# Biometrics: Dynamic signature

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## 1 Introduction

In this report I will test GMM and DTW methods and describe its result. Also I will try to optimize results and tune hyperparameters to better performances. In the end of report I will show work of methods on my own signatures.

I'm 12th in the student list, so I have signatures IDs:

persons = [1 2 4 7 8 10 13 18 26 27 29 31 32 34 38]

### 1.1 Choosing threshold strategy

To choose threshold, we should know what is our main aim. Dynamic signatures are usually used for person verification, so I decided to set threshold, that's maximum permissible False Negative Rate (fake signature perceived as genuine) is 10% ( $max\_FN = 0.1$ ).

### 1.2 Abbreviations

- FP or FPR is False Positive Rate.

- FN or FNR is False Negative Rate.

## 2 GMM method

### 2.1 Algorithm for finding threshold

I write a simple algorithm for finding threshold.

1. Set variable $global\_threshold = 0$.

2. for person $i$ do:

3.     Make GMM model using training signatures (by defaul $trainSamplesNum = 3$ and $gausianNum = 3$, using coordinates and pressure).

4.     Find scores of testing set using computed model.

5.     Using function $get\_err(clss, scores)$ get results of thresholding by every score in scores. Using this data, find the first score occurrence, where FN is less then $max\_FN$, lable it $iteration\_threshold$.

6.     Update $global\_threshold$ this way: $global\_threshold = global\_threshold + \frac{iteration\_threshold}{persons\_amount}$.

### 2.2 Testing the algorithm

#### 2.2.1 Testing with just 5 persons

Let's start testing with signature from 5 different persons.

After making 50 start of algorithm the results are:

- Threshold fog GMM is -3561.

- Amount of test cases is 185.

- Amount of False Negatives is 15.

- Amount of False Positives is 50.

- Error is: 0.351.

- False Negative error: 0.081.

- False Positive error: 0.270.

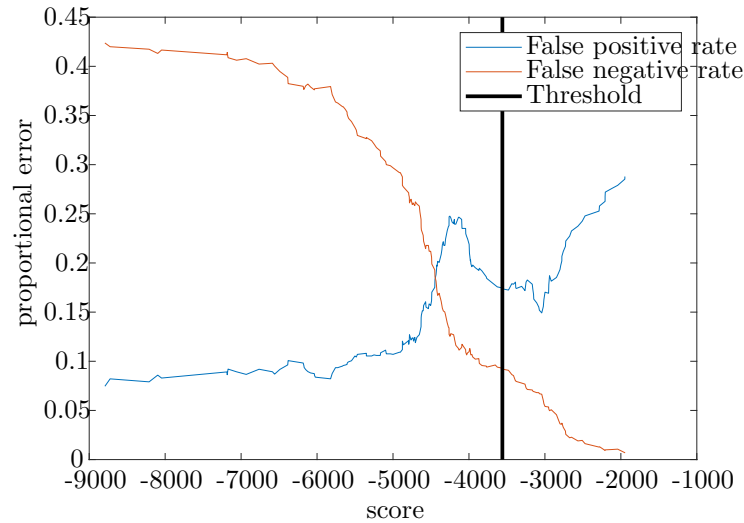Let's put all test cases on the graph with threshold.



Figure 1: FPR/FNR of 5 persons computed using GMM model.

### 2.2.2  Testing with 12 persons

Let's start testing with signature from 12 different persons. After making 50 start of algorithm the results are:

- Threshold fog GMM is -4084.

- Amount of test cases is 444.

- Amount of False Negatives is 25.

- Amount of False Positives is 111.

- Error is: 0.306.

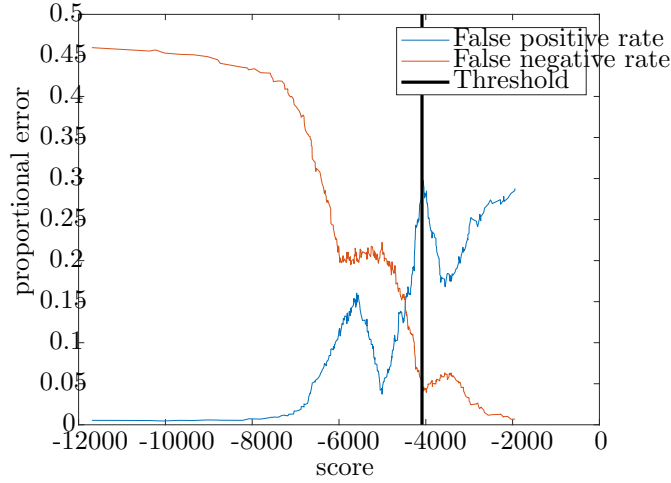- False Negative error: 0.056.

- False Positive error: 0.250.

Figure 2: FPR/FNR of 12 persons computed using GMM model.

