# lab8-hpl

## 硬件环境

### (i) Info

Model name: AMD Ryzen 7 7840 H with Radeon 780 M Graphics

Thread (s) per core: 2
Core (s) per socket: 8
Socket (s): 1

CPU frequency: 3.80 GHz

avx version: avx2

Mem: 13GB

### 理论峰值计算

7 0	EUs	2 × 256-bit FMA		
Zen 2 Zen 3	DP	16 FLOPs/cycle	2 x 8 FLOPs	AVX2 & FMA (256-bit)
20.10	SP	32 FLOPs/cycle	2 x 16 FLOPs	

$$FLOPs = 4 \times 2 \times 2 \times 3.80 \text{GHz} \times 8 = 486.4 \, gflops$$

## 软件环境

## 操作系统版本

 $\label{linux} LAPTOP-BGRVTJ4L~5.15.153.1-microsoft-standard-WSL2~\#1~SMP~Fri~Mar~29~23:14:13~UTC~2024~x86\_64~x86\_64~x86\_64~GNU/Linux$ 

Ubuntu 22.04.4 LTS

# 库版本

```
mpirun (Open MPI) 4.1.2
```

OPENBLAS\_VERSION " OpenBLAS 0.3.20 "

# HPL 参数调整过程与测试结果

首先,根据笔记本配置从<u>自动参数调整网站</u>获取推荐配置,这里采纳了 P 和 Q 的推荐值。尽管这台笔记本为八核十六线程,但是经过实际测试, PxQ 取 2x4 的 gflops 值比 4x4 高。因此在下面的测试中,**确定 P 和 Q 分别为 2 和 4**。

# of process grids (P x Q)
Ps
Qs

#### N

接下来确定 N 的值。根据官方调优文档中的说明,N 的最佳值满足下面的式子:

$$N^2 \times 8 = \mathrm{Mem} \times 0.8$$

其中,Mem 为计算机内存大小(单位为 byte)。

这台计算机的内存大小为 13 GB,经过计算,取 N=37312。

#### NB

官方文档中对 NB 的取值有如下说明:

### (i) Info

HPL 将块大小 NB 用于数据分布和计算粒度。从数据分布的角度来看,NB 越小,负载平衡就越好。你肯定希望 NB 值不要太大。从计算角度看,NB 值过小可能会大大限制计算性能,因为在内存层次结构的最高层几乎不会出现数据重用。信息的数量也会增加。高效的矩阵乘法例程通常会出现内部阻塞。对于 HPL 来说,这个阻塞因子的小倍数可能就是良好的块大小。

总之,"好"的数据块大小几乎总是在[32...256]之间。

由于 NB 值对性能的影响受很多因素影响,其最佳取值可能差异较大。因此这里选择在一定范围内通过测试的方式找到最佳的 NB 取值。

参考官方的推荐范围,确定需要测试的 NB 值为:

16 64 128 256 512 768

测量后,得到各自取值的 gflops 值,如下表所示:

NB	16	64	128	256	512	768
1 gflops	18.904	35.958	49.030	63.316	69.903	60.146

其中,当 NB 取 512 时 gflops 最大,因此最终取 NB 为 512。

### 最优结果

#### 最优参数如下表所示:

	N	NB	PxQ
1	37312	512	2 x 4

#### 测试结果如下:

T/V	N	NB	Р	Q	Time	Gflops
WR11C2R4	37312	512	2	4	495.44	6.9903e+01

最优参数下的 gflops 值为 69.903 gflops。

Gflops 与 CPU 峰值性能之比为:  $\frac{69.903}{486.4} = 0.1437$ 

### 附录

#### 运行结果:

HPLinpack 2.3 -- High-Performance Linpack benchmark -- December 2, 2018 Written by A. Petitet and R. Clint Whaley, Innovative Computing Laboratory, UTK Modified by Piotr Luszczek, Innovative Computing Laboratory, UTK Modified by Julien Langou, University of Colorado Denver

An explanation of the input/output parameters follows:

T/V : Wall time / encoded variant.

N : The order of the coefficient matrix A.

NB : The partitioning blocking factor.

P : The number of process rows.

Q : The number of process columns.

Time : Time in seconds to solve the linear system.

Gflops : Rate of execution for solving the linear system.

