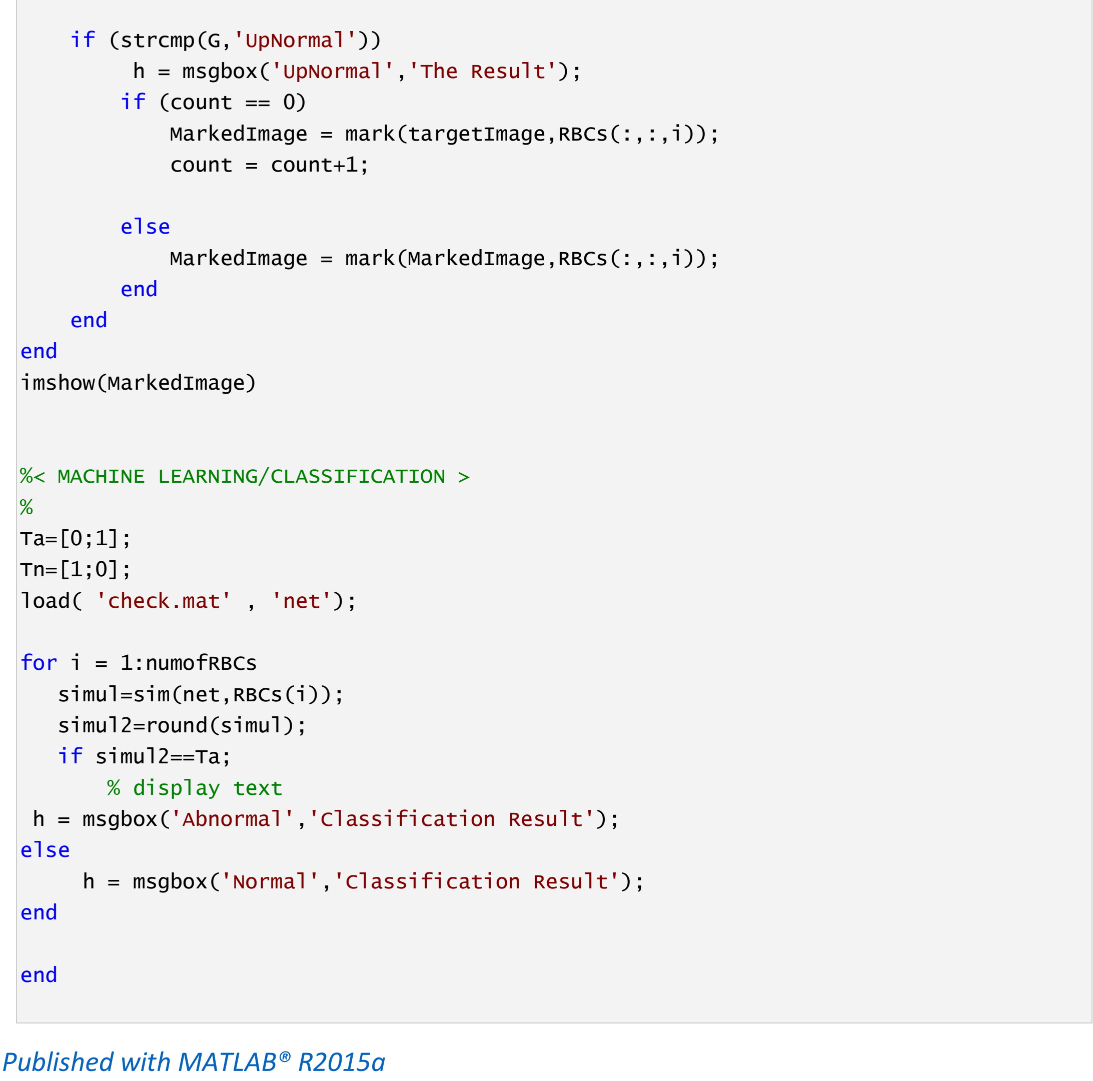
Appendix A: MATLAB code

```
close all , clear , clc

% Automated detection of malaria parasite
% Our goal here is to EXPLORE options for developing an automated
% function to DETECT the presence of the malaria parasite in thin blood
% smears, and to QUANTIFY the portion of RBCs in a sample that are
% infected.


% Main steps:
% Pre-processing
% Segmentation
% Feature Extraction
% Classfication
% GUI


global targetImage;
global count;
global Bgray;
global RBCs;
global Variation;
global Skewness;
global infected;
global MarkedImage;
global numofRBCs;


Image=imread('F:\im\image.jpg');
MarkedImage = Image;
imshow(Image)


%preprocessing
targetImage = imresize(Image, [300 300]);
Bgray = rgb2gray(Image); % convert to gray scale image
Bgray = medfilt2(Bgray,[7 7]); % apply median filter to remove the noise


%segmentation

[RBCs,numofRBCs] = m_segmentation(Bgray);

% Feature Extraction

[infected,Variation,Skewness] = m_feature(RBCs);


% classification by using m_classify function
for i = 1:numofRBCs
    G = m_classify(infected(i),Skewness(i),Variation(i));
```



```
    if (strcmp(G,'UpNormal'))
         h = msgbox('UpNormal','The Result');
        if (count == 0)
            MarkedImage = mark(targetImage,RBCs(:,:,i));
            count = count+1;

        else
            MarkedImage = mark(MarkedImage,RBCs(:,:,i));
        end
    end
end
imshow(MarkedImage)


%< MACHINE LEARNING/CLASSIFICATION >
%
Ta=[0;1];
Tn=[1;0];
load( 'check.mat' , 'net');

for i = 1:numofRBCs
   simul=sim(net,RBCs(i));
   simul2=round(simul);
   if simul2==Ta;
       % display text
 h = msgbox('Abnormal','Classification Result');
else
     h = msgbox('Normal','Classification Result');
end

end
```

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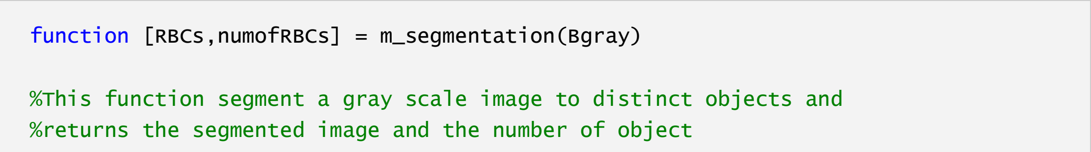
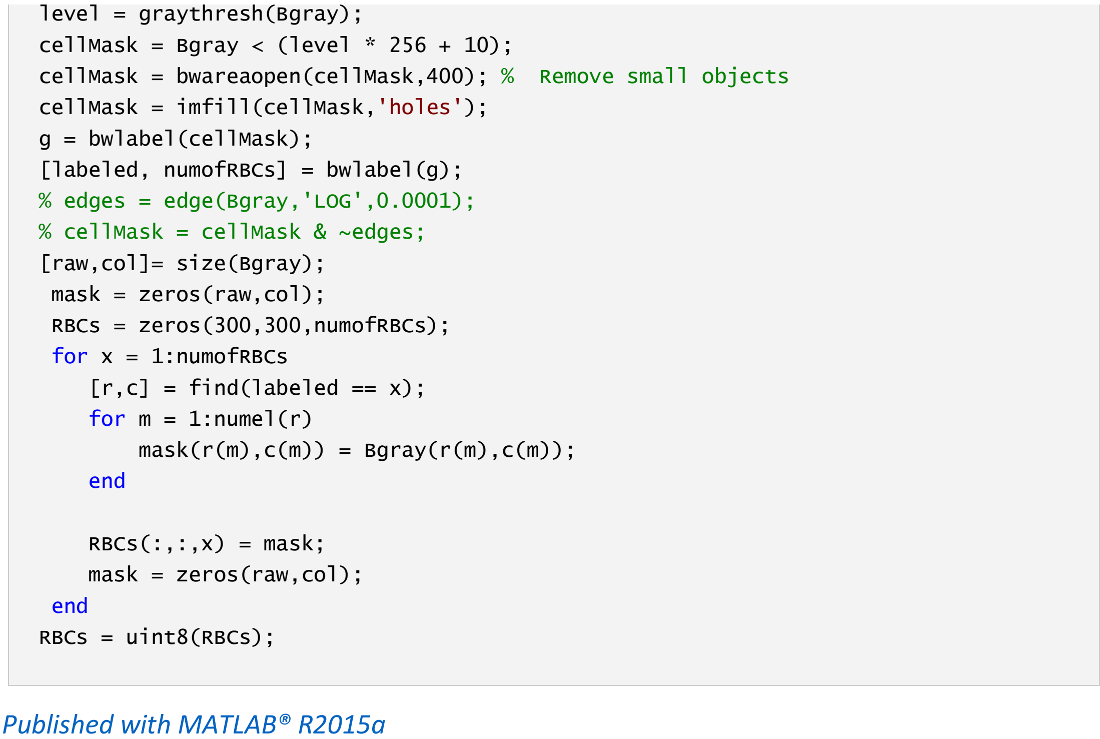


```
function [RBCs,numofRBCs] = m_segmentation(Bgray)

%This function segment a gray scale image to distinct objects and
%returns the segmented image and the number of object
```



```
level = graythresh(Bgray);
cellMask = Bgray < (level * 256 + 10);
cellMask = bwareaopen(cellMask,400); %  Remove small objects
cellMask = imfill(cellMask,'holes');
g = bwlabel(cellMask);
[labeled, numofRBCs] = bwlabel(g);
% edges = edge(Bgray,'LOG',0.0001);
% cellMask = cellMask & ~edges;
[raw,col]= size(Bgray);
 mask = zeros(raw,col);
 RBCs = zeros(300,300,numofRBCs);
 for x = 1:numofRBCs
    [r,c] = find(labeled == x);
    for m = 1:numel(r)
        mask(r(m),c(m)) = Bgray(r(m),c(m));
    end

    RBCs(:,:,x) = mask;
    mask = zeros(raw,col);
 end
RBCs = uint8(RBCs);
```

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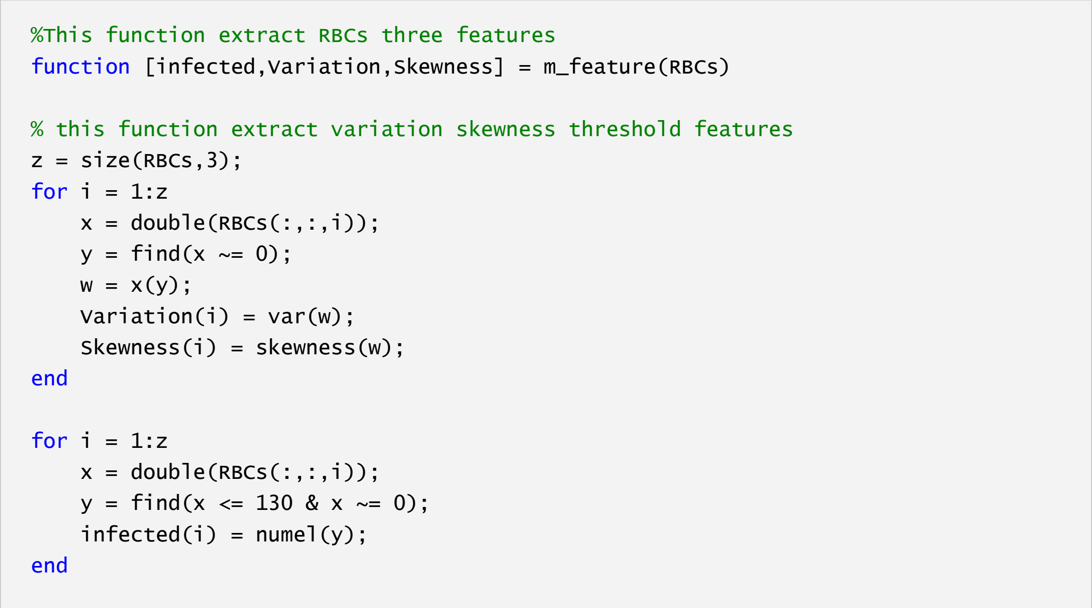
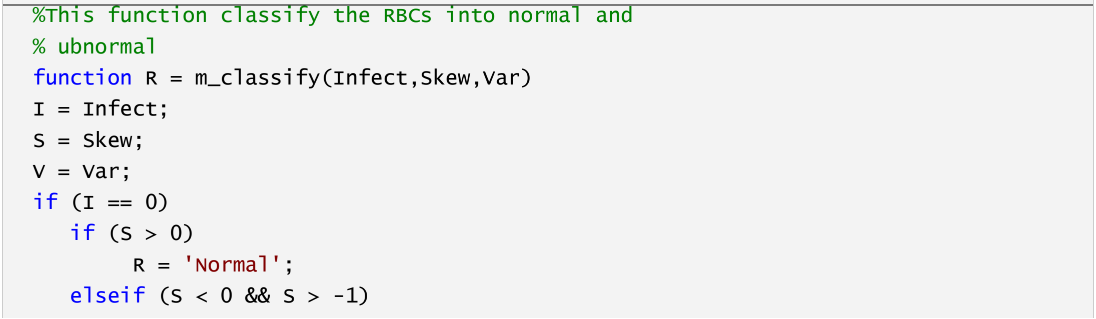


```
%This function extract RBCs three features
function [infected,Variation,Skewness] = m_feature(RBCs)

% this function extract variation skewness threshold features
z = size(RBCs,3);
for i = 1:z
    x = double(RBCs(:,:,i));
    y = find(x ~= 0);
    w = x(y);
    Variation(i) = var(w);
    Skewness(i) = skewness(w);
end

for i = 1:z
    x = double(RBCs(:,:,i));
    y = find(x <= 130 & x ~= 0);
    infected(i) = numel(y);
end
```



```
%This function classify the RBCs into normal and
% ubnormal
function R = m_classify(Infect,Skew,Var)
I = Infect;
S = Skew;
V = Var;
if (I == 0)
   if (S > 0)
        R = 'Normal';
   elseif (S < 0 && S > -1)
```

```
        if (V < 200)
            R = 'Normal';
        end
    elseif (S > -2)
            if (V < 100)
                R = 'Normal';
            end
    elseif (S < -2 && S > -5)
        if (V < 200)
            R = 'UpNormal';
        end
    end
elseif (I > 0 & I < 500)
    if (S < -4)
        if (V < 100)
            R = 'Normal';
        end
    elseif (S > 0)
            R = 'Normal';
    else
        R = 'UpNormal';
    end
elseif (I > 500)
       R = 'UpNormal';

end
```

```
function M = mark(image,cell)
%this function mark the infected RBC into gray
temp = image;
y = cell;

t1 = temp(:,:,1);
t2 = temp(:,:,2);
t3 = temp(:,:,3);

x = find(cell < 180 & cell ~= 0);

t1(x) = 255;
t2(x) = 0;
t3(x) = 0;
```

```
temp(:,:,1) = t1;
temp(:,:,2) = t2;
temp(:,:,3) = t3;

M = temp;
```

```
function numOFcells = RBC_count(labeled,numofObjects,RBCs)