### 2.2.3 Testing analysis

As we can see, that the global error is bigger when we computing threshold using 5 person's data instead of 12 persons.

## 3 DTW method

I implemented DTW algorithm in scripts *make_model*.m and *score*.m.

### 3.1 Algorithm for finding threshold

It's easier to find threshold in DTW, because model contained only example signatures and it shouldn't learn.

1. Set variable $global\_threshold = 0$.

2. for person $i$ do:

3. Save example signatures to DTW model ( by default $trainSamplesNum = 3$, using coordinates and pressure).

4. Find scores of testing set using DTW model.

5. Using function $get\_err(clss, scores)$ get results of thresholding by every score in scores. Using this data, find the first score occurrence, where FN is less then $max\_FN$, label it $iteration\_threshold$.

6. Update $global\_threshold$ this way: $global\_threshold = global\_threshold + \frac{iteration\_threshold}{persons\_amount}$.

### 3.2 Testing the algorithm

#### 3.2.1 Testing with just 5 persons

- Threshold fog DTW is -102608.

- Amount of test cases is 185.

- Amount of False Negatives is 7.

- Amount of False Positives is 42.

- Error is: 0.265.

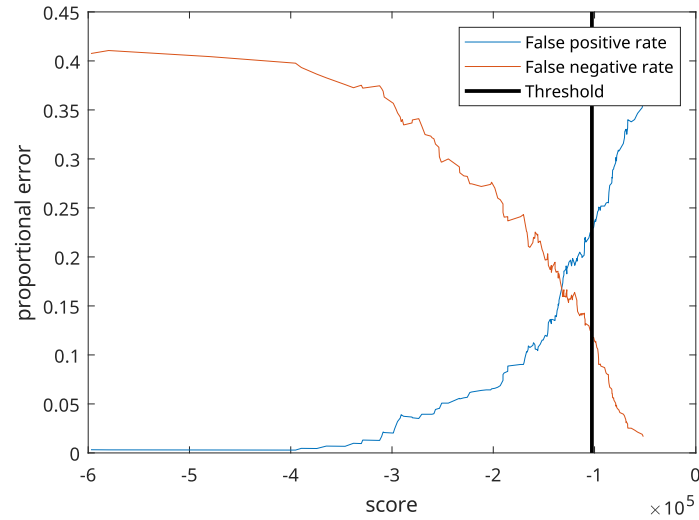- False Negative error: 0.038.

- False Positive error: 0.227.



Figure 3: FPR/FNR of 5 persons computed using DTW model.

### 3.2.2 Testing with 12 persons

- Threshold fog DTW is -110191.

- Amount of test cases is 444.

- Amount of False Negatives is 11.

- Amount of False Positives is 112.

- Error is: 0.277.

- False Negative error: 0.025.
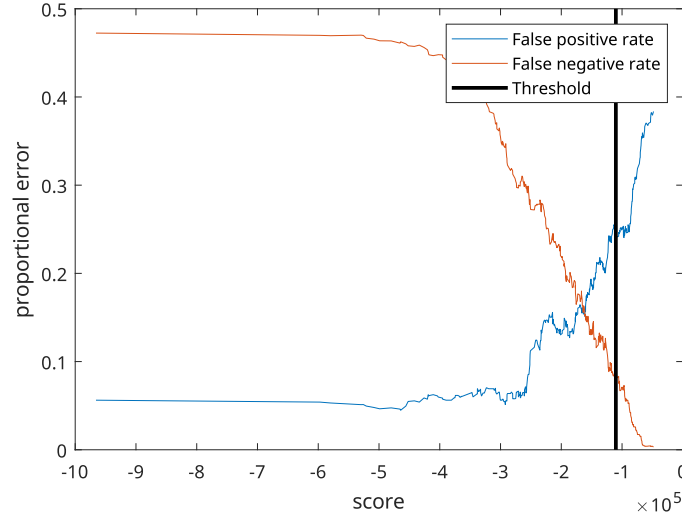
- False Positive error: 0.252.

Figure 4: FPR/FNR of 12 persons computed using DTW model.

### 3.2.3 Testing analysis

As we can see, that results are more accurate when we use more testing data to find optimal threshold.
Using DTW method we have less error then using GMM.

# 4 Optimization

## 4.1 Data normalization

Implementation in *preprocess.m*
We can normalize features using formula $x_{normalized} = \frac{x - \mu}{sigma^2}$.

- Error is: 0.313.