The following parameter values will be used:

N : 37312 NB : 64

PMAP : Row-major process mapping

P : 2
Q : 4
PFACT : Right
NBMIN : 4
NDIV : 2
RFACT : Crout
BCAST : 1ringM
DEPTH : 1

SWAP : Mix (threshold = 64)

L1 : transposed form
U : transposed form

EQUIL : yes

ALIGN : 8 double precision words

- The matrix A is randomly generated for each test.
- The following scaled residual check will be computed:

- The relative machine precision (eps) is taken to be 1.110223e-16

- Computational tests pass if scaled residuals are less than

16.0

T/V	N	NB	Р	Q	Time	Gflops
WR11C2R4	37312	64	2	4	963.13	3.5958e+01
HPL_pdgesv()	start time	Fri	Sep 20	17:19:21	2024	

HPL\_pdgesv() end time Fri Sep 20 17:35:25 2024

 $||Ax-b||_{oo/(eps*(||A||_{oo*||x||_{oo+||b||_{oo}*N})} = 1.54895800e-03 \dots$  PASSED

Finished 1 tests with the following results:

1 tests completed and passed residual checks,

O tests completed and failed residual checks,

O tests skipped because of illegal input values.

End of Tests.

HPLinpack 2.3 -- High-Performance Linpack benchmark -- December 2, 2018 Written by A. Petitet and R. Clint Whaley, Innovative Computing Laboratory, UTK Modified by Piotr Luszczek, Innovative Computing Laboratory, UTK Modified by Julien Langou, University of Colorado Denver

An explanation of the input/output parameters follows:

T/V : Wall time / encoded variant.

: The order of the coefficient matrix A.

: The partitioning blocking factor.

: The number of process rows. : The number of process columns.

Time : Time in seconds to solve the linear system.

Gflops: Rate of execution for solving the linear system.

The following parameter values will be used:

: 37312 N

NB : 16 128 256 PMAP : Row-major process mapping Р : 4 Q : PFACT : Right NBMIN : NDIV : 2 RFACT : Crout BCAST : 1ringM DEPTH: 1 SWAP : Mix (threshold = 64) L1 : transposed form : transposed form EQUIL : yes ALIGN : 8 double precision words - The matrix A is randomly generated for each test. - The following scaled residual check will be computed: ||Ax-b||\_oo / ( eps \* ( || x ||\_oo \* || A ||\_oo + || b ||\_oo ) \* N ) - The relative machine precision (eps) is taken to be 1.110223e-16 - Computational tests pass if scaled residuals are less than 16.0 T/V NB Q Time Gflops WR11C2R4 37312 16 2 1831.98 1.8904e+01 HPL\_pdgesv() start time Fri Sep 20 19:00:46 2024 HPL\_pdgesv() end time Fri Sep 20 19:31:18 2024  $||Ax-b||_{oo/(eps*(||A||_{oo*||x||_{oo+||b||_{oo}}*N)}=1.71679441e-03....$  PASSED T/V NB Q Time Gflops WR11C2R4 37312 128 706.35 2 4.9030e+01 HPL\_pdgesv() start time Fri Sep 20 19:32:01 2024 HPL\_pdgesv() end time Fri Sep 20 19:43:47 2024  $||Ax-b||_{oo/(eps*(||A||_{oo*}||x||_{oo+}||b||_{oo})*N)=$  1.71322043e-03 ..... PASSED T/V N NB Q Time Gflops WR11C2R4 37312 256 546.97 6.3316e+01 HPL\_pdgesv() start time Fri Sep 20 19:44:28 2024 HPL\_pdgesv() end time Fri Sep 20 19:53:35 2024

```
Finished 3 tests with the following results:

3 tests completed and passed residual checks,

0 tests completed and failed residual checks,

1 tests skipped because of illegal input values.

End of Tests.
```

HPLinpack 2.3 -- High-Performance Linpack benchmark -- December 2, 2018 Written by A. Petitet and R. Clint Whaley, Innovative Computing Laboratory, UTK Modified by Piotr Luszczek, Innovative Computing Laboratory, UTK Modified by Julien Langou, University of Colorado Denver

An explanation of the input/output parameters follows:

T/V : Wall time / encoded variant.

N  $\hspace{1cm}:\hspace{1cm}$  The order of the coefficient matrix A.

NB : The partitioning blocking factor.

P : The number of process rows.
Q : The number of process columns.

Time : Time in seconds to solve the linear system.

Gflops: Rate of execution for solving the linear system.