info = regionprops(labeled,'all');
totalArea = 0;
totalMajorAxisLength = 0;
totalPerimeter = 0;
for i = 1:numofObjects
Area(i) =  totalArea + info(i).Area;
MajorAxisLength(i) = totalMajorAxisLength + info(i).MajorAxisLength;
Perimeter(i) = totalPerimeter + info(i).Perimeter;
end

Area = sort(Area);
MajorAxisLength = sort(MajorAxisLength);
Perimeter = sort(Perimeter);

for i = 1:min(10,numofObjects)
totalArea =  totalArea + Area(i);
totalMajorAxisLength = totalMajorAxisLength + MajorAxisLength(i);
totalPerimeter = totalPerimeter + Perimeter(i);
end

averageArea = totalArea / 10;
averageMajorAxisLength = totalMajorAxisLength / 10;
averagePerimeter = totalPerimeter / 10;

for i = 1:numofObjects
    if (info(i).Area < averageArea * 2)
        votArea = 1;
    elseif (info(i).Area > averageArea * 2 && info(i).Area < averageArea * 3)
        votArea = 2;
    elseif (info(i).Area > averageArea * 3 && info(i).Area < averageArea * 4)
        votArea = 3;
    elseif (info(i).Area > averageArea * 4 && info(i).Area < averageArea * 5)
        votArea = 4;
    elseif (info(i).Area > averageArea * 5 && info(i).Area < averageArea * 6)
        votArea = 5;
    end



    if (info(i).Perimeter < averagePerimeter * 2)
        votPerimeter = 1;
    elseif (info(i).Perimeter > averagePerimeter * 2 && info(i).Perimeter <
averagePerimeter * 3)
        votPerimeter = 2;
    elseif (info(i).Perimeter > averagePerimeter * 3 && info(i).Perimeter <
averagePerimeter * 4)
```

```
        votPerimeter = 3;
    elseif (info(i).Perimeter > averagePerimeter * 4 && info(i).Perimeter <
averagePerimeter * 5)
        votPerimeter = 4;
    elseif (info(i).Perimeter > averagePerimeter * 5 && info(i).Perimeter <
averagePerimeter * 6)
        votPerimeter = 5;
    end



    if (info(i).MajorAxisLength < averageMajorAxisLength * 2)
        votMajor = 1;
    elseif (info(i).MajorAxisLength > averageMajorAxisLength * 2 &&
info(i).MajorAxisLength < averageMajorAxisLength * 3)
        votMajor = 2;
    elseif (info(i).MajorAxisLength > averageMajorAxisLength * 3 &&
info(i).MajorAxisLength < averageMajorAxisLength * 4)
        votMajor = 3;
    elseif (info(i).MajorAxisLength > averageMajorAxisLength * 4 &&
info(i).MajorAxisLength < averageMajorAxisLength * 5)
        votMajor = 4;
    elseif (info(i).MajorAxisLength > averageMajorAxisLength * 5 &&
info(i).MajorAxisLength < averageMajorAxisLength * 6)
        votMajor = 5;
    end


   if (votArea == votPerimeter)
       num = votArea;
   elseif (votArea == votMajor)
       num = votArea;
   elseif (votPerimeter == votMajor)
       num = votPerimeter;
   else
       num = fix(((votArea + votPerimeter + votMajor) / 3));
   end
    cells(i) = num;
end
numOFcells = sum(cells);
```

```
% Solve a Pattern Recognition Problem with a Neural Network
% Script generated by NPRTOOL
% define the input and target data
close all
inputs = [0 2.125684       120.205283
0    1.82916 153.06687
0    1.79175 144.762478
0    2.902268       62.677799
0    1.488967       59.346151
0    2.343142       42.66493
```

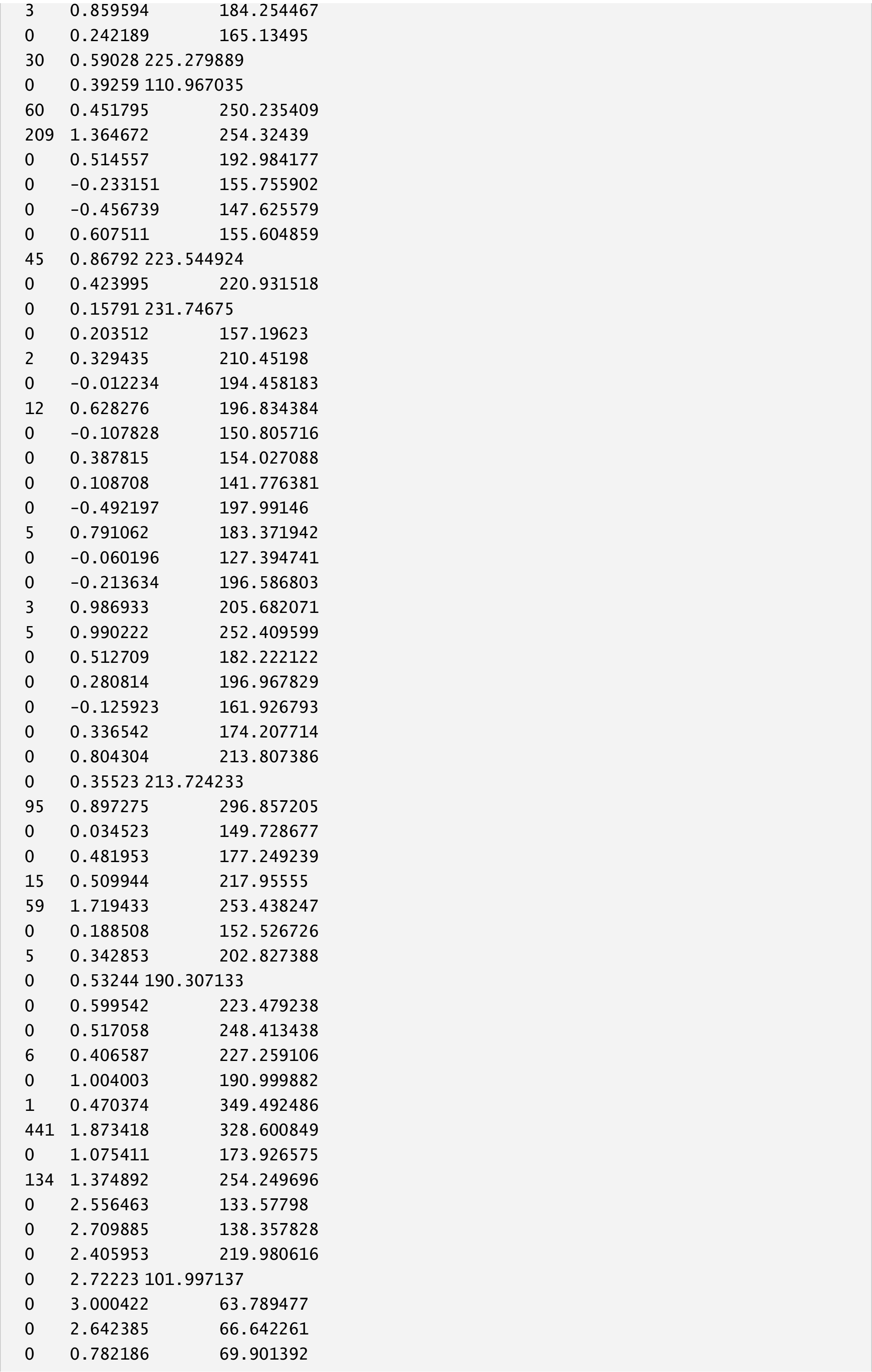
```
0    1.556758       102.769279
0    1.882386       78.723221
0    0.920976       60.684793
0    1.479416       61.783314
0    1.770229       91.077139
0    2.216171       110.821456
0    2.092904       124.105874
0    1.822031       25.434587
0    2.135144       52.444653
0    1.886247       107.978281
0    2.04494 80.211785
0    1.33143 162.278842
0    1.889007       111.552217
0    1.339748       38.568569
0    2.12894 60.053488
0    1.809403       85.490495
0    1.014506       90.87292
0    0.939598       25.221328
0    1.442492       68.019278
0    2.105557       114.442382
0    1.231324       35.02549
0    0.978822       43.644952
0    -0.127558      39.199294
0    1.364244       52.507444
0    0.588792       47.726623
0    0.174729       62.157515
0    -0.623174      19.479868
0    0.18973 26.479776
0    2.489924       43.320129
0    2.186308       55.9451
0    2.043841       53.786581
0    0.778412       32.94562
0    0.068603       113.728049
0    1.787026       32.252182
0    2.166731       39.205616
0    1.676734       39.320705
0    1.8822  42.904471
0    1.526014       35.334016
0    1.749518       61.262387
0    1.362317       90.201655
0    2.084055       72.105393
