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```
% this experiment is to test whether pqn1 can work for the example given
% by help spgl1
```

addpath for PQN working

```
addpath(genpath('/Volumes/Users/linamiao/Dropbox/PQN/'))
```

problem setting

```
m = 120; n = 512; k = 20; % m rows, n cols, k nonzeros.
p = randperm(n); x0 = zeros(n,1); x0(p(1:k)) = sign(randn(k,1));
A = randn(m,n); [Q,R] = qr(A',0); A = Q';
b = A*x0 + 0.005 * randn(m,1);

opts.optTol = 1e-4;
opts.iterations = 200;
```

spgl1

```
[x_spg,r_spg,g_spg,info_spg] = spgl1(A, b, 0, 1e-3, [], opts); % Find BP sol'n.
```

```
=====
SPGL1_SLIM v. 46 (Tue, 14 Jun 2011) based on v.1017
=====
```

| | | | | | |
|-------------------|---|----------|--------------------|---|----------|
| No. rows | : | 120 | No. columns | : | 512 |
| Initial tau | : | 0.00e+00 | Two-norm of b | : | 2.41e+00 |
| Optimality tol | : | 1.00e-04 | Target objective | : | 1.00e-03 |
| Basis pursuit tol | : | 1.00e-06 | Maximum iterations | : | 200 |

| Iter | Objective | Relative Gap | Rel Error | gNorm | stepG | nnzX |
|------|---------------|---------------|-----------|-----------|-------|------|
| 0 | 2.4096982e+00 | 0.0000000e+00 | 1.00e+00 | 4.903e-01 | 0.0 | 0 |
| 1 | 2.2800942e+00 | 1.9758670e+00 | 1.00e+00 | 3.627e-01 | -0.3 | 1 |
| 2 | 1.1953236e+00 | 1.0665335e+00 | 9.99e-01 | 1.814e-01 | 0.0 | 51 |
| 3 | 1.0509740e+00 | 4.8981611e-01 | 9.99e-01 | 1.335e-01 | 0.0 | 57 |
| 4 | 9.9536591e-01 | 3.0657888e-01 | 9.94e-01 | 1.255e-01 | 0.0 | 42 |
| 5 | 9.4847920e-01 | 2.0938906e-01 | 9.47e-01 | 1.186e-01 | 0.0 | 28 |
| 6 | 9.4579081e-01 | 5.6020560e-01 | 9.45e-01 | 1.584e-01 | 0.0 | 20 |
| 7 | 9.4852139e-01 | 5.5588309e-01 | 9.48e-01 | 1.434e-01 | 0.0 | 20 |

| | | | | | | |
|----|---------------|---------------|----------|-----------|------|-----|
| 8 | 9.3405573e-01 | 4.9130180e-02 | 9.33e-01 | 1.101e-01 | 0.0 | 20 |
| 9 | 9.3396581e-01 | 1.4404507e-02 | 9.33e-01 | 1.071e-01 | 0.0 | 20 |
| 10 | 9.3395753e-01 | 6.6255477e-03 | 9.33e-01 | 1.065e-01 | 0.0 | 20 |
| 11 | 2.9042217e-01 | 1.0009531e+00 | 2.89e-01 | 4.946e-02 | 0.0 | 63 |
| 12 | 2.0350578e-01 | 2.2538958e-01 | 2.03e-01 | 3.076e-02 | 0.0 | 180 |
| 13 | 1.6529181e-01 | 2.1838471e-01 | 1.64e-01 | 2.319e-02 | 0.0 | 161 |
| 14 | 1.5561130e-01 | 1.3942386e-01 | 1.55e-01 | 1.976e-02 | 0.0 | 147 |
| 15 | 1.3679280e-01 | 1.1441621e-01 | 1.36e-01 | 1.713e-02 | 0.0 | 125 |
| 16 | 1.0716422e-01 | 1.1536397e-01 | 1.06e-01 | 1.499e-02 | 0.0 | 90 |
