CS5312 High Performance Computer Architecture

Take Home Lab 2

Step 4

Task 5.1

Please note that these times are in milliseconds.

Dimensions		Execution Time				
		Listing 5	Listing 6	Speed Up	Listing 6 SSE	Speed Up
100*100	100*1	0.0302	0.0187	1.61	0.0169	1.79
200*200	200*1	0.1176	0.0744	1.58	0.0624	1.88
400*400	400*1	0.4665	0.2945	1.58	0.2549	1.83
800*800	800*1	1.8452	1.1682	1.58	1.0421	1.77
1600*1600	1600*1	7.3952	4.718	1.57	4.1406	1.79

Task 6.1 and 7.1

Dimensions		Execution Time				
		Listing 7	Listing 7 SSE	Speed Up	Listing 7 Auto Vectorization	Speed Up
100*100	100*100	3.9738	2.4122	1.65	0.95	4.18
200*200	200*200	31.4334	19.1806	1.64	8.497	3.70
400*400	400*400	286.8759	171.6214	1.67	72.952	3.93
800*800	800*800	2596.103	1747.9119	1.49	649.634	4.00
1600*1600	1600*1600	23502.365	19013.4422	1.24	6057.310	3.88

Step 5

Specifications of the machine used

```
Architecture:          x86_64
CPU op-mode(s):        32-bit, 64-bit
Byte Order:            Little Endian
Address sizes:         46 bits physical, 48 bits virtual
CPU(s):                4
On-line CPU(s) list:   0-3
Thread(s) per core:    2
Core(s) per socket:    2
Socket(s):             1
NUMA node(s):          1
Vendor ID:             GenuineIntel
CPU family:            6
Model:                 85
Model name:            Intel(R) Xeon(R) CPU
Stepping:              7
CPU MHz:               2800.180
BogoMIPS:              5600.36
Hypervisor vendor:     KVM
Virtualization type:   full
L1d cache:             32K
L1i cache:             32K
L2 cache:              1024K
L3 cache:              33792K
NUMA node0 CPU(s):     0-3
```

Matrix-Vector multiplication

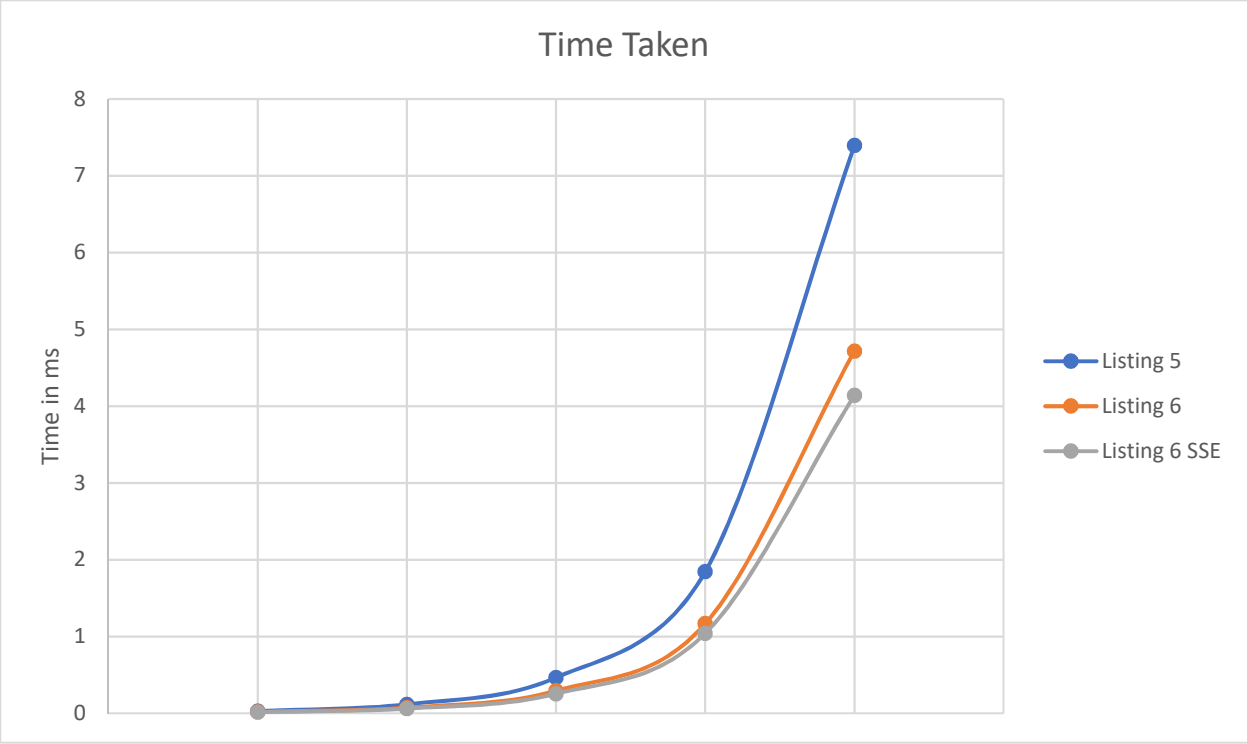
In Matrix-Vector multiplication first we have taken time using the naïve method. Then we tested the same method with loop unrolling with unrolling 4 iterations. Later we tested with 128 bit vectors which accommodates 4 elements at once. Which is parallel to the manual loop unrolling we have done.

