Assignment-2

(Roll Number: 20161076)

1)

a) funct7() requires the most computing time

i) If funct7() is parallelized all these 260 calls can be ~ to single call and get significant drop in exclusive time of the callee funct8()

```
-----------------------------------------------
                1.31   16.00      13/26          funct6() [5]
                1.31   16.00      13/26          funct5() [2]
[3]     87.7    2.62   32.00      26          funct8() [3]
               26.17    0.00     260/260          funct7() [4]
                1.32    4.51      26/39          funct2() [6]
-----------------------------------------------
               26.17    0.00     260/260          funct8() [3]
[4]     66.3   26.17    0.00     260          funct7() [4]
```

ii) Funct7() is called 260 times in total, all calls are from funct8() only

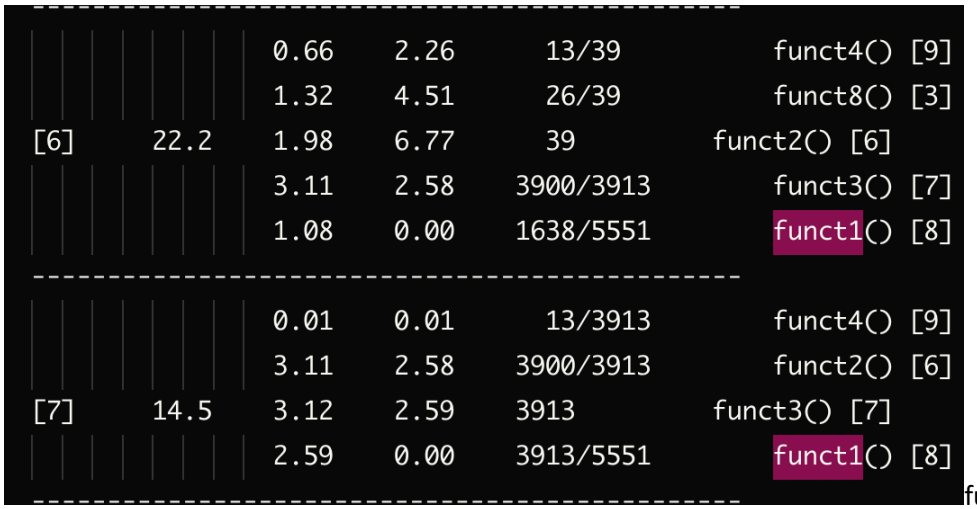
iii) Funct7() does 260 calls funct8()

b)

```
 9.33      29.84      3.67      5551      0.00      0.00  funct1()
 7.92      32.96      3.12      3913      0.00      0.00  funct3()
```

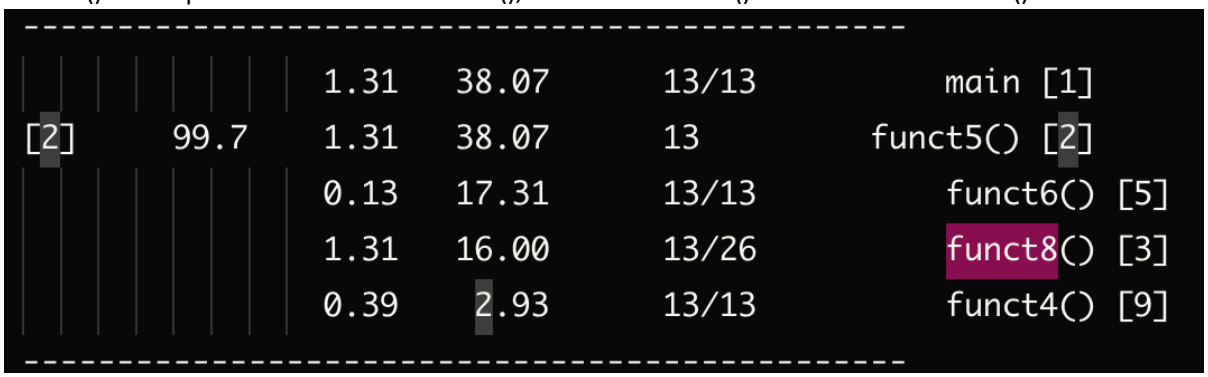
Funct1() has highest number of calls, followed by funct3()

```
-----------------------------------------------
                0.66    2.26      13/39          funct4() [9]
                1.32    4.51      26/39          funct8() [3]
[6]     22.2    1.98    6.77      39          funct2() [6]
                3.11    2.58    3900/3913          funct3() [7]
                1.08    0.00    1638/5551          funct1() [8]
-----------------------------------------------
                0.01    0.01      13/3913          funct4() [9]
                3.11    2.58    3900/3913          funct2() [6]
[7]     14.5    3.12    2.59    3913          funct3() [7]
                2.59    0.00    3913/5551          funct1() [8]
-----------------------------------------------
```