| 17 | 1.3697070e-01 | 3.2544833e-01 | 1.36e-01 | 2.121e-02 | -0.3 | 84 |
| 18 | 1.1179929e-01 | 2.1413535e-01 | 1.11e-01 | 2.028e-02 | 0.0 | 127 |
| 19 | 8.4083442e-02 | 1.0146375e-01 | 8.31e-02 | 1.196e-02 | 0.0 | 126 |
| 20 | 7.9851842e-02 | 6.2935369e-02 | 7.89e-02 | 1.005e-02 | 0.0 | 114 |
| 21 | 7.5895457e-02 | 6.4934212e-02 | 7.49e-02 | 9.675e-03 | 0.0 | 102 |
| 22 | 6.3320251e-02 | 6.9713872e-02 | 6.23e-02 | 9.109e-03 | 0.0 | 86 |
| 23 | 5.9450906e-02 | 7.2509511e-02 | 5.85e-02 | 8.327e-03 | -0.3 | 89 |
| 24 | 5.6811733e-02 | 2.9916798e-02 | 5.58e-02 | 6.451e-03 | 0.0 | 96 |
| 25 | 5.4869305e-02 | 4.8882906e-02 | 5.39e-02 | 6.853e-03 | 0.0 | 90 |
| 26 | 5.3125231e-02 | 2.5881968e-02 | 5.21e-02 | 5.838e-03 | 0.0 | 88 |
| 27 | 5.1481880e-02 | 4.5511392e-02 | 5.05e-02 | 6.360e-03 | 0.0 | 90 |
| 28 | 5.0163461e-02 | 2.9184582e-02 | 4.92e-02 | 5.751e-03 | 0.0 | 88 |
| 29 | 4.8672613e-02 | 3.9626256e-02 | 4.77e-02 | 5.838e-03 | 0.0 | 87 |
| 30 | 4.7436062e-02 | 1.7467757e-02 | 4.64e-02 | 4.828e-03 | 0.0 | 90 |
| 31 | 4.6494331e-02 | 2.4913357e-02 | 4.55e-02 | 5.039e-03 | 0.0 | 89 |
| 32 | 4.4478227e-02 | 1.7465952e-02 | 4.35e-02 | 4.574e-03 | 0.0 | 88 |
| 33 | 4.5029599e-02 | 5.5439607e-02 | 4.40e-02 | 5.923e-03 | -0.3 | 84 |
| 34 | 4.3782655e-02 | 4.2867489e-02 | 4.28e-02 | 5.768e-03 | 0.0 | 89 |
| 35 | 4.1333012e-02 | 1.7271594e-02 | 4.03e-02 | 4.171e-03 | 0.0 | 94 |
| 36 | 4.0990307e-02 | 1.2708131e-02 | 4.00e-02 | 3.920e-03 | 0.0 | 92 |
| 37 | 3.9467308e-02 | 8.0616546e-03 | 3.85e-02 | 3.513e-03 | 0.0 | 87 |
| 38 | 4.0992395e-02 | 6.6047141e-02 | 4.00e-02 | 5.845e-03 | 0.0 | 61 |
| 39 | 3.8277553e-02 | 1.9637340e-02 | 3.73e-02 | 3.766e-03 | -0.3 | 74 |
| 40 | 3.7627097e-02 | 1.6286457e-02 | 3.66e-02 | 3.429e-03 | 0.0 | 68 |
| 41 | 3.7421922e-02 | 1.0712377e-02 | 3.64e-02 | 3.212e-03 | 0.0 | 68 |
| 42 | 3.7351385e-02 | 4.6673970e-03 | 3.64e-02 | 2.913e-03 | 0.0 | 68 |
| 43 | 3.7290623e-02 | 4.8824833e-03 | 3.63e-02 | 2.947e-03 | 0.0 | 68 |
| 44 | 3.7263145e-02 | 6.4400928e-03 | 3.63e-02 | 3.046e-03 | 0.0 | 66 |
| 45 | 3.7240983e-02 | 4.3857565e-03 | 3.62e-02 | 2.947e-03 | -0.3 | 65 |
| 46 | 3.7224505e-02 | 1.2136918e-03 | 3.62e-02 | 2.792e-03 | 0.0 | 65 |
| 47 | 3.7222411e-02 | 9.9986141e-04 | 3.62e-02 | 2.783e-03 | 0.0 | 65 |
| 48 | 3.7213278e-02 | 5.3798225e-04 | 3.62e-02 | 2.772e-03 | 0.0 | 65 |
| 49 | 3.7214096e-02 | 2.3046599e-03 | 3.62e-02 | 2.858e-03 | 0.0 | 66 |
| 50 | 1.5618269e-02 | 5.5144926e-02 | 1.46e-02 | 2.268e-03 | 0.0 | 111 |
