clear; clc; close all;

% Load Data

global sb\_11 sb\_22 %sx\_11 sx\_22 sy\_11 sy\_22

% global lam\_sb lam\_sx lam\_sy

% global ss\_11 ss\_22

load\_data

ss\_data = [sb\_11 sb\_22];%[ss\_11 ss\_22];

lambda = [ss\_data(:,1) ss\_data(:,3)];

stress = [ss\_data(:,2) ss\_data(:,4)];

lambda = F\_construct(lambda); %now Lambda = F = diag(l11,l22,l33)

% Energy

W\_b = exp\_strain\_energy([sb\_11 sb\_22]);

% W\_b = W\_b - W\_b(1);

% W\_1 = exp\_strain\_energy([sx\_11 sx\_22]);

% W\_1 = W\_1 - W\_1(1);

% W\_2 = exp\_strain\_energy([sy\_11 sy\_22]);

% W\_2 = W\_2 - W\_2(1);

F0 = lambda'; % X

W0 = W\_b;%[W\_b;W\_1;W\_2]'; % Y

%% Deep NN

numLayers = 5;

numNeurons = 10;

numOrient = 2; % to be used later by adding it to numOutput

numInput = 1+numOrient; % I1, I4(n)

numOutput = 2+numOrient; % W, W'\_1, W'\_4(n), TO BE ADDED : alpha

parameters = struct;

sz = [numNeurons numInput];

parameters.fc1\_Weights = initializeHe(sz,numInput,"double");

parameters.fc1\_Bias = initializeZeros([numNeurons 1],"double");

for layerNumber=2:numLayers-1

name = "fc"+layerNumber;

sz = [numNeurons numNeurons];

numIn = numNeurons;

parameters.(name + "\_Weights") = initializeHe(sz,numIn,"double");

parameters.(name + "\_Bias") = initializeZeros([numNeurons 1],"double");

end

sz = [numOutput numNeurons];

numIn = numNeurons;

parameters.("fc" + numLayers + "\_Weights") = initializeHe(sz,numIn,"double");

parameters.("fc" + numLayers + "\_Bias") = initializeZeros([numOutput 1],"double");

% Train NN

iter = 1000;

options = optimoptions("fmincon", ...

'Display','iter', ...

HessianApproximation="lbfgs", ...

MaxIterations=iter, ...

MaxFunctionEvaluations=iter, ...

OptimalityTolerance=1e-5, ...

SpecifyObjectiveGradient=true);

[parametersV,parameterNames,parameterSizes] = parameterStructToVector(parameters);

parametersV = extractdata(parametersV);

orient = [0 90];

g = calc\_g(orient); % direction(s)

I0 = calc\_l2i(g, F0'); % invariants

I0 = dlarray(I0,"BC");

W0 = dlarray(W0',"CB");

S0 = dlarray(stress',"CB");

g = dlarray(g,"CB");

F0 = dlarray(F0,"CB");

objFun = @(parameters) objectiveFunction(parameters,I0,W0,S0,g,F0,parameterNames,parameterSizes);

parametersV = fmincon(objFun,parametersV,[],[],[],[],[],[],[],options);