The following parameter values will be used:

N : 37312 NB : 512

PMAP : Row-major process mapping

P : 2
Q : 4
PFACT : Right
NBMIN : 4
NDIV : 2
RFACT : Crout
BCAST : 1ringM
DEPTH : 1

SWAP : Mix (threshold = 64)

L1 : transposed form
U : transposed form

EQUIL : yes

ALIGN : 8 double precision words

\_\_\_\_\_\_

- The matrix A is randomly generated for each test.
- The following scaled residual check will be computed:

- The relative machine precision (eps) is taken to be

1.110223e-16

- Computational tests pass if scaled residuals are less than

16.0

T/V	N	NB	Р	Q	Time	Gflops
WR11C2R4	37312	512	2	4	495.44	6.9903e+01
HPL pdgesv()	start tim	ne Fri	Sep 20	19:56:08 2	1024	

HPL\_pdgesv() end time Fri Sep 20 20:04:24 2024

 $||Ax-b||_{oo/(eps*(||A||_{oo*||x||_{oo+||b||_{oo}*N})} = 1.66563432e-03 \dots$  PASSED

Finished 1 tests with the following results:

1 tests completed and passed residual checks,

O tests completed and failed residual checks,

0 tests skipped because of illegal input values.

End of Tests.

HPLinpack 2.3 -- High-Performance Linpack benchmark -- December 2, 2018 Written by A. Petitet and R. Clint Whaley, Innovative Computing Laboratory, UTK Modified by Piotr Luszczek, Innovative Computing Laboratory, UTK Modified by Julien Langou, University of Colorado Denver

An explanation of the input/output parameters follows:

: Wall time / encoded variant. T/V

: The order of the coefficient matrix A.

: The partitioning blocking factor.

: The number of process rows.

: The number of process columns.

Time : Time in seconds to solve the linear system.

Gflops: Rate of execution for solving the linear system.

The following parameter values will be used:

37312 N 768 NB :

```
: Row-major process mapping
Р
      :
              2
PFACT : Right
NBMIN :
NDIV
RFACT : Crout
BCAST : 1ringM
DEPTH :
              1
SWAP : Mix (threshold = 64)
     : transposed form
L1
    : transposed form
EQUIL : yes
ALIGN : 8 double precision words
- The matrix A is randomly generated for each test.
- The following scaled residual check will be computed:
      || Ax-b || _oo / ( eps * ( || x || _oo * || A || _oo + || b || _oo ) * N )
- The relative machine precision (eps) is taken to be
                                                                  1.110223e-16
- Computational tests pass if scaled residuals are less than
                                                                          16.0
T/V
                       NB
                                                    Time
                                                                         Gflops
                                    Q
                                                                    6.0146e+01
WR11C2R4
              37312
                    768
                                                  575.81
                              2
HPL_pdgesv() start time Fri Sep 20 20:30:20 2024
HPL_pdgesv() end time Fri Sep 20 20:39:56 2024
||Ax-b||_{oo/(eps*(||A||_{oo*}||x||_{oo+}||b||_{oo})*N)= 1.67683814e-03 ..... PASSED
Finished
             1 tests with the following results:
             1 tests completed and passed residual checks,
             O tests completed and failed residual checks,
             0 tests skipped because of illegal input values.
End of Tests.
```

Dataview (in	nline field	1 		=====		
T/V	N	NB	Р	Q	Time	Gflops
WR11C2R4	37312	512	2	4	495. 44	6.9903e+01'): Error:

```
-- PARSING FAILED --
2 | T/V
                     N
                         NB
                               P
                                    Q
                                            Time
                                                       Gflops
Expected one of the following:
'(', 'null', boolean, date, duration, file link, list ('[1, 2, 3]'), negated field, number,
object ('{ a: 1, b: 2}'), string, variable
Dataview (inline field
'-----
HPLinpack 2.3 -- High-Performance Linpack benchmark -- December 2, 2018
Written by A. Petitet and R. Clint Whaley, Innovative Computing Laboratory, UTK
Modified by Piotr Luszczek, Innovative Computing Laboratory, UTK
Modified by Julien Langou, University of Colorado Denver
An explanation of the input/output parameters follows:
T/V
     : Wall time / encoded variant.
      : The order of the coefficient matrix A.
NB
     : The partitioning blocking factor.
     : The number of process rows.
     : The number of process columns.
     : Time in seconds to solve the linear system.
Gflops: Rate of execution for solving the linear system.
The following parameter values will be used:
N
         37312
NB
     :
           64
PMAP
     : Row-major process mapping
Р
     :
            4
PFACT : Right
NBMIN :
NDIV :
            2
RFACT : Crout
BCAST : 1ringM
DEPTH :
            1
SWAP : Mix (threshold = 64)
    : transposed form
  : transposed form
EQUIL : yes
ALIGN: 8 double precision words
```

```
- The matrix A is randomly generated for each test.
- The following scaled residual check will be computed:
     ||Ax-b|| oo / (eps * ( || x || oo * || A || oo + || b || oo ) * N )
- The relative machine precision (eps) is taken to be
                                                               1.110223e-16
- Computational tests pass if scaled residuals are less than
                                                                        16.0
T/V
                      NB
                                   Q
                                                  Time
                                                                      Gflops
WR11C2R4
              37312
                      64
                                                963.13
                                                                  3.5958e+01
HPL_pdgesv() start time Fri Sep 20 17:19:21 2024
HPL pdgesv() end time Fri Sep 20 17:35:25 2024
||Ax-b||_{oo}/(eps*(||A||_{oo}*||x||_{oo}+||b||_{oo})*N)=1.54895800e-03.... PASSED
Finished
             1 tests with the following results:
             1 tests completed and passed residual checks,
             O tests completed and failed residual checks,
             O tests skipped because of illegal input values.
End of Tests.
=======:): Error:
-- PARSING FAILED --
 2 | HPLinpack 2.3 -- High-Performance Linpack benchmark -- December 2, 2018
 3 | Written by A. Petitet and R. Clint Whaley, Innovative Computing Laboratory, UTK
Expected one of the following:
'(', 'null', boolean, date, duration, file link, list ('[1, 2, 3]'), negated field, number,
object ('{ a: 1, b: 2}'), string, variable
Dataview (inline field
HPLinpack 2.3 -- High-Performance Linpack benchmark -- December 2, 2018
Written by A. Petitet and R. Clint Whaley, Innovative Computing Laboratory, UTK
Modified by Piotr Luszczek, Innovative Computing Laboratory, UTK
Modified by Julien Langou, University of Colorado Denver
```