| 51 | 9.2184329e-03 | 9.1176975e-03 | 8.22e-03 | 1.110e-03 | 0.0 | 143 |
| 52 | 6.9761488e-03 | 8.6651625e-03 | 5.98e-03 | 7.329e-04 | 0.0 | 127 |
| 53 | 6.5068219e-03 | 6.0188165e-03 | 5.51e-03 | 6.295e-04 | 0.0 | 132 |
| 54 | 5.8995899e-03 | 3.0050206e-03 | 4.90e-03 | 5.244e-04 | 0.0 | 142 |
| 55 | 5.9329652e-03 | 8.8599130e-03 | 4.93e-03 | 6.965e-04 | 0.0 | 137 |
| 56 | 5.7173730e-03 | 4.8443168e-03 | 4.72e-03 | 6.119e-04 | 0.0 | 138 |
| 57 | 5.4702748e-03 | 2.4041696e-03 | 4.47e-03 | 4.402e-04 | 0.0 | 138 |
| 58 | 5.4217386e-03 | 1.6311325e-03 | 4.42e-03 | 4.049e-04 | 0.0 | 138 |
| 59 | 5.3407659e-03 | 1.4973178e-03 | 4.34e-03 | 3.960e-04 | 0.0 | 136 |
| 60 | 5.3667239e-03 | 7.9305687e-03 | 4.37e-03 | 7.201e-04 | 0.0 | 129 |
| 61 | 5.0037342e-03 | 1.9164260e-03 | 4.00e-03 | 4.195e-04 | -0.3 | 128 |

| | | | | | | |
|-----|---------------|---------------|----------|-----------|------|-----|
| 62 | 4.9397142e-03 | 9.2483709e-04 | 3.94e-03 | 3.625e-04 | 0.0 | 128 |
| 63 | 4.9067244e-03 | 9.8246194e-04 | 3.91e-03 | 3.608e-04 | 0.0 | 127 |
| 64 | 4.8260460e-03 | 1.5851398e-03 | 3.83e-03 | 3.807e-04 | 0.0 | 125 |
| 65 | 4.8024716e-03 | 1.4016524e-03 | 3.80e-03 | 3.752e-04 | -0.3 | 125 |
| 66 | 4.7806837e-03 | 1.5608463e-03 | 3.78e-03 | 3.770e-04 | 0.0 | 124 |
| 67 | 4.7589823e-03 | 1.1314943e-03 | 3.76e-03 | 3.590e-04 | 0.0 | 124 |
| 68 | 4.7420687e-03 | 1.1050957e-03 | 3.74e-03 | 3.552e-04 | 0.0 | 123 |
| 69 | 4.7229717e-03 | 9.1972733e-04 | 3.72e-03 | 3.470e-04 | 0.0 | 123 |
| 70 | 4.7099159e-03 | 2.0622337e-03 | 3.71e-03 | 3.979e-04 | 0.0 | 122 |
| 71 | 4.6809728e-03 | 1.1888853e-03 | 3.68e-03 | 3.595e-04 | -0.3 | 121 |
| 72 | 4.6661844e-03 | 7.5083703e-04 | 3.67e-03 | 3.359e-04 | 0.0 | 121 |
| 73 | 4.6556596e-03 | 5.9595577e-04 | 3.66e-03 | 3.283e-04 | 0.0 | 121 |
| 74 | 4.5603534e-03 | 1.6330303e-03 | 3.56e-03 | 3.721e-04 | 0.0 | 116 |
| 75 | 4.6495541e-03 | 3.4382338e-03 | 3.65e-03 | 4.774e-04 | -0.3 | 116 |
| 76 | 4.5356163e-03 | 1.6321979e-03 | 3.54e-03 | 3.694e-04 | 0.0 | 117 |
| 77 | 4.5127999e-03 | 5.6377838e-04 | 3.51e-03 | 3.215e-04 | 0.0 | 116 |
| 78 | 4.5062104e-03 | 5.1939922e-04 | 3.51e-03 | 3.182e-04 | 0.0 | 115 |
| 79 | 4.4242040e-03 | 7.7069442e-04 | 3.42e-03 | 3.282e-04 | 0.0 | 114 |
| 80 | 4.4971061e-03 | 3.2667407e-03 | 3.50e-03 | 4.342e-04 | -0.3 | 114 |
| 81 | 4.3948149e-03 | 1.0005589e-03 | 3.39e-03 | 3.408e-04 | -0.3 | 114 |
| 82 | 4.3748465e-03 | 7.2274010e-04 | 3.37e-03 | 3.194e-04 | 0.0 | 113 |
