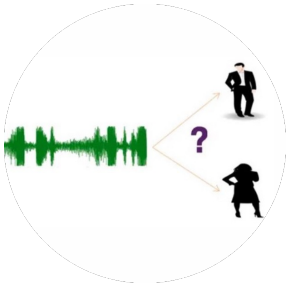

Final NLA Project

Voice Gender Detection using Tensor Power Method

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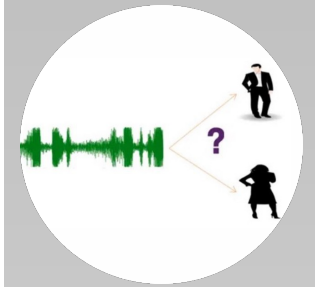
& Oleg Desheulin & Denis Rakitin & Anita Soloveva

December 17, 2020



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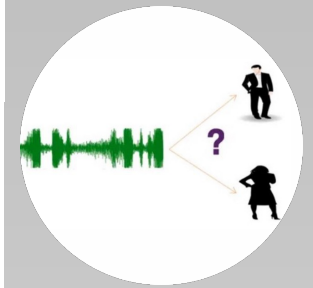
Problem Description

- Gender detection as one of the tasks of Speech Recognition, which has recently gained much popularity with the development of voice-based systems like Alexa, Siri and etc.
- Classical method for gender detection task is Gaussian Mixture Model (GMM) on Mel Frequency Cepstral Coefficients (MFCCs) (Neti & Roukos, 1997). Here we try another approach proposed by (Roy, Bhagath, & Das, 2020) which applies tensor power method to a tensor formed from MFCCs and compare this approach to GMM.



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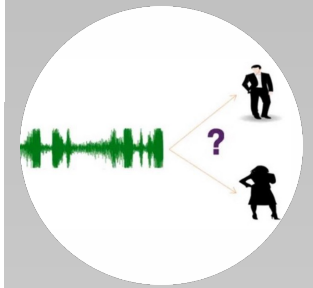
Our goals

- Evaluate the accuracy of gender detection, perfomed by the approach proposed in (Roy et al., 2020), using different sizes of feature vectors, different number of eigenvectors, testing on two datasets:
  - TIMIT DR1 (New England dialect data)
  - SHRUTI (Bengali (minor Indo-Aryan language) data)

Additionally:

- Compare the performance with other approaches
- Test on our own Khanty (minor Finno-Ugric language) corpus



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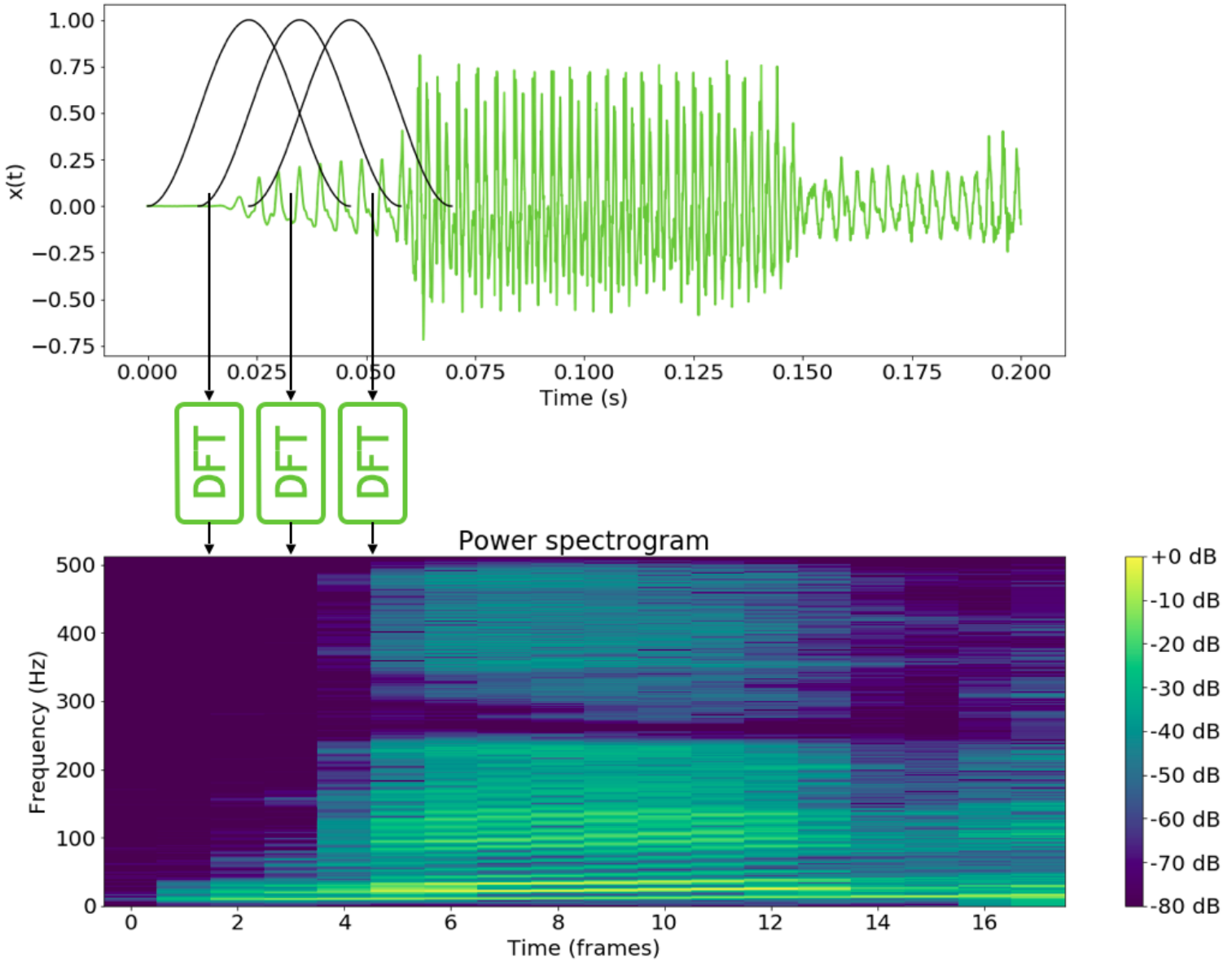
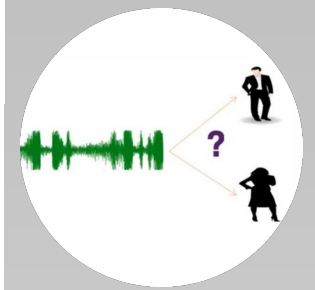
Mel-frequency cepstral coefficients





