Support Vector Data Description (SVDD) of Roller Bearing time series

Detection of Outliers in Rolling Element Bearing Datasets using Support Vector Data Description

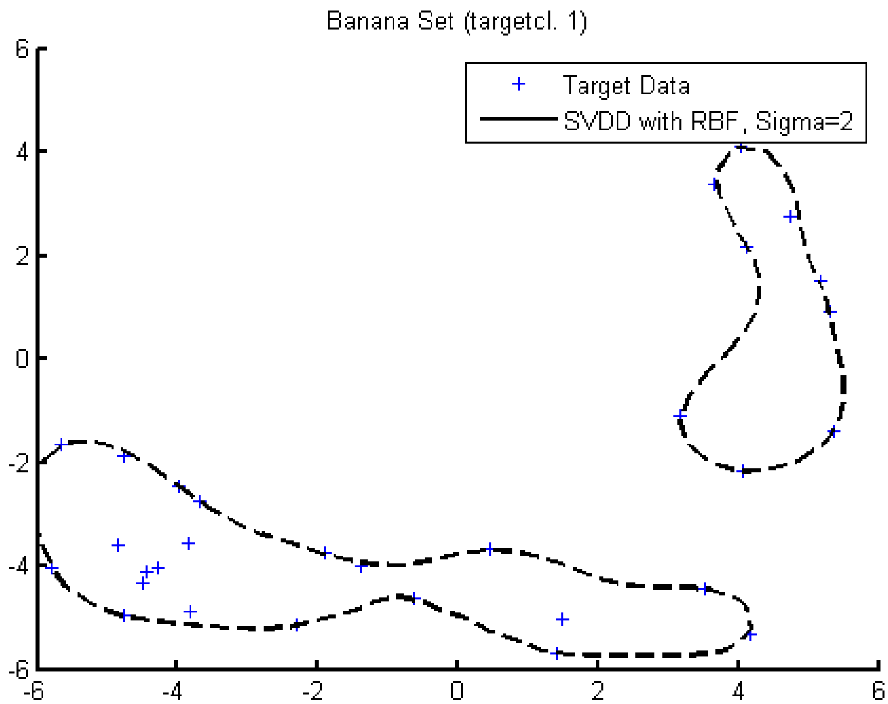
Contents

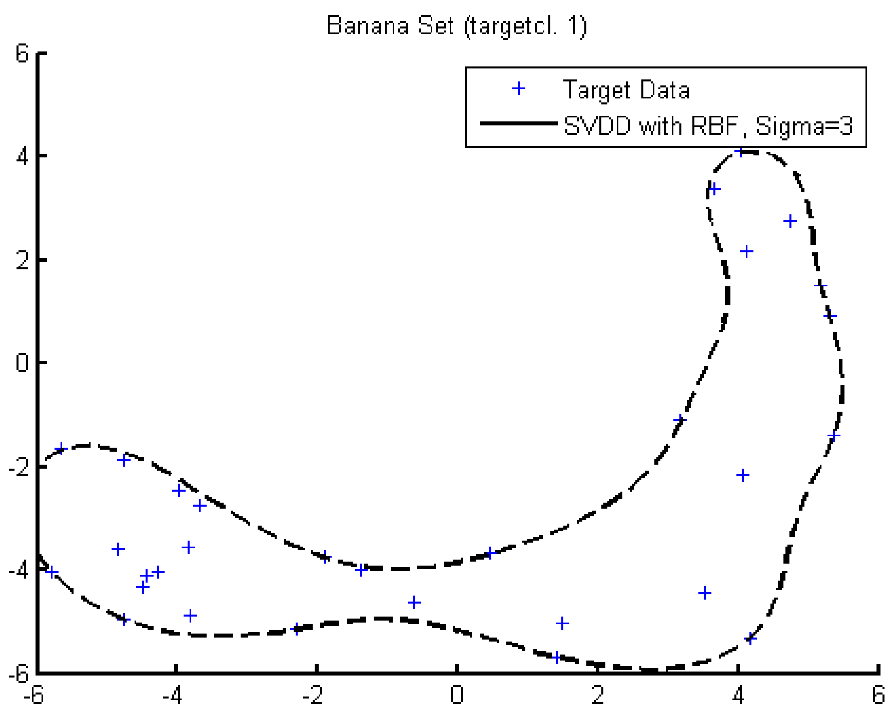
SVDD sample

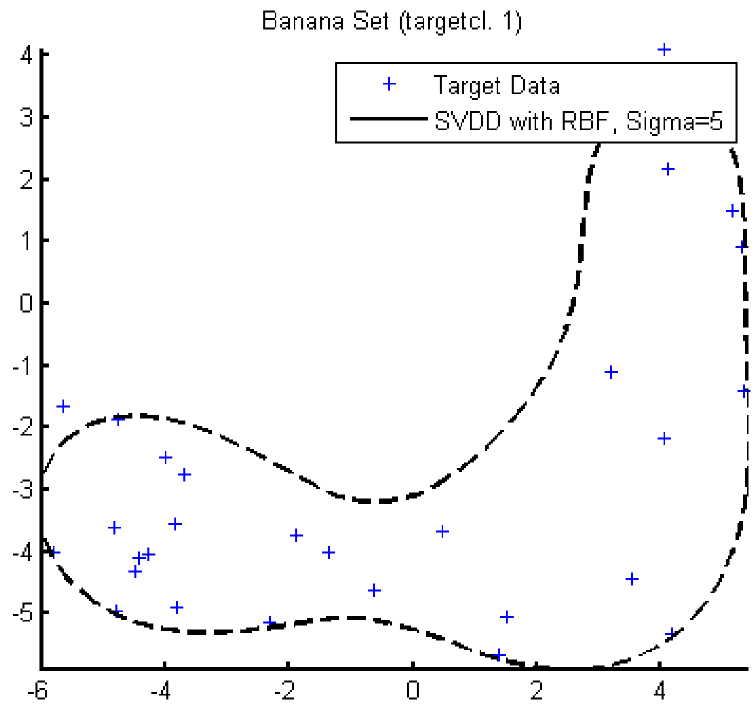
Creates a banana-shaped one-class dataset and calculates three different SVDD mappings with Radial Basis Functions with different Sigma values (1)

```
a = gendatb([30 30]);
% Setting of the second class as target class
a = oc_set(a,'1');
a = target_class(a);
% Generation of test data
b = oc_set(gendatb(200),'1');
V = axis; axis(1.5*V);
% Training of three SVDDs
H=[0;0];
fracrej = 0.2;
figure(1); clf; hold on;
s=scatterd(a);
w1 = svdd(a,fracrej,2);
h=plotc(w1,'k--');
H(1)=s;
H(2)=h;
legend(H,'Target Data','SVDD with RBF, Sigma=2');
hold off;
figure(2); clf; hold on;
s=scatterd(a);
w2 = svdd(a,fracrej,3);
h=plotc(w2,'k--');
H(1)=s;
H(2)=h;
legend(H,'Target Data','SVDD with RBF, Sigma=3');
hold off;
figure(3); clf; hold on;
s=scatterd(a);
w3 = svdd(a,fracrej,5);
h=plotc(w3,'k--');
H(1)=s;
H(2)=h;
legend(H,'Target Data','SVDD with RBF, Sigma=5');
axis equal;
axis image;
```

```
Warning: Divide by zero.
Warning: Divide by zero.
Warning: Divide by zero.
```


Banana Set (targetcl. 1)
Target Data
SVDD with RBF, Sigma=2
6
4
2
0
-2
-4
-6
-6
-4
-2
0
2
4
6


Banana Set (targetcl. 1)
Target Data
SVDD with RBF, Sigma=3
6
4
2
0
-2
-4
-6
-6
-4
-2
0
2
4
6



