Parallel Programming Techniques CPSC524

Assignment 1

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## Environment/Software

###### Module

Langs/Intel/14

###### Output of env command

|  |
| --- |
| MKLROOT=/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer\_xe\_2013\_sp1.2.144/mkl  MANPATH=/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer\_xe\_2013\_sp1.2.144/man/en\_US:/usr/share/man:/opt/moab/share/man:  MKL\_LINK=-L/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer\_xe\_2013\_sp1.2.144/mkl/lib/intel64 -Wl,--start-group -lmkl\_intel\_lp64 -lmkl\_intel\_thread -lmkl\_core -Wl,--end-group -lpthread -lm  HOSTNAME=compute-14-1.local  IPPROOT=/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer\_xe\_2013\_sp1.2.144/ipp  INTEL\_LICENSE\_FILE=/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer\_xe\_2013\_sp1.2.144/licenses:/opt/intel/licenses:/home/apps/fas/Licenses/intel\_site.lic  TERM=xterm  SHELL=/bin/bash  HISTSIZE=1000  SSH\_CLIENT=10.191.63.253 60496 22  LIBRARY\_PATH=/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer\_xe\_2013\_sp1.2.144/ipp/../compiler/lib/intel64:/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer\_xe\_2013\_sp1.2.144/ipp/lib/intel64:/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer\_xe\_2013\_sp1.2.144/compiler/lib/intel64:/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer\_xe\_2013\_sp1.2.144/mkl/lib/intel64:/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer\_xe\_2013\_sp1.2.144/tbb/lib/intel64/gcc4.4  PERL5LIB=/opt/moab/lib/perl5  FPATH=/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer\_xe\_2013\_sp1.2.144/mkl/include:/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer\_xe\_2013\_sp1.2.144/mkl/include/intel64/lp64  QTDIR=/usr/lib64/qt-3.3  QTINC=/usr/lib64/qt-3.3/include  MIC\_LD\_LIBRARY\_PATH=/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer\_xe\_2013\_sp1.2.144/mpirt/lib/mic:/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer\_xe\_2013\_sp1.2.144/compiler/lib/mic:/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer\_xe\_2013\_sp1.2.144/mkl/lib/mic:/opt/intel/mic/coi/device-linux-release/lib:/opt/intel/mic/myo/lib:/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer\_xe\_2013\_sp1.2.144/tbb/lib/mic  SSH\_TTY=/dev/pts/8  ANT\_HOME=/opt/rocks  USER=bs744  LD\_LIBRARY\_PATH=/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer\_xe\_2013\_sp1.2.144/mpirt/lib/intel64:/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer\_xe\_2013\_sp1.2.144/ipp/../compiler/lib/intel64:/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer\_xe\_2013\_sp1.2.144/ipp/lib/intel64:/opt/intel/mic/coi/host-linux-release/lib:/opt/intel/mic/myo/lib:/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer\_xe\_2013\_sp1.2.144/compiler/lib/intel64:/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer\_xe\_2013\_sp1.2.144/mkl/lib/intel64:/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer\_xe\_2013\_sp1.2.144/tbb/lib/intel64/gcc4.4  MIC\_LIBRARY\_PATH=/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer\_xe\_2013\_sp1.2.144/tbb/lib/mic  ROCKS\_ROOT=/opt/rocks  CPATH=/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer\_xe\_2013\_sp1.2.144/ipp/include:/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer\_xe\_2013\_sp1.2.144/mkl/include:/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer\_xe\_2013\_sp1.2.144/tbb/include  