

对称值问题的计算方法实验报告

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1 问题描述

1. 利用过关 Jacobi 方法求实对称三对角阵全部特征值和特征向量
2. 先利用二分法求实对称三对角阵指定特征值，再利用反幂法求对应特征向量

2 程序运行结果

2.1 过关 Jacobi 方法

$n = 50$ Q_k, A_k

```
A =
2.00379 2.28316e-08 -2.30501e-08 1.96004e-07 4.25591e-08 1.81543e-07 -1.63068e-07 -4.82649e-08 -4.25946e-08 -4.05156e-08 7.09249e-08 -3.20631e-08 8.57161e-0
8 8.38226e-09 -1.50829e-09 -1.21885e-10 1.60851e-08 2.4396e-09 2.2119e-08 -2.10523e-07 -5.33051e-09 4.7725e-08 1.42856e-08 -1.44639e-08 -3.470e-09 1.0457
7e-08 2.38402e-09 1.38028e-10 -2.51728e-09 2.42005e-09 -1.15025e-08 -5.0066e-10 -3.69632e-10 -3.7839e-10 -4.8305e-11 1.78645e-10 1.74627e-10 1.43124e-10
2.74208e-10 5.74785e-11 1.15586e-10 9.85185e-11 -1.0805e-10 -1.14055e-11 3.52074e-07 7.78779e-07 -1.57446e-09 -9.82126e-11 3.44881e-07 -1.9439e-07
8.28316e-08 5.9921 2.00135e-09 -5.44235e-09 -7.60926e-09 6.88773e-08 -1.71262e-07 5.69154e-08 7.10442e-08 -1.95392e-08 1.03701e-08 2.82563e-08 1.06956e-07
-7.95508e-08 -3.00385e-08 -9.74945e-08 4.80183e-08 6.0584e-08 -2.63079e-09 4.2169e-09 5.2001e-09 -2.63795e-09 -1.55915e-09 -2.83008e-09 6.80034e-10 -1.2932
4e-09 5.64127e-10 -3.17833e-10 5.92594e-09 -2.88095e-09 -1.42053e-06 -6.7715e-10 -2.4939e-10 -5.73384e-10 -2.74438e-10 -3.85518e-10 -5.7224e-10 2.84942e-10
1.57375e-10 2.13544e-10 3.77734e-11 -5.06115e-10 1.08345e-09 -1.24185e-11 -1.13056e-06 3.34045e-10 5.59578e-07 -6.85752e-07 -5.99975e-11 1.48419e-12
2.30501e-08 2.06135e-09 4.06159 -1.01811e-09 1.07953e-08 -5.87666e-09 1.05093e-08 8.69939e-10 -1.76979e-09 -5.56453e-10 -1.51061e-09 2.96481e-07 1.1371e-06
4.225e-10 1.23929e-06 -3.27643e-10 -1.34837e-09 1.45777e-09 -2.64041e-09 -7.1138e-09 2.1739e-10 -4.39073e-10 -5.02505e-10 -1.05318e-09 2.81087e-09 1.80181
e-09 -2.75398e-10 4.0372e-10 3.7895e-09 -1.36596e-06 2.35462e-10 5.03684e-07 9.42193e-07 2.00968e-10 6.44223e-11 -5.98854e-07 -1.88763e-07 7.93613e-10 3.217
0e-10 1.02408e-09 1.08011e-09 -1.07892e-09 4.01421e-07 5.24455e-11 -1.10401e-09 -3.68311e-09 -5.74333e-11 -1.54055e-06 -1.44793e-10 2.07915e-07
1.96004e-07 -8.44235e-09 -1.01811e-09 3.35229 6.49214e-09 8.73679e-07 -7.52009e-09 -6.29172e-09 4.00222e-09 -1.6194e-08 9.9682e-10 -2.79882e-09 7.4677e-09
-4.3346e-09 1.58779e-08 -2.50907e-08 6.7276e-11 9.7808e-09 -5.85953e-09 -1.55555e-09 -4.1856e-10 -1.29999e-09 1.44717e-08 4.69243e-09 -5.45027e-09 -6.1464
1e-10 3.02538e-09 6.03459e-09 -2.67471e-08 -5.99182e-10 -1.30312e-07 -1.40079e-06 4.38432e-11 2.29901e-10 -9.12821e-11 -5.14903e-10 9.56122e-09 -3.9848e-07
1.94752e-11 2.20559e-10 2.86506e-07 1.70968e-09 1.51356e-06 4.62527e-07 -4.30766e-12 -1.20694e-09 -2.33575e-07 6.44818e-09 -1.46498e-12 -1.7754e-07