Preprocessing

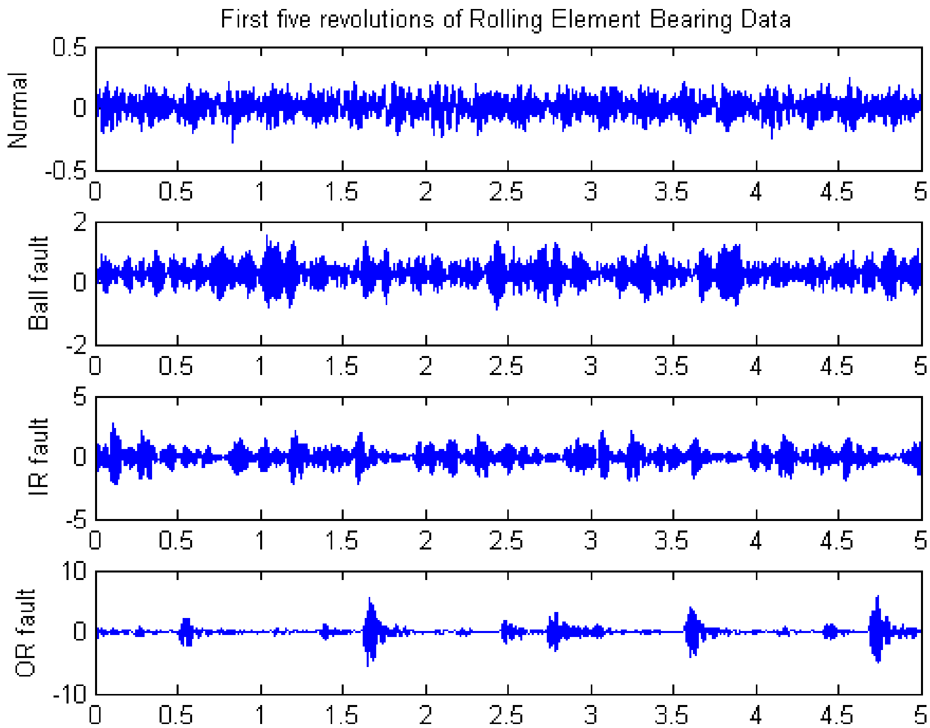
Partitions Roller Bearing time signals into segments of 5 revolutions (2,3)

```
numberOfRevolutionsPerSegment=5;
rpm=1796;
sampleFrequency=48000;
normalSegments=SegmentRotationTimeSignal(...
    normalRawData1797rpm48k,...
    rpm,...
    sampleFrequency,...
    numberOfRevolutionsPerSegment);
ballFaultSegments=SegmentRotationTimeSignal(...
    ballFaultRawData1797rpm48k,...
    rpm,...
    sampleFrequency,...
    numberOfRevolutionsPerSegment);
innerRacewayFaultSegments=SegmentRotationTimeSignal(...
    innerRacewayFaultRawData1797rpm48k,...
     rpm,...
     sampleFrequency,...
     numberOfRevolutionsPerSegment);
 outerRacewayFaultSegments=SegmentRotationTimeSignal(...
    outerRacewayRawData1797rpm48k,...
     rpm,...
     sampleFrequency,...
     numberOfRevolutionsPerSegment);

 numberOfDataPoints = size(normalSegments,1);
 deltaX = numberOfRevolutionsPerSegment/numberOfDataPoints;
 xScale = (0+deltaX):deltaX:numberOfRevolutionsPerSegment;

%Plots the first segment of each dataset
figure(1); clf;
subplot(4,1,1),
    plot(xScale,normalSegments(:,1)),
    title('First five revolutions of Rolling Element Bearing Data')
    ylabel('Normal');
subplot(4,1,2),
    plot(xScale,ballFaultSegments(:,1)),
```

```
    ylabel('Ball fault');
subplot(4,1,3),
    plot(xScale,innerRacewayFaultSegments(:,1)),
    ylabel('IR fault');
subplot(4,1,4),
    plot(xScale,outerRacewayFaultSegments(:,1));
    ylabel('OR fault');
```