0    1.273434       109.90749
0    0.66273 70.859084
0    0.675361       120.293068
0    2.424709       82.297447
0    2.664837       40.17635
0    1.315524       40.864058
0    2.005415       118.481422
0    1.307991       63.341921
0    2.22092 84.842916
0    2.485074       77.976251
0    1.549085       87.939435
0    1.956408       126.887887
0    2.119814       82.959659
0    1.968308       101.983203
```

```
0	0.894197	132.481984
0	2.254796	76.858531
0	2.191941	117.85483
0	0.969355	66.881282
0	1.581131	48.425135
0	-0.353586	76.338686
0	1.177521	22.732963
0	1.909862	24.448703
0	1.249937	47.448718
0	2.076479	31.57818
3	0.947308	234.535883
3	1.20285 190.353487
73	1.849899	227.116643
0	1.384208	162.99412
2	1.174098	159.455233
0	0.715679	171.72284
0	0.936943	281.877921
1	1.060464	273.356066
0	1.105497	164.70945
0	0.587727	230.719134
0	0.452569	138.18232
1	0.551679	150.363203
0	-0.09721	131.323403
0	0.962764	150.368017
0	0.795033	142.126495
12	0.66285 180.715967
0	0.756232	203.006842
0	0.733912	161.30777
14	0.877956	188.168127
0	0.012076	174.87517
0	0.239814	198.490322
0	0.264286	185.369137
1	0.942913	181.95277
0	0.068396	153.593679
0	0.964964	155.027863
0	0.931688	149.87069
16	0.6824	192.2378
0	0.807769	211.522557
0	0.827893	168.379868
14	0.956534	195.092679
0	0.362359	184.135288
0	1.065495	354.57998
0	0.773922	179.377279
0	0.375592	154.4844
0	0.428195	156.910946
0	0.290987	152.922779
0	1.037933	196.547791
0	0.692538	166.407653
0	0.545944	183.117771
0	0.819001	160.367438
0	1.101108	194.284908
0	1.140875	173.054811
0	0.91499 184.579681
0	0.51277 195.329572
19	0.952202	180.37005
```

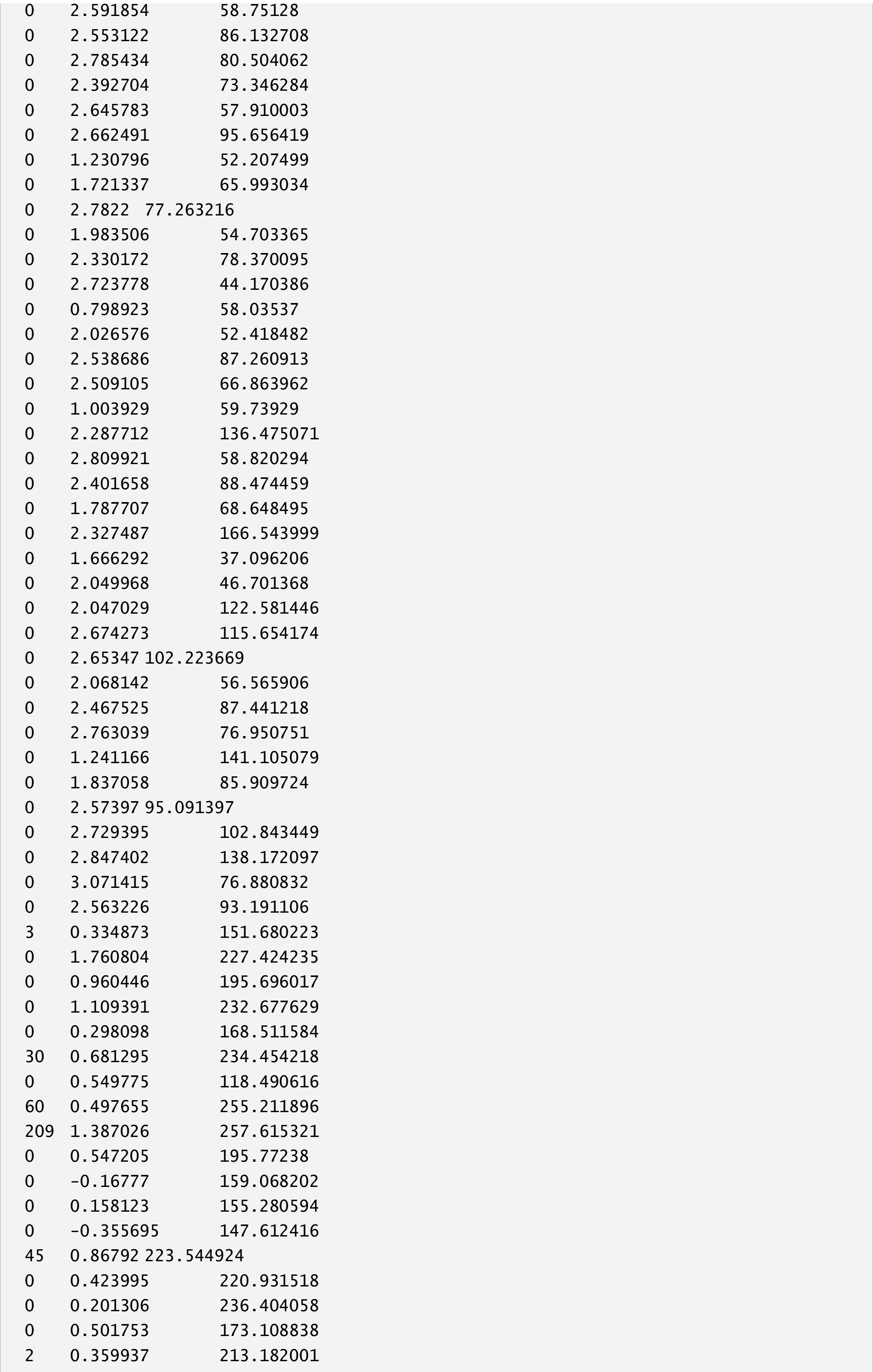
```
0   0.772699       161.203335
9   0.98728 223.290254
0   1.150377       130.306954
0   1.00427 174.645724
0   1.342342       94.966865
0   0.933684       124.157465
0   1.587621       152.458599
0   1.672443       73.621256
0   1.43009 206.584577
0   1.64081 86.444023
0   1.69861 51.984118
0   0.861757       109.617508
0   1.21244 90.700872
0   1.359122       165.211041
0   1.016429       117.206165
0   1.915526       60.167562
0   1.583874       126.15416
0   0.813116       156.338968
0   1.170593       57.377844
0   1.135427       41.279874
0   0.931083       53.741349
0   2.078252       138.85675
0   0.984409       115.020683
0   0.868067       185.961968
0   1.023168       398.524769
0   1.132405       208.182091
0   1.284945       116.760975
0   1.401805       218.18476
0   2.131945       148.08862
0   0.860965       149.56011
0   1.229087       138.367149
0   1.430026       68.52642
0   1.914577       183.847671
0   2.075161       111.41617
0   0.866064       153.817553
0   1.714809       69.703561
0   0.747998       65.691382
0   0.693942       133.766204
0   1.809291       80.108636
0   1.041881       83.431626
0   1.62983 89.111352
0   1.50203 22.032332
0   1.0165  104.772416
0   1.171143       186.437158
0   0.67392 38.041313
3   0.421932       160.021281
0   -0.132592      135.066873
0   0.968924       147.123059
0   0.887445       149.497988
0   0.778989       217.159995
0   0.683029       163.12099
28  0.706859       173.766149
0   0.325137       171.238215
0   1.037333       369.73056
0   0.681479       187.690862
```

```
0	0.330538	149.785754
0	0.317975	146.259038
0	0.324047	149.939268
10	0.846823	196.240491
0	1.267168	174.37732
0	0.359469	168.904152
0	0.748996	159.29243
0	1.136657	199.117561
0	1.130743	171.309612
2	0.932893	188.993964
0	0.444419	188.792701
17	1.075512	193.279875
0	0.755698	165.456377
21	0.941347	220.038309
0	1.152162	112.273952
0	0.910309	99.198757
0	0.896375	74.886965
0	1.58681 88.069217
0	0.878296	130.869117
0	0.859809	70.325909
0	0.367635	105.900016
0	0.98269 110.409287
0	0.147074	74.188306
0	-0.464611	69.26721
0	0.866155	90.279523
0	1.001137	111.241564
0	0.662386	82.27752
0	1.553484	112.203646
0	0.648623	103.672678
0	0.297951	54.060712
0	1.266922	82.682355
0	1.376963	206.132598
0	1.535303	118.353613
0	0.789008	86.073396
0	1.330042	258.455651
0	2.083968	106.10403
0	1.491167	118.705017
0	0.99794 149.795982
0	0.521952	180.443342
0	1.09031 80.528075
0	0.57153 63.954829
0	1.392166	101.119704
0	1.43982 86.336793
0	0.549627	328.292202
0	0.846641	153.335877
0	0.931736	225.678915
0	0.30072 199.158419
0	2.583081	109.580658
0	2.500338	126.47234
0	1.934682	209.615517