4.25591e-08 -7.60926e-09 1.07653e-08 4.49214e-09 2.52192 2.94765e-09 1.8054e-09 3.76394e-11 1.0921e-09 2.48974e-09 -1.15373e-09 -5.46079e-10 -3.94302e-09
2.90229e-09 2.07613e-09 7.16818e-09 1.88209e-10 -7.42767e-09 -1.01008e-08 -2.63225e-09 -1.51723e-09 -4.42718e-10 -8.01421e-09 -2.95193e-09 2.39122e-09 2.342
5e-09 -3.35471e-09 -1.78773e-09 -2.48266e-09 7.78088e-10 -1.60737e-09 4.4773e-09 2.86058e-09 1.31187e-10 -4.55277e-10 -8.79396e-07 8.17379e-07 3.20728e-09 -1
.52785e-08 -4.97894e-10 -1.61326e-10 1.47824e-07 3.51227e-10 -5.8233e-11 -6.50668e-08 1.26437e-10 3.43408e-07 -4.21768e-10 7.40082e-12 2.47823e-07
1.81543e-07 6.88773e-08 -5.87666e-09 8.73679e-07 2.94765e-09 5.47802 -1.05278e-08 1.7829e-09 1.93007e-08 5.97655e-09 -3.2244e-08 -1.86541e-08 -1.05557e-08 4
52835e-09 6.64075e-09 9.6728e-09 -2.77519e-08 -3.60161e-09 1.51258e-09 7.99669e-09 2.29372e-09 -6.00534e-10 -7.94089e-09 6.55216e-09 5.997e-09 9.72815e-09
2.02423e-10 8.46047e-10 -1.4176e-08 3.90794e-09 -3.14637e-10 -1.23786e-08 1.36264e-08 2.93071e-08 2.77348e-10 -1.10076e-09 6.52723e-10 -8.89826e-10 8.30889e
-11 -3.90771e-10 9.41233e-11 6.8899e-10 2.29832e-11 -4.5031e-10 4.39112e-12 2.17004e-10 6.75719e-07 -1.41474e-10 1.22403e-09 -5.33335e-07
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e-08 -1.70842e-09 1.87104e-09 -1.26e-08 9.48151e-09 3.23727e-09 -3.4823e-08 1.6321e-06 4.21339e-08 1.92422e-09 -1.9158e-09 3.45191e-08 2.8986e-09 -8.392
28e-10 3.83985e-11 1.11506e-06 -5.13665e-09 -1.893e-10 -5.39331e-11 -8.83193e-07 2.92204e-10 9.03012e-07 -5.18806e-07 1.02807e-06 1.10827e-06
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26783e-09 5.54064e-09 4.7367e-09 -1.808e-09 -6.44855e-09 -3.4354e-09 -6.48488e-09 6.35127e-10 1.01571e-10 1.35196e-08 -2.73916e-09 3.95689e-09 4.88169e-09
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51223e-09 2.40002e-11 -1.58525e-08 -1.35359e-08 -1.34403e-08 -1.11034e-08 -2.96488e-09 1.56209e-09 1.61803e-09 4.75991e-10 -3.04591e-10 4.78122e-11 4.17175e
-11 2.66441e-10 -4.44803e-10 2.49507e-11 -1.20556e-08 2.43305e-11 -4.56484e-12 8.77981e-07 3.1747e-11 -4.20298e-07 -2.61444e-11 1.66571e-07 -5.83972e-07
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94691e-09 8.81249e-09 5.88056e-09 1.00739e-08 2.50049e-09 -2.05031e-08 -8.21808e-09 1.01457e-09 2.01892e-09 -1.9621e-09 1.51246e-09 -4.61901e
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2.9081e-07 -1.30884e-07 -1.64079e-07 7.6088e-09 4.99534e-09 1.44979e-08 -4.66291e-09 -2.91883e-09 -1.10308e-08 2.46569e-08 7.01109e-09 3.41816e-11 -4.08021e
-09 4.62588e-10 1.37561e-09 -2.21537e-10 7.04074e-10 4.64739e-09 1.6169e-09 2.77395e-09 -7.23456e-11 3.36871e-11 7.1788e-07 5.72406e-10 -2.96884e-10 -1.4645