Feature Extraction

Extracts Kurtosis (k),Mel Frequency Cepstrum Coefficients (c) and Multifractal Dimensions (m) as 27-tupels in the format (c1...c13,m1...,m13,k) (3)

```
    normalFeatures = ...
        ExtractRollerBearingFeatures(normalSegments, sampleFrequency);
    %First normal features vector:
    normalFeatures(1,:)
    ballFaultFeatures =...
        ExtractRollerBearingFeatures(ballFaultSegments,sampleFrequency);
    %First ball fault features vector
    ballFaultFeatures(1,:)
    innerRacewayFaultFeatures =...
        ExtractRollerBearingFeatures(innerRacewayFaultSegments,sampleFrequency);
    %First inner raceway fault features
    innerRacewayFaultFeatures(1,:)
    outerRacewayFaultFeatures=...
        ExtractRollerBearingFeatures( outerRacewayFaultSegments,sampleFrequency);
    %First outer raceway fault features
    outerRacewayFaultFeatures(1,:)
    %ToDo: PCA to remove redundancies in dataset
```

```
ans =

  Columns 1 through 5

   93.2835   -4.5085   -0.4379   -8.3268    1.6988
```

```
  Columns 6 through 10

   -7.0603   -9.3236    7.2506    1.0004    2.6586

  Columns 11 through 15

    7.8623   -4.8782   -2.4223    1.2117    1.2668

  Columns 16 through 20

    1.3252    1.3862    1.4548    1.5351    1.6284

  Columns 21 through 25

    1.7247    1.7949    1.8255    1.8279    1.8174

  Columns 26 through 27

    1.8034    2.8706


ans =

  Columns 1 through 5

  110.4900  -11.2485    3.4535   -4.2647    1.8583

  Columns 6 through 10

    9.1920  -13.9305   13.3238   -3.7039    3.7564

  Columns 11 through 15

    9.4294    3.2273    2.1557    1.0654    1.0873

  Columns 16 through 20

    1.1120    1.1404    1.1719    1.2073    1.2458

  Columns 21 through 25

    1.2880    1.3342    1.3846    1.4401    1.5013

  Columns 26 through 27

    1.5676    3.2507


ans =

  Columns 1 through 5

  116.9204  -16.0576    2.6369   -7.1706  -20.4653

  Columns 6 through 10

   -4.5033  -13.7211    7.0555   -7.6276   15.8025

  Columns 11 through 15

    4.1259    1.8448   -2.5223    1.0527    1.0726

  Columns 16 through 20

    1.0967    1.1235    1.1541    1.1884    1.2270

  Columns 21 through 25

    1.2699    1.3183    1.3725    1.4342    1.5051

  Columns 26 through 27

    1.5871    3.9930
```

```
ans =

  Columns 1 through 5

  113.5618  -13.7492    4.9438   -7.4862   -4.8346

  Columns 6 through 10

  -14.2957  -15.5283   20.2440   -0.5760    9.8308

  Columns 11 through 15

    0.8089   -1.9020   10.2831    1.0773    1.1036

  Columns 16 through 20

    1.1325    1.1653    1.2015    1.2425    1.2877

  Columns 21 through 25

    1.3385    1.3962    1.4615    1.5357    1.6177

  Columns 26 through 27

    1.6972   19.1720
```

Training and test set generation

Creates a target dataset with normal features for training and a dataset with target and outlier samples for testing a Support Vector Data Description (1)

```
normalFeaturesDataSet=dataset(normalFeatures);
ballFaultFeaturesDataSet=dataset(ballFaultFeatures);
innerRacewayFaultFeaturesDataset=dataset( innerRacewayFaultFeatures );
outerRacewayFaultFeaturesDataset=dataset(  outerRacewayFaultFeatures);
%Creates a target data training set with normal features
targetData =...
    gendatoc(normalFeaturesDataSet);
%Creates an outlier dataset with ball fault features
ballFaultOutliers =...
    gendatoc([],  ballFaultFeaturesDataSet);
%Creates an outlier dataset with inner raceway fault features
innerRacewayFaultOutliers=...
    gendatoc([],  innerRacewayFaultFeaturesDataset);
%Creates an outlier dataset with outer raceway fault features
outerRacewayFaultOutliers=...
    gendatoc([],  outerRacewayFaultFeaturesDataset);

%Creates a test dataset with 50 random samples drawn from each dataset
numberOfTestSamples=50;
[targetTestData,targetTrainingData]=...
    gendat(targetData, numberOfTestSamples);
[ballFaultTestData,]=...
    gendat(ballFaultOutliers, numberOfTestSamples);
[innerRacewayFaultTestData,]=...
    gendat(innerRacewayFaultOutliers,numberOfTestSamples);
[outerRacewayFaultTestData,]=...
    gendat(outerRacewayFaultOutliers,numberOfTestSamples);
testData=[targetTestData;...
          ballFaultTestData;...
          innerRacewayFaultTestData;...
          outerRacewayFaultTestData];
```