YHPC\_COMPILER=Intel  NLSPATH=/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer\_xe\_2013\_sp1.2.144/compiler/lib/intel64/locale/%l\_%t/%N:/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer\_xe\_2013\_sp1.2.144/ipp/lib/intel64/locale/%l\_%t/%N:/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer\_xe\_2013\_sp1.2.144/mkl/lib/intel64/locale/%l\_%t/%N:/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer\_xe\_2013\_sp1.2.144/debugger/gdb/intel64\_mic/py26/share/locale/%l\_%t/%N:/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer\_xe\_2013\_sp1.2.144/debugger/gdb/intel64/py26/share/locale/%l\_%t/%N:/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer\_xe\_2013\_sp1.2.144/debugger/intel64/locale/%l\_%t/%N  MAIL=/var/spool/mail/bs744  PATH=/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer\_xe\_2013\_sp1.2.144/mpirt/bin/intel64:/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer\_xe\_2013\_sp1.2.144/debugger/gdb/intel64\_mic/py26/bin:/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer\_xe\_2013\_sp1.2.144/debugger/gdb/intel64/py26/bin:/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer\_xe\_2013\_sp1.2.144/bin/intel64:/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer\_xe\_2013\_sp1.2.144/bin/intel64\_mic:/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer\_xe\_2013\_sp1.2.144/debugger/gui/intel64:/home/apps/fas/Modules:/usr/lib64/qt-3.3/bin:/opt/moab/bin:/usr/local/bin:/bin:/usr/bin:/usr/local/sbin:/usr/sbin:/sbin:/usr/java/latest/bin:/opt/rocks/bin:/opt/rocks/sbin:/home/apps/bin:/home/fas/cpsc424/bs744/bin  YHPC\_COMPILER\_MINOR=2  TBBROOT=/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer\_xe\_2013\_sp1.2.144/tbb  F90=ifort  PWD=/home/fas/cpsc424/bs744/lab1  \_LMFILES\_=/home/apps/fas/Modules/Base/yale\_hpc:/home/apps/fas/Modules/Langs/Intel/14  YHPC\_COMPILER\_MAJOR=0  JAVA\_HOME=/usr/java/latest  IDB\_HOME=/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer\_xe\_2013\_sp1.2.144/bin/intel64  GDB\_CROSS=/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer\_xe\_2013\_sp1.2.144/debugger/gdb/intel64\_mic/py26/bin/gdb-mic  DOMAIN=omega  LANG=en\_US.iso885915  MODULEPATH=/home/apps/fas/Modules  MOABHOMEDIR=/opt/moab  YHPC\_COMPILER\_RELEASE=14  LOADEDMODULES=Base/yale\_hpc:Langs/Intel/14  KDEDIRS=/usr  F77=ifort  CXX=icpc  SSH\_ASKPASS=/usr/libexec/openssh/gnome-ssh-askpass  HISTCONTROL=ignoredups  SHLVL=1  HOME=/home/fas/cpsc424/bs744  MKL\_LINK\_SEQUENTIAL=-L/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer\_xe\_2013\_sp1.2.144/mkl/lib/intel64 -Wl,--start-group -lmkl\_intel\_lp64 -lmkl\_sequential -lmkl\_core -Wl,--end-group -lpthread  FC=ifort  LOGNAME=bs744  QTLIB=/usr/lib64/qt-3.3/lib  CVS\_RSH=ssh  SSH\_CONNECTION=10.191.63.253 60496 10.191.10.209 22  MODULESHOME=/usr/share/Modules  LESSOPEN=||/usr/bin/lesspipe.sh %s  arch=intel64  CC=icc  INCLUDE=/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer\_xe\_2013\_sp1.2.144/mkl/include:/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer\_xe\_2013\_sp1.2.144/mkl/include/intel64/lp64  G\_BROKEN\_FILENAMES=1  BASH\_FUNC\_module()=() { eval `/usr/bin/modulecmd bash $\*`  }  \_=/bin/env  OLDPWD=/home/fas/cpsc424/bs744 |