2e-10 -1.68039e-10 6.4509e-07 2.63721e-10 2.66719e-10 -4.27906e-13 -1.33318e-06 1.49374e-06 -5.08672e-10 4.37446e-12 4.1778e-08 1.14407e-07
6.57101e-08 1.06956e-07 1.1371e-08 7.46779e-09 -5.94362e-09 -1.06875e-08 2.17213e-08 8.82303e-09 2.50585e-07 -1.20389e-08 5.30459e-08 4.43761e-08 2.18307 -3.2
9031e-08 8.82457e-08 1.25955e-08 2.91434e-07 -4.94988e-09 5.20963e-09 -8.5334e-09 -2.36889e-07 -3.05823e-08 -1.80142e-08 1.28019e-08 3.32016e-08 -2.322e-08
-2.48956e-08 3.67896e-11 2.83397e-09 -2.15546e-08 1.3033e-08 -2.37389e-09 8.75197e-09 -2.23337e-09 -1.3065e-09 -1.17054e-09 2.42375e-09 -8.81958e-09 7.051
83e-10 -6.0646e-11 -1.44038e-09 -7.72196e-09 5.6026e-10 -1.30521e-10 7.34869e-11 1.83467e-09 -0.0719e-11 -5.92458e-07 -3.99315e-07 1.89944e-07
8.38205e-09 -7.95508e-08 -6.225e-10 -4.3346e-09 3.90229e-09 4.52835e-09 -3.66546e-08 -4.26783e-09 3.58676e-09 -1.81401e-08 2.94691e-09 2.29081e-07 -3.29031e
-08 4.77957 -2.15486e-10 -1.81869e-08 3.26071e-08 -2.36852e-08 -2.83555e-11 -1.38526e-08 -1.34819e-09 5.62444e-10 5.57535e-07 2.3289e-09 -1.626e-08 4.981e-0
9 1.62638e-08 2.43336e-08 1.14141e-10 -2.8296e-08 6.40847e-09 2.35173e-10 6.60667e-11 -1.96389e-09 -4.09154e-10 -8.03721e-10 -1.07465e-10 -9.47489e-10 -1
82934e-10 -1.07178e-09 7.00748e-10 3.25301e-07 -4.0744e-12 -2.03206e-11 -3.8496e-11 -7.76879e-10 -2.60551e-12 7.30131e-08 1.9206e-08 -2.29399e-07
-1.50826e-08 -3.00985e-08 1.23282e-06 1.56797e-08 2.07613e-09 6.64075e-09 -2.27434e-08 5.54064e-09 5.26528e-09 -1.28261e-09 -8.81249e-09 -1.30684e-07 4.8245
7e-09 -2.15486e-10 5.98484 2.63103e-09 -5.02202e-08 -3.02335e-08 6.45138e-09 9.65956e-09 2.24747e-08 -1.9931e-09 -2.51049e-08 -7.71437e-09 1.82138e-07 -2.35
488e-09 -2.02056e-07 3.0912e-09 -3.3847e-10 -1.22645e-08 -6.44382e-10 8.05636e-10 6.65377e-10 -2.14004e-09 -2.24468e-09 4.91846e-10 -2.22597e-09 1.07516e
-09 4.51027e-11 -1.90841e-11 2.97832e-10 7.31133e-10 -1.87833e-09 7.10494e-07 -5.3871e-12 -5.21112e-07 5.55718e-07 -1.39495e-06 -4.90964e-10 1.01987e-13
-1.21886e-10 -9.74045e-08 -3.27543e-10 -2.50967e-09 1.08189e-09 9.6728e-09 -7.11644e-09 4.7367e-09 5.34407e-09 -5.74139e-09 -5.68056e-09 -1.64079e-07 1.2595
5e-08 -1.61866e-08 2.63107e-08 3.45257 -7.05226e-09 1.75484e-08 7.80666e-09 3.40102e-10 2.45458e-09 0.07657e-10 1.34192e-08 -1.05987e-08 8.6031e-08 2.1823
7e-09 -3.24449e-09 -1.1297e-08 1.27979e-09 -1.35783e-09 -1.09041e-09 1.60304e-07 4.28349e-07 -1.25612e-09 -4.44538e-10 -5.1101e-10 -1.90703e-10 1.7023e-07 5
83092e-11 1.44772e-06 -4.49282e-10 -1.42263e-09 1.77634e-11 3.65743e-10 -5.92246e-11 5.94487e-10 -4.00005e-13 -1.49191e-06 2.65929e-08 -1.93116e-07
```