| 83 | 4.3678980e-03 | 4.9094158e-04 | 3.37e-03 | 3.094e-04 | 0.0 | 113 |
| 84 | 4.3531708e-03 | 5.0256408e-04 | 3.35e-03 | 3.078e-04 | 0.0 | 112 |
| 85 | 4.3472376e-03 | 1.4052825e-03 | 3.35e-03 | 3.618e-04 | -0.3 | 110 |
| 86 | 4.3561993e-03 | 2.7479665e-03 | 3.36e-03 | 4.051e-04 | -0.3 | 110 |
| 87 | 4.3191981e-03 | 5.6060169e-04 | 3.32e-03 | 3.127e-04 | 0.0 | 109 |
| 88 | 4.3160540e-03 | 4.0373577e-04 | 3.32e-03 | 3.032e-04 | 0.0 | 109 |
| 89 | 4.3062475e-03 | 4.3224868e-04 | 3.31e-03 | 3.048e-04 | 0.0 | 109 |
| 90 | 4.3174797e-03 | 2.8834888e-03 | 3.32e-03 | 4.227e-04 | -0.3 | 107 |
| 91 | 4.2490280e-03 | 8.5208813e-04 | 3.25e-03 | 3.345e-04 | -0.3 | 107 |
| 92 | 4.2375892e-03 | 5.9914989e-04 | 3.24e-03 | 3.147e-04 | 0.0 | 107 |
| 93 | 4.2320577e-03 | 2.7885915e-04 | 3.23e-03 | 2.992e-04 | 0.0 | 106 |
| 94 | 4.2258233e-03 | 5.2855110e-04 | 3.23e-03 | 3.064e-04 | 0.0 | 106 |
| 95 | 4.2248902e-03 | 6.1638772e-04 | 3.22e-03 | 3.169e-04 | -0.3 | 107 |
| 96 | 4.2217237e-03 | 7.5440431e-04 | 3.22e-03 | 3.159e-04 | 0.0 | 107 |
| 97 | 4.2190511e-03 | 2.1187725e-04 | 3.22e-03 | 2.929e-04 | 0.0 | 107 |
| 98 | 4.2178697e-03 | 2.2771079e-04 | 3.22e-03 | 2.930e-04 | 0.0 | 107 |
| 99 | 4.2092907e-03 | 2.1030897e-04 | 3.21e-03 | 2.928e-04 | 0.0 | 107 |
| 100 | 4.2169922e-03 | 1.9672889e-03 | 3.22e-03 | 3.689e-04 | -0.3 | 107 |
| 101 | 4.2028013e-03 | 1.8467485e-04 | 3.20e-03 | 2.913e-04 | -0.3 | 107 |
| 102 | 4.2018376e-03 | 1.8961899e-04 | 3.20e-03 | 2.904e-04 | 0.0 | 107 |
| 103 | 4.2001601e-03 | 1.7740403e-04 | 3.20e-03 | 2.898e-04 | 0.0 | 107 |
| 104 | 4.1714675e-03 | 1.9475835e-03 | 3.17e-03 | 3.685e-04 | 0.0 | 104 |
| 105 | 4.1761553e-03 | 1.2526585e-03 | 3.18e-03 | 3.472e-04 | -0.3 | 105 |
| 106 | 4.1535763e-03 | 6.2963500e-04 | 3.15e-03 | 3.064e-04 | 0.0 | 105 |
| 107 | 4.1518498e-03 | 1.7011036e-04 | 3.15e-03 | 2.863e-04 | 0.0 | 105 |
| 108 | 4.1512786e-03 | 1.8997329e-04 | 3.15e-03 | 2.871e-04 | 0.0 | 105 |
| 109 | 4.1475642e-03 | 2.0100655e-04 | 3.15e-03 | 2.884e-04 | 0.0 | 104 |
| 110 | 4.1466368e-03 | 3.2011977e-04 | 3.15e-03 | 2.929e-04 | -0.3 | 104 |
| 111 | 4.1475706e-03 | 3.7359294e-04 | 3.15e-03 | 2.992e-04 | 0.0 | 104 |
| 112 | 4.1453867e-03 | 3.9338148e-04 | 3.15e-03 | 2.959e-04 | 0.0 | 104 |
| 113 | 4.1447125e-03 | 1.0534678e-04 | 3.14e-03 | 2.834e-04 | 0.0 | 104 |
| 114 | 4.1444126e-03 | 1.1729045e-04 | 3.14e-03 | 2.838e-04 | 0.0 | 104 |
| 115 | 4.1379488e-03 | 2.0810071e-04 | 3.14e-03 | 2.901e-04 | 0.0 | 105 |