###### Steps/commands used to compile, link, and run the submitted code

Makefile

|  |
| --- |
| all: q1 q2  q1: q1.c timing.o  icc main.c dummy.c timing.o q1.c -o q1.1 -g -O0 -fno-alias -std=c99  icc main.c dummy.c timing.o q1.c -o q1.2 -g -O1 -fno-alias -std=c99  icc main.c dummy.c timing.o q1.c -o q1.3 -g -O3 -no-vec -no-simd -fno-alias -std=c99  icc main.c dummy.c timing.o q1.c -o q1.4 -g -O3 -xHost -fno-alias -std=c99  q2: q2.c timing.o  icc main.c dummy.c timing.o q2.c -o q2.1 -g -O0 -fno-alias -std=c99  icc main.c dummy.c timing.o q2.c -o q2.2 -g -O1 -fno-alias -std=c99  icc main.c dummy.c timing.o q2.c -o q2.3 -g -O3 -no-vec -no-simd -fno-alias -std=c99  icc main.c dummy.c timing.o q2.c -o q2.4 -g -O3 -xHost -fno-alias -std=c99  timing.o:  cp ~ahs3/cpsc424/utils/timing/timing.o ./  clean:  rm -f \*.1 \*.2 \*.3 \*.4 |

Submit.sh

|  |
| --- |
| #!/bin/bash  #PBS -l procs=8,tpn=8,mem=34gb,walltime=15:00  #PBS -q cpsc424  echo q1.1  ./lab1/q1.1  echo q1.2  ./lab1/q1.2  echo q1.3  ./lab1/q1.3  echo q1.4  ./lab1/q1.4  for filename in q2.1 q2.2 q2.3 q2.4  do  echo $filename  for i in {3..24}  do  ./lab1/$filename $i  done  done |