First-order Norm of

Iter F-count f(x) Feasibility optimality step

0 1 3.053527e+01 0.000e+00 8.301e+00

1 11 2.956285e+01 0.000e+00 3.136e+00 6.358e-01

2 12 2.758488e+01 0.000e+00 1.103e+00 2.211e-01

3 13 2.734654e+01 0.000e+00 6.613e-01 9.776e-02

4 14 2.731440e+01 0.000e+00 3.272e-01 2.536e-02

5 15 2.727046e+01 0.000e+00 3.201e-01 6.313e-02

6 16 2.722209e+01 0.000e+00 4.235e-01 7.949e-02

7 17 2.697282e+01 0.000e+00 1.030e+00 4.409e-01

8 18 2.672827e+01 0.000e+00 1.314e+00 1.488e-01

9 22 2.642722e+01 0.000e+00 3.025e+00 1.389e-01

10 24 2.636839e+01 0.000e+00 8.213e+00 2.559e-01

11 25 2.611004e+01 0.000e+00 1.566e+00 1.337e-01

12 26 2.592516e+01 0.000e+00 9.713e-01 7.834e-02

13 28 2.542093e+01 0.000e+00 8.186e+00 2.667e-01

14 29 2.474187e+01 0.000e+00 2.052e+01 3.820e-01

15 31 2.419159e+01 0.000e+00 8.917e+00 3.549e-01

16 32 2.385934e+01 0.000e+00 1.182e+01 1.555e-01

17 33 2.357474e+01 0.000e+00 1.764e+00 1.016e-01

18 34 2.331809e+01 0.000e+00 1.118e+01 2.373e-01

19 35 2.300213e+01 0.000e+00 1.299e+01 2.287e-01

20 36 2.157877e+01 0.000e+00 4.916e+00 1.032e+00

21 38 2.121773e+01 0.000e+00 7.072e+00 5.242e-01

22 40 2.084087e+01 0.000e+00 6.862e+00 6.103e-01

23 41 2.032847e+01 0.000e+00 3.302e+00 1.049e-01

24 43 1.932320e+01 0.000e+00 4.646e+01 4.717e-01

25 44 1.882032e+01 0.000e+00 1.486e+01 4.171e-01

26 45 1.785433e+01 0.000e+00 2.231e+01 5.920e-01

27 46 1.754695e+01 0.000e+00 3.755e+01 3.996e-01

28 47 1.701135e+01 0.000e+00 2.218e+01 9.293e-02

29 48 1.599958e+01 0.000e+00 6.216e+00 7.807e-01

30 49 1.529217e+01 0.000e+00 3.883e+00 7.527e-01

First-order Norm of

Iter F-count f(x) Feasibility optimality step

31 51 1.481419e+01 0.000e+00 4.771e+00 5.710e-01

32 52 1.430414e+01 0.000e+00 3.803e+00 7.889e-01

33 53 1.376108e+01 0.000e+00 1.773e+01 3.508e-01

34 54 1.352348e+01 0.000e+00 1.398e+01 7.279e-02

35 55 1.336070e+01 0.000e+00 1.072e+01 2.032e-01

36 56 1.307720e+01 0.000e+00 2.796e+00 5.303e-01

37 57 1.304373e+01 0.000e+00 4.975e+01 1.608e+00

38 58 1.252670e+01 0.000e+00 1.461e+01 4.173e-01

39 59 1.223929e+01 0.000e+00 5.081e+00 6.047e-01

40 62 1.192419e+01 0.000e+00 2.958e+01 9.926e-01

41 63 1.163106e+01 0.000e+00 1.955e+01 3.392e-01

42 64 1.101125e+01 0.000e+00 6.376e+00 8.306e-01

43 65 1.040885e+01 0.000e+00 1.093e+01 6.662e-01

44 66 9.721817e+00 0.000e+00 7.571e+01 2.443e-01

45 68 8.162806e+00 0.000e+00 1.238e+01 4.745e-01

46 75 7.971266e+00 0.000e+00 9.136e+01 2.373e-01

47 77 7.245267e+00 0.000e+00 2.807e+01 2.373e-01

48 78 6.642362e+00 0.000e+00 7.059e+00 4.543e-01

49 79 6.298889e+00 0.000e+00 4.296e+01 2.997e-01

50 80 5.749539e+00 0.000e+00 5.485e+01 7.684e-01

51 81 5.060648e+00 0.000e+00 3.643e+01 3.265e-01

52 82 4.744937e+00 0.000e+00 1.011e+02 9.577e-01

53 83 4.487676e+00 0.000e+00 6.348e+00 2.640e-01

54 84 4.341436e+00 0.000e+00 5.972e+00 4.986e-01

55 85 4.078112e+00 0.000e+00 7.524e+00 3.108e-01

56 89 3.940543e+00 0.000e+00 5.637e+01 2.102e-01

57 90 3.670090e+00 0.000e+00 2.964e+01 3.174e-01

58 91 3.423446e+00 0.000e+00 4.882e+00 2.072e-01

59 92 3.245839e+00 0.000e+00 1.823e+01 5.158e-02

60 93 2.947847e+00 0.000e+00 2.410e+01 1.305e-01

First-order Norm of

Iter F-count f(x) Feasibility optimality step

61 94 2.673618e+00 0.000e+00 4.619e+01 2.597e-01

62 95 2.501540e+00 0.000e+00 3.690e+01 1.240e-01

63 96 2.433871e+00 0.000e+00 5.609e+00 3.063e-02

64 97 2.421124e+00 0.000e+00 1.277e+01 1.388e-02

65 98 2.410368e+00 0.000e+00 2.029e+01 1.577e-02

66 99 2.374003e+00 0.000e+00 3.427e+01 4.353e-02

67 100 2.307809e+00 0.000e+00 4.165e+01 4.687e-02

68 101 2.181911e+00 0.000e+00 3.268e+01 6.829e-02

69 103 2.143725e+00 0.000e+00 5.164e+01 2.816e-02

70 104 2.035994e+00 0.000e+00 1.249e+01 1.287e-01

71 105 2.012875e+00 0.000e+00 7.314e+00 4.283e-02

72 106 1.994934e+00 0.000e+00 2.800e+00 1.267e-02

73 107 1.980681e+00 0.000e+00 2.125e+00 9.253e-03

74 108 1.935124e+00 0.000e+00 6.328e+00 4.829e-02

75 109 1.886277e+00 0.000e+00 2.226e+01 1.603e-01

76 110 1.817972e+00 0.000e+00 8.205e+00 1.140e-01

77 111 1.778177e+00 0.000e+00 1.529e+01 9.585e-02

78 112 1.754805e+00 0.000e+00 1.643e+00 1.286e-02

79 113 1.721121e+00 0.000e+00 1.003e+01 2.538e-02

80 114 1.664710e+00 0.000e+00 2.233e+01 4.111e-02

81 115 1.602619e+00 0.000e+00 2.291e+01 4.797e-02

82 120 1.564007e+00 0.000e+00 5.291e+01 4.360e-02

83 121 1.501039e+00 0.000e+00 2.825e+00 5.268e-02

84 122 1.473905e+00 0.000e+00 1.624e+01 3.824e-02

85 123 1.451840e+00 0.000e+00 2.139e+01 1.966e-02

86 124 1.427035e+00 0.000e+00 1.845e+01 1.901e-02

87 127 1.420522e+00 0.000e+00 7.927e+00 3.450e-02

88 128 1.402509e+00 0.000e+00 6.382e+00 2.859e-02

89 129 1.391360e+00 0.000e+00 6.012e+00 2.502e-02

90 130 1.385420e+00 0.000e+00 9.813e+00 1.480e-02

First-order Norm of

Iter F-count f(x) Feasibility optimality step

91 131 1.372832e+00 0.000e+00 1.410e+01 1.859e-02

92 132 1.349419e+00 0.000e+00 1.131e+01 3.613e-02

93 133 1.316907e+00 0.000e+00 5.862e+00 4.668e-02

94 134 1.310204e+00 0.000e+00 6.336e+01 8.718e-02

95 135 1.270422e+00 0.000e+00 1.606e+01 2.338e-02

96 136 1.254506e+00 0.000e+00 2.822e+00 1.311e-02

97 137 1.241153e+00 0.000e+00 3.034e+00 2.769e-02

98 138 1.237449e+00 0.000e+00 8.994e-01 2.644e-02

99 140 1.235809e+00 0.000e+00 1.449e+00 3.751e-02

100 141 1.231345e+00 0.000e+00 4.201e+00 3.188e-02

101 142 1.224341e+00 0.000e+00 6.895e+00 2.858e-02

102 143 1.209036e+00 0.000e+00 9.788e+00 4.205e-02

103 144 1.197421e+00 0.000e+00 4.346e+00 1.165e-02

104 145 1.188176e+00 0.000e+00 3.022e+00 2.896e-02

105 146 1.182306e+00 0.000e+00 1.295e+01 3.664e-02

106 147 1.175993e+00 0.000e+00 1.192e+01 1.134e-02

107 148 1.173268e+00 0.000e+00 5.673e+00 9.344e-03

108 149 1.171825e+00 0.000e+00 9.423e-01 1.086e-02

109 150 1.171103e+00 0.000e+00 8.119e-01 3.970e-03

110 151 1.170035e+00 0.000e+00 1.295e+00 4.083e-03

111 153 1.169198e+00 0.000e+00 2.455e+00 7.687e-03

112 154 1.166572e+00 0.000e+00 6.411e+00 1.499e-02

113 155 1.164828e+00 0.000e+00 5.445e+00 3.693e-03

114 156 1.161107e+00 0.000e+00 3.190e+00 1.130e-02

115 157 1.158138e+00 0.000e+00 5.055e-01 1.242e-02

116 158 1.155131e+00 0.000e+00 1.003e+00 1.477e-02

117 162 1.154887e+00 0.000e+00 7.100e+00 3.694e-03

118 163 1.152433e+00 0.000e+00 4.480e+00 8.489e-03

119 164 1.148256e+00 0.000e+00 7.238e-01 1.419e-02

120 165 1.142793e+00 0.000e+00 4.665e+00 2.324e-02

First-order Norm of

Iter F-count f(x) Feasibility optimality step