funct1() called 5551 times which has 1638 calls from funct2() and 3913 calls from funct3()

c) Funct5() is composed of 13 calls to funct6(), 13 calls to funct8() and 13 calls to funct4()



d)

```
Flat profile:

Each sample counts as 0.01 seconds.
  %   cumulative   self              self     total
 time   seconds   seconds    calls   s/call   s/call  name
 66.46     26.17    26.17      260     0.10     0.10  funct7()
  9.33     29.84     3.67     5551     0.00     0.00  funct1()
  7.92     32.96     3.12     3913     0.00     0.00  funct3()
  6.65     35.57     2.62       26     0.10     1.33  funct8()
  5.02     37.55     1.98       39     0.05     0.22  funct2()
  3.34     38.86     1.31       13     0.10     3.03  funct5()
  0.99     39.26     0.39       13     0.03     0.26  funct4()
  0.33     39.39     0.13       13     0.01     1.34  funct6()
  0.25     39.49     0.10                             main
  0.00     39.49     0.00        1     0.00     0.00  _GLOBAL__sub_I__Z6funct1v
  0.00     39.49     0.00        1     0.00     0.00  __static_initialization_and_destruction_0(int, int)
```

```
index % time    self  children    called     name
                                                 <spontaneous>
[1]    100.0    0.10   39.39                 main [1]
                1.31   38.07      13/13          funct5() [2]
-----------------------------------------------

                1.31   38.07      13/13          main [1]
[2]     99.7    1.31   38.07      13         funct5() [2]
                0.13   17.31      13/13          funct6() [5]
                1.31   16.00      13/26          funct8() [3]
                0.39    2.93      13/13          funct4() [9]
-----------------------------------------------

                1.31   16.00      13/26          funct6() [5]
                1.31   16.00      13/26          funct5() [2]
[3]     87.7    2.62   32.00      26         funct8() [3]
               26.17    0.00     260/260         funct7() [4]
                1.32    4.51      26/39          funct2() [6]
-----------------------------------------------

               26.17    0.00     260/260         funct8() [3]
[4]     66.3   26.17    0.00     260         funct7() [4]
-----------------------------------------------
```

```
index % time    self  children    called     name
                                                 <spontaneous>
[1]    100.0    0.10   39.39                 main [1]
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[2]     99.7    1.31   38.07      13         funct5() [2]
                0.13   17.31      13/13          funct6() [5]
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               26.17    0.00     260/260         funct7() [4]
                1.32    4.51      26/39          funct2() [6]
-----------------------------------------------

               26.17    0.00     260/260         funct8() [3]
[4]     66.3   26.17    0.00     260         funct7() [4]
-----------------------------------------------
```

