Assignment 1
Bo Song

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_sp
1.2.144/ipp/lib/intel64:/opt/intel/mic/coi/host-linux-release/lib:/opt/intel/mic/myo/lib:/home/a
pps/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/a
pps/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_sp1.2.14
4/tbb/lib/mic
ROCKS_ROOT=/opt/rocks
CPATH=/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer_xe_2013_sp1.2.144/ipp/includ
e:/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer_xe_2013_sp1.2.144/mkl/include:/ho
me/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/com
poser_xe_2013_sp1.2.144/mkl/lib/intel64/locale/%l_%t/%N:/home/apps/fas/Langs/Intel/icsxe/2
013.1.046/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/in
tel64:/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer_xe_2013_sp1.2.144/debugger/gd
b/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_201
3_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:/o
pt/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/in
tel64
GDB_CROSS=/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer_xe_2013_sp1.2.144/debu
gger/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_sp
1.2.144/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/incl
ude:/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer_xe_2013_sp1.2.144/mkl/include/i
ntel64/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.

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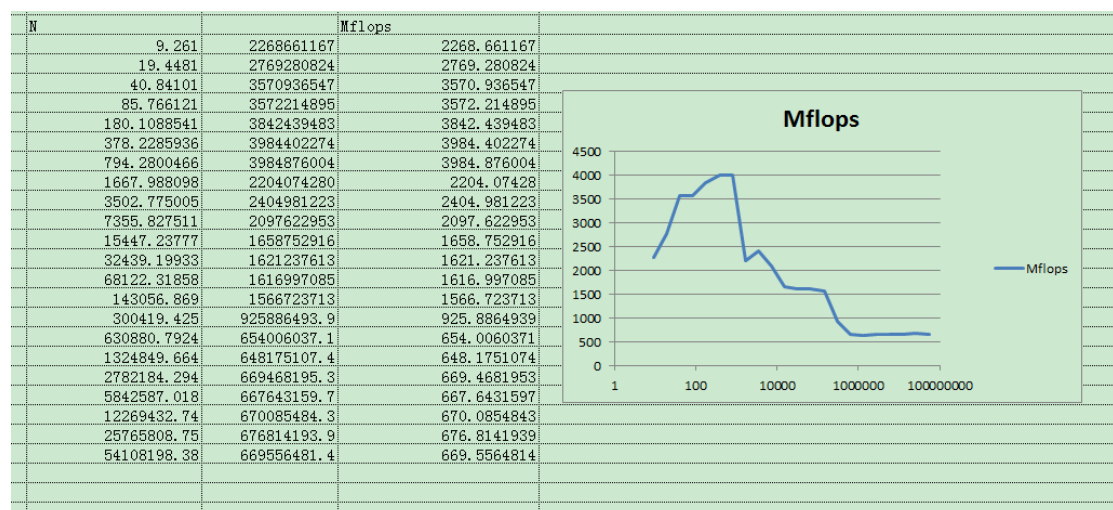
    -O3 provides the best optimizations. With the help of simd vectorization, the performance is improved a lot.

2. 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.

N		Mflops	
9.261	2268661167		2268.661167
19.4481	2769280824		2769.280824
40.84101	3570936547		3570.936547
85.766121	3572214895		3572.214895
180.1088541	3842439483		3842.439483
378.2285936	3984402274		3984.402274
794.2800466	3984876004		3984.876004
1667.988098	2204074280		2204.07428
3502.775005	2404981223		2404.981223
7355.827511	2097622953		2097.622953
15447.23777	1658752916		1658.752916
32439.19933	1621237613		1621.237613
68122.31858	1616997085		1616.997085
143056.869	1566723713		1566.723713
300419.425	925886493.9		925.8864939
630880.7924	654006037.1		654.0060371
1324849.664	648175107.4		648.1751074
2782184.294	669468195.3		669.4681953
5842587.018	667643159.7		667.6431597
12269432.74	670085484.3		670.0854843
25765808.75	676814193.9		676.8141939
54108198.38	669556481.4		669.5564814

Mflops

3.

    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.