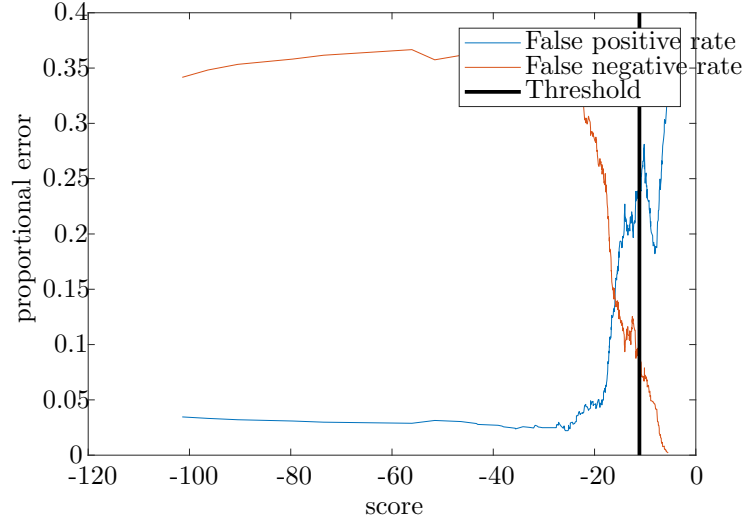- False Negative error: 0.052.

- False Positive error: 0.261.

Figure 5: FPR/FNR of DTW method using normalized input data.

Results are worse while we are using normalization. I think it's because after normalization we loss details of signature contour creation.

## 4.2 Adding extra features

Implementation in *extract_features.m*
I added extra features, velocity $v_t$ and acceleration $a_t$ in every time step.
The results are:

- Error is: 0.273.

- False Negative error: 0.023.
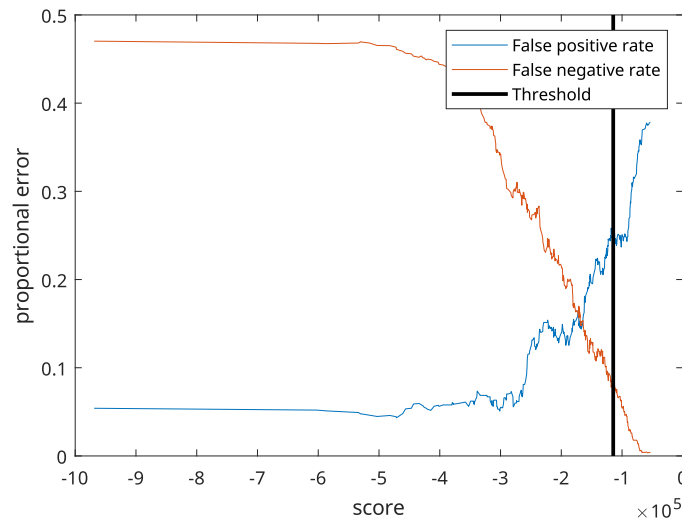
- False Positive error: 0.250.



Figure 6: FPR/FNR of DTW method with extra features $v_t$ and $a_t$.

Results are better, because of bigger amount of information about signature contour creating.

# 5 Size of testing set

In this section I'll classify signatures with extra features using DTW with different (by size) test sets.

- 1 signature

  - Error is: 0.314.
  - False Negative error: 0.011.
  - False Positive error: 0.303.

- 3 signatures (default)

  - Error is: 0.273.
  - False Negative error: 0.023.
  - False Positive error: 0.250.

- 5 signatures

  - Error is: 0.260.
  - False Negative error: 0.012.
  - False Positive error: 0.248.

- 7 signatures

  - Error is: 0.232.
  - False Negative error: 0.061.
  - False Positive error: 0.172.

As we can see that results are improving in proportion to the number of test samples. But in real life using more then 3 samples is time consuming, so the most commonly used value is 3.

# 6 Classification of own signature

I captured my own signature on tablet for dynamic signatures. Also I asked a classmate to falsify my signature.
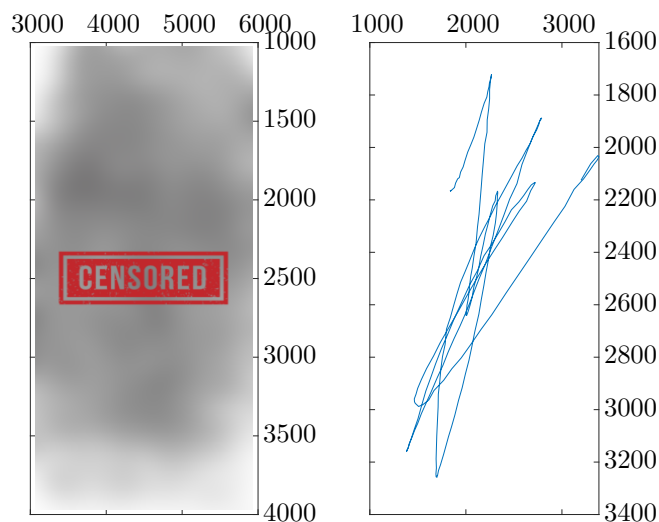


Figure 7: Original (left) and fake (right) signatures.

I chose optimal hyperparameters from other tests.