An explanation of the input/output parameters follows:

T/V : Wall time / encoded variant.

N : The order of the coefficient matrix A.

NB: The partitioning blocking factor.

P : The number of process rows.

Q : The number of process columns.

Time : Time in seconds to solve the linear system.

Gflops: Rate of execution for solving the linear system.

The following parameter values will be used:

N : 37312

NB : 16 128 256 PMAP : Row-major process mapping

P : 2
Q : 4
PFACT : Right
NBMIN : 4
NDIV : 2
RFACT : Crout
BCAST : 1ringM
DEPTH : 1

SWAP : Mix (threshold = 64)

L1 : transposed form U : transposed form

EQUIL : yes

ALIGN: 8 double precision words

\_\_\_\_\_

- The matrix A is randomly generated for each test.
- The following scaled residual check will be computed:

- The relative machine precision (eps) is taken to be 1.110223e-16

- Computational tests pass if scaled residuals are less than 16.0

\_\_\_\_\_

HPL\_pdgesv() start time Fri Sep 20 19:00:46 2024

HPL\_pdgesv() end time Fri Sep 20 19:31:18 2024

 $||Ax-b||_{oo/(eps*(||A||_{oo*}||x||_{oo+}||b||_{oo})*N)} = 1.71679441e-03.....$  PASSED

T/V N NB P Q Time Gflops

I/V N NB P Q IIME GITOPS

WR11C2R4 37312 128 2 4 706.35 4.9030e+01

HPL\_pdgesv() start time Fri Sep 20 19:32:01 2024

HPL\_pdgesv() end time Fri Sep 20 19:43:47 2024

\_\_\_\_\_\_

```
||Ax-b|| oo/(eps*(||A|| oo*||x|| oo+||b|| oo)*N)= 1.71322043e-03 ..... PASSED
T/V
                      NB
                             Р
                                  Q
                                                 Time
                                                                    Gflops
WR11C2R4
             37312
                     256
                             2
                                               546.97
                                                                 6.3316e+01
                                  4
HPL pdgesv() start time Fri Sep 20 19:44:28 2024
HPL pdgesv() end time Fri Sep 20 19:53:35 2024
||Ax-b||_{oo}/(eps*(||A||_{oo}*||x||_{oo}+||b||_{oo})*N)= 1.62340918e-03 ..... PASSED
Finished
            3 tests with the following results:
             3 tests completed and passed residual checks,
             O tests completed and failed residual checks,
             O tests skipped because of illegal input values.
End of Tests.
-----': Error:
-- PARSING FAILED ----
 2 | HPLinpack 2.3 -- High-Performance Linpack benchmark -- December 2, 2018
 3 | Written by A. Petitet and R. Clint Whaley, Innovative Computing Laboratory, UTK
Expected one of the following:
'(', 'null', boolean, date, duration, file link, list ('[1, 2, 3]'), negated field, number,
object ('{ a: 1, b: 2}'), string, variable
```

#### Dataview (inline field

, \_\_\_\_\_\_,

HPLinpack 2.3 -- High-Performance Linpack benchmark -- December 2, 2018 Written by A. Petitet and R. Clint Whaley, Innovative Computing Laboratory, UTK Modified by Piotr Luszczek, Innovative Computing Laboratory, UTK Modified by Julien Langou, University of Colorado Denver

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An explanation of the input/output parameters follows:

T/V : Wall time / encoded variant.