0	2.72821 133.908704
0	2.375825	113.038887
0	2.772808	80.301399
0	2.516929	95.41621
0	2.68838 103.551083
```

```
0    2.499352        73.00408
0    2.422688        89.8742
0    2.207585        176.612721
0    2.620007        52.063689
0    2.393999        82.25722
0    2.576096        120.184404
0    1.922256        61.221258
0    1.387592        46.782558
0    1.980181        79.210938
0    2.422177        87.988294
0    0.303338        62.412279
0    1.579102        58.370499
0    1.416906        27.082084
0    1.599628        11.424708
0    1.498806        27.133829
0    1.667221        51.504715
0    2.428543        65.964424
0    0.45196 48.694318
0    2.389038        64.307405
0    0.916433        43.101425
0    2.433077        83.434624
0    2.317134        67.035487
0    2.912584        74.018336
0    2.754163        56.861832
0    2.537771        92.74774
0    2.626628        62.838699
0    2.822289        109.485674
0    1.949916        55.922763
0    2.608548        69.239986
0    2.588857        106.021804
0    2.534178        98.709848
0    2.498434        135.449183
0    2.009861        104.338394
0    2.48708 44.173384
0    2.764831        111.106578
0    2.355287        102.782288
0    0.754866        193.069803
0    1.182647        546.271731
0    0.911718        286.048109
0    0.842662        633.603234
0    0.748678        462.666241
0    1.039719        423.190302
0    1.032924        221.413534
0    1.20375 389.401021
0    1.008577        265.99323
0    0.851045        448.071498
0    0.902813        407.132894
0    0.889812        184.323007
0    0.384684        174.09566
0    1.273334        426.311962
0    0.534037        588.216974
0    1.209122        350.789044
0    1.158864        264.82022
3    0.333673        149.297366
4    1.540857        200.89496
```



```
3    0.859594       184.254467
0    0.242189       165.13495
30   0.59028 225.279889
0    0.39259 110.967035
60   0.451795       250.235409
209  1.364672       254.32439
0    0.514557       192.984177
0    -0.233151      155.755902
0    -0.456739      147.625579
0    0.607511       155.604859
45   0.86792 223.544924
0    0.423995       220.931518
0    0.15791 231.74675
0    0.203512       157.19623
2    0.329435       210.45198
0    -0.012234      194.458183
12   0.628276       196.834384
0    -0.107828      150.805716
0    0.387815       154.027088
0    0.108708       141.776381
0    -0.492197      197.99146
5    0.791062       183.371942
0    -0.060196      127.394741
0    -0.213634      196.586803
3    0.986933       205.682071
5    0.990222       252.409599
0    0.512709       182.222122
0    0.280814       196.967829
0    -0.125923      161.926793
0    0.336542       174.207714
0    0.804304       213.807386
0    0.35523 213.724233
95   0.897275       296.857205
0    0.034523       149.728677
0    0.481953       177.249239
15   0.509944       217.95555
59   1.719433       253.438247
0    0.188508       152.526726
5    0.342853       202.827388
0    0.53244 190.307133
0    0.599542       223.479238
0    0.517058       248.413438
6    0.406587       227.259106
0    1.004003       190.999882
1    0.470374       349.492486
441  1.873418       328.600849
0    1.075411       173.926575
134  1.374892       254.249696
0    2.556463       133.57798
0    2.709885       138.357828
0    2.405953       219.980616
0    2.72223 101.997137
0    3.000422       63.789477
0    2.642385       66.642261
0    0.782186       69.901392
```



```
0	2.591854	58.75128
0	2.553122	86.132708
0	2.785434	80.504062
0	2.392704	73.346284
0	2.645783	57.910003
0	2.662491	95.656419
0	1.230796	52.207499
0	1.721337	65.993034
0	2.7822	77.263216
0	1.983506	54.703365
0	2.330172	78.370095
0	2.723778	44.170386
0	0.798923	58.03537
0	2.026576	52.418482
0	2.538686	87.260913
0	2.509105	66.863962
0	1.003929	59.73929
0	2.287712	136.475071
0	2.809921	58.820294
0	2.401658	88.474459
0	1.787707	68.648495
0	2.327487	166.543999
0	1.666292	37.096206
0	2.049968	46.701368
0	2.047029	122.581446
0	2.674273	115.654174
0	2.65347	102.223669
0	2.068142	56.565906
0	2.467525	87.441218
0	2.763039	76.950751
0	1.241166	141.105079
0	1.837058	85.909724
0	2.57397	95.091397
0	2.729395	102.843449
0	2.847402	138.172097
0	3.071415	76.880832
0	2.563226	93.191106
3	0.334873	151.680223
0	1.760804	227.424235