- Used method: DTW.

- Threshold fog DTW: -114529.

- Amount of train samples: 3.

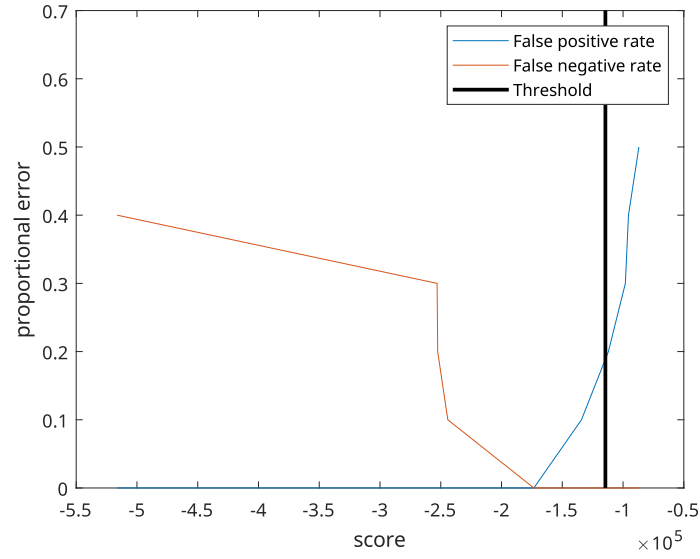- Extra features: velocity, acceleration.

- Normalization: No.



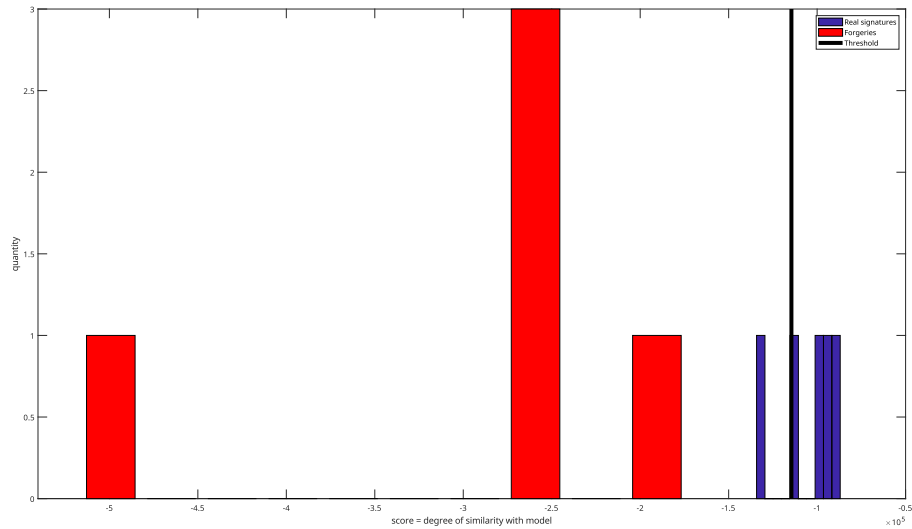Figure 8: FPR/FNR of signatures set.



Figure 9: Ratio of score and right classification.

The results of classification are:

- Amount of test cases is 10.

- Amount of False Negatives is 0.

- Amount of False Positives is 1.

- Error is: 0.100.

- False Negative error: 0.000.

- False Positive error: 0.100.

Only one of the original signatures was classified as fake, it's good result.
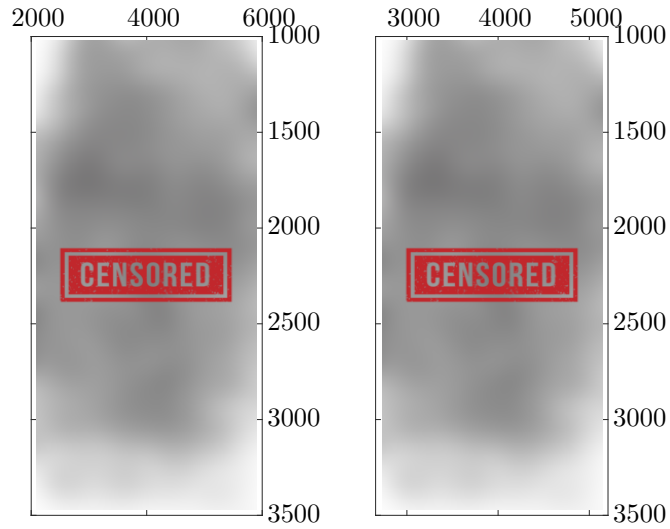


Figure 10: Classified right signature (left) and misclassified signature (right)

# 7    Conclusion

DTF method has better results then GMM. Results of threshold are better proportionally to the amount of train data. Optimal amount of signatures for creating signature model is 3, but bigger amount has better results. Normalization make results worse. Extra features improve accuracy.