121 166 1.138314e+00 0.000e+00 6.062e+00 3.558e-02

122 170 1.137492e+00 0.000e+00 2.378e+00 5.997e-03

123 171 1.135588e+00 0.000e+00 1.211e+00 1.591e-02

124 172 1.132915e+00 0.000e+00 5.268e-01 8.873e-03

125 175 1.131488e+00 0.000e+00 7.492e+00 1.044e-02

126 176 1.124046e+00 0.000e+00 4.877e+00 9.195e-03

127 177 1.115750e+00 0.000e+00 2.035e+00 1.726e-02

128 178 1.109805e+00 0.000e+00 1.329e+01 2.971e-02

129 179 1.107466e+00 0.000e+00 5.372e+00 2.743e-02

130 180 1.105990e+00 0.000e+00 2.102e+00 5.847e-03

131 181 1.105672e+00 0.000e+00 2.901e+00 1.612e-03

132 182 1.104498e+00 0.000e+00 4.096e+00 1.007e-02

133 183 1.103251e+00 0.000e+00 5.038e+00 1.198e-02

134 184 1.102821e+00 0.000e+00 1.694e+00 4.719e-02

135 185 1.096623e+00 0.000e+00 1.213e+00 2.713e-02

136 186 1.093751e+00 0.000e+00 1.986e+00 1.437e-02

137 187 1.090783e+00 0.000e+00 4.733e+00 1.567e-02

138 188 1.088652e+00 0.000e+00 6.733e+00 1.122e-02

139 191 1.088459e+00 0.000e+00 1.394e+00 6.528e-03

140 192 1.087974e+00 0.000e+00 2.294e+00 5.733e-03

141 194 1.087790e+00 0.000e+00 2.820e+00 9.204e-03

142 195 1.087495e+00 0.000e+00 1.233e+00 2.901e-03

143 196 1.087092e+00 0.000e+00 7.446e-01 2.556e-03

144 197 1.086491e+00 0.000e+00 2.503e+00 3.414e-03

145 198 1.085958e+00 0.000e+00 2.558e+00 3.329e-03

146 200 1.085496e+00 0.000e+00 1.803e+00 7.085e-03

147 201 1.084602e+00 0.000e+00 8.629e-01 1.103e-02

148 202 1.083935e+00 0.000e+00 2.661e+00 2.057e-03

149 203 1.082628e+00 0.000e+00 4.951e+00 8.351e-03

150 204 1.082538e+00 0.000e+00 4.075e+00 8.742e-03

First-order Norm of

Iter F-count f(x) Feasibility optimality step

151 205 1.081913e+00 0.000e+00 1.128e+00 3.551e-03

152 206 1.081621e+00 0.000e+00 2.185e+00 2.267e-03

153 207 1.081436e+00 0.000e+00 1.402e+00 2.985e-03

154 208 1.081403e+00 0.000e+00 1.274e+00 2.145e-03

155 209 1.081347e+00 0.000e+00 8.374e-01 1.628e-03

156 210 1.081222e+00 0.000e+00 9.891e-01 1.360e-03

157 211 1.080795e+00 0.000e+00 6.997e-01 2.704e-03

158 213 1.080578e+00 0.000e+00 6.638e-01 6.625e-03

159 214 1.079993e+00 0.000e+00 3.442e-01 1.993e-03

160 215 1.079544e+00 0.000e+00 6.236e-01 3.691e-03

161 216 1.079508e+00 0.000e+00 8.260e+00 7.300e-03

162 217 1.078948e+00 0.000e+00 2.676e+00 2.032e-03

163 218 1.078693e+00 0.000e+00 6.140e-01 2.127e-03

164 219 1.078362e+00 0.000e+00 1.260e+00 5.663e-03

165 220 1.078195e+00 0.000e+00 1.320e+00 4.437e-03

166 225 1.074885e+00 0.000e+00 4.863e+00 8.874e-03

167 227 1.073390e+00 0.000e+00 1.148e+00 1.442e-02

168 228 1.069695e+00 0.000e+00 4.512e+00 2.615e-02

169 229 1.067756e+00 0.000e+00 3.161e+00 1.457e-02

170 230 1.066120e+00 0.000e+00 4.307e-01 1.253e-02

171 231 1.065010e+00 0.000e+00 4.302e-01 1.418e-02

172 234 1.064764e+00 0.000e+00 1.146e+01 8.047e-03

173 235 1.063488e+00 0.000e+00 4.328e+00 8.760e-03

174 236 1.062859e+00 0.000e+00 1.224e+00 4.188e-03

175 237 1.061972e+00 0.000e+00 2.227e+00 5.980e-03

176 238 1.061289e+00 0.000e+00 2.469e+00 6.007e-03

177 242 1.061157e+00 0.000e+00 3.570e+00 5.050e-03

178 243 1.060309e+00 0.000e+00 1.033e+00 6.692e-03

179 244 1.059764e+00 0.000e+00 1.017e+00 3.831e-03

180 245 1.058934e+00 0.000e+00 1.976e+00 7.144e-03

First-order Norm of

Iter F-count f(x) Feasibility optimality step

181 246 1.057929e+00 0.000e+00 6.892e+00 1.073e-02

182 247 1.056913e+00 0.000e+00 1.741e+00 1.061e-02

183 248 1.056265e+00 0.000e+00 4.049e+00 1.279e-02

184 249 1.055914e+00 0.000e+00 4.076e+00 4.710e-03

185 251 1.055042e+00 0.000e+00 1.344e+01 2.302e-02

186 253 1.052855e+00 0.000e+00 3.986e-01 6.449e-03

187 254 1.051954e+00 0.000e+00 4.285e+00 1.700e-02

188 255 1.051646e+00 0.000e+00 1.048e+00 3.744e-03

189 256 1.051496e+00 0.000e+00 5.253e-01 2.979e-03

190 257 1.051388e+00 0.000e+00 1.208e+00 3.431e-03

191 258 1.051230e+00 0.000e+00 1.422e+00 2.822e-03

192 259 1.050395e+00 0.000e+00 2.301e+00 8.605e-03

193 260 1.049400e+00 0.000e+00 1.200e+00 7.301e-03

194 264 1.049233e+00 0.000e+00 4.616e+00 2.242e-02

195 265 1.048340e+00 0.000e+00 1.330e+00 1.067e-02

196 266 1.047998e+00 0.000e+00 1.610e-01 5.692e-03

197 267 1.047843e+00 0.000e+00 5.992e-01 1.949e-03

198 270 1.047835e+00 0.000e+00 1.627e+00 2.346e-03

199 271 1.047675e+00 0.000e+00 5.820e-01 2.575e-03

200 272 1.047604e+00 0.000e+00 7.264e-01 2.364e-03

201 273 1.047568e+00 0.000e+00 1.948e+00 5.915e-03

202 274 1.047504e+00 0.000e+00 3.780e-01 1.904e-03

203 275 1.047471e+00 0.000e+00 8.936e-01 5.940e-04

204 276 1.047329e+00 0.000e+00 2.448e+00 1.365e-03

205 277 1.047146e+00 0.000e+00 3.606e+00 1.238e-03

206 278 1.046798e+00 0.000e+00 4.239e+00 3.079e-03

207 279 1.046416e+00 0.000e+00 2.680e+00 7.005e-03

208 280 1.046182e+00 0.000e+00 1.466e+00 9.166e-03

209 281 1.046053e+00 0.000e+00 1.514e+00 8.208e-03

210 282 1.045957e+00 0.000e+00 1.495e+00 3.046e-03

First-order Norm of

Iter F-count f(x) Feasibility optimality step

211 283 1.045127e+00 0.000e+00 7.886e-01 8.981e-03

212 284 1.044486e+00 0.000e+00 8.714e-01 4.682e-02

213 297 1.043803e+00 0.000e+00 6.366e+00 3.596e-04

214 298 1.041331e+00 0.000e+00 1.677e+00 2.790e-02

215 299 1.040689e+00 0.000e+00 1.509e+00 2.463e-02

216 303 1.040611e+00 0.000e+00 5.330e+00 1.005e-02

217 304 1.040336e+00 0.000e+00 9.844e-01 6.182e-03

218 305 1.040307e+00 0.000e+00 4.312e-01 1.356e-03

219 306 1.040234e+00 0.000e+00 5.444e-01 2.291e-03

220 307 1.040129e+00 0.000e+00 1.434e+00 1.615e-03

221 308 1.039903e+00 0.000e+00 2.603e+00 2.060e-03

222 309 1.039433e+00 0.000e+00 3.963e+00 4.295e-03

223 310 1.038713e+00 0.000e+00 4.718e+00 8.072e-03

224 313 1.038601e+00 0.000e+00 3.780e+00 7.398e-03

225 315 1.038087e+00 0.000e+00 4.647e+00 2.214e-02

226 316 1.037673e+00 0.000e+00 5.047e-01 1.069e-02

227 317 1.037470e+00 0.000e+00 4.887e-01 2.592e-03

228 320 1.037448e+00 0.000e+00 2.210e+00 2.504e-03

229 321 1.037370e+00 0.000e+00 9.196e-01 4.093e-03

230 322 1.037317e+00 0.000e+00 5.170e-01 1.777e-03

231 323 1.037120e+00 0.000e+00 5.448e-01 3.926e-03

232 324 1.036931e+00 0.000e+00 1.070e+00 2.986e-03

233 325 1.036671e+00 0.000e+00 1.122e+00 2.947e-03

234 326 1.036033e+00 0.000e+00 9.706e-01 6.719e-03

235 329 1.035617e+00 0.000e+00 7.844e-01 1.897e-02

236 330 1.033893e+00 0.000e+00 1.323e+00 2.422e-02

237 340 1.032856e+00 0.000e+00 1.104e+01 1.514e-03

238 341 1.031165e+00 0.000e+00 9.882e+00 1.284e-02

239 343 1.030244e+00 0.000e+00 4.232e-01 1.644e-02

240 344 1.026462e+00 0.000e+00 1.159e+00 4.252e-02

First-order Norm of

