Report - Assignment 1

Inderpreet Singh Chera

Problem Statement:

To understand the effect of Cache.

System Setup:

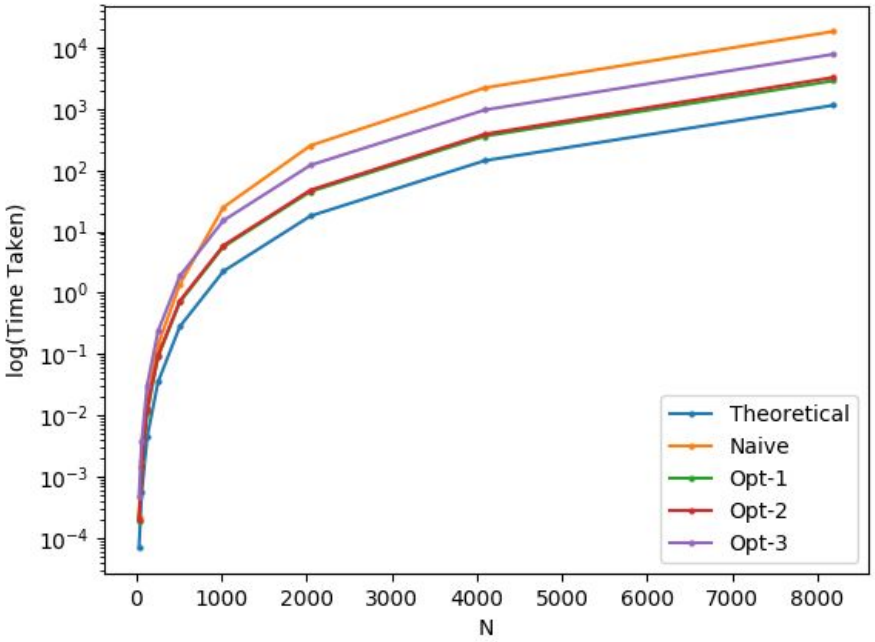
- Clock Speed:
  CPU max MHz: 1900.00
  CPU min MHz: 500.00
- Memory Size: 8076584 kB = 7887 MB
- Cache Sizes:
  L1d cache: 32K
  L1i cache: 32K
  L2 cache: 256K
  L3 cache: 3072K
- Theoretical Estimations for different values of 'N':
  Assumptions: Multiplication requires 3 clock cycles and Addition requires 1 clock cycle. We are assuming both the matrices are of sizes NxN.
  Now for matrix multiplication, we have for each element N multiplications and N-1 additions. And we do this for all N^2 elements, hence theoretically we will be requiring $N^2(3N_{\text{(for multiplication)}} + (N-1)_{\text{(for addition)}}) = N^2(4N-1)$ clock cycles. Hence theoretical time required is $(4N^3 - N^2)/(\text{Clock Speed})$.
  I am taking maximum clock speed of my pc, hence 1900 MHz.
  - N=32:
    $(4*32^3 - 32^2)/(1.9 \times 10^9) = 68.449 \times 10^{-6}$ s.
  - N=64:
    $(4*64^3 - 64^2)/(1.9 \times 10^9) = 0.000549726$ s.
    SImilarly,
  - N=128: 0.00440643 s.
  - N=256: 0.035286 s.
  - N=512: 0.282426 s.
  - N=1024: 2.25996 s.
  - N=2048: 18.0819 s.
  - N=4096: 144.664 s.
  - N=8192: 1157.35 s.