```

116  4.1387592e-03  6.9659308e-04  3.14e-03  3.090e-04  -0.3  105
117  4.1370667e-03  1.7223230e-04  3.14e-03  2.874e-04   0.0  105
118  4.1367290e-03  9.6108808e-05  3.14e-03  2.826e-04   0.0  105
119  4.1365099e-03  7.3232204e-05  3.14e-03  2.816e-04   0.0  105
120  4.1325758e-03  3.5212971e-04  3.13e-03  2.948e-04   0.0  105
121  4.1324089e-03  3.0668121e-04  3.13e-03  2.941e-04  -0.3  105
122  1.5024129e-03  1.7790388e-03  5.02e-04  1.563e-04   0.0  107
123  1.4095313e-03  6.1419313e-04  4.10e-04  1.113e-04   0.0  107
124  1.3741615e-03  5.4110805e-04  3.74e-04  1.069e-04   0.0  107
125  1.3168841e-03  7.4299882e-04  3.17e-04  1.159e-04   0.0  107
126  1.3149082e-03  9.5453128e-04  3.15e-04  1.185e-04  -0.3  107
127  1.2904341e-03  5.2055420e-04  2.90e-04  1.053e-04   0.0  107
128  1.2771421e-03  2.5669954e-04  2.77e-04  8.899e-05   0.0  107
129  1.2733089e-03  2.1564386e-04  2.73e-04  8.730e-05   0.0  107
130  1.2616716e-03  2.2762056e-04  2.62e-04  8.813e-05   0.0  107
131  1.2585676e-03  4.3975914e-04  2.59e-04  9.986e-05  -0.3  107
132  1.2629693e-03  8.8670200e-04  2.63e-04  1.204e-04  -0.3  108
133  1.2454767e-03  1.9491314e-04  2.45e-04  8.725e-05   0.0  107
134  1.2438283e-03  1.8267982e-04  2.44e-04  8.645e-05   0.0  107
135  1.2424145e-03  1.8067518e-04  2.42e-04  8.651e-05   0.0  107
136  1.2349274e-03  2.7110232e-04  2.35e-04  9.261e-05   0.0  108
137  1.2379391e-03  3.9264188e-04  2.38e-04  9.738e-05  -0.3  109
138  1.2316422e-03  1.3770650e-04  2.32e-04  8.513e-05   0.0  109
139  1.2307506e-03  1.2055147e-04  2.31e-04  8.414e-05   0.0  109
140  1.2300982e-03  1.1382149e-04  2.30e-04  8.375e-05   0.0  109
141  1.2270610e-03  4.0649279e-04  2.27e-04  1.004e-04   0.0  110
142  1.2291488e-03  5.5999441e-04  2.29e-04  1.065e-04  -0.3  109
143  1.2213175e-03  2.4983210e-04  2.21e-04  9.119e-05   0.0  109
144  1.2189122e-03  8.9669029e-05  2.19e-04  8.334e-05   0.0  109
145  1.2186623e-03  6.5016081e-05  2.19e-04  8.218e-05   0.0  109
146  1.2179534e-03  5.0568657e-05  2.18e-04  8.144e-05   0.0  109
147  1.2160760e-03  2.0785648e-04  2.16e-04  8.914e-05   0.0  109
148  1.2176659e-03  4.1626919e-04  2.18e-04  9.839e-05  -0.3  109
149  1.2148709e-03  1.3009544e-04  2.15e-04  8.560e-05   0.0  109
150  1.2143557e-03  4.9431124e-05  2.14e-04  8.122e-05   0.0  109
151  1.2142174e-03  4.9652630e-05  2.14e-04  8.125e-05   0.0  109
152  1.2121689e-03  6.7244168e-05  2.12e-04  8.192e-05   0.0  109
153  1.2121810e-03  1.8059513e-04  2.12e-04  8.848e-05  -0.3  109
154  1.0293025e-03  4.1412258e-04  2.93e-05  8.186e-05   0.0  109

```

```
EXIT -- Found a root
```

```

Products with A      :      201      Total time (secs) :      0.8
Products with A'     :      155      Project time (secs) :      0.1
Newton iterations    :           5      Mat-vec time (secs) :      0.3
Line search its      :           78      Subspace iterations :           0

```

pqnl1

```
[x_pqn,r_pqn,g_pqn,info_pqn] = pqnl1_2(A, b, 0, 1e-3, zeros(size(A,2),1), opts); %
```

```

=====
PQNL1_SLIM v. 46  (Tue, 14 Jun 2011) based on v.1017
=====

```

```

No. rows           :      120      No. columns           :      512
Initial tau        : 0.00e+00      Two-norm of b        : 2.41e+00
Optimality tol     : 1.00e-04      Target objective     : 1.00e-03
Basis pursuit tol  : 1.00e-06      Maximum iterations   :      200

```