2

3

4

不同阶数矩阵特征值

```
exercice7.1
n=50, 迭代次数为: 4979
用时:607.05ms

特征值从小到大的排列为:
2.00379 2.01516 2.03405 2.06041 2.09412 2.13506 2.18307 2.23798 2.29957 2.36761 2.44184 2.52198 2.60773 2.69876 2.79473 2.89527 3 3.10852 3.22043 3.3529 3.45
267 3.57213 3.69322 3.81546 3.93841 4.06159 4.18454 4.30678 4.42787 4.54733 4.66471 4.77957 4.89148 5 5.10473 5.20527 5.30124 5.39227 5.47802 5.55816 5.63239
5.70043 5.76202 5.81693 5.86494 5.90588 5.93959 5.96595 5.98484 5.99621

n=60, 迭代次数为: 7416
用时:1107.14ms

特征值从小到大的排列为:
2.00285 2.0106 2.02382 2.04229 2.06594 2.09473 2.12857 2.16737 2.21103 2.25943 2.31245 2.36994 2.43176 2.49774 2.5677 2.64145 2.71881 2.79957 2.88351 2.97041
3.06005 3.15217 3.24684 3.34292 3.44103 3.54062 3.64144 3.7432 3.84565 3.9489 4.0515 4.15435 4.258 4.3636 4.4708 4.5797 4.68708 4.79346 4.8973 4.9995 5.
02959 5.11649 5.20043 5.28119 5.35855 5.4323 5.50226 5.56824 5.63006 5.68755 5.74057 5.78897 5.83263 5.87143 5.90527 5.93406 5.95771 5.97618 5.9894 5.99735

n=70, 迭代次数为: 10163
用时:1779.38ms

特征值从小到大的排列为:
2.00196 2.00783 2.01789 2.03124 2.04875 2.07007 2.09517 2.124 2.1565 2.19261 2.23226 2.27537 2.32186 2.37163 2.42458 2.48063 2.53964 2.60152 2.66613 2.73335 2
.80306 2.8751 2.94935 3.02665 3.10387 3.18383 3.2654 3.3484 3.43263 3.51806 3.6044 3.6915 3.77921 3.86735 3.95576 4.04424 4.13265 4.22079 4.308 4.3956 4.4819
4 4.56732 4.6516 4.7346 4.81617 4.89613 4.97435 5.05065 5.1249 5.19694 5.26665 5.33387 5.39848 5.46036 5.51937 5.57542 5.62837 5.67814 5.72463 5.76774 5.80739
5.8435 5.876 5.90483 5.92993 5.95125 5.96876 5.98241 5.99217 5.99804

n=80, 迭代次数为: 13931
用时:3207.49ms

特征值从小到大的排列为:
2.0015 2.00601 2.01352 2.02402 2.03749 2.05391 2.07326 2.0955 2.12061 2.14855 2.17927 2.21273 2.24888 2.28767 2.32902 2.3729 2.41921 2.46791 2.51891 2.57214 2
.62752 2.68496 2.74438 2.80568 2.86879 2.93359 3 3.06791 3.13723 3.20784 3.27964 3.35253 3.42639 3.50112 3.57659 3.6527 3.72934 3.80638 3.88371 3.96122 4.0387
3 4.11629 4.19362 4.27066 4.3473 4.42341 4.49888 4.57361 4.64747 4.72036 4.79216 4.86277 4.93209 5 5.06641 5.13121 5.19432 5.25562 5.31504 5.37248 5.42786 5.4
5109 5.50209 5.55079 5.6271 5.67098 5.71233 5.75112 5.78727 5.82073 5.85145 5.87839 5.9045 5.92674 5.94609 5.96251 5.97598 5.98646 5.99399 5.9985

n=90, 迭代次数为: 17573
用时:4581.57ms

特征值从小到大的排列为:
2.00119 2.00477 2.01372 2.01904 2.02672 2.04275 2.05812 2.07579 2.09576 2.115 2.14248 2.16918 2.19806 2.22909 2.26222 2.29743 2.32467 2.37389 2.41505 2.45806
2.50288 2.54965 2.59804 2.64811 2.69979 2.75302 2.80774 2.86387 2.92136 2.98013 3.04013 3.10126 3.16346 3.22667 3.29079 3.35576 3.4215 3.48792 3.55496 3.62252
3.69054 3.75993 3.8276 3.89448 3.96548 4.03452 4.10352 4.1724 4.24107 4.30946 4.37748 4.44504 4.51208 4.5785 4.64424 4.70921 4.77333 4.83654 4.89874 4.95987
5.01987 5.07864 5.13613 5.19226 5.24698 5.30021 5.35189 5.40196 5.45035 5.49702 5.54191 5.58495 5.62611 5.66533 5.70257 5.73778 5.77091 5.80194 5.83082 5.8575
5.882 5.90424 5.92421 5.94188 5.95725 5.97028 5.98096 5.98928 5.99523 5.99881

n=100, 迭代次数为: 21955
用时:6723.79ms

特征值从小到大的排列为:
2.00097 2.00387 2.0087 2.01546 2.02414 2.03473 2.04722 2.0616 2.07786 2.09597 2.11593 2.13771 2.16129 2.18665 2.21377 2.24261 2.27316 2.30537 2.33922 2.37468
2.41172 2.45029 2.49035 2.53188 2.57483 2.61916 2.66482 2.71178 2.75998 2.80938 2.85994 2.91159 2.9643 3.01801 3.07267 3.12823 3.18463 3.24182 3.29975 3.35835
3.41757 3.47736 3.53765 3.59829 3.65951 3.72097 3.7827 3.84463 3.90672 3.9689 4.0311 4.09228 4.1537 4.2173 4.27903 4.34049 4.40161 4.46235 4.52264 4.58243 4
.64165 4.70025 4.75818 4.81537 4.87177 4.92733 4.98199 5.0357 5.08841 5.14006 5.19062 5.24002 5.28822 5.33518 5.38084 5.42517 5.46812 5.50965 5.54971 5.58828
5.62532 5.66078 5.69463 5.72684 5.75739 5.78623 5.81335 5.83871 5.86229 5.88407 5.90403 5.92214 5.9384 5.95278 5.96527 5.97586 5.98454 5.9913 5.99613 5.99903
```