SVDD Training

Uses the target data to calculate an SVD mapping with a rejection rate of 0.2 and an RBF-Kernel with Sigma=5 (4)

```
w = svdd( targetData,0.2,5);
```

```
Warning: Divide by zero.
Warning: Your Hessian is not symmetric. Resetting
H=(H+H')/2.
```

Error evaluation

Calculates false negative (rejected targets) and false positive (accepted outliers) rates and plots a ROC curve (1)

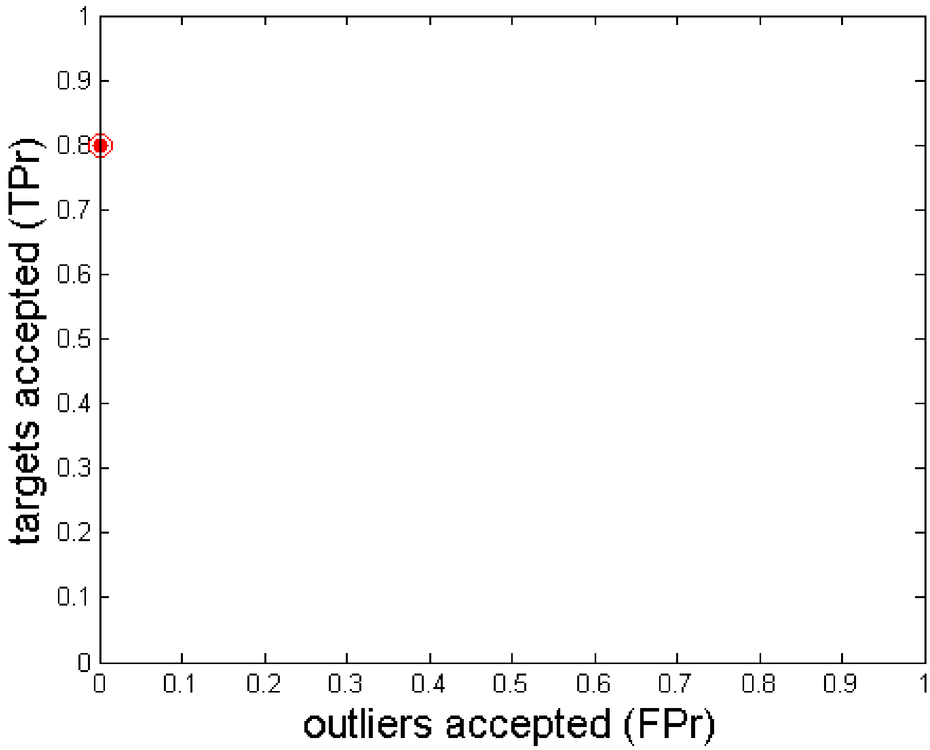
```
e = dd_error(testData,w);
%False Negatives:
e(1)
%False Positives:
e(2)
%Roc
figure(2); clf;
plotroc(dd_roc(testData*w),'r');
```

```
ans =

    0.2000


ans =

     0
```



References

1. PRTools4, A Matlab Toolbox for Pattern Recognition Version 4.1 (R.P.W. Duin,D.M.J. Tax et al.)
2. http://csegroups.case.edu/bearingdatacenter/pages/welcome-case-western-reserve-university-bearing-data-center-website
3. "Early Classification Of Bearing Faults Using Hidden Markov Models,Gaussian Mixture Models,

Mel-Frequency Cepstral Coefficients and Fractals" (Marwala et al)
4. "Support Vector Data Description" (Tax,Duin)
http://mediamatica.ewi.tudelft.nl/sites/default/files/ML_SVDD_04.pdf

Published with MATLAB® 7.8