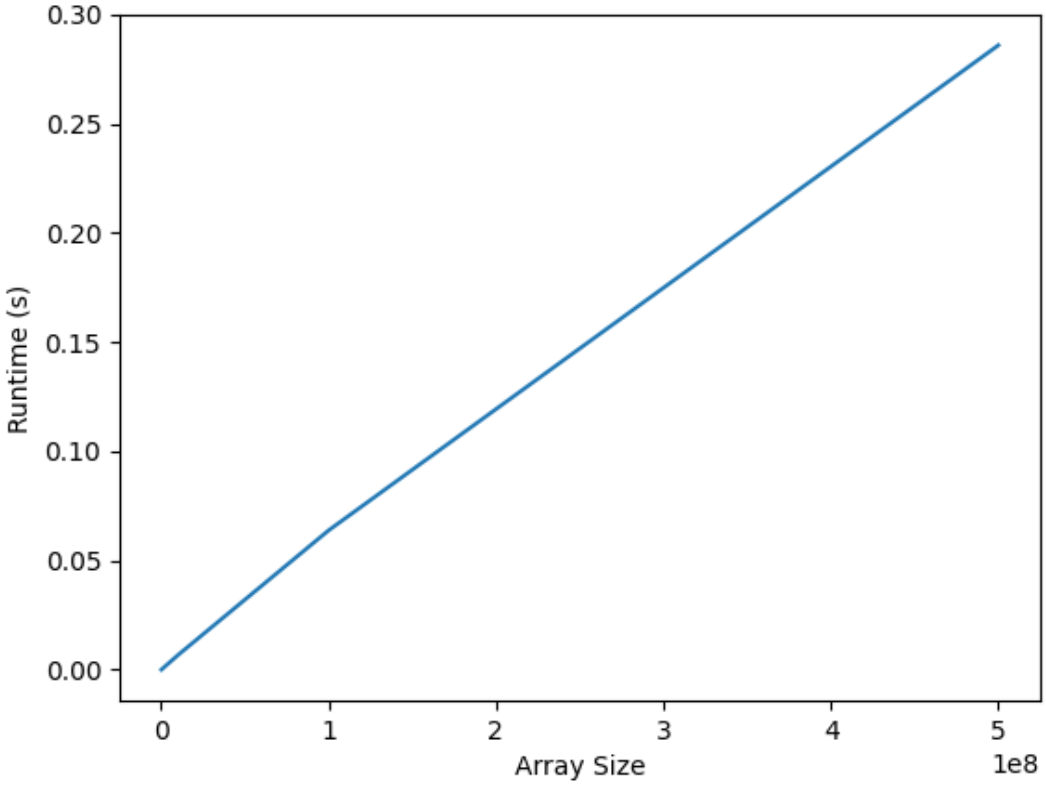
- Operational Intensity : 0.25 for float and 0.125 for double
- Execution times (Input size $1e^8$)

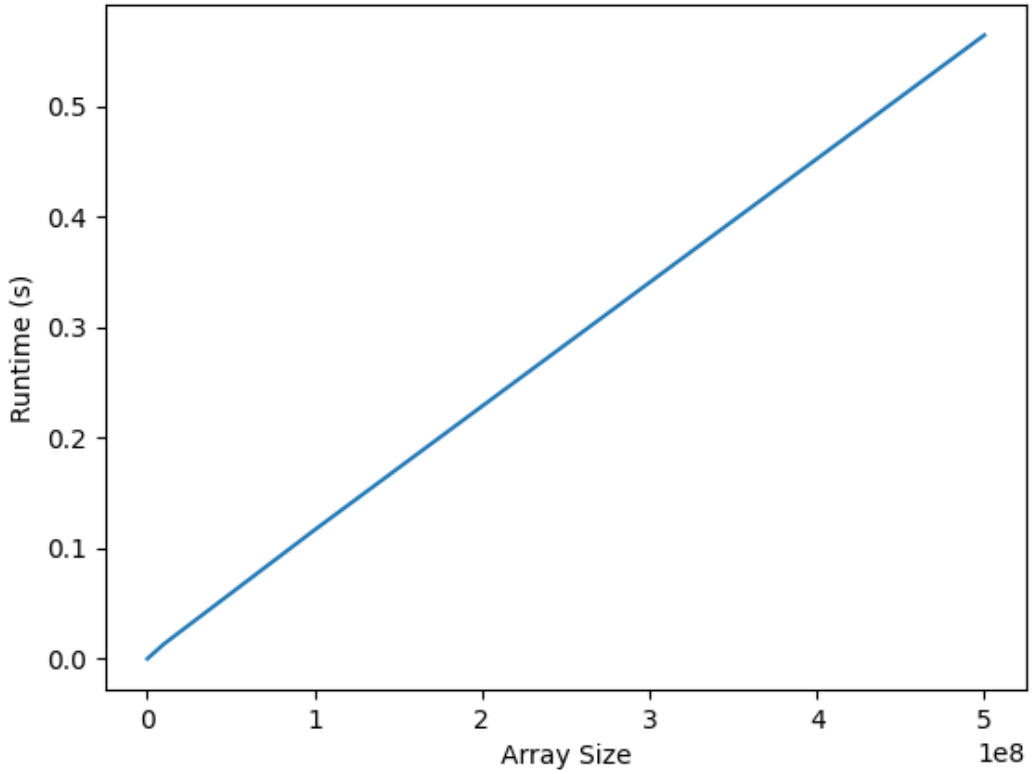
```
saxpy with gcc : 60ms
saxpy with icc : 75ms

daxpy with gcc : 115ms
daxpy with icc : 130ms
```

