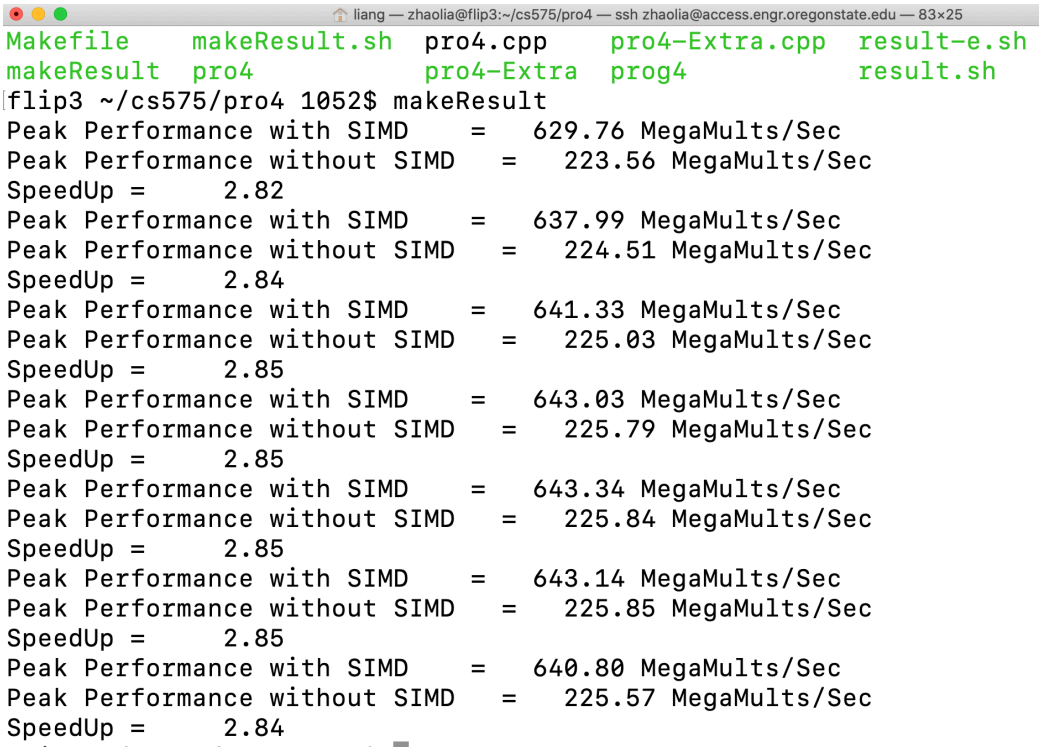
CS 475/575 -- Spring Quarter 2020

Project #4

Vectorized Array Multiplication/Reduction using SSE

60 Points

Due: May 11



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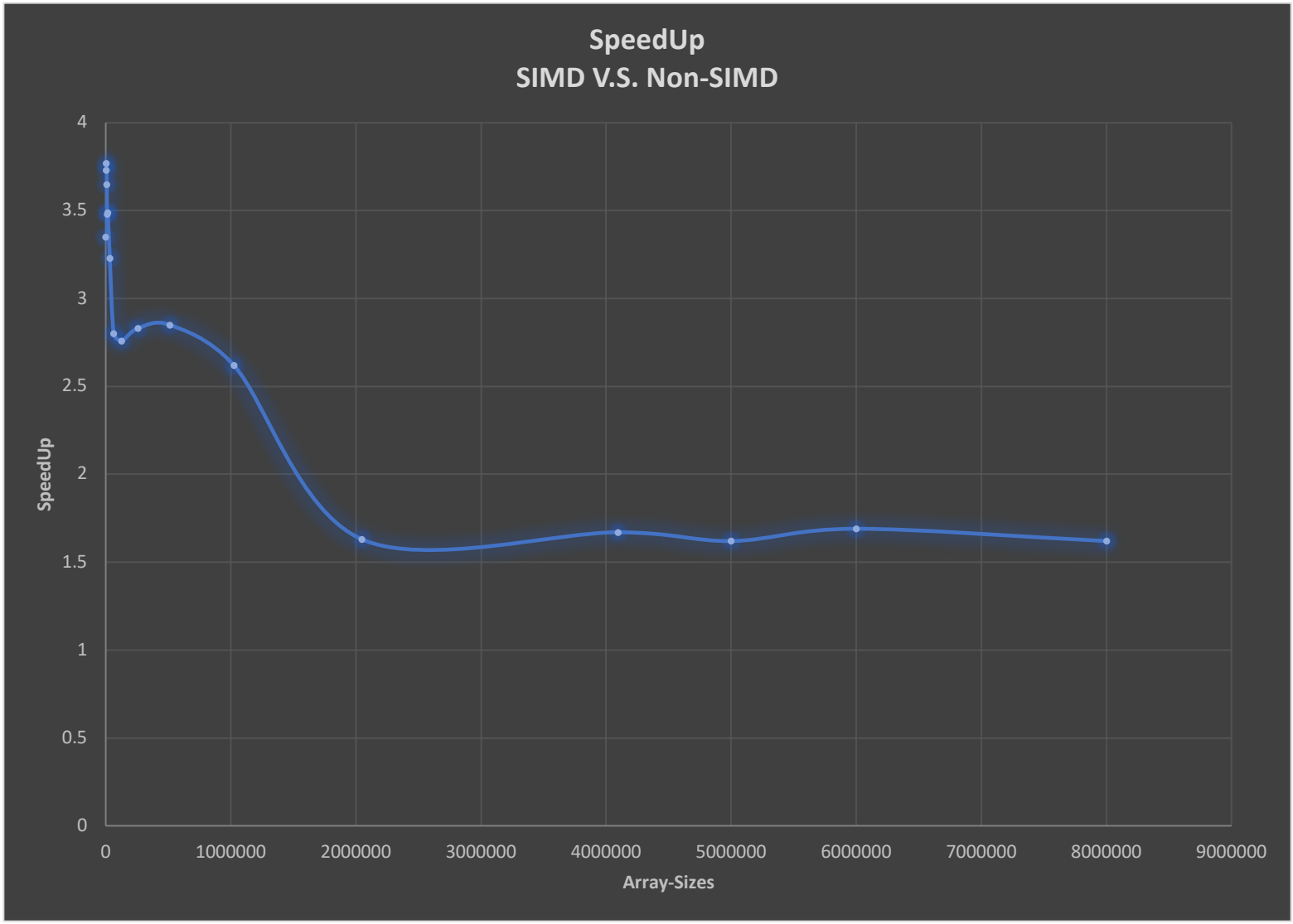
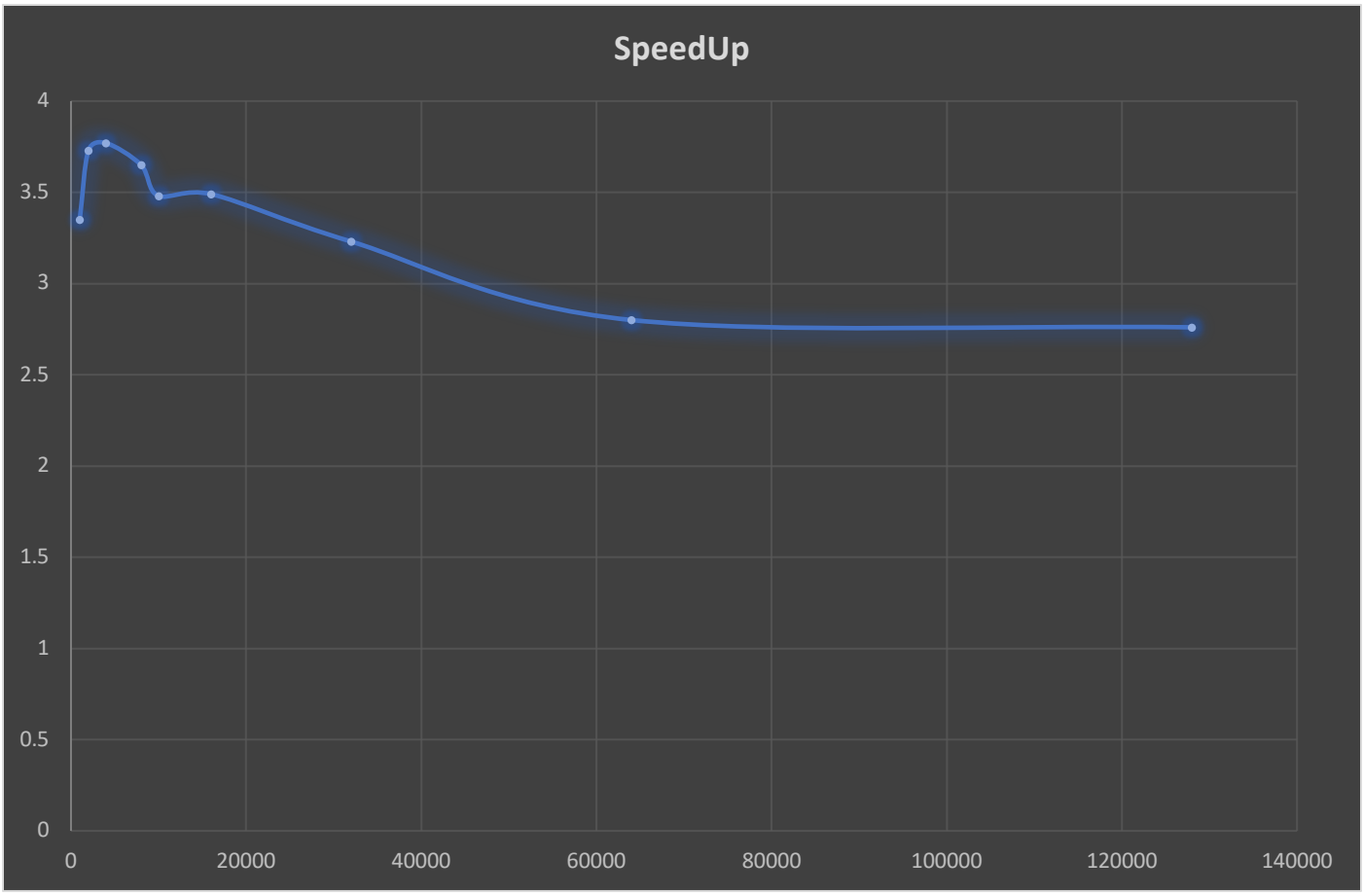
Hi there, my program run on OSU Linux server: access.engr.oregonstate.edu. I used a bash script to automatically adjust the number of Array-Sizes and SimdPerformance, NonSimdPerformance, SpeedUp, and save the results in a csv file. Let us first look at the results of the experiment.