```

      0  2.4096982e+00  0.0000000e+00  1.00e+00  4.903e-01  0.0  0

```

Running PQN...

Number of L-BFGS Corrections to store: 50

Spectral initialization of SPG: 1

Maximum number of SPG iterations: 500

SPG optimality tolerance: 1.00e-06

PQN optimality tolerance: 1.00e-06

Quadratic initialization of line search: 1

Maximum number of function evaluations: 200

Maximum number of projections: 100000

| Iteration | FunEvals | Projections | Step Length | Function Val | O |
|-----------|----------|-------------|-------------|--------------|-------|
| 1 | 2 | 4 | 1.00000e+00 | 8.87061e-01 | 3.604 |
| 2 | 3 | 19 | 1.00000e+00 | 7.01206e-01 | 2.067 |
| 3 | 4 | 38 | 1.00000e+00 | 5.66122e-01 | 1.148 |
| 4 | 5 | 53 | 1.00000e+00 | 5.12731e-01 | 7.523 |
| 5 | 6 | 72 | 1.00000e+00 | 4.80196e-01 | 5.584 |
| 6 | 7 | 91 | 1.00000e+00 | 4.53013e-01 | 3.783 |
| 7 | 8 | 106 | 1.00000e+00 | 4.42879e-01 | 2.122 |
| 8 | 9 | 121 | 1.00000e+00 | 4.38542e-01 | 1.268 |
| 9 | 10 | 136 | 1.00000e+00 | 4.36867e-01 | 5.934 |
| 10 | 11 | 151 | 1.00000e+00 | 4.36316e-01 | 3.029 |
| 11 | 12 | 164 | 1.00000e+00 | 4.36239e-01 | 2.082 |
| 12 | 13 | 179 | 1.00000e+00 | 4.36169e-01 | 1.115 |

Directional Derivative below optTol

