lab8-hpl

硬件环境

> 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

Zen 2 Zen 3	**EUs**	2 × 256-bit FMA		AVX2 & FMA (256-bit)
	DP	16 FLOPs/cycle	2 x 8 FLOPs	
	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

```
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

PxQ

首先，根据笔记本配置从自动参数调整网站获取推荐配置，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**。

```
1            # of process grids (P x Q)
2            Ps
4            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：

> ⓘ 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     P     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:
      ||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                N    NB     P     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 ...... PASSED
================================================================================

Finished      1 tests with the following results:
              1 tests completed and passed residual checks,
              0 tests completed and failed residual checks,
              0 tests skipped because of illegal input values.
--------------------------------------------------------------------------------

End of Tests.
================================================================================
```

```
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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

________________________________________________________________________________

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- 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                N    NB     P     Q               Time                 Gflops
--------------------------------------------------------------------------------
WR11C2R4       37312    16     2     4            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                N    NB     P     Q               Time                 Gflops
--------------------------------------------------------------------------------
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                N    NB     P     Q               Time                 Gflops
--------------------------------------------------------------------------------
WR11C2R4       37312   256     2     4             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

________________________________________________________________________________
```

```
||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,
              0 tests completed and failed residual checks,
              0 tests skipped because of illegal input values.
--------------------------------------------------------------------------------

End of Tests.
================================================================================
```

```
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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     :     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:
      ||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                N    NB     P     Q               Time                 Gflops
--------------------------------------------------------------------------------
WR11C2R4       37312   512     2     4             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,
              0 tests completed and failed residual checks,
              0 tests skipped because of illegal input values.
--------------------------------------------------------------------------------

End of Tests.
================================================================================
```

```
================================================================================
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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     :     768
```

```
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

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- 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                N    NB     P     Q               Time                 Gflops
--------------------------------------------------------------------------------
WR11C2R4       37312   768     2     4             575.81             6.0146e+01
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,
              0 tests completed and failed residual checks,
              0 tests skipped because of illegal input values.
--------------------------------------------------------------------------------

End of Tests.
================================================================================
```

```
Dataview (inline field
'========================================================================
T/V                N    NB     P     Q         Time         Gflops
------------------------------------------------------------------------
WR11C2R4       37312   512     2     4       495.44     6.9903e+01'): Error:
```

```
-- PARSING FAILED -----------------------------------------------

> 1 | ================================================================================
    | ^
  2 | T/V                N    NB     P     Q         Time        Gflops
  3 | --------------------------------------------------------------------------------

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
'================================================================================
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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

--------------------------------------------------------------------------------
```

```
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================================================================================
T/V                N    NB     P     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 ...... PASSED
================================================================================

Finished      1 tests with the following results:
              1 tests completed and passed residual checks,
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              0 tests skipped because of illegal input values.
--------------------------------------------------------------------------------

End of Tests.
================================================================================'): Error:
-- PARSING FAILED -----------------------------------------------

> 1 | ================================================================================
    | ^
  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
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Dataview (inline field
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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

--------------------------------------------------------------------------------

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T/V                N    NB     P     Q               Time                 Gflops
--------------------------------------------------------------------------------
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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
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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     P     Q               Time                 Gflops
--------------------------------------------------------------------------------
WR11C2R4       37312   256     2     4             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

--------------------------------------------------------------------------------
||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,
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--------------------------------------------------------------------------------

End of Tests.
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-- PARSING FAILED -----------------------------------------------

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Expected one of the following:

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```

```
Dataview (inline field
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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

--------------------------------------------------------------------------------

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HPL_pdgesv() end time   Fri Sep 20 20:04:24 2024

--------------------------------------------------------------------------------
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Finished      1 tests with the following results:
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End of Tests.
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    | ^
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Expected one of the following:

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Dataview (inline field
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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     :     768
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
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```

```
- Computational tests pass if scaled residuals are less than                16.0

================================================================================
T/V                N    NB     P     Q               Time                 Gflops
--------------------------------------------------------------------------------
WR11C2R4       37312   768     2     4             575.81             6.0146e+01
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:
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