Iter F-count f(x) Feasibility optimality step

241 346 1.024606e+00 0.000e+00 6.229e+00 2.015e-02

242 347 1.022697e+00 0.000e+00 8.646e-01 1.204e-02

243 348 1.022244e+00 0.000e+00 8.482e-01 1.741e-02

244 349 1.021809e+00 0.000e+00 1.090e+01 2.046e-02

245 350 1.020893e+00 0.000e+00 1.825e+00 4.207e-03

246 351 1.020415e+00 0.000e+00 7.629e-01 1.518e-02

247 352 1.019797e+00 0.000e+00 1.235e+00 1.133e-02

248 353 1.018802e+00 0.000e+00 4.670e-01 1.761e-02

249 356 1.018499e+00 0.000e+00 5.557e-01 6.565e-03

250 357 1.018127e+00 0.000e+00 5.430e-01 1.003e-02

251 358 1.017531e+00 0.000e+00 2.293e+00 7.139e-03

252 359 1.016308e+00 0.000e+00 3.324e+00 1.121e-02

253 360 1.015518e+00 0.000e+00 8.100e+00 1.981e-02

254 361 1.014601e+00 0.000e+00 2.395e+00 6.037e-03

255 362 1.014272e+00 0.000e+00 3.876e-01 9.116e-03

256 363 1.014128e+00 0.000e+00 1.432e+00 5.213e-03

257 364 1.013964e+00 0.000e+00 2.302e-01 8.549e-03

258 366 1.013888e+00 0.000e+00 1.895e+00 3.929e-03

259 367 1.013809e+00 0.000e+00 7.028e-01 1.319e-03

260 368 1.013729e+00 0.000e+00 6.436e-01 3.357e-03

261 369 1.013696e+00 0.000e+00 6.896e-01 9.288e-04

262 370 1.013486e+00 0.000e+00 1.123e+00 1.010e-02

263 371 1.013235e+00 0.000e+00 1.429e+00 1.059e-02

264 372 1.013066e+00 0.000e+00 1.494e+00 1.293e-03

265 377 1.011628e+00 0.000e+00 7.958e-01 2.585e-03

266 378 1.009735e+00 0.000e+00 1.226e+01 1.306e-02

267 379 1.007208e+00 0.000e+00 6.755e+00 2.233e-02

268 380 1.005609e+00 0.000e+00 4.071e+00 2.490e-02

269 381 1.004539e+00 0.000e+00 3.682e-01 2.316e-02

270 382 1.004359e+00 0.000e+00 2.682e-01 6.990e-03

First-order Norm of

Iter F-count f(x) Feasibility optimality step

271 388 1.004091e+00 0.000e+00 2.060e+00 6.990e-03

272 389 1.003829e+00 0.000e+00 6.178e-01 3.742e-03

273 390 1.003617e+00 0.000e+00 1.289e+00 7.042e-03

274 391 1.003277e+00 0.000e+00 1.423e+00 7.685e-03

275 392 1.003187e+00 0.000e+00 6.125e+00 1.632e-02

276 393 1.002020e+00 0.000e+00 1.390e+00 9.161e-03

277 394 1.001818e+00 0.000e+00 1.674e+00 8.943e-03

278 403 1.001658e+00 0.000e+00 6.413e+00 1.118e-03

279 404 1.001300e+00 0.000e+00 3.523e+00 7.330e-03

280 405 1.000755e+00 0.000e+00 8.042e-01 1.242e-02

281 406 9.998816e-01 0.000e+00 2.371e+00 2.059e-02

282 407 9.993400e-01 0.000e+00 2.551e+00 1.180e-02

283 414 9.991899e-01 0.000e+00 1.258e+00 1.973e-03

284 415 9.989630e-01 0.000e+00 1.788e-01 1.726e-03

285 416 9.988641e-01 0.000e+00 4.364e-01 3.190e-03

286 419 9.988207e-01 0.000e+00 1.416e-01 6.039e-03

287 420 9.987144e-01 0.000e+00 1.141e-01 1.728e-02

288 421 9.984144e-01 0.000e+00 4.457e-01 2.182e-02

289 423 9.982754e-01 0.000e+00 3.529e+00 3.742e-03

290 424 9.978778e-01 0.000e+00 1.083e+00 2.042e-03

291 425 9.971548e-01 0.000e+00 1.873e+00 8.402e-03

292 426 9.961734e-01 0.000e+00 2.911e+00 2.270e-02

293 427 9.958732e-01 0.000e+00 7.421e+00 4.559e-02

294 428 9.955826e-01 0.000e+00 1.900e+00 7.058e-03

295 429 9.953518e-01 0.000e+00 5.653e-01 4.324e-03

296 430 9.953260e-01 0.000e+00 4.865e-01 7.295e-04

297 431 9.951349e-01 0.000e+00 4.707e-01 5.808e-03

298 432 9.945490e-01 0.000e+00 2.476e+00 2.283e-02

299 433 9.941024e-01 0.000e+00 1.696e+00 8.739e-03

300 434 9.935723e-01 0.000e+00 1.371e+00 1.208e-02

First-order Norm of

Iter F-count f(x) Feasibility optimality step

301 435 9.934180e-01 0.000e+00 1.058e+00 5.855e-03

302 436 9.932998e-01 0.000e+00 1.644e-01 3.345e-03

303 437 9.931839e-01 0.000e+00 5.069e-01 9.959e-04

304 438 9.930776e-01 0.000e+00 6.189e-01 3.490e-03

305 439 9.928190e-01 0.000e+00 2.153e+00 4.954e-03

306 441 9.927556e-01 0.000e+00 1.412e-01 3.651e-03

307 442 9.926702e-01 0.000e+00 1.539e-01 2.323e-03

308 443 9.925074e-01 0.000e+00 2.356e-01 5.434e-03

309 444 9.922668e-01 0.000e+00 4.375e-01 7.801e-03

310 446 9.921986e-01 0.000e+00 2.110e+00 1.087e-02

311 447 9.919628e-01 0.000e+00 2.264e+00 3.844e-02

312 448 9.916383e-01 0.000e+00 1.128e+00 7.317e-03

313 449 9.914432e-01 0.000e+00 1.435e+00 1.436e-03

314 450 9.909876e-01 0.000e+00 1.348e+00 5.212e-03

315 453 9.908862e-01 0.000e+00 7.451e+00 4.186e-02

316 454 9.903165e-01 0.000e+00 3.693e+00 7.772e-03

317 455 9.896240e-01 0.000e+00 1.179e+00 3.031e-03

318 456 9.889877e-01 0.000e+00 3.843e+00 1.407e-02

319 457 9.885434e-01 0.000e+00 3.546e+00 6.615e-03

320 460 9.884099e-01 0.000e+00 7.020e-01 8.828e-03

321 461 9.879714e-01 0.000e+00 6.240e-01 5.437e-03

322 462 9.876112e-01 0.000e+00 1.037e+00 9.011e-03

323 467 9.867292e-01 0.000e+00 1.153e+00 3.737e-03

324 469 9.862360e-01 0.000e+00 3.852e-01 2.616e-02

325 470 9.830116e-01 0.000e+00 1.570e+00 3.534e-02

326 473 9.828413e-01 0.000e+00 1.281e+00 1.671e-02

327 474 9.825359e-01 0.000e+00 1.403e+00 7.735e-03

328 475 9.824807e-01 0.000e+00 4.885e-01 1.830e-03

329 476 9.824467e-01 0.000e+00 5.130e-01 1.333e-03

330 477 9.813055e-01 0.000e+00 2.832e-01 9.198e-03

First-order Norm of

Iter F-count f(x) Feasibility optimality step

331 478 9.797007e-01 0.000e+00 7.017e-01 1.973e-02

332 486 9.796406e-01 0.000e+00 1.056e+01 4.932e-03

333 487 9.773821e-01 0.000e+00 4.815e+00 3.465e-02

334 488 9.751884e-01 0.000e+00 4.712e-01 4.614e-02

335 489 9.726790e-01 0.000e+00 4.489e+00 4.806e-02

336 490 9.715439e-01 0.000e+00 3.437e+00 1.986e-02

337 492 9.714660e-01 0.000e+00 4.596e-01 6.908e-03

338 493 9.713416e-01 0.000e+00 2.796e-01 7.018e-03

339 494 9.711938e-01 0.000e+00 2.784e-01 5.069e-03

340 500 9.706029e-01 0.000e+00 5.117e+00 5.069e-03

341 501 9.694603e-01 0.000e+00 1.770e+00 1.421e-02

342 502 9.684432e-01 0.000e+00 3.842e-01 2.278e-02

343 503 9.678089e-01 0.000e+00 4.501e+00 1.882e-02

344 504 9.674525e-01 0.000e+00 6.305e-01 1.670e-02

345 505 9.671916e-01 0.000e+00 5.782e-01 1.690e-02

346 506 9.670003e-01 0.000e+00 3.649e+00 6.410e-03

347 507 9.666978e-01 0.000e+00 2.500e+00 5.749e-03

348 508 9.662197e-01 0.000e+00 2.415e-01 5.331e-03

349 509 9.659388e-01 0.000e+00 5.958e-01 4.875e-03

350 510 9.653579e-01 0.000e+00 7.988e-01 1.553e-02

351 514 9.652846e-01 0.000e+00 2.572e+00 7.721e-03

352 515 9.646987e-01 0.000e+00 1.367e+00 2.486e-02

353 516 9.639555e-01 0.000e+00 7.504e-01 4.587e-02

354 525 9.638186e-01 0.000e+00 7.696e+00 5.734e-03

355 526 9.632424e-01 0.000e+00 3.460e+00 1.243e-02

356 527 9.629325e-01 0.000e+00 1.444e+00 2.344e-03

357 528 9.623717e-01 0.000e+00 1.784e+00 6.037e-03

358 529 9.618193e-01 0.000e+00 3.236e+00 1.026e-02

359 530 9.608533e-01 0.000e+00 3.999e+00 1.327e-02

360 534 9.607006e-01 0.000e+00 5.692e+00 6.303e-03