```

      13  9.3398983e-01  2.4240568e-02  9.33e-01  1.081e-01  0.0  20

```

Running PQN...

Number of L-BFGS Corrections to store: 50

Spectral initialization of SPG: 1

Maximum number of SPG iterations: 500

SPG optimality tolerance: 1.00e-06

PQN optimality tolerance: 1.00e-06

Quadratic initialization of line search: 1

Maximum number of function evaluations: 200

Maximum number of projections: 100000

| Iteration | FunEvals | Projections | Step Length | Function Val | O |
|-----------|----------|-------------|-------------|--------------|-------|
| 14 | 2 | 4 | 1.00000e+00 | 6.32283e-02 | 1.488 |
| 15 | 3 | 15 | 1.00000e+00 | 4.72205e-02 | 9.971 |
| 16 | 4 | 34 | 1.00000e+00 | 3.02569e-02 | 5.298 |
| 17 | 5 | 53 | 1.00000e+00 | 2.32632e-02 | 3.957 |
| 18 | 6 | 72 | 1.00000e+00 | 1.82610e-02 | 3.266 |
| 19 | 7 | 97 | 1.00000e+00 | 1.40045e-02 | 2.916 |
| 20 | 8 | 126 | 1.00000e+00 | 1.06239e-02 | 2.633 |
| 21 | 9 | 155 | 1.00000e+00 | 8.30289e-03 | 2.161 |
| 22 | 10 | 166 | 1.00000e+00 | 6.31623e-03 | 1.331 |
| 23 | 11 | 193 | 1.00000e+00 | 4.51102e-03 | 1.533 |
| 24 | 12 | 211 | 1.00000e+00 | 3.51615e-03 | 1.444 |

| | | | | | |
|----|----|-----|-------------|-------------|-------|
| 25 | 13 | 241 | 1.00000e+00 | 2.47785e-03 | 1.159 |
| 26 | 14 | 269 | 1.00000e+00 | 1.91944e-03 | 9.072 |
| 27 | 15 | 298 | 1.00000e+00 | 1.60840e-03 | 6.884 |
| 28 | 16 | 315 | 1.00000e+00 | 1.38913e-03 | 5.747 |
| 29 | 17 | 335 | 1.00000e+00 | 1.19242e-03 | 5.052 |
| 30 | 18 | 348 | 1.00000e+00 | 1.13919e-03 | 3.435 |
| 31 | 19 | 359 | 1.00000e+00 | 1.09543e-03 | 1.748 |
| 32 | 20 | 370 | 1.00000e+00 | 1.08640e-03 | 1.589 |
| 33 | 21 | 377 | 1.00000e+00 | 1.08086e-03 | 1.271 |
| 34 | 22 | 386 | 7.04994e-01 | 1.07212e-03 | 8.958 |
| 35 | 23 | 395 | 1.00000e+00 | 1.06576e-03 | 6.820 |
| 36 | 24 | 400 | 1.00000e+00 | 1.06481e-03 | 6.004 |

Function value changing by less than optTol

| | | | | | | |
|----|---------------|---------------|----------|-----------|-----|----|
| 37 | 4.6147914e-02 | 4.2700391e-03 | 4.51e-02 | 3.778e-03 | 0.0 | 60 |
|----|---------------|---------------|----------|-----------|-----|----|

Running PQN...

Number of L-BFGS Corrections to store: 50

Spectral initialization of SPG: 1

Maximum number of SPG iterations: 500

SPG optimality tolerance: 1.00e-06

PQN optimality tolerance: 1.00e-06

Quadratic initialization of line search: 1

Maximum number of function evaluations: 200

Maximum number of projections: 100000

| Iteration | FunEvals | Projections | Step Length | Function Val | O |
|-----------|----------|-------------|-------------|--------------|-------|
| 38 | 2 | 4 | 1.00000e+00 | 9.94345e-05 | 6.900 |
| 39 | 3 | 11 | 1.00000e+00 | 8.10198e-05 | 4.796 |
| 40 | 4 | 20 | 1.00000e+00 | 6.10621e-05 | 3.124 |
| 41 | 5 | 29 | 1.00000e+00 | 4.93509e-05 | 1.945 |
| 42 | 6 | 38 | 1.00000e+00 | 4.38603e-05 | 1.323 |
| 43 | 7 | 47 | 1.00000e+00 | 3.98932e-05 | 1.040 |

Directional Derivative below optTol

| | | | | | | |
|----|---------------|---------------|----------|-----------|-----|-----|
| 44 | 8.9323266e-03 | 2.8172341e-03 | 7.93e-03 | 6.823e-04 | 0.0 | 161 |
|----|---------------|---------------|----------|-----------|-----|-----|

Running PQN...

Number of L-BFGS Corrections to store: 50

Spectral initialization of SPG: 1

Maximum number of SPG iterations: 500

SPG optimality tolerance: 1.00e-06

PQN optimality tolerance: 1.00e-06

Quadratic initialization of line search: 1

Maximum number of function evaluations: 200

Maximum number of projections: 100000

| Iteration | FunEvals | Projections | Step Length | Function Val | O |
|-----------|----------|-------------|-------------|--------------|-------|
| 45 | 2 | 4 | 1.00000e+00 | 4.87790e-06 | 1.284 |

Directional Derivative below optTol

| | | | | | | |
|----|---------------|---------------|----------|-----------|-----|-----|
| 46 | 3.1234273e-03 | 1.7281036e-03 | 2.12e-03 | 2.689e-04 | 0.0 | 177 |
|----|---------------|---------------|----------|-----------|-----|-----|

Running PQN...

Number of L-BFGS Corrections to store: 50

Spectral initialization of SPG: 1

Maximum number of SPG iterations: 500

SPG optimality tolerance: 1.00e-06

PQN optimality tolerance: 1.00e-06

Quadratic initialization of line search: 1

Maximum number of function evaluations: 200

Maximum number of projections: 100000

```

      Iteration   FunEvals Projections   Step Length   Function Val   0.
          47         2         4   1.00000e+00   1.44225e-06   7.078
Directional Derivative below optTol
      48  1.6983808e-03  1.1463109e-03   6.98e-04   1.535e-04     0.0     178
Running PQN...
Number of L-BFGS Corrections to store: 50
Spectral initialization of SPG: 1
Maximum number of SPG iterations: 500
SPG optimality tolerance: 1.00e-06
PQN optimality tolerance: 1.00e-06
Quadratic initialization of line search: 1
Maximum number of function evaluations: 200
Maximum number of projections: 100000
      Iteration   FunEvals Projections   Step Length   Function Val   0.
          48         2         4   1.00000e+00   3.47150e-07   3.631
Directional Derivative below optTol
      49  8.3324708e-04  6.6808950e-04   1.67e-04   7.945e-05     0.0     182
Running PQN...
Number of L-BFGS Corrections to store: 50
Spectral initialization of SPG: 1
Maximum number of SPG iterations: 500
SPG optimality tolerance: 1.00e-06
PQN optimality tolerance: 1.00e-06
Quadratic initialization of line search: 1
Maximum number of function evaluations: 200
Maximum number of projections: 100000
      Iteration   FunEvals Projections   Step Length   Function Val   0.
          49         2         4   1.00000e+00   3.47150e-07   3.631
Directional Derivative below optTol
      50  8.3324708e-04  6.6808950e-04   1.67e-04   7.945e-05     0.0     182
Running PQN...
Number of L-BFGS Corrections to store: 50
Spectral initialization of SPG: 1
Maximum number of SPG iterations: 500
SPG optimality tolerance: 1.00e-06
PQN optimality tolerance: 1.00e-06
Quadratic initialization of line search: 1
Maximum number of function evaluations: 200
Maximum number of projections: 100000
      Iteration   FunEvals Projections   Step Length   Function Val   0.
          49         2         4   1.00000e+00   3.47150e-07   3.631
Directional Derivative below optTol