0	0.960446	195.696017
0	1.109391	232.677629
0	0.298098	168.511584
30	0.681295	234.454218
0	0.549775	118.490616
60	0.497655	255.211896
209	1.387026	257.615321
0	0.547205	195.77238
0	-0.16777	159.068202
0	0.158123	155.280594
0	-0.355695	147.612416
45	0.86792	223.544924
0	0.423995	220.931518
0	0.201306	236.404058
0	0.501753	173.108838
2	0.359937	213.182001
```

```
0    0.073143       209.332799
12   0.652   198.766295
0    -0.069568      152.997572
0    0.440657       157.524244
0    0.123247       142.528427
0    -0.409896      191.394714
3    0.991083       208.25935
4    0.765365       230.771567
0    0.769021       148.551985
3    0.68149 159.90713
0    0.176222       145.336443
0    -0.208239      197.130983
3    1.00512 207.72231
0    0.554907       186.16024
0    0.295114       198.186697
0    -0.213517      165.233356
0    0.364038       176.537583
0    0.858631       220.130878
0    0.698707       179.038871
0    0.461547       224.408193
0    0.104587       154.02643
0    0.590415       186.446883
15   0.526473       219.576663
59   1.719433       253.438247
0    0.450722       162.726298
0    0.57693 194.18968
0    0.599542       223.479238
0    0.545078       253.425145
9    0.833181       241.094495
0    1.061299       196.58782
1    0.47892 352.282391
247  2.028424       344.517247
0    1.238552       240.162279
88   1.589175       365.65509
0    1.221078       101.653261
0    1.056712       185.349621
0    1.298414       167.82689
0    0.960968       100.869421
0    0.910345       76.604152
0    1.350832       75.796696
0    1.109487       203.756866
0    1.1568  231.738846
0    1.616419       81.59103
0    0.897862       125.14663
0    0.847548       121.307135
0    1.423578       128.438707
0    1.155877       197.458253
0    0.999264       115.721082
0    1.324866       115.602027
0    1.476706       315.488757
0    1.555379       183.375927
0    1.232956       215.568061
0    1.452371       116.343291
0    1.169156       125.251694
0    1.208446       157.907043
```

```
0    2.132555       170.400175
0    1.175597       272.798796
0    1.172374       142.176166
0    1.090851       178.412038
0    1.39083 202.702612
0    1.011412       130.290409
0    0.672846       233.092483
0    1.36439 172.319299
0    0.324813       167.073716
0    0.805738       219.683069
0    0.637544       170.223134
0    0.752772       295.65116
0    1.070328       290.888078
0    0.701706       269.424125
0    1.23134 124.209322
0    1.113305       198.805991
0    0.739651       154.761879
0    0.677885       359.846916
0    0.595772       311.501073
0    0.691548       240.967793
0    0.866503       156.576514
0    0.76779 227.456987
0    0.82544 188.881825
0    0.499284       203.255612
0    0.740643       230.216709
0    0.88163 416.392295
0    1.529856       102.450992
0    0.90711 366.491331
0    0.665979       286.436617
0    0.946729       348.467969
0    1.075268       227.397565
0    0.859064       265.94537
0    0.7045  272.244371
0    0.705184       274.135974
0    0.809095       317.922508
0    0.909699       190.542218
0    0.975952       192.681343
0    0.701062       337.325429
0    0.629505       285.405687
0    0.795198       469.550042
0    0.659065       227.001205
0    2.700713       73.928453
0    3.059916       61.134881
0    2.884503       53.567072
0    2.457841       60.525211
0    2.733332       42.30188
0    2.645717       39.729019
0    2.463325       47.758032
0    2.087892       68.591699
0    1.43479 72.308397
0    2.103627       40.457249
0    2.6313  62.095669
0    2.086362       37.020115
0    2.005511       52.049202
0    2.317143       92.472754
```

```
0    2.45804 56.892829
0    1.330499        61.550146
0    2.646474        71.672217
0    2.423313        68.982369
0    0.728462        110.223798
0    1.296937        82.271088
0    2.199846        38.2083
0    2.145749        51.418972
0    2.12145 50.558195
0    2.307221        101.672737
0    2.481208        60.719086
0    2.596475        80.756094
0    2.147493        73.971446
0    1.266042        59.878937
0    1.539093        75.27186
0    1.504908        37.576643
0    1.861123        57.723726
0    2.215004        85.634318
0    2.632215        72.333686
0    2.456287        78.405637
0    2.827827        67.156645