- Baseline execution time : 650ms
  Best execution time : 60ms
- Speedup : $10\times$
- Baseline GFLOPS : 0.3

  Best GFLOPS : 3.5
- Optimization strategies : O3 and Vectorization
- Memory bandwidth : 16 GB/s
- Problem is memory bound





3.2 BLAS Level 2

xGEMV

- Operational Intensity : $\frac{3MN+M}{sizeof(unit)\times(MN+M+N)}$
- Execution times (Input size $1e^8$)

```
sgemv with gcc : 15ms
sgemv with icc : 19ms

dgemv with gcc : 28ms
dgemv with icc : 32ms
```

- Baseline execution time : 300ms
  Best execution time : 15ms
- Speedup : $20\times$
- Baseline GFLOPS : 0.2
  Best GFLOPS : 10
- Optimization strategies : `-03` , parallelization with OpenMP and vectorization
- Memory bandwidth : 28 GB/s
- Problem is CPU bound

3.3 BLAS Level 3

xGEMM

- Operational Intensity : $\frac{3MNK+MN}{sizeof(unit)\times(MN+NK+MN)}$
- Execution times (Matrix sizes $1e^4$)

```
sgemm with gcc : 38ms
sgemm with icc : 60ms

dgemm with gcc : 80ms
dgemm with icc : 95ms
```

- Baseline execution time : 2700ms
  Best execution time : 38ms
- Speedup : $71\times$
- Baseline GFLOPS : 1.12
  Best GFLOPS : 7
- Optimization strategies : `-03`, parallelization with OpenMP and vectorization
- Memory bandwidth :
- Problem is CPU bound

Comparision with blis

Operation	My Implementation	Blis
`sscal`	50ms	50ms
`dscal`	100ms	100ms
`sdot`	40ms	40ms
`ddot`	75ms	77ms
`saxpy`	58ms	56ms
`daxpy`	112ms	113ms
`sgemv`	15ms	12ms
`dgemv`	28ms	28ms
`sgemm`	38ms	25ms
`dgemm`	80ms	50ms

2D Stencil

- Operational Intensity : $\frac{2\times k^2\times hw}{sizeof(unit)\times hw+k^2}$
- Execution times

```
HD:
gcc : 10ms
icc : 50ms

UHD:
gcc : 30ms
icc : 130ms
```

  `icc` looks heavily unoptimized. This might be due to the fact that its being tested on an AMD processor rather than an Intel one.

- Baseline execution time : 130ms
  Best execution time : 10ms

  > Note that the baseline execution time is after compiling with gcc rather than icc

- Speedup : $13\times$
- With k = 3 and HD image
  Baseline GFLOPS : 0.32
  Best GFLOPS : 3.87
- Optimization strategies : `-03` and parallelization with openmp
- Memory bandwidth : 1.12 GB/s
- The problem is compute bound

On HD image with varying stencil size the runtime varies exponentially as expected.