First-order Norm of

Iter F-count f(x) Feasibility optimality step

361 535 9.593439e-01 0.000e+00 3.133e+00 1.120e-02

362 536 9.583995e-01 0.000e+00 1.273e+00 2.705e-02

363 537 9.579810e-01 0.000e+00 3.521e+00 1.471e-02

364 538 9.577368e-01 0.000e+00 3.072e+00 7.733e-03

365 539 9.572480e-01 0.000e+00 6.837e+00 6.751e-03

366 540 9.563257e-01 0.000e+00 3.129e+00 1.312e-02

367 541 9.555466e-01 0.000e+00 1.565e+00 2.286e-02

368 542 9.547432e-01 0.000e+00 8.279e-01 2.168e-02

369 543 9.541087e-01 0.000e+00 5.651e-01 3.435e-02

370 555 9.537437e-01 0.000e+00 1.173e+00 5.367e-04

371 556 9.535326e-01 0.000e+00 3.159e+00 1.507e-02

372 557 9.534146e-01 0.000e+00 4.155e+00 4.264e-02

373 558 9.529141e-01 0.000e+00 9.060e-01 2.795e-02

374 559 9.528035e-01 0.000e+00 3.974e-01 1.588e-03

375 560 9.525386e-01 0.000e+00 9.167e-01 8.482e-03

376 561 9.520498e-01 0.000e+00 5.013e-01 1.483e-02

377 563 9.518524e-01 0.000e+00 5.639e+00 5.696e-03

378 564 9.513523e-01 0.000e+00 1.253e+00 6.171e-03

379 565 9.511000e-01 0.000e+00 9.285e-01 6.806e-03

380 566 9.510153e-01 0.000e+00 9.802e-01 6.721e-03

381 568 9.509714e-01 0.000e+00 3.267e+00 1.087e-02

382 569 9.497710e-01 0.000e+00 1.038e+00 1.218e-02

383 570 9.492222e-01 0.000e+00 2.541e+00 1.086e-02

384 572 9.489114e-01 0.000e+00 1.478e+00 2.114e-02

385 573 9.485630e-01 0.000e+00 3.009e-01 9.372e-03

386 574 9.480215e-01 0.000e+00 2.264e+00 1.439e-02

387 575 9.473339e-01 0.000e+00 3.963e+00 2.119e-02

388 576 9.462327e-01 0.000e+00 2.202e+00 3.957e-02

389 578 9.462203e-01 0.000e+00 1.445e+01 2.940e-02

390 579 9.444314e-01 0.000e+00 4.322e+00 2.495e-03

First-order Norm of

Iter F-count f(x) Feasibility optimality step

391 580 9.433611e-01 0.000e+00 6.431e-01 1.094e-02

392 581 9.426772e-01 0.000e+00 1.490e+00 2.094e-02

393 582 9.423289e-01 0.000e+00 4.144e-01 6.887e-03

394 583 9.419699e-01 0.000e+00 9.430e-01 3.195e-02

395 584 9.414302e-01 0.000e+00 5.966e-01 2.257e-03

396 585 9.386830e-01 0.000e+00 2.865e+00 3.071e-02

397 586 9.341047e-01 0.000e+00 2.418e+00 1.207e-01

398 589 9.327381e-01 0.000e+00 1.065e+01 1.435e-02

399 590 9.318500e-01 0.000e+00 5.738e+00 1.510e-02

400 591 9.310453e-01 0.000e+00 6.167e-01 5.396e-03

401 592 9.308225e-01 0.000e+00 2.783e+00 1.421e-02

402 593 9.306218e-01 0.000e+00 1.594e+00 1.559e-02

403 594 9.302052e-01 0.000e+00 8.379e-01 1.299e-02

404 595 9.296042e-01 0.000e+00 1.577e+00 1.872e-02

405 596 9.286890e-01 0.000e+00 7.089e-01 3.303e-02

406 597 9.273593e-01 0.000e+00 1.423e+00 4.206e-02

407 599 9.262475e-01 0.000e+00 1.127e+00 1.328e-02

408 600 9.240240e-01 0.000e+00 2.077e+00 6.323e-02

409 603 9.237969e-01 0.000e+00 6.597e+00 5.934e-03

410 604 9.232158e-01 0.000e+00 2.564e+00 1.022e-02

411 605 9.224020e-01 0.000e+00 2.223e+00 2.165e-02

412 606 9.216615e-01 0.000e+00 5.273e+00 1.581e-02

413 607 9.209450e-01 0.000e+00 3.955e+00 1.265e-02

414 608 9.205017e-01 0.000e+00 3.698e-01 8.785e-03

415 609 9.203451e-01 0.000e+00 1.704e+00 1.173e-02

416 610 9.202380e-01 0.000e+00 2.368e+00 1.417e-03

417 611 9.197891e-01 0.000e+00 3.291e+00 2.722e-03

418 612 9.191675e-01 0.000e+00 3.572e+00 7.510e-03

419 614 9.187556e-01 0.000e+00 1.160e+00 1.626e-02

420 615 9.182338e-01 0.000e+00 2.599e+00 1.461e-02

First-order Norm of

Iter F-count f(x) Feasibility optimality step

421 617 9.174374e-01 0.000e+00 4.675e+00 2.635e-02

422 618 9.167443e-01 0.000e+00 3.398e+00 9.443e-03

423 619 9.153278e-01 0.000e+00 8.432e-01 1.982e-02

424 620 9.141183e-01 0.000e+00 2.904e+00 4.493e-02

425 621 9.126451e-01 0.000e+00 1.001e+00 1.957e-02

426 623 9.120924e-01 0.000e+00 4.589e+00 1.746e-02

427 624 9.112912e-01 0.000e+00 8.326e-01 1.211e-02

428 625 9.110571e-01 0.000e+00 3.497e-01 1.348e-02

429 626 9.105830e-01 0.000e+00 6.839e-01 3.500e-03

430 627 9.104914e-01 0.000e+00 9.617e+00 1.853e-02

431 628 9.094066e-01 0.000e+00 2.147e+00 1.643e-02

432 629 9.092059e-01 0.000e+00 1.270e+00 1.044e-03

433 630 9.082314e-01 0.000e+00 2.038e+00 7.763e-03

434 631 9.075457e-01 0.000e+00 2.513e+00 6.743e-03

435 633 9.075315e-01 0.000e+00 3.525e+00 1.610e-02

436 634 9.070243e-01 0.000e+00 1.121e+00 3.888e-03

437 635 9.068741e-01 0.000e+00 5.022e-01 1.305e-02

438 636 9.068633e-01 0.000e+00 1.969e+00 8.779e-03

439 637 9.066178e-01 0.000e+00 8.806e-01 6.153e-03

440 638 9.064824e-01 0.000e+00 3.743e-01 5.132e-03

441 639 9.062291e-01 0.000e+00 8.599e-01 8.443e-03

442 640 9.057808e-01 0.000e+00 1.857e+00 1.360e-02

443 641 9.049402e-01 0.000e+00 1.452e+00 1.626e-02

444 642 9.035825e-01 0.000e+00 1.981e+00 1.521e-02

445 643 9.021841e-01 0.000e+00 2.621e+00 1.804e-02

446 644 9.017625e-01 0.000e+00 2.354e+00 1.251e-02

447 645 9.013914e-01 0.000e+00 3.932e-01 4.390e-03

448 646 9.006248e-01 0.000e+00 4.241e+00 8.849e-03

449 647 9.002397e-01 0.000e+00 4.122e+00 4.402e-03

450 649 8.999497e-01 0.000e+00 1.993e+00 8.499e-03

First-order Norm of

Iter F-count f(x) Feasibility optimality step

451 650 8.993628e-01 0.000e+00 2.134e+00 1.595e-02

452 654 8.992482e-01 0.000e+00 1.620e+00 1.287e-02

453 655 8.985918e-01 0.000e+00 1.731e+00 7.308e-03

454 657 8.983338e-01 0.000e+00 1.051e+00 7.649e-03

455 658 8.975289e-01 0.000e+00 1.248e+00 5.807e-03

456 659 8.968299e-01 0.000e+00 4.643e-01 6.888e-03

457 660 8.960049e-01 0.000e+00 9.124e-01 1.748e-02

458 661 8.958421e-01 0.000e+00 5.826e+00 7.900e-03

459 662 8.954966e-01 0.000e+00 3.465e+00 2.765e-03

460 663 8.943473e-01 0.000e+00 2.017e+00 5.163e-03

461 664 8.934114e-01 0.000e+00 4.137e+00 9.245e-03

462 665 8.928767e-01 0.000e+00 3.165e+00 1.697e-02

463 667 8.927698e-01 0.000e+00 1.526e+00 5.654e-03

464 668 8.925698e-01 0.000e+00 4.806e-01 1.019e-02

465 669 8.924579e-01 0.000e+00 1.334e+00 5.766e-03

466 670 8.923880e-01 0.000e+00 1.403e+00 2.761e-03

467 671 8.922546e-01 0.000e+00 1.294e+00 3.195e-03

468 672 8.918850e-01 0.000e+00 2.069e-01 8.447e-03

469 673 8.917882e-01 0.000e+00 9.163e+00 2.124e-02

470 674 8.910653e-01 0.000e+00 5.250e+00 6.794e-03

471 675 8.897761e-01 0.000e+00 7.008e-01 7.267e-03

472 676 8.881514e-01 0.000e+00 3.310e+00 3.074e-02

473 677 8.873338e-01 0.000e+00 3.566e+00 3.454e-02

474 681 8.872460e-01 0.000e+00 2.455e+00 4.116e-03

475 682 8.864856e-01 0.000e+00 1.764e+00 2.901e-02

476 683 8.856867e-01 0.000e+00 4.664e+00 2.521e-02

477 684 8.848621e-01 0.000e+00 4.910e+00 1.332e-02

478 685 8.847246e-01 0.000e+00 8.664e+00 5.510e-02

479 686 8.826548e-01 0.000e+00 2.623e-01 3.007e-02