Array-Sizes	SimdPerformance	NonSimdPerformance	SpeedUp
1000	3381.86	956.14	3.35
2000	3591.11	962.13	3.73
4000	3658.4	969.3	3.77
8000	3345.64	972.04	3.65
10000	3386.66	972.55	3.48
16000	3394.22	973.56	3.49
32000	3139.17	971.41	3.23
64000	2704.91	966.31	2.8
128000	2673.91	969.34	2.76
256000	2735.28	968.21	2.83
512000	2726.67	957.53	2.85
1024000	2439.85	930.75	2.62
2048000	1342	821.9	1.63
4096000	1360.11	816	1.67
5000000	1282.86	837.58	1.62
6000000	1410.74	836.2	1.69
8000000	1356.04	844.96	1.62

And the graph of SIMD/non-SIMD speedup versus array size:



Let's zoom in on the data of 1-128000 Array-Sizes. We can see subtle changes in the speedup data.



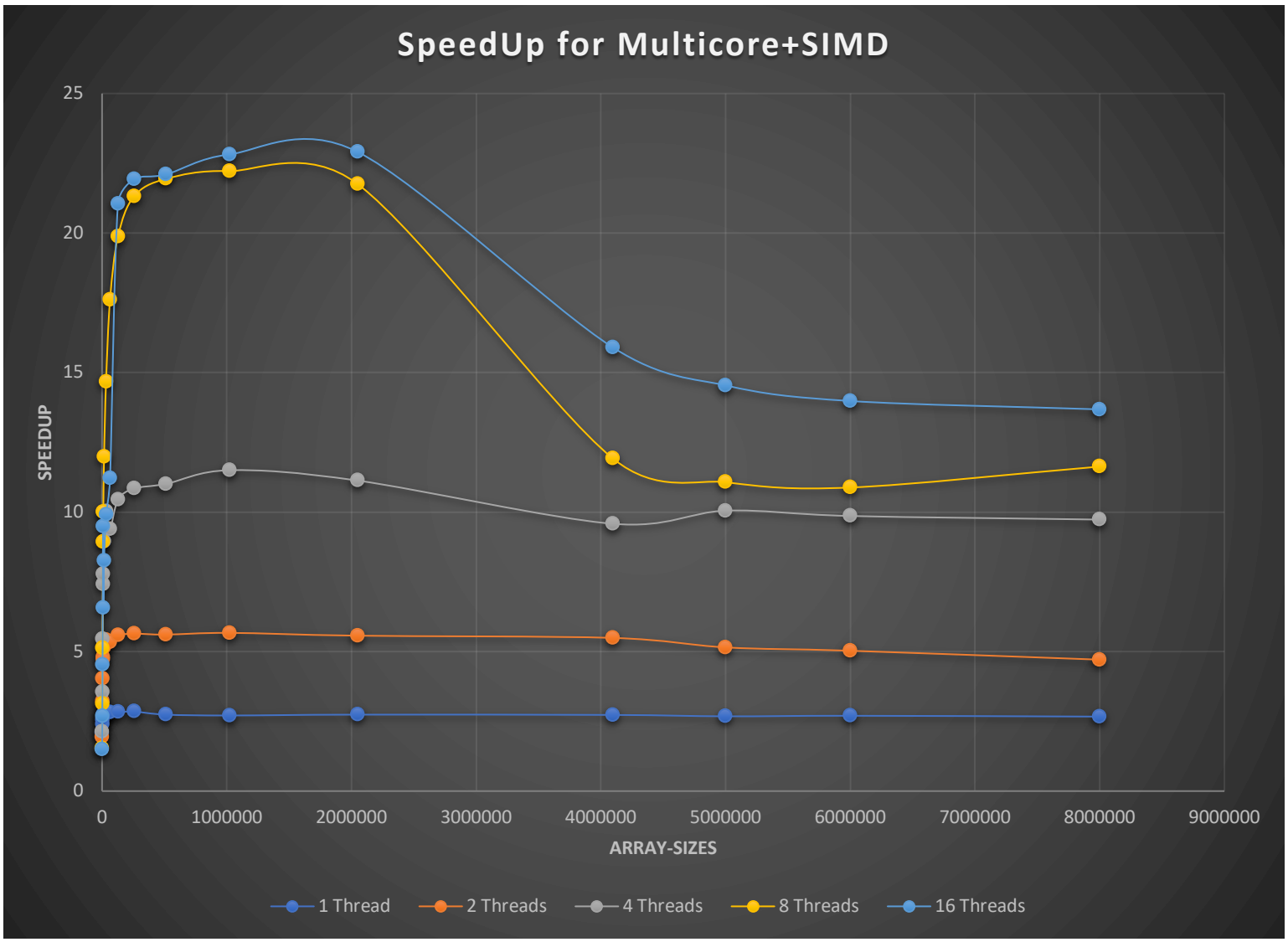
We can see that the maximum speedup is 3.77, which the array size is 4000. I later improved g ++ 's compile command and added "-O3". The performance of the program was improved. Speedup increased during the process of size 1-4000, and gradually decreased to 1.62 after 4000. I also tested that when the array size is close to infinity, the speedup is around 1.5. This may be the limit data of speedup. If the data size is too small, the benefit of SIMD will be shaded by the additional work for SIMD. And the temporal coherence is violated when the size of data set is too much. I think data in cache line is possibly only used once and then be replaced.

I also did the extra credit. The core code is like this:

```
omp_set_num_threads(NUMT);

