并行程序设计 第七次作业

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文件结构

`source` 目录下主要文件(目录)及其功能如下表格所示:

文件(目录)名	文件(目录)功能
lapack-3.11/	blas和lapack库的源代码及库文件
autotest.py	自用测试脚本(可忽略)
input.cpp	输入类实现
input.h	输入类声明及接口
mat_demo.cpp	矩阵类实现
mat_demo.h	矩阵类声明及接口
mytimer.cpp	计时器类实现
mytimer.h	计时器类声明及接口
main.cpp	主程序源码
Makefile	makefile

编译说明

`Makefile` 中提供了4个目标 `main`,`lapack`,`all`,`clean`.

运行 `make lapack` 会编译 `lapack` 及 `blas` 库,并将生成的 `.a` 文件放在 `source/lapack-3.11/build/` 下.

运行 `make main` 会在 `lapack` 库顺利编译后编译生成可执行文件 `main`.

运行 `make all` 会依次执行上述两者.

运行 `make clean` 会清除生成的可执行文件和库文件.

运行说明

在命令行中执行

```
./main [FILE]
```

即可以 `[FILE]` 为输入文件运行程序.

Matmul 结果

用脚本 `autotest.py` 对 `matmul` 的五组测试点进行测试, `main` 比较后发现两种方法的输出结果是一**致的**, 而运行时间对比如下表:

time / s	case_1	case_2	case_3	case_4	case_5
BLAS	0.000451	0.002047	0.010311	0.117164	1.14699
Mat_Demo operator *	0.001234	0.007610	0.048661	0.362996	10.2669

可以发现自己实现的矩阵乘法**远慢于** `BLAS` 库的实现, 且随着输入规模的增大, 差距也越来越明显. 这样的结果也是必然的, 毕竟自己实现的矩阵乘法复杂度是 $O(n^3)$, 且没有考虑 `cache miss` 等情况和使用 `SIMD` 等技术.

RSMDiago 结果

计算消耗时间如下表:

time / s	case_1	case_2	case_3
lapack_diago	0.000052	0.000637	0.013117

计算结果分别如下(特征向量按行存储):

case_1

```
Eigenvalues:
-227.6 -146.855 -107.223 -93.2809 -81.5663 -54.7406 -45.7866 5.01474 14.6776
18.2649 22.8454 79.1435 134.188 174.545 187.168 788.899
Eigenvectors:
0.264307 -0.128844 -0.243718 0.0628014 0.0662602 0.248469 0.368538 0.00401287
0.0830353 0.1612 0.136554 -0.625053 -0.347121 -0.0835458 -0.198633 0.19771
-0.355954 0.120123 -0.107124 0.161833 -0.175097 -0.356284 -0.0178945 0.0911273
-0.305616 0.520391 0.232945 -0.241061 0.216244 -0.0297792 0.22514 0.282953
-0.331252 0.482088 0.0992995 0.157807 -0.191121 0.0548878 -0.0498434 0.094394
0.478629 -0.432099 0.185702 -0.192449 0.0271145 -0.0814659 -0.0746306 0.268155
0.0826592 -0.368465 0.356476 0.187589 -0.541964 -0.0259826 0.0295985 0.0789088
-0.202986 -0.207419 -0.370616 -0.0942517 -0.0230749 -0.316462 0.0238605 0.248833
-0.358058 -0.0284918 0.221638 -0.326539 0.304447 -0.263314 0.333192 -0.258976
-0.315238 -0.274475 -0.113077 -0.114367 -0.0380169 0.176762 -0.294102 0.235289
0.473592 0.208759 -0.410039 -0.244661 -0.126621 -0.424764 -0.0275804 -0.0595785
-0.0598334 -0.310738 -0.0611282 0.0255952 -0.0822417 0.0813839 0.305955 0.303061
-0.127437 -0.0230826 -0.510534 0.122507 -0.17311 0.16155 -0.258383 -0.428785
0.00936689 0.0715902 -0.322214 0.0630384 0.23773 0.0380609 -0.445177 0.178145
0.124858 -0.00617696 0.168044 -0.549779 -0.285716 0.266094 -0.13496 0.341375
0.0383147 0.170198 0.0239541 -0.0840901 0.239556 0.442365 -0.171679 0.214612
-0.0995852 0.103081 -0.109503 -0.0767347 0.0139237 0.607424 0.0289959 -0.0675519
-0.464346 -0.158089 0.293311 0.285826 -0.0939434 -0.178491 0.233914 0.288582
-0.177412 -0.319254 -0.26003 0.368861 0.287861 0.0356785 -0.0420431 0.518099
-0.0153209 -0.222527 -0.172186 0.0558866 -0.0280079 0.406638 0.0992389 0.223795
0.286186 0.257444 0.329723 0.431767 -0.0177278 0.0800309 0.298491 -0.287712
0.0538025 0.212329 -0.0801748 0.235058 0.00361145 0.443006 0.0566916 0.262576
0.389878 -0.00984678 0.214928 0.177372 0.377835 -0.137063 -0.388443 0.10091
-0.144917 -0.0499148 0.295926 0.00354725 0.232934 -0.235889 -0.386444 0.278046
```

```
-0.0352881 0.369621 -0.0461251 -0.120634 0.128804 -0.0404007 0.147132 0.399014
0.0345721 0.310071 -0.42226 0.315638 -0.265273 -0.343707 -0.219921 0.185021
-0.155602 -0.259642 0.108623 -0.0824636 -0.0816768 -0.140764 -0.404436 -0.183884
0.197783 0.16846 0.202299 0.190032 -0.665717 0.116833 -0.0295247 0.252336
-0.0292833 0.0195113 0.17644 -0.142334 0.401127 0.199974 -0.303434 -0.206015
0.180141 0.120339 -0.411108 -0.316024 0.108106 -0.114427 0.470428 0.223761
-0.0306395 -0.415324 -0.0804777 -0.156779 0.0638851 -0.0641116 0.379295 -0.064126
0.460862 0.0799943 0.190817 0.323734 0.346771 -0.237394 0.0911104 0.307291
```