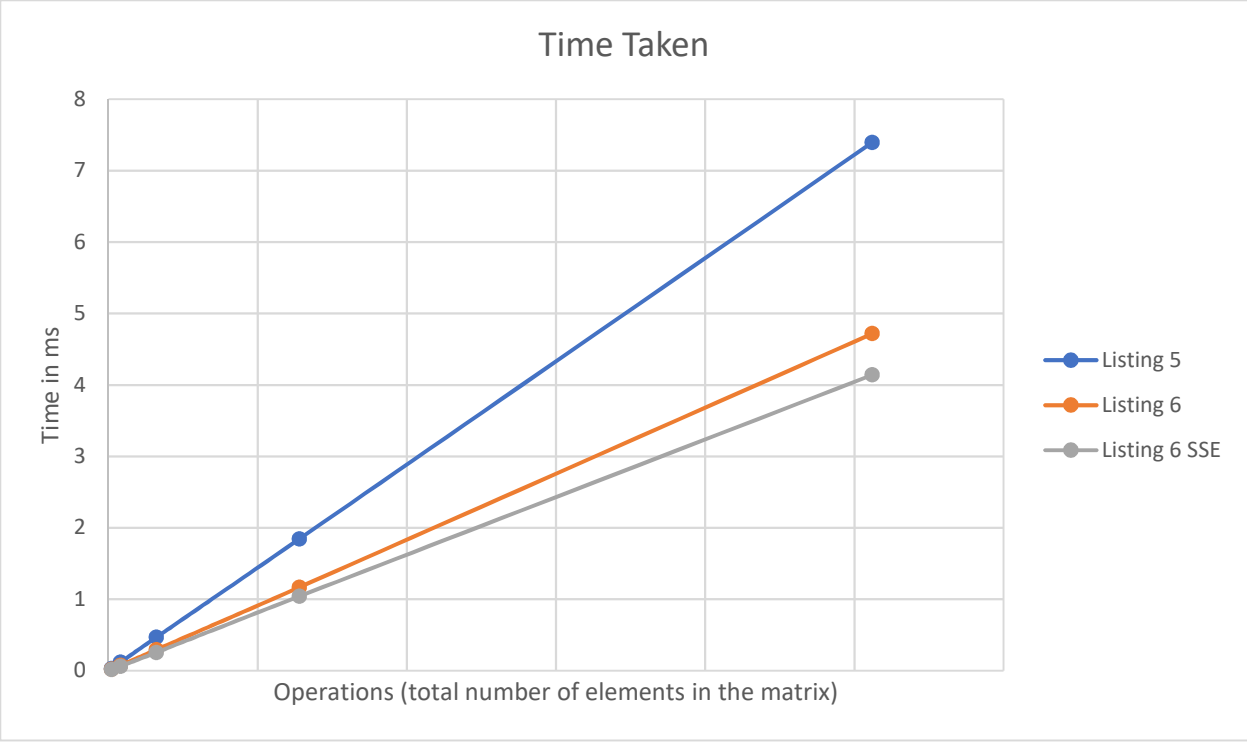
As we can see from the data we acquired we have achieved considerable amount of speedup (nearly 1.6 times) by loop unrolling. This is mainly due to the fact that unrolling loops reduce the overhead occurs when running each iteration. By unrolling the loop 4 times we have reduced a significant amount of overhead per iteration. Hence resulting in the speedup.

In the next test, SSE is used for the same matrix vector multiplication. We have compiled the files to match the native SSE/AVX of the machine. 128 bit SSE variables were used which can hold 4, 32bit floats.

As we can see from the data this has given a significant boost to the speed up compared to the naïve version (nearly 1.8 speedup). Also when compared to the manual loop unrolled version this has provided nearly 1.12X speedup thanks to the streaming operations done through the special hardware.

I have provided some charts below. This problem corresponds to $O(n^2)$ problem. Therefore better comparison can be done using the approximate number of multiplications happen.


Time Taken
Time in ms
0
1
2
3
4
5
6
7
8
Listing 5
Listing 6
Listing 6 SSE


Time Taken
Time in ms
0
1
2
3
4
5
6
7
8
Operations (total number of elements in the matrix)
Listing 5
Listing 6
Listing 6 SSE

Matrix-Matrix multiplication

This graph shows the time taken for each test. As we can see SSE version performs significantly better compared to the naïve version (nearly 1.5 times better). But as you can see the speedup drops with the size of the matrix. This can be attributed to limitations of the memory system. As the number of elements increase, the memory becomes saturated and cache misses increase. Which results in higher delays.

Auto vectorized method is much better compared to the SSE version. It provided nearly 4X improvement over the naïve method and nearly 2.6X improvement over the SSE version. In the compile time we could observe the message that

matmat_auto.c:74:13: note: loop vectorized

matmat_auto.c:74:13: note: loop with 2 iterations completely unrolled (header execution count 72506056)

Which indicates that a main loop is completely unrolled with vectorization. Which explains the huge gain in speedup.

This problem is $O(n^3)$. Hence x axis of the graph provided corresponds to the cube of the dimension of the matrix.