0    0.763975        64.656734
0    1.372569        63.467694
0    0.236856        77.032701
0    1.719292        49.255601
0    1.456167        85.733667
0    0.022919        39.986724
0    0.274424        188.597614
0    -1.82271        46.214813
0    1.347615        98.898197
0    2.089519        104.80876
0    1.702301        105.20869
0    2.178251        86.785448
0    1.326142        81.490482
0    1.349752        81.630533
0    2.682708        55.610386
0    3.089579        53.161615
0    2.089347        62.741263
0    1.16026 121.670564
0    2.537272        62.576447
0    1.96639 87.386654
0    2.894203        70.296266
0    1.952882        72.301196
0    2.733463        82.445701
0    1.541441        105.704672
0    0.882681        119.346192
0    1.613791        69.528567
0    1.787334        76.924391
0    1.378024        118.51678
0    2.311564        63.596703
0    1.564312        111.696963
0    1.571881        98.477443
0    1.944633        65.084307
0    1.393721        154.009137
0    2.419376        103.173381
```

```
0	1.337548	123.222893
0	0.614627	215.056007
0	1.447399	91.579051
0	1.445849	106.804735
0	1.638546	80.809581
0	2.631099	71.965239
0	1.722374	133.569481
0	2.414397	115.394427
0	1.981806	196.352816
0	2.1755	118.830824
0	2.225366	76.602006
0	2.474834	85.427093
0	1.1683	189.712984
0	0.983538	127.159681
4	1.08675	166.329943
0	2.824233	108.748763
0	1.93982	146.029083
3	2.044873	131.811977
0	2.453556	159.042882
0	2.216645	140.218757
0	2.379156	116.606943
0	2.159798	149.996132
0	1.180565	173.960005
0	1.436483	105.497131
0	2.202018	118.139103
0	2.110874	117.188873
0	1.762323	91.123847
0	1.784746	153.441499
0	1.291899	175.833614
0	1.148216	123.153944
0	1.577923	139.43189
0	2.162595	89.668514
0	2.026493	59.623394
0	1.184109	220.850745
0	1.318479	106.846282
0	2.77989	64.236554
0	2.32404	104.106565
0	1.998603	67.927631
0	2.495626	74.591352
0	1.591345	85.353142
0	2.675091	77.515364
0	2.90013	71.855977
0	2.783095	52.22435
0	2.535043	81.23054
0	2.484983	84.730542
0	2.432689	78.485859
0	2.521222	61.396124
0	2.53286	64.920743
0	2.018177	68.287602
0	2.311986	151.807475
0	0.82716	245.298901
0	2.597855	80.44302
0	2.464794	100.183016
0	2.628576	86.954682
0	1.716632	34.634078
```

```
0    2.990979       26.2416
0    3.110345       40.37433
4    -4.53177       48.069052
0    1.854571       38.154976
0    2.349743       45.385153
0    2.281269       27.942216
0    2.936241       36.048191
0    2.933776       25.576604
0    1.778413       31.149922
0    0.952263       24.18769
0    1.730222       30.096331
0    2.251606       32.389685
0    3.163039       29.105848
0    2.824717       24.625498
0    3.286673       25.806342
0    1.811273023    98.83957208
0    1.531505103    128.1160459
32   1.212973593    214.39584
0    1.948271339    99.34944324
0    1.046817195    229.5674147
0    0.848544702    147.1780561
63   1.142777143    304.9796766
0    1.716608354    112.2828851
0    0.942525122    366.4525765
0    1.170747511    208.6137203
0    1.464758519    148.4568109
0    1.811273023    98.83957208
0    1.531505103    128.1160459
32   1.212973593    214.39584
0    1.948271339    99.34944324
0    1.046817195    229.5674147
0    0.848544702    147.1780561
63   1.142777143    304.9796766
0    1.716608354    112.2828851
0    0.942525122    366.4525765
922  -0.8   1031.7
912  -1.760909993   887.6001441
2213 -0.409719729   677.582447
497  -1.969872683   665.8308231
69   -1.309264085   387.6455309
13   -1.46116013    239.0371965
740  -0.385506129   1387.637046
107  -0.488165289   544.6130546
155  -1.424625155   1298.49016
0    -2.054043834   148.9659262
87   -0.838722029   414.5248564
2463 -0.111251813   1375.519011
1571 -0.263970797   971.3149555
179  -1.704544519   660.1588
95   -1.834598959   615.7155809
25   -0.403837483   239.110877
760  -0.538851156   1099.333579
0    -2.855872624   77.91734352
14   -1.362205185   266.9689219
14   -0.417630183   295.7470605
```

```
12   -2.91525608    183.5178547
9    -2.590126607   192.3220903
9    -1.06146378    193.9777819
670  -0.810621233   1553.587326
669  -0.452269278   1230.55412
477  -0.337637506   868.4834187
60   -3.444831843   229.5664844
857  -0.697865031   1675.56713
49   -3.538307116   299.6300782
117  -2.387887414   451.0331455
857  -0.710246407   1629.42891