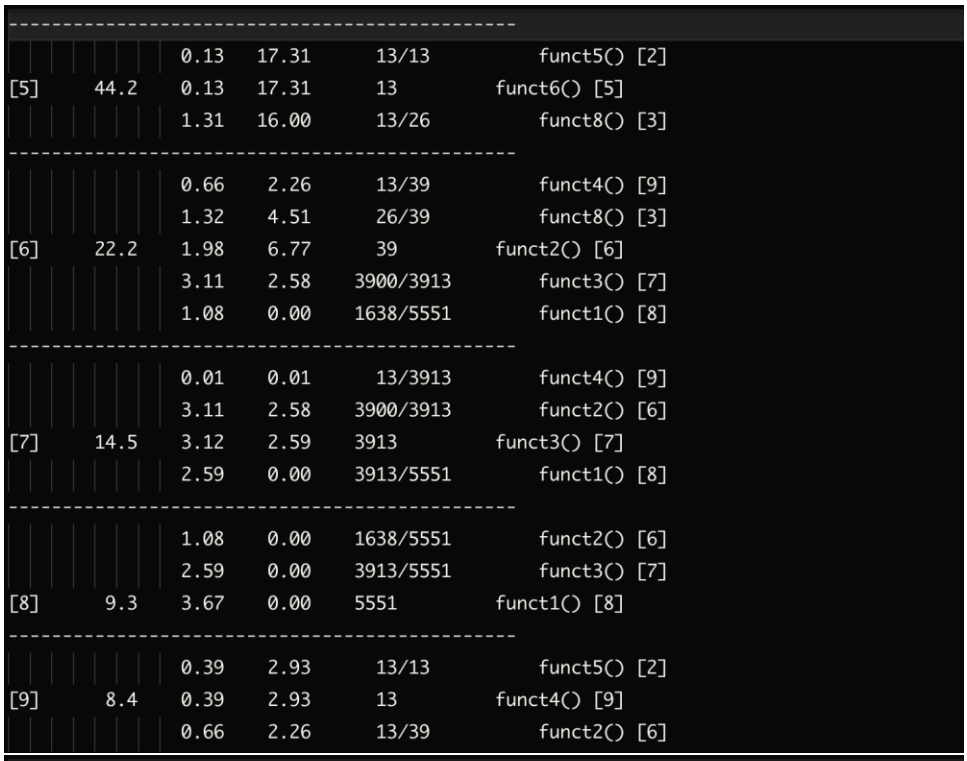

```
-----------------------------------------------
                0.13   17.31      13/13          funct5() [2]
[5]     44.2    0.13   17.31      13         funct6() [5]
                1.31   16.00      13/26          funct8() [3]
-----------------------------------------------
                0.66    2.26      13/39          funct4() [9]
                1.32    4.51      26/39          funct8() [3]
[6]     22.2    1.98    6.77      39         funct2() [6]
                3.11    2.58    3900/3913        funct3() [7]
                1.08    0.00    1638/5551        funct1() [8]
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                0.01    0.01      13/3913        funct4() [9]
                3.11    2.58    3900/3913        funct2() [6]
[7]     14.5    3.12    2.59    3913         funct3() [7]
                2.59    0.00    3913/5551        funct1() [8]
-----------------------------------------------
                1.08    0.00    1638/5551        funct2() [6]
                2.59    0.00    3913/5551        funct3() [7]
[8]      9.3    3.67    0.00    5551         funct1() [8]
-----------------------------------------------
                0.39    2.93      13/13          funct5() [2]
[9]      8.4    0.39    2.93      13         funct4() [9]
                0.66    2.26      13/39          funct2() [6]
```


```
-----------------------------------------------
                0.13   17.31      13/13          funct5() [2]
[5]     44.2    0.13   17.31      13         funct6() [5]
                1.31   16.00      13/26          funct8() [3]
-----------------------------------------------
                0.66    2.26      13/39          funct4() [9]
                1.32    4.51      26/39          funct8() [3]
[6]     22.2    1.98    6.77      39         funct2() [6]
                3.11    2.58    3900/3913        funct3() [7]
                1.08    0.00    1638/5551        funct1() [8]
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[7]     14.5    3.12    2.59    3913         funct3() [7]
                2.59    0.00    3913/5551        funct1() [8]
-----------------------------------------------
                1.08    0.00    1638/5551        funct2() [6]
                2.59    0.00    3913/5551        funct3() [7]
[8]      9.3    3.67    0.00    5551         funct1() [8]
-----------------------------------------------
                0.39    2.93      13/13          funct5() [2]
[9]      8.4    0.39    2.93      13         funct4() [9]
                0.66    2.26      13/39          funct2() [6]
```

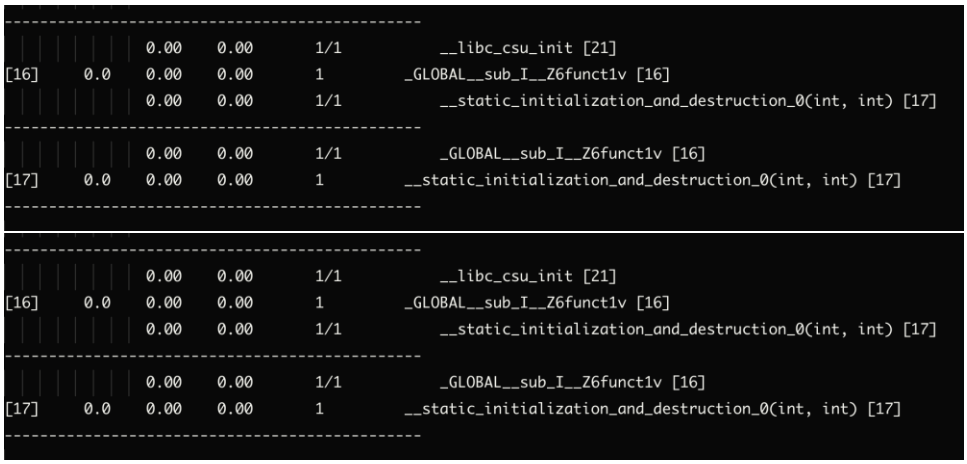

2) Co1b.c is faster compared to co1a.c because of the extra variables that are defined in co1a. Average real time (in sec) for co1a.c 0.164 is and co1b.c is 0.110.