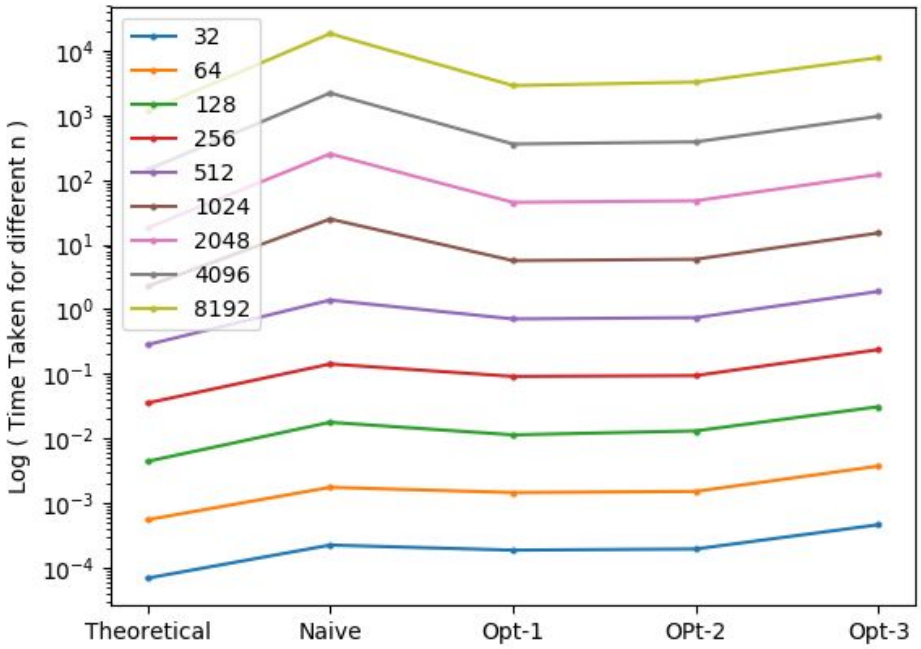
- Theoretical estimation of ‘s’ for optimization 2:
  s^2 = O(Memory Size)
  Therefore s = O($\sqrt{M}$)
  Now, cache memory size is 32kB = 32 x 1024 Bytes.
  Assuming 1 integer takes 4 bytes,
  The max. number of integers that can fit in L1d cache = sqrt(32*1024/4) = 90.5.
  Keeping s power of 2 for good division of matrices, s = 64.

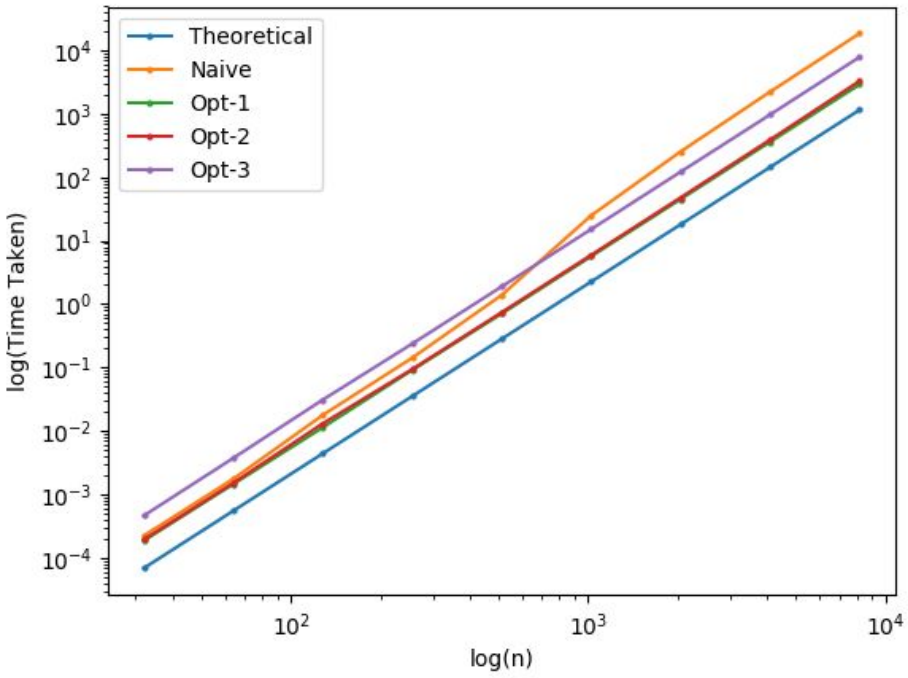
Values Observed:

I have taken 2 values of ‘s’ for optimisation 2, s=32 and s=64.

N	Theoretical	Naive	Opt-1	Opt-2 (s = 32)	Opt-2 (s = 64)	Opt-3
32	6.84463e-05	0.000223	0.000186	0.000194		0.000461
64	0.000549726	0.001749	0.001451	0.001511		0.003732
128	0.0044063	0.017780	0.011352	0.013084		0.031031
256	0.035286	0.142042	0.091328	0.093948		0.237299
512	0.282426	1.388570	0.708196	0.742125		1.891817
1024	2.25996	24.969940	5.667843	5.950698		15.196035
2048	18.0819	254.911866	45.265446	47.896635		122.090300
4096	144.664	2233.643528	362.500027	391.200087		973.819655
8192	1157.35	18600.95048	2914.189976	3304.406717		7894.428863


log(Time Taken)
N
Theoretical
Naive
Opt-1
Opt-2
Opt-3


Log (Time Taken for different n)
32
64
128
256
512
1024
2048
4096
8192
Theoretical
Naive
Opt-1
OPt-2
Opt-3


Theoretical
Naive
Opt-1
Opt-2
Opt-3
log(Time Taken)
log(n)
10^{4}
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{2}
10^{3}
10^{4}