87   -1.151370599   256.0718978
83   -1.350681253   325.8616296
14   -1.499817871   203.1020517
503  -1.409025829   798.2887031
37   -3.230765599   366.3080834
51   -0.046248232   401.4051228
33   -0.135669388   498.3526535
34   -1.688416979   403.7208183
19   -0.733101174   364.2223251
192  -0.845314997   837.8468405
198  -0.786747412   917.6335911
31   -0.087046988   303.9503752
53   -1.503252879   281.2613413
767  -1.019369797   2484.803101
53   -2.725550459   262.4546978
31   -1.311650533   381.0831385
23   -1.024754791   212.2936018
29   -2.195369931   110.2851313
134  -1.755397696   345.8128591
119  -0.746291608   282.5541721
285  -0.103239489   1442.380679
29   -0.109650926   1227.763525
83   -0.2837722     917.2780621
70   -0.750336425   1121.351676
72   -0.057843226   621.8955162
69   -1.309264085   387.6455309
13   -1.46116013    239.0371965
4    -0.03373855    239.0791789
22   -2.262782778   253.2144395
928  0.256356649    833.3600434
928  0.256356649    833.3600434
18   -0.25381       369.89276
17   -3.569355      307.408652
14   -2.689029      301.037041
49   -0.439829      246.138452
49   -0.323712      256.855494
0    -2.819363      105.972454
0    -2.475825      113.950059
42   -0.310905      249.014143
33   -0.182281      504.667453
34   -1.688417      403.720818
90   -0.021711      268.007571
40   -0.331248      200.401066
227  -0.426115      1059.182354
```

```
22   -0.733275      187.068925
34   -0.66766       283.538761
26   -1.58592       259.507112
26   -1.263438      269.25185
4    1.134556       179.084877
81   -0.078549      475.17004
22   -0.662135      190.666154
22   -1.209866      199.778939
197  -1.230757      635.150715
15   -0.293925      459.747354
390  -0.339458      858.528525
177  -0.483175      879.388122
177  -0.467529      889.968587
49   -0.558871      875.444951
264  -0.93343       1151.237866
];
targets=[ones(1,646),zeros(1,90);zeros(1,646),ones(1,90)];
inputs=inputs';

% Create a Pattern Recognition Network
hiddenLayerSize = 20;
net = patternnet(hiddenLayerSize);
% Set up Division of Data for Training, Validation, Testing
net.divideParam.trainRatio = 70/100;
net.divideParam.valRatio = 15/100;
net.divideParam.testRatio = 15/100;


% Train the Network
[net,tr] = train(net,inputs,targets);

% Test the Network
outputs = net(inputs);
errors = gsubtract(targets,outputs);
performance = perform(net,targets,outputs);

% View the Network
view(net)
 %%Plots

 figure, plotperform(tr)
figure, plottrainstate(tr)
figure, plotconfusion(targets,outputs)
 figure, ploterrhist(errors)
save( 'Test.mat' , 'net');
```

```
%%This code used to test ANN
%the test data consist of 182 RBCs , 170 of them
%are normal and others are upnormal
```

```
testt=[0   0.98815 172.717344
0   0.709085       153.854339
0   1.247148       132.007612
0   1.141364       119.711457
0   0.789824       139.040024
0   0.525203       166.080176
0   0.745341       153.504513
0   0.827923       245.072408
0   1.709796       153.784847
0   2.697017       61.226868
0   2.488151       126.772601
0   2.901116       58.853824
0   2.622807       48.407469
0   1.870208       61.287109
0   1.162042       162.575787
0   3.108736       49.861678
0   2.201177       101.492285
0   2.829606       84.684626
0   2.375967       47.249846
0   1.573631       91.518405
0   2.413716       55.665908
0   2.840734       74.035568
0   3.058056       71.939916
0   2.723685       64.582391
0   2.817628       80.13353
0   2.472991       74.269086
0   2.677701       98.85334
0   2.588687       52.607535
0   2.708916       47.645483
0   2.914635       78.483093
0   2.134952       65.660829
0   0.998061       84.545059
0   0.434481       152.560809
0   0.390869       211.033597
0   1.654269       125.05818
0   0.73679 278.745689
0   0.705384       162.030688
0   0.351784       150.639618
0   1.347507       87.150426
0   0.928108       125.014476
0   1.044291       174.508078
0   1.485119       158.423317
0   1.311931       109.658109
0   0.397024       68.32769
0   0.850723       128.875703
0   1.324923       83.958287
0   1.329614       87.048028
0   0.874826       91.997994
0   0.634135       191.265031
0   0.375877       94.661261
0   1.573721       95.029554
0   0.697414       173.239552
0   1.037796       130.244013
0   0.912209       351.597971