480 687 8.824449e-01 0.000e+00 9.515e-01 9.396e-03

First-order Norm of

Iter F-count f(x) Feasibility optimality step

481 688 8.823608e-01 0.000e+00 3.213e-01 7.679e-03

482 689 8.823257e-01 0.000e+00 4.863e-01 5.073e-03

483 690 8.821958e-01 0.000e+00 3.324e+00 8.741e-03

484 691 8.820173e-01 0.000e+00 3.164e+00 1.892e-03

485 692 8.812032e-01 0.000e+00 2.484e+00 6.624e-03

486 693 8.794522e-01 0.000e+00 3.786e-01 1.946e-02

487 694 8.791243e-01 0.000e+00 5.044e-01 2.599e-03

488 698 8.788702e-01 0.000e+00 2.248e+00 2.994e-02

489 699 8.780317e-01 0.000e+00 5.434e-01 5.202e-03

490 700 8.777044e-01 0.000e+00 2.596e-01 1.166e-03

491 701 8.769490e-01 0.000e+00 4.711e-01 8.090e-03

492 702 8.768125e-01 0.000e+00 3.644e+00 1.038e-02

493 703 8.764580e-01 0.000e+00 1.896e+00 6.981e-03

494 704 8.759006e-01 0.000e+00 2.280e+00 1.151e-02

495 705 8.753762e-01 0.000e+00 2.858e+00 1.900e-02

496 713 8.745640e-01 0.000e+00 5.364e+00 4.751e-03

497 714 8.744656e-01 0.000e+00 4.230e+00 4.749e-02

498 715 8.736109e-01 0.000e+00 9.225e-01 1.112e-02

499 716 8.734482e-01 0.000e+00 5.317e-01 4.315e-03

500 717 8.731811e-01 0.000e+00 1.232e+00 2.277e-02

501 719 8.728122e-01 0.000e+00 3.234e+00 2.465e-02

502 720 8.724353e-01 0.000e+00 2.328e+00 4.548e-03

503 721 8.720540e-01 0.000e+00 1.792e-01 8.589e-03

504 722 8.720202e-01 0.000e+00 7.518e-01 2.350e-04

505 723 8.719037e-01 0.000e+00 2.111e+00 1.180e-03

506 724 8.717437e-01 0.000e+00 2.554e+00 1.660e-03

507 725 8.713771e-01 0.000e+00 1.553e+00 4.582e-03

508 727 8.711305e-01 0.000e+00 5.579e+00 8.293e-03

509 728 8.706646e-01 0.000e+00 1.423e+00 3.867e-03

510 729 8.703396e-01 0.000e+00 1.665e+00 2.270e-03

First-order Norm of

Iter F-count f(x) Feasibility optimality step

511 730 8.701473e-01 0.000e+00 2.234e+00 1.547e-03

512 731 8.697846e-01 0.000e+00 2.787e+00 3.752e-03

513 733 8.697341e-01 0.000e+00 1.467e+00 1.002e-02

514 734 8.692011e-01 0.000e+00 7.284e-01 8.123e-03

515 735 8.689710e-01 0.000e+00 1.214e+00 2.096e-03

516 736 8.687734e-01 0.000e+00 7.511e-01 2.249e-03

517 737 8.686620e-01 0.000e+00 2.019e-01 3.597e-03

518 738 8.685255e-01 0.000e+00 2.835e+00 1.005e-02

519 739 8.680494e-01 0.000e+00 3.450e+00 4.722e-03

520 747 8.679024e-01 0.000e+00 7.919e+00 1.180e-03

521 748 8.670586e-01 0.000e+00 1.820e+00 9.892e-03

522 749 8.665314e-01 0.000e+00 9.732e-01 1.251e-02

523 750 8.662763e-01 0.000e+00 6.805e-01 1.037e-02

524 751 8.657788e-01 0.000e+00 4.944e-01 6.331e-03

525 757 8.657295e-01 0.000e+00 2.852e+00 6.331e-03

526 758 8.649740e-01 0.000e+00 8.828e-01 5.922e-03

527 759 8.646075e-01 0.000e+00 1.012e+00 5.644e-03

528 761 8.644414e-01 0.000e+00 1.467e+00 1.272e-02

529 762 8.635298e-01 0.000e+00 1.148e+00 1.877e-02

530 763 8.628973e-01 0.000e+00 5.936e+00 2.422e-02

531 764 8.621192e-01 0.000e+00 3.077e+00 3.388e-03

532 765 8.619487e-01 0.000e+00 1.105e+00 1.970e-03

533 766 8.618423e-01 0.000e+00 3.278e-01 2.953e-03

534 767 8.614765e-01 0.000e+00 1.241e+00 8.819e-03

535 768 8.607978e-01 0.000e+00 2.954e+00 1.375e-02

536 769 8.598382e-01 0.000e+00 2.705e+00 2.074e-02

537 776 8.592022e-01 0.000e+00 4.859e+00 1.037e-02

538 778 8.583113e-01 0.000e+00 1.437e+00 2.074e-02

539 779 8.574157e-01 0.000e+00 5.101e-01 2.195e-02

540 780 8.566949e-01 0.000e+00 4.180e-01 5.712e-03

First-order Norm of

Iter F-count f(x) Feasibility optimality step

541 782 8.543321e-01 0.000e+00 3.516e+00 5.205e-02

542 785 8.540272e-01 0.000e+00 1.210e+01 4.259e-03

543 786 8.523549e-01 0.000e+00 5.653e-01 1.173e-02

544 787 8.517223e-01 0.000e+00 1.979e+00 2.022e-02

545 789 8.514768e-01 0.000e+00 1.692e+00 2.530e-02

546 790 8.499491e-01 0.000e+00 3.801e+00 2.119e-02

547 791 8.470976e-01 0.000e+00 1.033e+00 5.149e-03

548 792 8.461388e-01 0.000e+00 7.190e-01 3.026e-02

549 793 8.457886e-01 0.000e+00 1.715e+00 8.810e-03

550 794 8.454379e-01 0.000e+00 1.150e+00 6.415e-03

551 795 8.445159e-01 0.000e+00 1.207e+00 2.318e-02

552 796 8.435696e-01 0.000e+00 5.700e-01 7.562e-03

553 803 8.433922e-01 0.000e+00 1.088e+01 3.781e-03

554 804 8.420239e-01 0.000e+00 6.367e-01 3.695e-03

555 805 8.418712e-01 0.000e+00 4.492e-01 2.870e-03

556 806 8.416567e-01 0.000e+00 5.549e-01 1.499e-03

557 810 8.415706e-01 0.000e+00 1.213e+00 3.244e-02

558 811 8.402173e-01 0.000e+00 3.176e+00 3.115e-02

559 812 8.391574e-01 0.000e+00 2.982e-01 1.437e-02

560 813 8.383662e-01 0.000e+00 6.797e-01 2.854e-02

561 814 8.376345e-01 0.000e+00 3.952e+00 7.316e-02

562 815 8.371642e-01 0.000e+00 5.162e-01 9.487e-03

563 816 8.369765e-01 0.000e+00 8.261e-01 1.150e-02

564 817 8.367634e-01 0.000e+00 1.742e+00 1.696e-02

565 820 8.367010e-01 0.000e+00 6.125e-01 3.780e-03

566 821 8.365231e-01 0.000e+00 4.662e-01 6.662e-03

567 822 8.363339e-01 0.000e+00 7.617e-01 3.804e-03

568 823 8.356509e-01 0.000e+00 2.556e-01 2.830e-03

569 824 8.335714e-01 0.000e+00 1.462e+00 9.178e-03

570 825 8.320027e-01 0.000e+00 1.753e+00 1.311e-02

First-order Norm of

Iter F-count f(x) Feasibility optimality step

571 829 8.318764e-01 0.000e+00 6.103e-01 1.846e-02

572 830 8.306623e-01 0.000e+00 7.504e-01 1.325e-02

573 834 8.306436e-01 0.000e+00 2.578e+00 8.270e-03

574 835 8.302584e-01 0.000e+00 1.014e+00 1.227e-02

575 836 8.298369e-01 0.000e+00 3.318e-01 4.453e-03

576 837 8.292662e-01 0.000e+00 4.106e+00 5.740e-03

577 838 8.288477e-01 0.000e+00 2.538e-01 1.730e-02

578 839 8.285246e-01 0.000e+00 2.284e-01 7.282e-03

579 840 8.281259e-01 0.000e+00 1.100e+00 3.656e-03

580 841 8.275553e-01 0.000e+00 5.895e-01 4.582e-03

581 842 8.267283e-01 0.000e+00 3.590e-01 9.500e-03

582 843 8.261079e-01 0.000e+00 3.865e+00 5.317e-02

583 844 8.251493e-01 0.000e+00 5.128e-01 7.261e-03

584 845 8.248546e-01 0.000e+00 9.059e-01 5.556e-03

585 853 8.247648e-01 0.000e+00 5.767e+00 1.389e-03

586 854 8.244805e-01 0.000e+00 2.271e+00 1.001e-02

587 855 8.243290e-01 0.000e+00 1.696e-01 7.192e-03

588 856 8.242579e-01 0.000e+00 8.009e-01 5.051e-03

589 857 8.242264e-01 0.000e+00 6.675e-01 1.860e-03

590 858 8.241006e-01 0.000e+00 2.642e-01 1.728e-03

591 860 8.240961e-01 0.000e+00 5.950e-01 7.697e-03

592 862 8.239072e-01 0.000e+00 1.761e+00 1.299e-02

593 863 8.237947e-01 0.000e+00 1.338e+00 1.576e-03

594 864 8.235486e-01 0.000e+00 1.430e+00 2.920e-03

595 865 8.234733e-01 0.000e+00 2.139e+00 5.139e-02

596 866 8.228583e-01 0.000e+00 5.430e+00 2.852e-02

597 867 8.226232e-01 0.000e+00 6.424e+00 1.538e-02

598 868 8.220692e-01 0.000e+00 1.523e+00 1.284e-02