case_2

```
Eigenvalues:
-299.992 -258.838 -216.092 -200.494 -188.479 -182.525 -166.308 -152.194 -128.893
-112.541 -104.913 -73.3463 -59.6352 -18.3744 -3.30868 2.28268 18.7427 30.3941
45.0735 69.158 83.2053 97.9615 107.854 133.447 156.588 169.289 180.668 206.185
214.648 237.675 294.725 1585.62
Eigenvectors:
-0.0823737 -0.123959 -0.137569 -0.0832472 0.0373758 -0.248616 0.170229 -0.262357
-0.363014 0.0586366 0.207066 0.134827 -0.205537 0.390683 -0.200593 -0.134537
-0.0326848 -0.0539806 -0.253625 -0.0183049 -0.0330271 0.0472835 0.0408263
-0.0733429 0.0942731 -0.330715 0.185071 0.211632 0.0447939 -0.138872 -0.109903
0.17834
0.218372 -0.00294492 0.352577 0.193532 -0.0613144 -0.0168077 -0.0144677 0.0778329
0.0594231 -0.0649837 -0.0160145 -0.118977 -0.196482 0.00394346 -0.0837338
0.0449149 0.0669442 0.108086 -0.212236 0.224842 0.28176 0.189832 0.115723
-0.267659 -0.286105 -0.120694 -0.288257 0.238531 -0.071974 -0.188995 0.304459
0.16789
0.0479132 -0.0500151 0.00680177 -0.126084 -0.296257 0.00775228 -0.419175 0.111842
0.0428979 -0.0781687 -0.0072784 0.205292 -0.205754 -0.0360383 -0.297315 0.262238
-0.113459 -0.0191531 0.291791 -0.0440899 -0.0688164 -0.106649 0.302207 0.0423069
-0.0909858 -0.116388 0.288676 -0.120263 -0.216233 -0.235972 0.0112024 0.143271
-0.0574824 0.0460284 0.200874 -0.335742 0.171482 -0.0285181 -0.208219 -0.172131
-0.0684414 -0.308912 -0.0935875 -0.249116 0.278994 0.347915 0.0773092 0.188033
-0.0500856 0.18488 0.0164858 0.249838 -0.164437 0.20801 0.162314 0.139964
-0.0932594 -0.0505002 0.0172016 -0.0956156 0.110374 0.226697 0.0199088 0.163943
-0.169919 -0.275734 0.0015751 0.0272207 0.316039 -0.0228955 -0.00215093 0.0484299
-0.374908 -0.044415 0.153215 0.0679493 -0.063458 -0.212397 0.225381 0.0674481
0.0164371 -0.0751616 0.304828 -0.0214981 0.352195 -0.113384 -0.079541 0.184612
-0.343356 -0.0444734 0.113505 -0.026669 0.166667 0.049538 0.210814 0.178178
0.270653 0.126543 0.0157088 -0.136959 0.0458805 -0.0846241 0.40056 0.276702
0.0601238 -0.187772 -0.305295 0.0629939 0.104368 0.0798126 -0.281467 0.243955
-0.0204126 0.00075506 0.118056 -0.354419 0.0937395 0.0118544 -0.282797 0.0497548
-0.112543 -0.15305 0.0514353 0.138259 0.0445981 0.137149 -0.0901198 0.187849
0.100383 0.167077 0.0797672 0.222578 0.070866 0.340413 -0.00203373 -0.062551
-0.109363 0.0185472 -0.154763 0.110182 -0.0888869 0.228196 0.325519 0.0380921
0.0196309 -0.209688 0.063876 -0.0980721 0.0793903 -0.115274 0.140082 -0.365125
-0.00470399 -0.262221 -0.0678481 -0.358447 -0.0374971 0.126194 -0.284974 0.185762
-0.293073 0.188894 0.135687 0.135265 -0.237755 0.0577929 0.0246288 -0.0471127