0   1.319386       132.489352
```

```
0   0.919143        116.37307
0   2.03729 100.51745
0   1.189398        87.125513
0   2.299317        70.657488
0   1.858781        66.869141
0   2.430107        71.219065
0   0.566932        260.765096
0   0.61022 147.440878
0   1.860456        143.407653
0   1.861006        75.612555
0   1.709119        96.851605
0   1.146415        80.546312
0   1.33449 47.214255
0   1.924564        49.177341
0   1.967525        45.098739
0   1.445386        45.618993
0   2.167371        37.894764
0   1.663395        47.281768
0   1.265407        64.797081
0   1.637982        44.404425
0   1.522138        51.795934
0   0.620845        73.197459
0   1.463354        47.250953
0   1.764251        42.034572
0   1.388224        74.777412
0   0.522727        49.414044
0   1.530808        33.135182
0   0.963072        41.749434
0   1.311813        52.04676
0   1.254718        46.923722
0   1.453056        66.447132
0   1.818816        82.450158
0   0.871501        69.351031
0   2.128561        40.762196
0   0.392506        115.084699
0   1.812758        40.950967
0   0.817551        48.989464
0   1.853118        42.689602
0   1.473535        34.761249
0   1.263123        126.087356
0   2.569951        61.112802
0   2.5837  63.300783
0   1.875603        74.954441
0   1.374346        55.28924
0   1.928459        69.823063
0   1.086126        101.805224
0   1.947466        101.800074
0   1.633723        56.325187
0   1.464983        57.24091
0   1.325688        50.149469
0   2.290104        72.947633
0   1.343982        64.368258
0   2.153117        51.52735
0   1.581466        68.072051
0   2.240214        99.807075
```

```
0  1.645188        116.693327
0  2.184984        58.561796
0  1.312351        72.219435
0  0.955246        67.317319
0  2.300384        98.321119
0  1.383355        53.069699
0  1.264092        111.835887
0  1.184033        137.059041
0  2.193272        78.317015
0  1.483387        70.215452
0  2.293085        64.110962
0  2.541966        58.455834
0  1.074821        148.999649
0  2.532687        73.526856
0  2.400971        91.147738
0  1.275184        70.137429
0  0.883677        154.561188
0  0.995209        71.745298
0  2.032468        68.319889
0  1.472697        105.270756
0  1.800219        54.016417
0  1.684106        55.058216
0  0.953688        103.703978
0  2.247849        60.530091
0  1.893365        136.189371
0  1.913169        83.848848
0  1.804868        119.632653
0  1.819349        66.594104
0  2.279766        111.952322
0  2.531015        39.940129
0  1.850325        57.862691
0  1.993963        45.164808
0  0.620507        29.603235
0  0.606198        28.681941
0  1.880772        44.768475
0  0.922177        40.790049
0  1.491552        21.652418
0  2.428627        49.803114
0  0.593946        26.345912
0  0.885074        25.392751
0  1.50021 31.254712
0  1.26066 45.427185
0  1.0636  50.894314
0  1.016056        42.954059
0  2.156904        38.830756
0  2.484885        33.538682
0  1.642314        41.77722
0  0.480235        140.474675
0  1.891251        87.645332
0  2.40713 105.953267
0  1.900604        86.457811
0  0.546668        104.519977
0  0.231848        150.261891
0  0.678779        122.821333
0  0.821358        164.666895
```

```
0  1.982078       131.519052
0  0.721494       117.748907
0  2.106338       122.687612
0  0.898603       80.988743
0  1.407155       101.271866
111-0.529483      231.404658
50 -0.820042      188.918638
101-0.329668      272.129617
123-0.895998      404.924612
70 -1.693785      296.404843
66 -0.976387      271.427186
233-0.364425      275.685063
69 -0.81849       233.147919
60 -0.527409      214.820505
92 -0.943495      1034.293048
0  -4.546387      80.273199
0  -2.135362      79.821638
];

Ta=[0;1];
Tn=[1;0];
x=0;
y=0;
load( 'check.mat' , 'net');

for i=1:170
simul=sim(net,testt(i,:)');
simul2=round(simul);
if simul2 == Tn;
    x=x+1;
end
end
for i=171:182
simul=sim(net,testt(i,:)');
simul2=round(simul);
if simul2==Ta;
    y=y+1;
end
end
 % display text
% if simul2==Ta;
%  h = msgbox('Abnormal','Classification Result');
% else
%      h = msgbox('Normal','Classification Result');
% end
%the number of normal RBCs is x
%the number of upnormal RBCs is y
x =
   170
y =
    12
```

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