double maxMegaMultsSimd = 0.;
double maxMegaMultsNonSimd = 0.;

//Computing SimdMulSum performance
for( int t = 0; t < NUMTRIES; t++ )
{
    double time0 = omp_get_wtime( );

    //SimdMulSum(a_array, b_array, ARRAYSIZE);

    #pragma omp parallel
    {
        int e = omp_get_thread_num( ) * (ARRAYSIZE/NUMT);
        SimdMulSum(&a_array[e], &b_array[e], (ARRAYSIZE/NUMT));
    }

    double time1 = omp_get_wtime( );
    double megaMults = (double)ARRAYSIZE/(time1-time0)/1000000.;
    if( megaMults > maxMegaMultsSimd )
        maxMegaMultsSimd = megaMults;


}
```

SpeedUP		1 Thread	2 Threads	4 Threads	8 Threads	16 Threads
Array-Sizes	1000	2.07	1.93	2.12	1.53	1.5
	2000	2.4	3.23	3.55	3.12	2.68
	4000	2.56	4.03	5.46	5.13	4.52
	8000	2.7	4.8	7.41	8.92	9.48
	10000	2.73	4.72	7.78	10	6.56
	16000	2.78	5.15	8.94	11.99	8.26

	32000	2.8	5.41	10.02	14.67	9.9
	64000	2.82	5.33	9.39	17.61	11.21
	128000	2.83	5.58	10.44	19.88	21.05
	256000	2.85	5.64	10.84	21.31	21.93
	512000	2.74	5.61	11.01	21.94	22.1
	1024000	2.71	5.67	11.5	22.22	22.82
	2048000	2.74	5.57	11.13	21.76	22.91
	4096000	2.73	5.49	9.58	11.92	15.9
	5000000	2.68	5.15	10.05	11.07	14.54
	6000000	2.7	5.03	9.86	10.88	13.98
	8000000	2.67	4.71	9.73	11.63	13.68



Data set size is critical to performance. If the size of the data set is too small, the advantages of SIMD will be masked by the extra work of SIMD. If the data set is too large, it will destroy temporal coherence and reduce performance.