0.059653 -0.0367207 0.212055 -0.0596176 -0.221363 -0.134845 -0.107971 0.120403
-0.0355285 0.182996 0.178633 0.0663167 0.338129 0.312953 -0.116343 0.12795
0.418997 -0.112224 -0.0134394 -0.0338833 0.134017 0.226921 -0.174828 0.171824
-0.209584 -0.13227 0.0329259 -0.0574449 -0.0219567 -0.0723928 -0.248577
-0.0422086 0.398721 -0.018095 -0.209292 -0.146987 -0.101789 0.180431 0.226132
-0.271084 0.229428 -0.18475 0.0523345 -0.384441 0.0346578 -0.00173557 -0.061377
0.217723 0.114695 -0.242099 -0.094757 0.139116 -0.00305707 -0.0912686 0.187693
0.198249
```

```
-0.183349 0.259606 -0.228792 0.233548 0.119647 0.154164 -0.221982 0.126513
-0.0827055 -0.0383683 0.192317 -0.112459 0.0378259 -0.0690995 -0.0794959
0.0771708 -0.211797 0.237195 -0.0224017 -0.158633 -0.373339 -0.244475 -0.128677
-0.17083 -0.00937003 -0.215261 -0.147417 0.229173 0.0393763 0.14653 0.257357
0.175215
-0.142692 -0.0663071 0.255677 0.0796317 0.413821 0.224656 0.0182132 0.060174
0.295769 -0.012338 0.140397 0.00560492 -0.0208146 -0.0898196 -0.254558 0.0610586
-0.0624171 -0.486701 -0.051694 0.259113 -0.190174 -0.0300818 -0.0566264 0.0799639
0.000496132 0.0349983 0.072165 0.184286 0.0113787 -0.0614386 -0.251035 0.169948
-0.0741586 -0.130549 -0.142351 0.289698 0.102743 -0.183252 0.109549 0.124969
0.12089 -0.416003 -0.0361573 0.0886666 -0.0515091 -0.0174651 -0.0535434 -0.398907
0.168764 0.309051 0.0882306 0.128906 -0.0434883 -0.0982295 0.205041 0.0198613
-0.0909215 0.100459 0.0342951 -0.0057847 -0.285343 0.189773 -0.254123 0.189121
0.146089 -0.0961991 -0.287388 -0.115742 0.0086141 -0.189364 -0.033885 0.541815
0.0657787 -0.144423 0.246775 -0.115446 -0.0945284 0.235573 0.203582 0.0595676
-0.143442 -0.160847 -0.0410338 0.215935 0.0523714 0.0167864 -0.153616 -0.0885534
0.256456 0.11044 -0.116432 -0.229361 0.0515333 -0.145069 0.0565033 0.183551
0.0664137 0.23148 -0.317157 -0.285665 -0.0361391 0.432724 -0.0316986 0.156488
-0.0959483 0.16283 -0.084077 -0.189631 0.0702816 4.61e-07 -0.114799 -0.366776
0.125205 -0.0196609 0.117345 0.123723 0.217406 0.0803416 0.208795 -0.0540423
-0.0421333 0.121596 0.156045 0.256744 0.142335 -0.0326402 -0.028598 0.200064
-0.0969811 -0.055785 -0.0813598 -0.234162 0.0899522 -0.251576 -0.172814 0.0635899
-0.00625716 0.257703 -0.402389 0.208753 -0.0510367 -0.300907 0.208333 0.090491
-0.285871 0.10967 -0.15973 0.159229 0.0709194 -0.0549665 0.07592 -0.0417756
0.0659726 -0.0687587 -0.22984 0.230563 -0.00108968 0.0702385 -0.300121 0.183862
0.0449535 -0.0477211 0.303162 -0.231321 0.141837 -0.0410882 0.314589 0.016963
0.216824 0.306964 0.28156 -0.158147 -0.0435258 0.0286213 0.156795 0.0906626
0.0234368 0.342566 0.127896 -0.160862 -0.0346056 -0.331997 0.271706 -0.127646