EXIT -- Found a root

Products with A      :      53      Total time (secs) :      1.3
Products with A'     :      53      Project time (secs) :      1.3
Newton iterations    :       8      Mat-vec time (secs) :      0.1

```

show result

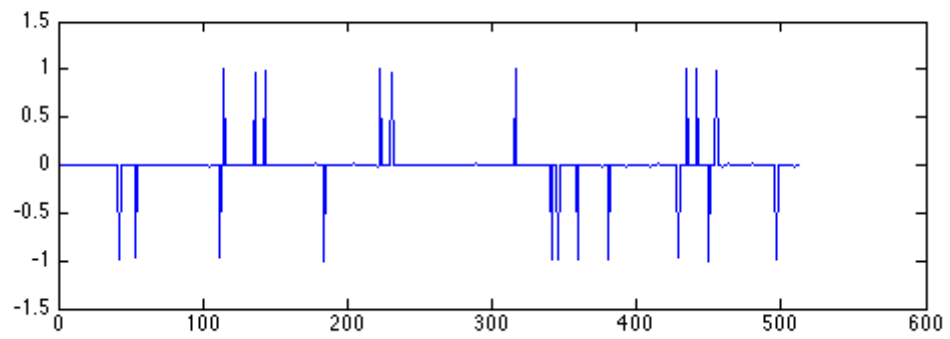
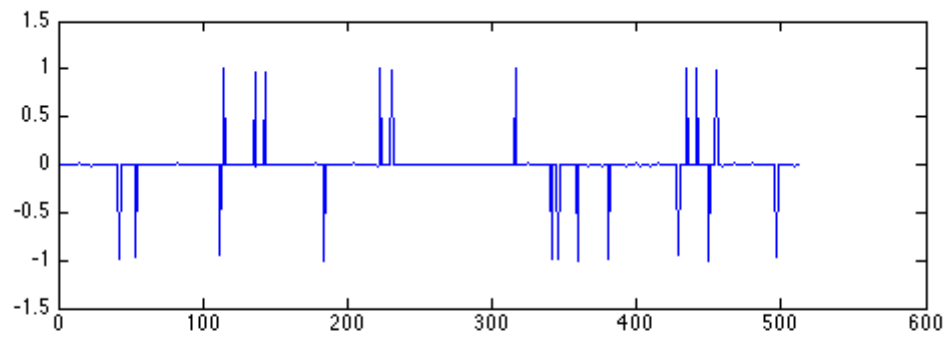
```

figure; subplot(2,1,1);plot(x_spg);subplot(2,1,2);plot(x_pqn);
info_spg
info_pqn

```

```
info_spg =  
  
    tau: 20.5370  
    rNorm: 0.0010  
    rGap: 4.1412e-04  
    gNorm: 8.1862e-05  
    stat: 1  
    iter: 154  
    nProdA: 201  
    nProdAt: 155  
    nNewton: 5  
    timeProject: 0.1468  
    timeMatProd: 0.2875  
    itnLSQR: 0  
    options: [1x1 struct]  
    timeTotal: 0.7561  
    xNorm1: [154x1 double]  
    rNorm2: [154x1 double]  
    lambda: [154x1 double]
```

```
info_pqn =  
  
    tau: 20.5954  
    rNorm: 9.1639e-04  
    rGap: 7.0835e-04  
    gNorm: 8.6180e-05  
    stat: 1  
    iter: 50  
    nProdA: 53  
    nProdAt: 53  
    nNewton: 8  
    timeProject: 1.3326  
    timeMatProd: 0.1477  
    itnLSQR: 0  
    options: [1x1 struct]  
    timeTotal: 1.3258  
    xNorm1: [50x1 double]  
    rNorm2: [50x1 double]  
    lambda: [50x1 double]
```

check functions

```
open ./minConF_PQN_2.m  
open ./pqnl1_2.m
```

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