Sno	Co1a (in sec)	Co1b (in sec)
1	0.164	0.109
2	0.170	0.110
3	0.155	0.113
4	0.161	0.110
5	0.171	0.112

3) Co2b.c is faster compared to co2a.c because in co2b.c has sequential access to data where as co2a.c has non-sequential access to data so it is slower. Average real time (in sec) for co2a.c 1.5424 is and co2b.c is 0.2554.

Sno	Co2a (in sec)	Co2b (in sec)
1	1.469	0.281
2	1.625	0.248
3	1.627	0.252
4	1.499	0.247
5	1.492	0.249

4) Co4a - Naïve Matrix Multiplication, co4b – Transposed Matrix Multiplication, co4c – Cache-Blocking Matrix Multiplication
   a) Time taken by each variation of matrix multiplication vs size of matrix

Matrix Size\Time	Co4a (in sec)	Co4b (in sec)	Co4c (in sec)
1000	9.159	4.471	0.065
2000	1:27.63	35.246	0.244
4000	17:44.03	5:09.55	1.046

   b) From the table above it can be clearly understood that Cache-Blocking matrix multiplication (co4c) runs faster than other variants
   c) Likwid-profiling for cache misses

i) Naïve Matrix Multiplication

```
--------------------------------------------------------------------------------
Group 1: L2CACHE
+----------------------+---------+-------------+
|         Event        | Counter |    Core 0   |
+----------------------+---------+-------------+
|   INSTR_RETIRED_ANY  |  FIXC0  | 37037834796 |
| CPU_CLK_UNHALTED_CORE |  FIXC1  | 25635164977 |
|  CPU_CLK_UNHALTED_REF |  FIXC2  | 20963793509 |
| L2_TRANS_ALL_REQUESTS |   PMC0  |  1747906918 |
|     L2_RQSTS_MISS    |   PMC1  |   180959783 |
+----------------------+---------+-------------+

+----------------------+-----------+
|        Metric        |   Core 0  |
+----------------------+-----------+
|  Runtime (RDTSC) [s] |    9.3124 |
| Runtime unhalted [s] |   11.1717 |
|      Clock [MHz]     | 2805.9606 |
|          CPI         |    0.6921 |
|    L2 request rate   |    0.0472 |
|     L2 miss rate     |    0.0049 |
|     L2 miss ratio    |    0.1035 |
+----------------------+-----------+
```

ii) Transpose Matrix Multiplication

```
--------------------------------------------------------------------------------
Group 1: L2CACHE
+----------------------+---------+-------------+
|         Event        | Counter |    Core 0   |
+----------------------+---------+-------------+
|   INSTR_RETIRED_ANY  |  FIXC0  | 37074834883 |
| CPU_CLK_UNHALTED_CORE |  FIXC1  | 12969594134 |
|  CPU_CLK_UNHALTED_REF |  FIXC2  | 10342022565 |
| L2_TRANS_ALL_REQUESTS |   PMC0  |   593975335 |
|     L2_RQSTS_MISS    |   PMC1  |   152988472 |
+----------------------+---------+-------------+

+----------------------+-----------+
|        Metric        |   Core 0  |
+----------------------+-----------+
|  Runtime (RDTSC) [s] |    4.5868 |
| Runtime unhalted [s] |    5.6528 |
|      Clock [MHz]     | 2877.2850 |
|          CPI         |    0.3498 |
|    L2 request rate   |    0.0160 |
|     L2 miss rate     |    0.0041 |
|     L2 miss ratio    |    0.2576 |
+----------------------+-----------+
```

iii) Cache-Blocking Matrix Multiplication

```
--------------------------------------------------------------------------------
Group 1: L2CACHE
+-----------------------+---------+-----------+
|         Event         | Counter |   Core 0  |
+-----------------------+---------+-----------+
|   INSTR_RETIRED_ANY   |  FIXC0  | 416818846 |
| CPU_CLK_UNHALTED_CORE |  FIXC1  | 149930780 |
|  CPU_CLK_UNHALTED_REF |  FIXC2  | 120353825 |
| L2_TRANS_ALL_REQUESTS |   PMC0  |   6045768 |
|     L2_RQSTS_MISS     |   PMC1  |   1966682 |
+-----------------------+---------+-----------+

+----------------------+-----------+
|        Metric        |   Core 0  |
+----------------------+-----------+
|  Runtime (RDTSC) [s] |    0.0677 |
| Runtime unhalted [s] |    0.0653 |
|      Clock [MHz]     | 2858.4227 |
|          CPI         |    0.3597 |
|    L2 request rate   |    0.0145 |
|     L2 miss rate     |    0.0047 |
|     L2 miss ratio    |    0.3253 |
+----------------------+-----------+
```