0.151117 0.107258 0.115283 0.0292469 -0.0282727 -0.0645497 0.00619331 0.181709
-0.188336 0.0300155 0.192867 0.0336499 -0.387892 -0.140265 0.0761202 0.338132
-0.0988891 0.221945 -0.00190566 -0.030009 0.0271329 -0.0869044 0.0346391
-0.0580595 0.344115 -0.0305653 -0.141017 0.110993 -0.346887 -0.0308173 -0.0210751
0.0651485 -0.281389 -0.119182 0.0599419 -0.163898 0.342404 0.0566849 -0.123775
0.15842
0.08755 -0.37309 0.221542 -0.0884011 -0.18725 0.252631 -0.0554406 0.0574318
-0.258855 0.050525 0.156249 0.0416006 0.43362 -0.0391075 -0.13128 -0.209479
-0.0851365 0.063696 0.0273511 -0.0980322 -0.00193213 -0.0151781 -0.155415
0.105021 0.131633 -0.0826736 -0.352206 -0.0538245 -0.266335 -0.0893546 -0.127496
0.203094
-0.0796397 -0.261335 -0.0713665 0.273086 -0.0101813 0.122377 0.162667 -0.00644755
-0.0213602 0.115988 -0.203743 -0.174686 -0.153466 0.0870973 0.0226908 -0.00197664
-0.416568 0.105442 0.0988204 -0.231587 -0.236429 0.408216 0.120063 0.0474523
-0.132812 0.275443 -0.0112499 -0.0704548 0.173719 -0.210313 -0.0559441 0.152086
0.0127903 0.14849 -0.158755 0.0743641 -0.102968 -0.0155294 0.372817 -0.119173
0.0667618 0.23733 -0.0897214 0.0342398 0.0921269 -0.0131397 0.17413 0.0263905
-0.0783939 -0.10145 0.25418 0.388191 -0.173719 0.101308 -0.0336632 0.228418
-0.00108802 -0.253335 0.0291962 -0.0185844 -0.402832 -0.0167941 0.300663 0.171798
-0.260518 -0.100335 -0.0696172 -0.229594 0.0067461 0.107552 0.272851 -0.103796
-0.113952 -0.353097 -0.201337 0.00724136 -0.0235485 -0.38411 -0.0841992 0.0951801
0.191714 -0.109539 -0.13611 -0.0418342 -0.133872 0.0223877 0.156932 -0.269612
0.276464 0.0247217 -0.0785476 -0.190213 0.0344077 -0.152393 0.267027 0.159057
0.306654 -0.0392526 0.106975 -0.173073 0.154522 0.180406 -0.141513 0.023371
-0.103671 0.101747 0.0280495 0.253547 -0.419475 -0.073919 0.0888329 -0.0766719
0.188669 0.114086 -0.143208 -0.0666408 -0.270626 0.269382 -0.235754 0.0758902
0.0774857 0.180937 0.120977 -0.0354266 -0.171163 0.300909 0.153046 0.161428
```

```
0.142506 -0.072234 -0.00734304 0.241245 -0.144768 -0.16142 -0.035924 0.0335415
-0.204677 0.0778626 -0.0186433 -0.281151 0.0913738 -0.0447111 -0.0321256 0.17136
-0.00383783 -0.357161 -0.211124 -0.15298 0.0706082 -0.0833671 0.359822 0.146781
0.180063 0.206021 0.0793512 0.138086 -0.153451 0.423981 0.103219 0.16124
0.0270594 0.17733 -0.252511 -0.169197 -0.143 0.136126 0.124521 -0.206722 0.21536
-0.131987 0.349882 0.151917 -0.0627925 -0.0664884 0.101045 0.120585 -0.0520529
-0.0434194 -0.317492 -0.167258 0.0690146 -0.0181153 0.151046 0.323429 -0.35231
0.0802299 -0.290402 -0.0872119 -0.000316373 -0.00813467 -0.11262 0.186202