output

|  |
| --- |
| q1.1  Repeat for 8 times. Wallclock time is 0.130742.  q1.2  Repeat for 16 times. Wallclock time is 0.114974.  q1.3  Repeat for 16 times. Wallclock time is 0.114965.  q1.4  Repeat for 32 times. Wallclock time is 0.114969.  q2.1  Repeat for 524288 times. Wallclock time is 0.128251.Argv is 3.  Repeat for 262144 times. Wallclock time is 0.143422.Argv is 4.  Repeat for 131072 times. Wallclock time is 0.138528.Argv is 5.  Repeat for 131072 times. Wallclock time is 0.177852.Argv is 6.  Repeat for 65536 times. Wallclock time is 0.180409.Argv is 7.  Repeat for 32768 times. Wallclock time is 0.173993.Argv is 8.  Repeat for 16384 times. Wallclock time is 0.196692.Argv is 9.  Repeat for 4096 times. Wallclock time is 0.100949.Argv is 10.  Repeat for 2048 times. Wallclock time is 0.106661.Argv is 11.  Repeat for 1024 times. Wallclock time is 0.111609.Argv is 12.  Repeat for 512 times. Wallclock time is 0.113920.Argv is 13.  Repeat for 256 times. Wallclock time is 0.121462.Argv is 14.  Repeat for 128 times. Wallclock time is 0.126771.Argv is 15.  Repeat for 64 times. Wallclock time is 0.132751.Argv is 16.  Repeat for 32 times. Wallclock time is 0.141232.Argv is 17.  Repeat for 16 times. Wallclock time is 0.149198.Argv is 18.  Repeat for 8 times. Wallclock time is 0.155950.Argv is 19.  Repeat for 4 times. Wallclock time is 0.164449.Argv is 20.  Repeat for 2 times. Wallclock time is 0.172209.Argv is 21.  Repeat for 1 times. Wallclock time is 0.180731.Argv is 22.  Repeat for 1 times. Wallclock time is 0.379868.Argv is 23.  Repeat for 1 times. Wallclock time is 0.797357.Argv is 24.  q2.2  Repeat for 8388608 times. Wallclock time is 0.104122.Argv is 3.  Repeat for 8388608 times. Wallclock time is 0.200025.Argv is 4.  Repeat for 4194304 times. Wallclock time is 0.186414.Argv is 5.  Repeat for 1048576 times. Wallclock time is 0.123629.Argv is 6.  Repeat for 524288 times. Wallclock time is 0.126811.Argv is 7.  Repeat for 262144 times. Wallclock time is 0.131249.Argv is 8.  Repeat for 131072 times. Wallclock time is 0.136885.Argv is 9.  Repeat for 65536 times. Wallclock time is 0.143285.Argv is 10.  Repeat for 32768 times. Wallclock time is 0.150215.Argv is 11.  Repeat for 16384 times. Wallclock time is 0.158969.Argv is 12.  Repeat for 8192 times. Wallclock time is 0.182483.Argv is 13.  Repeat for 2048 times. Wallclock time is 0.101617.Argv is 14.  Repeat for 1024 times. Wallclock time is 0.106611.Argv is 15.  Repeat for 512 times. Wallclock time is 0.117914.Argv is 16.  Repeat for 128 times. Wallclock time is 0.100327.Argv is 17.  Repeat for 64 times. Wallclock time is 0.149656.Argv is 18.  Repeat for 32 times. Wallclock time is 0.154980.Argv is 19.  Repeat for 16 times. Wallclock time is 0.161908.Argv is 20.  Repeat for 8 times. Wallclock time is 0.170403.Argv is 21.  Repeat for 4 times. Wallclock time is 0.177009.Argv is 22.  Repeat for 2 times. Wallclock time is 0.188449.Argv is 23.  Repeat for 1 times. Wallclock time is 0.195128.Argv is 24.  q2.3  Repeat for 8388608 times. Wallclock time is 0.106884.Argv is 3.  Repeat for 8388608 times. Wallclock time is 0.200107.Argv is 4.  Repeat for 4194304 times. Wallclock time is 0.190442.Argv is 5.  Repeat for 2097152 times. Wallclock time is 0.196599.Argv is 6.  Repeat for 524288 times. Wallclock time is 0.102140.Argv is 7.  Repeat for 262144 times. Wallclock time is 0.106136.Argv is 8.  Repeat for 131072 times. Wallclock time is 0.111602.Argv is 9.  Repeat for 65536 times. Wallclock time is 0.133016.Argv is 10.  Repeat for 32768 times. Wallclock time is 0.136557.Argv is 11.  Repeat for 16384 times. Wallclock time is 0.147439.Argv is 12.  Repeat for 8192 times. Wallclock time is 0.182241.Argv is 13.  Repeat for 4096 times. Wallclock time is 0.198519.Argv is 14.  Repeat for 1024 times. Wallclock time is 0.104433.Argv is 15.  Repeat for 512 times. Wallclock time is 0.111113.Argv is 16.  Repeat for 128 times. Wallclock time is 0.100084.Argv is 17.  Repeat for 64 times. Wallclock time is 0.139771.Argv is 18.  Repeat for 32 times. Wallclock time is 0.149987.Argv is 19.  Repeat for 16 times. Wallclock time is 0.157381.Argv is 20.  Repeat for 8 times. Wallclock time is 0.162865.Argv is 21.  Repeat for 4 times. Wallclock time is 0.171018.Argv is 22.  Repeat for 2 times. Wallclock time is 0.180446.Argv is 23.  Repeat for 1 times. Wallclock time is 0.186326.Argv is 24.  q2.4  Repeat for 16777216 times. Wallclock time is 0.142463.Argv is 3.  Repeat for 8388608 times. Wallclock time is 0.126041.Argv is 4.  Repeat for 8388608 times. Wallclock time is 0.200081.Argv is 5.  Repeat for 2097152 times. Wallclock time is 0.100638.Argv is 6.  Repeat for 2097152 times. Wallclock time is 0.197236.Argv is 7.  Repeat for 1048576 times. Wallclock time is 0.199291.Argv is 8.  Repeat for 262144 times. Wallclock time is 0.104991.Argv is 9.  Repeat for 131072 times. Wallclock time is 0.198972.Argv is 10.  Repeat for 65536 times. Wallclock time is 0.191654.Argv is 11.  Repeat for 16384 times. Wallclock time is 0.113423.Argv is 12.  Repeat for 8192 times. Wallclock time is 0.154089.Argv is 13.  Repeat for 4096 times. Wallclock time is 0.163936.Argv is 14.  Repeat for 2048 times. Wallclock time is 0.172598.Argv is 15.  Repeat for 1024 times. Wallclock time is 0.186928.Argv is 16.  Repeat for 256 times. Wallclock time is 0.164215.Argv is 17.  Repeat for 64 times. Wallclock time is 0.120433.Argv is 18.  Repeat for 32 times. Wallclock time is 0.128577.Argv is 19.  Repeat for 16 times. Wallclock time is 0.132625.Argv is 20.  Repeat for 8 times. Wallclock time is 0.141403.Argv is 21.  Repeat for 4 times. Wallclock time is 0.146868.Argv is 22.  Repeat for 2 times. Wallclock time is 0.155078.Argv is 23.  Repeat for 1 times. Wallclock time is 0.163370.Argv is 24. |