N : The order of the coefficient matrix A.

NB : The partitioning blocking factor.

P : The number of process rows.

Q : The number of process columns.

 $\hbox{\tt Time } \quad \hbox{\tt : Time in seconds to solve the linear system.}$ 

Gflops: Rate of execution for solving the linear system.

```
The following parameter values will be used:
N
         37312
NB
     :
          512
PMAP
     : Row-major process mapping
    :
            4
PFACT : Right
NBMIN :
          4
NDIV :
RFACT : Crout
BCAST : 1ringM
DEPTH: 1
SWAP : Mix (threshold = 64)
    : transposed form
U : transposed form
EQUIL : yes
ALIGN : 8 double precision words
- The matrix A is randomly generated for each test.
- The following scaled residual check will be computed:
     ||Ax-b||_oo / ( eps * ( || x ||_oo * || A ||_oo + || b ||_oo ) * N )
- The relative machine precision (eps) is taken to be
                                                      1.110223e-16
- Computational tests pass if scaled residuals are less than
______
T/V
                   NB
                                           Time
                                                             Gflops
WR11C2R4
            37312
                  512
                                          495.44
                                                         6.9903e+01
HPL_pdgesv() start time Fri Sep 20 19:56:08 2024
HPL_pdgesv() end time Fri Sep 20 20:04:24 2024
||Ax-b||_{oo/(eps*(||A||_{oo*}||x||_{oo+}||b||_{oo})*N)= 1. 66563432e-03 ..... PASSED
Finished
          1 tests with the following results:
           1 tests completed and passed residual checks,
           O tests completed and failed residual checks,
           O tests skipped because of illegal input values.
End of Tests.
_____
                                                       ======='): Error:
-- PARSING FAILED -----
```

```
2 | HPLinpack 2.3 -- High-Performance Linpack benchmark -- December 2, 2018
3 | Written by A. Petitet and R. Clint Whaley, Innovative Computing Laboratory, UTK

Expected one of the following:

'(', 'null', boolean, date, duration, file link, list ('[1, 2, 3]'), negated field, number, object ('{ a: 1, b: 2 }'), string, variable
```

```
Dataview (inline field
HPLinpack 2.3 -- High-Performance Linpack benchmark -- December 2, 2018
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An explanation of the input/output parameters follows:
      : Wall time / encoded variant.
       : The order of the coefficient matrix A.
N
      : The partitioning blocking factor.
Р
       : The number of process rows.
Q
      : The number of process columns.
      : Time in seconds to solve the linear system.
Gflops: Rate of execution for solving the linear system.
The following parameter values will be used:
N
          37312
            768
PMAP
      : Row-major process mapping
Р
       :
              4
PFACT :
          Right
NBMIN :
              4
NDIV :
              2
RFACT:
          Crout
BCAST : 1ringM
DEPTH :
SWAP : Mix (threshold = 64)
      : transposed form
      : transposed form
EQUIL : yes
ALIGN: 8 double precision words
- The matrix A is randomly generated for each test.
```

- The following scaled residual check will be computed:

- The relative machine precision (eps) is taken to be

 $||Ax-b||_{oo} / (eps * (|| x ||_{oo} * || A ||_{oo} + || b ||_{oo}) * N)$ 

1.110223e-16

- Computation	nal tests	pass if	fscale	d residua	ls are less than	16.0	
T/V	N	====== NB	P	Q	 Time	Gflops	
WR11C2R4 HPL_pdgesv()	37312 start tii	768 me Fri S	2 Sep 20	4 20:30:20	575. 81 2024	6. 0146e+01	
HPL_pdgesv()	end time	Fri S	Sep 20	20:39:56	2024		
Ax-b  _oo/	(eps*(  A	_00*	x  _oo	+  b  _oo	)*N)= 1.67683814e-0	93 PASSED	
Finished	1 tests 0 tests	complet	ted and ted and	failed r	ults: esidual checks, esidual checks, egal input values.		
End of Tests	======				=======================================	======'): Er	ror:
PARSING F	AILED						
		High	n-Perfo		npack benchmark	December 2, 2018 outing Laboratory, UTK	
Expected one	of the fo	ollowing	g:				
'(', 'null', object ('{ a					ink, list ('[1, 2, 3]	'), negated field, nu	ımber,