2.2 二分法 & 反幂法

```
-----/
exercice7.2
二分法迭代次数: 27用时:0.7229ms

最小特征值: 0.000967443
最小特征向量:
0.0311036 0.0621771 0.0931905 0.124114 0.154917 0.18557 -0.216044 0.246309 0.276335 0.306094 0.335557 0.364696 0.393481 0.421886 0.449883 0.477444 0.504544 0.5
31155 0.557253 0.582811 0.607806 0.632213 0.656008 0.679168 0.701672 0.723496 0.744621 0.765025 0.784689 0.803594 0.821722 0.839054 0.855575 0.871268 0.886118
0.900111 0.913224 0.925472 0.936816 0.947253 0.956772 0.965368 0.97303 0.979749 0.985521 0.99034 0.9942 0.997099 0.999033 1 1 0.999033 0.997099 0.9942 0.990
33 0.985521 0.979749 0.97303 0.965368 0.956773 0.947253 0.936816 0.925472 0.913224 0.900111 0.886118 0.871268 0.855575 0.839054 0.821722 0.803594 0.784689 0.76
5025 0.744621 0.723496 0.701672 0.679168 0.656008 0.632213 0.607806 0.582811 0.557253 0.531155 0.504544 0.477444 0.449883 0.421886 0.393481 0.364696 0.335557
0.306094 0.276335 0.246309 0.216044 0.18557 0.154917 0.124114 0.0931905 0.0621772 0.0311036

二分法迭代次数: 27用时:0.6627ms

最大特征值: 3.99903
最大特征向量:
-0.0311036 0.0621772 -0.0931905 0.124114 -0.154917 0.18557 -0.216044 0.246309 -0.276335 0.306094 -0.335557 0.364696 -0.393481 0.421886 -0.449883 0.477444 -0.5
04544 0.531155 -0.557253 0.582811 -0.607806 0.632213 -0.656008 0.679168 -0.701672 0.723496 -0.744621 0.765025 -0.784689 0.803594 -0.821722 0.839054 -0.855575
0.871268 -0.886118 0.900111 -0.913224 0.925472 -0.936816 0.947253 -0.956773 0.965368 -0.97303 0.979749 -0.985521 0.99034 -0.9942 0.997099 -0.999033 1 -1 0.999
033 -0.997099 0.9942 -0.99034 0.985521 -0.979749 0.97303 -0.965368 0.956773 -0.947253 0.936816 -0.925472 0.913224 -0.900111 0.886118 -0.871268 0.855575 -0.839
054 0.821722 -0.803594 0.784689 -0.765025 0.744621 -0.723496 0.701672 -0.679168 0.656008 -0.632213 0.607806 -0.582811 0.557253 -0.531155 0.504544 -0.477444 0.
449883 -0.421886 0.393481 -0.364696 0.335557 -0.306094 0.276335 -0.246309 0.216044 -0.18557 0.154917 -0.124114 0.0931905 -0.0621772 0.0311036
```

3 结果分析

- 1) 可以看出过关 jacobi 方法迭代次数较大，耗时相对较长，我们可以通过并行化方法或优化稀疏矩阵乘法的方法进行算法优化
- 2) 二分法求矩阵特征值迭代次数较少；在对矩阵特征值有较为合理估计时，用反幂法可以用较低的迭代次数求出特征向量，性能是比较好的。