

Env

```

MKLROOT=/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer_xe_2013_sp1.2.144/mkl
MANPATH=/home/apps/fas/MPI/OpenMPI/1.6.5-intel/share/man:/home/apps/fas/Langs/Intel/icsxe/2013.1.046/compose
r_xe_2013_sp1.2.144/man/en_US:/usr/share/man:/opt/roab/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/lice
nses:/home/apps/fas/Licenses/intel_site.lic
TERM=xterm
SHELL=/bin/bash
HISTSIZE=1000
SSH_CLIENT=10.191.63.253 51916 22
LIBRARY_PATH=/home/apps/fas/MPI/OpenMPI/1.6.5-intel/lib:/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer_x
e_2013_sp1.2.144/ipp/./compiler/lib/intel64:/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer_xe_2013_sp1.2.14
4/ipp/lib/intel64:/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer_xe_2013_sp1.2.144/compiler/lib/intel64:/hom
e/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
PERLLIB=/opt/roab/lib/perl5
FPATH=/home/apps/fas/MPI/OpenMPI/1.6.5-intel/include:/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer_xe_2
013_sp1.2.144/mkl/include:/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer_xe_2013_sp1.2.144/mkl/include/int
el64/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:/ho
me/apps/fas/Langs/Intel/icsxe/2013.1.046/composer_xe_2013_sp1.2.144/compiler/lib/mic:/home/apps/fas/Langs/Intel/i
csxe/2013.1.046/composer_xe_2013_sp1.2.144/mkl/lib/mic:/opt/intel/mic/coi/device-linux-release/lib:/opt/intel/mic/my
o/lib:/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer_xe_2013_sp1.2.144/tbb/lib/mic
SSH_TTY=/dev/pts/7
ANT_HOME=/opt/rocks
USER=bs744
LD_LIBRARY_PATH=/home/apps/fas/MPI/OpenMPI/1.6.5-intel/lib:/home/apps/fas/Langs/Intel/icsxe/2013.1.046/compose
r_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/i
ntel/mic/coi/host-linux-release/lib:/opt/intel/mic/myo/lib:/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer_xe_20
13_sp1.2.144/compiler/lib/intel64:/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer_xe_2013_sp1.2.144/mkl/lib/i
ntel64:/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/MPI/OpenMPI/1.6.5-intel/include:/home/apps/fas/Langs/Intel/icsxe/2013.1.046/composer_xe_2
013_sp1.2.144/ipp/include:/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
OMPI_MCA_orte_precondition_transports=f20cd2d28f432704-15e3f8c3bb8e89d6

```

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/MPI/OpenMPI/1.6.5-intel/bin:/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/cs424/BoSong_PS3_CPSC424

LMFILES=/home/apps/fas/Modules/Base/yale_hpc:/home/apps/fas/Modules/Langs/Intel/14:/home/apps/fas/Modules/MPI/OpenMPI/1.6.5

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:MPI/OpenMPI/1.6.5

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 51916 10.191.10.209 22

MODULESHOME=/usr/share/Modules

LESSOPEN=| /usr/bin/lesspipe.sh %s

```

arch=intel64
CC=icc
DISPLAY=localhost:12.0
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
MPI_PATH=/home/apps/fas/MPI/OpenMPI/1.6.5-intel
G_BROKEN_FILENAMES=1
BASH_FUNC_module()=( ) { eval `usr/bin/modulecmd bash $*`
}
_=/bin/env
OLDPWD=/home/fas/cpsc424/bs744

```

A make file is included in solution package.

Task1 Serial program performance

N	TIME (secs)
1000	0.1797
2000	2.2810
4000	19.3756
8000	153.9208
12000	518.4189

Task 2 Parallel program performance

Raw performance table, p = 8

		1 node		2 nodes		4 nodes	
#Proc		N = 8000	N=12000	N = 8000	N= 12000	N=8000	N=12000
0	Comm time	47.728039	168.069686	51.669500	139.064581	50.161624	133.829175
	Comp time	6.981728	23.841349	3.781539	15.188161	2.404897	11.083201
1	Comm time	30.928616	114.894897	36.895063	99.661204	35.560373	96.545476
	Comp time	18.261596	55.297461	10.245202	36.412500	9.167001	33.146939
2	Comm time	24.660388	85.390493	30.303248	78.393062	30.570016	61.168537
	Comp time	26.266741	89.514275	18.113911	61.868680	15.172678	75.852079
3	Comm time	21.454271	84.306025	26.883242	66.318063	26.997465	44.599300
	Comp time	30.268887	96.750693	22.730531	77.779222	19.668534	97.079598
4	Comm time	17.583461	56.590899	21.647295	55.586626	24.451651	62.652676
	Comp time	35.948178	126.443870	29.806568	92.655340	23.132160	79.088234
5	Comm time	15.946033	47.610591	19.981328	47.045172	22.606396	53.896293
	Comp time	38.721292	143.549835	32.386376	101.427900	25.926298	88.140114
6	Comm time	15.024184	66.171662	8.929359	47.225279	14.028019	50.843508
	Comp time	39.668731	125.682471	46.499145	106.968397	38.516393	94.009908
7	Comm time	15.380558	50.892414	17.340718	43.223844	17.292582	48.203713
	Comp time	39.329221	141.018594	38.110261	111.028759	35.273926	96.708664
Total	Real time	1m0.112s	3m17.247s	0m58.270s	2m38.940s	0m56.204s	2m30.506s

The table above shows the raw data of the performance under 3 configurations. Discussions are as below,

1. Raw performance – for the raw performance, it seems 1,2,4 nodes performs almost the same.

2. Load balance – Load balance is not good. Proc 0 always do the least computation work, while proc 7 always do the heaviest one. The computation time among different processes vary a lot.
3. Scalability – This algorithm is not scalable because the parallel efficiency decreases when p increases.