-0.273875 0.0437317 -0.155392 -0.0698869 0.0279253 -0.181187 -0.122692 -0.121462
0.00973812 0.191859 0.0792603 -0.222089 0.109828 0.0157318 -0.0538796 0.207716
0.248563 -0.0433181 0.0474665 -0.111941 0.0681054 0.201797 -0.284294 -0.362396
-0.2426 0.237083 0.0338132 -0.0499506 -0.40372 -0.0356258 -0.175285 0.173554
-0.175794 0.349219 0.156073 0.133473 0.120362 -0.167239 -0.0528907 0.0907111
-0.0596312 0.0902041 -0.000254378 0.55482 0.278539 0.213476 -0.0476812 -0.0527371
0.0535272 -0.0443627 0.0625603 -0.0954611 0.049079 0.113399 0.146448 0.0202054
0.118351 0.345807 -0.109149 0.00431163 0.0806318 -0.13472 0.213239 0.182021
0.284316 0.109471 -0.00862263 0.00484341 -0.0533265 -0.21623 -0.0567595 -0.368516
-0.119397 -0.0104195 -0.0569052 -0.139881 -0.219639 -0.0179896 -0.169291
-0.0686948 0.107767 -0.116394 0.389472 0.116127 -0.154499 -0.264025 -0.130281
0.0243864 0.0377613 0.225666 -0.38166 -0.0110745 0.23149 -0.0546805 -0.0737443
0.194189
0.181047 -0.200471 -0.131697 0.226803 -0.196035 0.157179 -0.0513235 -0.155364
0.0616439 -0.158565 0.0112804 0.164688 0.217376 0.0151428 0.328431 0.330696
0.2623 0.118231 0.000878813 0.103783 -0.0621697 -0.016515 -0.1223 -0.0350134
0.133685 0.0975229 0.217769 0.387744 0.173541 -0.192862 -0.113184 0.16821
-0.200195 -0.128324 0.0910338 -0.0473666 -0.297939 0.131901 0.0468138 -0.155602
0.153783 -0.0182364 -0.17066 0.0989939 -0.0423489 0.209731 -0.0784099 -0.113977
-0.29988 0.005996 -0.172958 0.165477 0.166121 -0.365529 -0.303119 -0.131088
-0.0988955 0.268419 0.197853 -0.0761887 0.0391117 0.215769 0.213997 0.185298
0.126494 0.393815 0.20495 0.0815229 0.0449693 -0.122892 -0.0766981 -0.0649115
-0.161692 -0.168619 -0.0582218 -0.227548 0.0537718 -0.249482 0.171769 -0.198307
-0.185681 0.0373825 -0.237472 -0.0733667 0.0403898 -0.0767583 -0.186402 0.166284
0.0458246 0.0297849 0.345047 -0.11779 -0.107283 -0.382637 -0.0965238 0.196477
0.287131 -0.100877 -0.0679127 0.00698095 0.00131311 -0.230197 -0.0910527
-0.190558 0.302992 0.048207 0.203151 0.100556 0.294441 -0.284204 -0.0474024
-0.236226 -0.168022 -0.0963294 0.0644353 -0.0601881 -0.00777289 0.241059
0.0402813 -0.314568 -0.0499088 -0.177249 0.181571 -0.15122 0.25526 0.189613
0.097713 0.17223
0.103038 -0.115429 -0.23036 0.215773 0.281164 0.061794 -0.103156 -0.0617015
0.11389 0.29575 -0.173174 -0.0534049 0.0881728 0.0327019 -0.328495 0.155072
0.224111 0.257642 -0.25222 0.0930759 0.167382 -0.113805 -0.0190035 0.227004
0.101189 -0.0991453 0.0149753 -0.390046 0.108943 -0.102998 0.0700982 0.153205
```

case_3

-638.668 -604.298 -585.123 -562.936 -549.066 -540.846 -525.734 -511.923 -505.182
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