599 869 8.217124e-01 0.000e+00 1.199e+00 1.316e-02

600 870 8.215135e-01 0.000e+00 1.258e+00 1.012e-02

First-order Norm of

Iter F-count f(x) Feasibility optimality step

601 874 8.214096e-01 0.000e+00 3.842e+00 4.989e-03

602 875 8.210117e-01 0.000e+00 1.463e+00 5.054e-03

603 876 8.203015e-01 0.000e+00 3.254e+00 6.576e-03

604 877 8.194073e-01 0.000e+00 7.017e+00 6.500e-03

605 878 8.178421e-01 0.000e+00 1.074e+01 1.392e-02

606 879 8.163316e-01 0.000e+00 1.067e+01 2.442e-02

607 881 8.155214e-01 0.000e+00 1.743e+01 8.216e-02

608 882 8.134319e-01 0.000e+00 3.196e+00 1.062e-02

609 883 8.124484e-01 0.000e+00 1.650e+00 2.698e-02

610 884 8.122049e-01 0.000e+00 1.491e+00 2.482e-02

611 894 8.119152e-01 0.000e+00 7.972e+00 1.551e-03

612 895 8.103554e-01 0.000e+00 3.085e+00 1.519e-02

613 896 8.098869e-01 0.000e+00 1.899e+00 8.283e-03

614 897 8.092039e-01 0.000e+00 8.096e-01 1.806e-02

615 898 8.089271e-01 0.000e+00 1.323e+00 3.889e-03

616 900 8.088639e-01 0.000e+00 1.101e+00 6.813e-03

617 901 8.087385e-01 0.000e+00 5.371e-01 5.348e-03

618 902 8.086465e-01 0.000e+00 4.938e-01 1.726e-03

619 906 8.086406e-01 0.000e+00 2.887e+00 5.260e-03

620 907 8.084159e-01 0.000e+00 1.591e+00 1.133e-02

621 908 8.081602e-01 0.000e+00 6.527e-01 1.274e-02

622 909 8.075093e-01 0.000e+00 1.044e+00 1.569e-02

623 910 8.064914e-01 0.000e+00 2.787e+00 8.201e-03

624 911 8.060424e-01 0.000e+00 2.777e-01 1.045e-02

625 912 8.057958e-01 0.000e+00 5.805e-01 1.074e-02

626 913 8.053412e-01 0.000e+00 4.573e+00 2.181e-02

627 914 8.050658e-01 0.000e+00 6.763e-01 6.296e-03

628 915 8.049668e-01 0.000e+00 1.026e+00 1.116e-03

629 916 8.048602e-01 0.000e+00 1.978e+00 3.822e-03

630 917 8.047394e-01 0.000e+00 1.023e+00 3.701e-03

First-order Norm of

Iter F-count f(x) Feasibility optimality step

631 918 8.045963e-01 0.000e+00 1.864e+00 1.153e-02

632 919 8.042513e-01 0.000e+00 1.182e+00 4.435e-03

633 920 8.039378e-01 0.000e+00 1.488e+00 6.680e-03

634 921 8.035535e-01 0.000e+00 2.268e+00 1.492e-02

635 922 8.032420e-01 0.000e+00 2.142e+00 1.738e-02

636 925 8.030924e-01 0.000e+00 9.905e-01 3.726e-02

637 926 8.026718e-01 0.000e+00 1.095e+00 1.844e-02

638 928 8.026447e-01 0.000e+00 2.064e+00 2.124e-03

639 929 8.025636e-01 0.000e+00 4.230e-01 1.237e-03

640 930 8.025439e-01 0.000e+00 6.738e-01 3.644e-04

641 931 8.024893e-01 0.000e+00 1.107e+00 5.660e-03

642 932 8.023979e-01 0.000e+00 8.779e-01 2.793e-03

643 933 8.022669e-01 0.000e+00 4.183e-01 1.609e-03

644 934 8.021226e-01 0.000e+00 8.590e-01 3.884e-03

645 936 8.020705e-01 0.000e+00 3.163e+00 2.179e-03

646 937 8.019537e-01 0.000e+00 2.392e+00 3.756e-03

647 938 8.015889e-01 0.000e+00 2.017e-01 1.600e-02

648 939 8.013414e-01 0.000e+00 8.919e-01 1.420e-02

649 940 8.011629e-01 0.000e+00 1.084e+00 1.127e-02

650 945 8.009500e-01 0.000e+00 1.531e+00 1.035e-03

651 946 8.006259e-01 0.000e+00 2.481e+00 7.601e-03

652 947 8.002508e-01 0.000e+00 1.469e+00 1.174e-02

653 948 7.994823e-01 0.000e+00 2.334e+00 1.623e-02

654 949 7.979512e-01 0.000e+00 1.945e+00 2.729e-02

655 950 7.966748e-01 0.000e+00 7.989e-01 1.345e-02

656 952 7.963725e-01 0.000e+00 4.230e+00 9.796e-03

657 953 7.958875e-01 0.000e+00 8.991e-01 4.651e-03

658 954 7.958347e-01 0.000e+00 4.599e-01 5.760e-04

659 955 7.956345e-01 0.000e+00 6.863e-01 6.054e-03

660 956 7.955566e-01 0.000e+00 5.208e-01 2.973e-03

First-order Norm of

Iter F-count f(x) Feasibility optimality step

661 957 7.953091e-01 0.000e+00 2.015e-01 6.869e-03

662 958 7.946203e-01 0.000e+00 4.095e-01 1.193e-02

663 963 7.935159e-01 0.000e+00 8.644e+00 2.387e-02

664 964 7.919404e-01 0.000e+00 5.713e+00 7.122e-03

665 965 7.868535e-01 0.000e+00 5.264e+00 4.549e-02

666 966 7.853819e-01 0.000e+00 4.555e+00 1.756e-02

667 969 7.850211e-01 0.000e+00 5.721e-01 1.365e-02

668 970 7.823691e-01 0.000e+00 2.808e+00 6.447e-02

669 972 7.818824e-01 0.000e+00 4.867e+00 2.739e-02

670 973 7.810655e-01 0.000e+00 1.050e+00 1.024e-02

671 974 7.806837e-01 0.000e+00 9.061e-01 9.186e-03

672 975 7.804321e-01 0.000e+00 1.350e+00 6.230e-03

673 976 7.798318e-01 0.000e+00 2.065e+00 1.622e-02

674 977 7.795035e-01 0.000e+00 5.884e+00 1.335e-02

675 978 7.788110e-01 0.000e+00 3.184e+00 3.636e-02

676 979 7.781819e-01 0.000e+00 8.167e-01 1.771e-02

677 980 7.779548e-01 0.000e+00 5.244e-01 4.525e-03

678 981 7.777749e-01 0.000e+00 2.487e+00 4.258e-03

679 982 7.775813e-01 0.000e+00 1.600e+00 2.539e-03

680 983 7.772360e-01 0.000e+00 6.134e-01 4.857e-03

681 984 7.755765e-01 0.000e+00 2.191e+00 3.885e-02

682 985 7.739266e-01 0.000e+00 4.876e+00 5.218e-02

683 987 7.732834e-01 0.000e+00 3.440e-01 3.928e-02

684 988 7.724636e-01 0.000e+00 1.493e+00 1.761e-02

685 989 7.721762e-01 0.000e+00 2.988e-01 3.456e-03

686 990 7.719492e-01 0.000e+00 2.834e-01 2.347e-03

687 993 7.719481e-01 0.000e+00 5.185e+00 1.663e-02

688 994 7.716697e-01 0.000e+00 2.538e+00 4.841e-03

689 995 7.713907e-01 0.000e+00 5.383e-01 1.729e-03

690 996 7.711227e-01 0.000e+00 9.488e-01 7.118e-03

First-order Norm of

Iter F-count f(x) Feasibility optimality step

691 997 7.710317e-01 0.000e+00 9.942e-01 5.911e-03

Solver stopped prematurely.

fmincon stopped because it exceeded the function evaluation limit,

options.MaxFunctionEvaluations = 1.000000e+03.

% parameters = parameterVectorToStruct(parametersV,parameterNames,parameterSizes);

% lossFcn = @(net) dlfeval(@modelLoss,net,I0,W0,S0,g,F0);

% % monitor\_option = true;

% monitor\_option = false;

%

% if monitor\_option

% monitor = trainingProgressMonitor( ...

% Metrics="TrainingLoss", ...

% Info="Epoch", ...

% XLabel="Epoch");

% for i = 1:numEpochs

% [net, solverState] = lbfgsupdate(net,lossFcn,solverState);

%

% updateInfo(monitor,Epoch=i);

% recordMetrics(monitor,i,TrainingLoss=solverState.Loss);

% end

% else

% for i = 1:numEpochs

% [net, solverState] = lbfgsupdate(net,lossFcn,solverState);

% end

% end

parameters = parameterVectorToStruct(parametersV,parameterNames,parameterSizes);

save("parameters.mat","parameters");

F0 = extractdata(F0);

% evaluate

% orient = [0,90];

g = calc\_g(orient); % direction(s)

I0 = calc\_l2i(g, F0')'; % invariants

% I0 = dlarray(I0,"BC");

W\_pred = model(parameters,I0);

figure

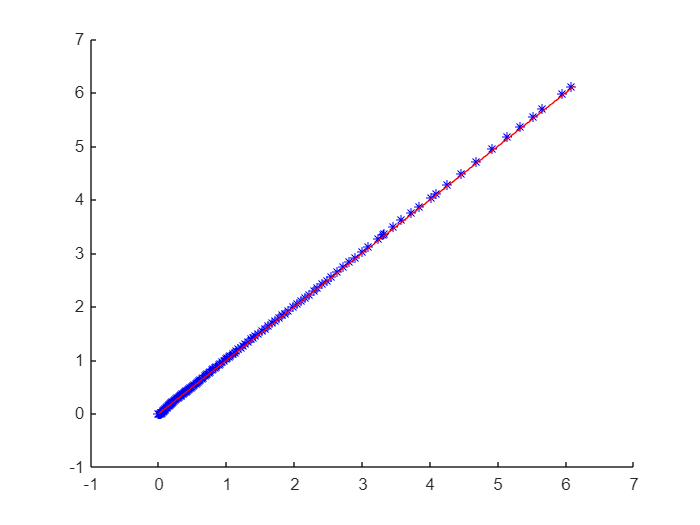
hold on

plot(W\_pred(1,:) - W\_pred(1,1),W0,'b\*');

pline = [min(W0) ceil(max(W0)\*1000)/1000];

plot(pline,pline,'r-');

hold off



% S0pred = calc\_sig(g, extractdata(W\_pred(2:end,:))', F0');