Suggestions,

1. Using no-blocking send/rcv function– For most processes, a lot of time is used on communication parts. One reason is we are using blocking send/rcv functions, which is safe but not efficient. Switching to non-blocking calls will improve the performance.
2. Allocate flexible number of rows – allocate more rows to one process when the number of elements in these rows is relatively small comparing to other rows. Therefore each process can compute approximately the same number of elements and achieve a load balance.

Conclusion from the set of results with p = 8:

Performance can't be improved by allocating more nodes for the task. We should focus on optimizing algorithm.

Task3 Non-blocking Communication

#Proc		1 node		2 nodes		4 nodes	
		N = 8000	N=12000	N = 8000	N= 12000	N=8000	N=12000
0	Comm time	40.147919	180.841691	34.780641	133.241363	31.903955	150.206143
	Comp time	5.713917	21.163299	3.543888	14.932478	2.154690	10.852372
1	Comm time	20.680917	105.873109	22.103681	80.179828	19.610803	96.206326
	Comp time	18.119205	59.589226	10.880871	50.288290	9.195730	36.843318
2	Comm time	14.253266	66.640101	17.204825	46.990116	13.579088	78.545088
	Comp time	24.534594	98.866857	15.784186	83.458723	15.226347	54.695498
3	Comm time	5.602875	59.478495	12.263480	58.844335	9.291479	29.303046
	Comp time	33.197228	106.031108	20.721139	71.759000	19.536430	103.993059
4	Comm time	7.468858	23.594143	5.853379	23.907193	6.650383	54.655600
	Comp time	34.632653	156.685365	27.132669	106.705502	23.176314	78.700284
5	Comm time	5.918056	30.401165	7.611315	28.871405	8.239846	48.826690
	Comp time	39.943796	171.603678	30.130560	113.998935	25.818788	87.590192
6	Comm time	2.166395	21.292271	5.716210	18.996820	2.555779	26.987083
	Comp time	43.637253	164.828519	32.608326	129.176970	31.199644	134.071434
7	Comm time	0.194748	0.516925	0.218334	0.489364	0.227734	0.929506
	Comp time	39.876985	170.502835	34.091956	133.305453	29.179112	138.361423
Total	Real time	0m49.768s	3m28.185s	0m42.134s	2m34.305s	0m37.564s	2m46.786s

Performance: No-blocking version performs better on small data set (N = 8000), but it doesn't improve performance when N = 12000.

Scalability: It's scalability is not strong. When node increases, the running time does not decreases much.

Load balance: the computation time varies a lot, process 0 runs much less time than process 7. It does not have load balance.

Task4 Load balance

Algorithm: Instead of assigning the same number of rows to each process, we assign nearly same number of elements in row vector to each process.

For example, p = 5, N = 10. Each process will be assigned to $(1+10) * 10 / 2 / 5 = 11$ elements for its permanent row vector.

		1 node	2 nodes	4 nodes
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#Proc		N = 8000	N=12000	N = 8000	N= 12000	N=8000	N=12000
0	Comm time	0.196519	0.428695	1.273652	0.611802	0.813960	2.729722
	Comp time	35.814230	124.612697	25.425006	90.961243	21.090369	76.023772
1	Comm time	3.999923	19.809957	3.519772	11.014565	2.603908	12.813473
	Comp time	32.010813	105.231392	23.156928	80.402356	19.230632	65.778477
2	Comm time	7.048572	22.460125	5.333823	18.124944	4.585132	19.663213
	Comp time	28.944405	102.539182	21.335805	73.276381	17.241855	58.911472
3	Comm time	7.199054	35.103928	7.509963	23.483392	6.050212	24.905482
	Comp time	28.801376	89.914006	19.145289	67.912339	15.796463	53.713203
4	Comm time	9.302175	36.233780	8.351240	34.204869	6.807402	10.926520
	Comp time	26.695225	88.756054	18.306229	57.272002	15.054875	67.731194
5	Comm time	10.968989	45.122707	9.842251	39.877871	4.153613	17.048088
	Comp time	25.026487	79.890252	16.830690	51.634965	17.750698	61.643371
6	Comm time	13.913002	55.073530	5.915458	43.846692	4.945262	36.938336
	Comp time	22.070625	69.929332	20.770545	47.698672	16.930925	41.784970
7	Comm time	14.675121	52.340765	10.910636	45.047446	6.199962	39.665753
	Comp time	21.307677	72.641300	15.788015	46.525616	15.689325	39.087747
Total	Real time	0m40.561s	2m10.642s	0m31.149s	1m36.447s	0m25.841s	1m23.266s

Row performance: The performance is best among these 3 tasks.

Scalability: As node increases, run time decreases a lot, It has some scalability but not that strong.

Load balance: Good load balance. All process spent nearly the same seconds.

Task5 Generalization

Padding N to p's multiple, do task4 algorithm. Then extract useful part of the result.