Question 1.

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| --- |
| 367MFlop/s -O0 -fno-alias  835MFlop/s -O1 -fno-alias  835MFlop/s -O3 -no-vec -no-simd -fno-alias  1670MFlop/s -O3 -xHost -fno-alias |

1. Try to explain results

According to the architecture of the X5560 processor and the gcc manual for optimization flags(https://gcc.gnu.org/onlinedocs/gcc/Optimize-Options.html), we can conclude following facts:

-O0 provides no optimizations, so the MFlop/s is the smallest one in 4 scenarios.

-O1 provides basic optimizations, so the performance doubles.

-O3 –no-vec –no-simd –fno-alias provides all optimizations that O1 provides without vectorization, simd and pointer aliasing.

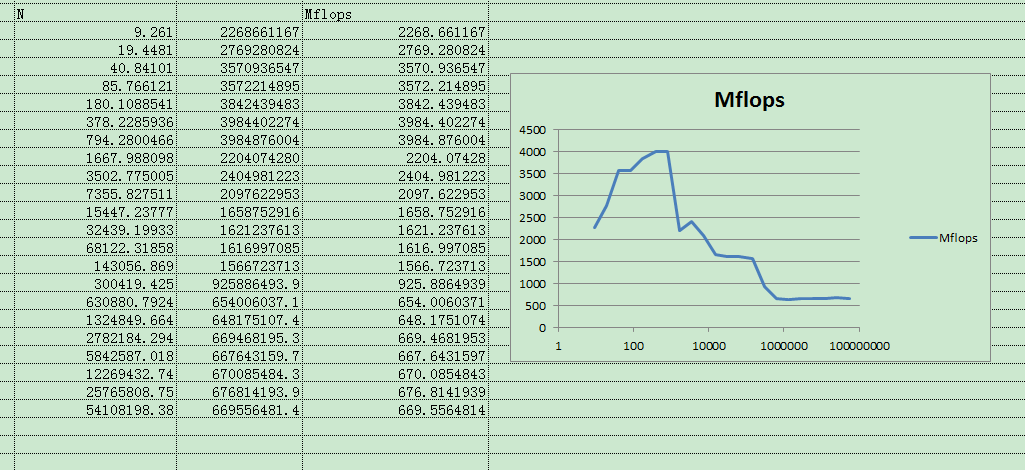
-O3 provides the best optimizations. With the help of simd vectorization, the performance is improved a lot.

1. Estimate the latency of division operation

I used q11.c to estimate the latency of division using –O3 optimization

|  |
| --- |
| for(int I = 0; I < SLICES; i++){  sum = 1.0 / I;  } |

The walltime is 0.00718125s. It performs 0.139GFlop/s. We assume the clock rate of the processor is 2.8GHz. So the latency of the divide operation is 20 cycles or so.

1. 

Memory bandwith = 4GFlops/s \* 8byte/Flop = 32GB/s

When N is below 1000, the Mflops increase when N increases. This is because cache can be fully utilized and the throughput of pipline could be maximized.

When N is above 1000, the Mflops jumps when N increases. This is because cache can not hold all the data at one time, the performance is hindered by the data transfer rate between main memory and cache.