Code:

```
#include <stdio.h>
#include <stdlib.h>
#include <omp.h>
#include <xmmintrin.h>


#ifndef NUMT
#define NUMT      4
#endif

#ifndef ARRAYSIZE
#define ARRAYSIZE 1000000
#endif

#ifndef NUMTRIES
#define NUMTRIES 100
#endif

#ifndef SSE_WIDTH
#define SSE_WIDTH 4
#endif



float Ranf( unsigned int *seedp,  float low, float high );
float SimdMulSum( float *a, float *b, int len );
float NonSimdMulSum( float *a, float *b, int len);

    float a_array[ARRAYSIZE];
    float b_array[ARRAYSIZE];

int main(int argc, char **argv)
{

//Verify OpenMP support
#ifndef _OPENMP
    fprintf( stderr, "No OpenMP support!\n" );
    return 1;
#endif

    //float * a_array = (float *)malloc(sizeof(float) * length);


    //Inialize the arrays:
```

```
	unsigned int seed = omp_get_wtime( );
	for(int i=0;i<ARRAYSIZE;i++)
	{
		a_array[i] = Ranf(&seed, 0.f, 1000.f );
		b_array[i] = Ranf(&seed, 0.f, 1000.f );
	}



	omp_set_num_threads(NUMT);

	double maxMegaMultsSimd = 0.;
	double maxMegaMultsNonSimd = 0.;

	//Computing SimdMulSum performance
	for( int t = 0; t < NUMTRIES; t++ )
	{
		double time0 = omp_get_wtime( );

		//SimdMulSum(a_array, b_array, ARRAYSIZE);

		#pragma omp parallel
		{
			int e = omp_get_thread_num( ) * (ARRAYSIZE/NUMT);
			SimdMulSum(&a_array[e], &b_array[e], (ARRAYSIZE/NUMT));
		}

		double time1 = omp_get_wtime( );
		double megaMults = (double)ARRAYSIZE/(time1-time0)/1000000.;
		if( megaMults > maxMegaMultsSimd )
			maxMegaMultsSimd = megaMults;


	}




	//Computing NonSimdMulSum performance
	for( int t = 0; t < NUMTRIES; t++ )
	{
		double time0 = omp_get_wtime( );
		NonSimdMulSum(a_array, b_array, ARRAYSIZE);
		double time1 = omp_get_wtime( );
		double megaMultsNonSimd = (double)ARRAYSIZE/(time1-time0)/1000000.;
```

```
        if( megaMultsNonSimd > maxMegaMultsNonSimd )
            maxMegaMultsNonSimd = megaMultsNonSimd;



    }

    //speedup
    printf( "Peak Performance with SIMD    = %8.2lf MegaMults/Sec\n", maxMegaMult
sSimd );
    printf( "Peak Performance without SIMD   = %8.2lf MegaMults/Sec\n", maxMegaMu
ltsNonSimd );

    double speedup = maxMegaMultsSimd/maxMegaMultsNonSimd;

    printf("SpeedUp = %8.2lf\n", speedup);


}







float Ranf(unsigned int *seedp, float low, float high) {
    float r = (float) rand_r(seedp);
    return (low + r * (high - low) / (float)RAND_MAX);
}




float SimdMulSum( float *a, float *b, int len )
{
    float sum[4] = { 0., 0., 0., 0. };
    int limit = ( len/SSE_WIDTH ) * SSE_WIDTH;
    register float *pa = a;
    register float *pb = b;

    __m128 ss = _mm_loadu_ps( &sum[0] );
    for( int i = 0; i < limit; i += SSE_WIDTH )
    {
        ss = _mm_add_ps( ss, _mm_mul_ps( _mm_loadu_ps( pa ), _mm_loadu_ps( pb ) )
 );
        pa += SSE_WIDTH;
```

```
        pb += SSE_WIDTH;
    }
    _mm_storeu_ps( &sum[0], ss );

    for( int i = limit; i < len; i++ )
    {
        sum[0] += a[i] * b[i];
    }

    return sum[0] + sum[1] + sum[2] + sum[3];
}



float NonSimdMulSum( float *a, float *b, int len)
{
    float sum = 0.;
    for(int i =0; i< len; i++)
    {
        sum += a[i] * b[i];
    }

    return sum;
}
```