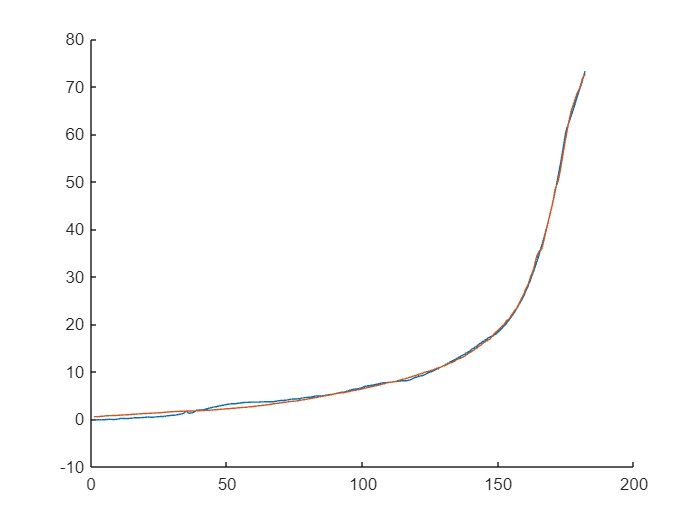
S0pred = calc\_sig(g, W\_pred(2:end,:)', F0');

figure; hold on

plot(S0(1,:))

plot(S0pred(:,1))

hold off

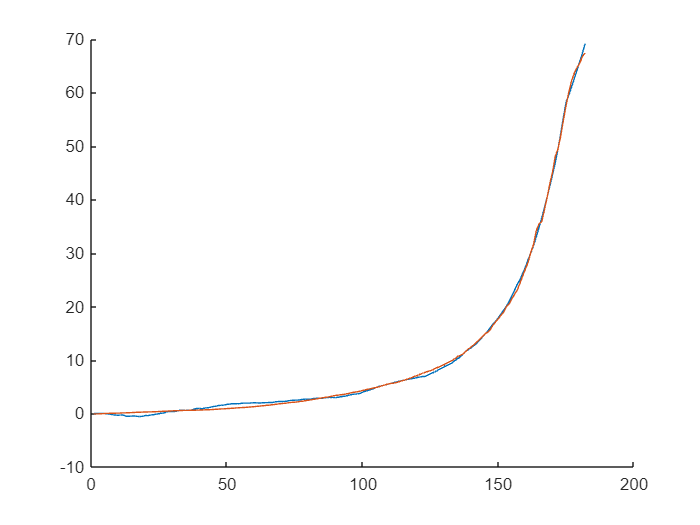


figure; hold on

plot(S0(end,:))

plot(S0pred(:,end))

hold off



function [loss,gradientsV] = objectiveFunction(parametersV,I0,W0,S0,g,F0,parameterNames,parameterSizes)

% Convert parameters to structure of dlarray objects.

parametersV = dlarray(parametersV);

parameters = parameterVectorToStruct(parametersV,parameterNames,parameterSizes);

% Evaluate model loss and gradients.

[loss,gradients] = dlfeval(@modelLoss,parameters,I0,W0,S0,g,F0);

% Return loss and gradients for fmincon.

gradientsV = parameterStructToVector(gradients);

gradientsV = extractdata(gradientsV);

loss = extractdata(loss);

end

function [loss,gradients] = modelLoss(parameters,I0,W0,S0,g,F0)

% model\_pred = forward(net,I0);

model\_pred = model4train(parameters,I0);

W0Pred = model\_pred(1,:);

mseW = custom\_l2loss(W0Pred, W0);

% Calculate derivatives with respect to I0.

model\_dWI = model\_pred(2:end,:);

gradientsW = dlgradient(sum(W0Pred,"all"),{I0},EnableHigherDerivatives=true);

dW\_auto = gradientsW{1}(:,:);

msedWI = custom\_l2loss(model\_dWI,dW\_auto);

% % FDM Derivative

% delI = 1e-6;

% dW\_FDM = zeros(size(I0));

% for i=1:size(I0,1)

% v = zeros(size(I0,1),1);

% v(i) = 1;

% delI\_i = delI \* v;

% Wp = forward(net,I0 + delI\_i);

% Wn = forward(net,I0 - delI\_i);

% dW\_FDM(i,:) = (Wp(1,:)-Wn(1,:)) / (2\*delI);

% end

% msedWI = custom\_l2loss(model\_dWI,dW\_FDM);

%

% Calculate stresses corresponding to the identified W and dWI

S0pred = dlarray(zeros(size(F0,2),2),"BC");

% Cauchy stress calculation

for i = 1:size(F0,2)

% Calculate S'

S\_PK2 = (model\_dWI(1,i).\*eye(3));

S\_PK2\_4 = zeros(3);

for j = 2:size(model\_dWI,1)

g\_temp = g(j-1,:);

S\_PK2\_4 = S\_PK2\_4 + model\_dWI(j,i) .\* (g\_temp(:) \* g\_temp(:).');

end

S\_PK2 = 2 \* (S\_PK2 + S\_PK2\_4);

% Calculate pressure, using BC: sigma\_33 = 0

% p = F0(3,i)^2 .\* S\_PK2(3,3);

% Calculate sigma\_11 & sigma\_22

% S0pred(1,i) = F0(1,i)^2 .\* S\_PK2(1,1) - p;

% S0pred(2,i) = F0(2,i)^2 .\* S\_PK2(2,2) - p;

S0pred(1:2,i) = F0(1:2,i).^2 .\* [S\_PK2(1,1) ; S\_PK2(2,2)] - (F0(3,i)^2 .\* S\_PK2(3,3));

end

mseS = custom\_frobenius\_norm(S0pred,S0);

% % Calculate Hessain

% dWII = cell(1,size(dW\_auto,1));

% for i = 1:size(dW\_auto,1)

% dWII{i} = dlgradient(sum(dW\_auto(i,:),"all"),{I0},EnableHigherDerivatives=true);

% end

% H = dlarray(zeros(size(dW\_auto,1),size(dW\_auto,1)),"BC");

% H\_trans = H;

% mseH = dlarray(zeros(1),"BC");

% mseM = dlarray(zeros(1),"BC");

% for i = 1:size(dW\_auto,2)

% % Enforce symmetry on Hessain

% for j = 1:size(dW\_auto,1)

% dWII\_temp = dWII{j}{1}(:,i);

% H(j,:) = dWII\_temp(:).';

% H\_trans(:,j) = dWII\_temp(:);

% end

% mseH = mseH + custom\_frobenius\_norm(H,H\_trans);

%

% minor = zeros(size(H,1),1);

% for j = 1:size(H,1)-1

% H\_temp = H;

% H\_temp(j+1,:) = [];

% H\_temp(:,j+1) = [];

% minor(j) = max(-custom\_det(H\_temp),0);

% end

% minor(j+1) = max(-custom\_det(H),0);

% mseM = mseM + max(minor(:));

% end

% Calculated loss to be minimized by combining errors.

a1 = 1;

a2 = 0.1;

% a3 = 0.008;

%

L1 = mseW + msedWI;

L2 = mseS;

% L3 = (mseH + mseM) / numel(W0);

% % loss = (L1^2 + L2^2) / (L1 + L2);

loss = a1 \* L1 + a2 \* L2;

% Calculate gradients with respect to the learnable parameters.

% gradients = dlgradient(dlarray(loss),net.Learnables);

gradients = dlgradient(loss,parameters);

end

function mse = custom\_l2loss(y,t)

mse = sum((y-t).^2,"all") / numel(y) \* size(y,1);

end

function mfd = custom\_frobenius\_norm(y,t)

mfd = (y - t);

mfd = sum(sqrt(sum(mfd.^2,2)),1) / numel(y) \* size(y,2);

end

function cdet = custom\_det(dl\_M)

M\_size = size(dl\_M,1);

switch M\_size

case 1

cdet = dl\_M;

case 2

cdet = dl\_M(1).\*dl\_M(4) - dl\_M(2).\*dl\_M(3);

case 3

Ma = [dl\_M(5) dl\_M(6) ; dl\_M(8) dl\_M(9)];

Mb = [dl\_M(4) dl\_M(6) ; dl\_M(7) dl\_M(9)];

Mc = [dl\_M(4) dl\_M(5) ; dl\_M(7) dl\_M(8)];

cdet = dl\_M(1).\*custom\_det(Ma) - dl\_M(2).\*custom\_det(Mb) + dl\_M(3).\*custom\_det(Mc);

end

end