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Tensor Formation

In order to build 3^{rd} order tensor we apply moment method.

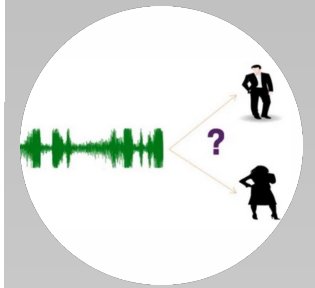
$$m_1 = \mathrm{E}[x] = \frac{1}{N}\sum_{i=1}^{N} x_i$$

$$M_2 = \mathrm{E}[x \odot x] - \sigma^2 I$$

where σ^2 is the smallest eigenvalue of covariance matrix $\Sigma = \mathrm{E}[x \odot x] - m_1 \odot m_1$ and M_2 can be decomposed as

$$M_2 = \sum_{i=1}^{r} w_i a_i \odot a_i \tag{1}$$

Naive approach is to calculate vectors a_i by eigendecomposition.



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Tensor Formation

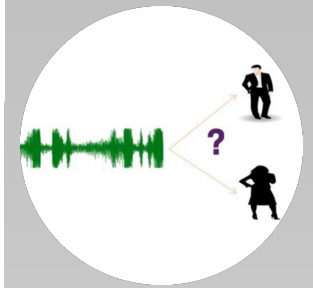
To avoid problems with highly correlated components authors suggests to calculate M_3 rather then M_2 using formulation (Hsu & Kakade, 2013):

$$M_3 = \mathrm{E}[x \odot x \odot x] - \sigma^2 \sum_{i=1}^{d} (m_1 \odot e_i \odot e_i + \cdots + e_i \odot e_i \odot m_1)$$

And like M_2 can be decomposed onto eigenvalue decomposition, for M_3 it also exists in following form:

$$M_3 = \sum_{i=1}^{r} w_i a_i \odot a_i \odot a_i$$

Where a_i is our target eigenvectors of M_2. Then eigenvectors of M_3 are also eigenvectors of M_2.



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Eigenvectors Computation

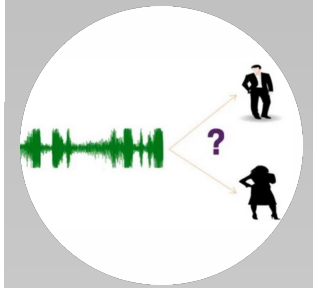
Similar to matrix eignevectors computation for tensors also exists Power Method:

$$a_{i,k+1} = \frac{A_i(I, a_{i,k}, a_{i,k})}{||A_i(I, a_{i,k}, a_{i,k})||_2}$$

And to project to next eigenvector space :

$$A_{i+1} = A_i - \lambda_i a_i \odot a_i \odot a_i$$

We apply this method to whitened M_3 and obtain our feature vectors.



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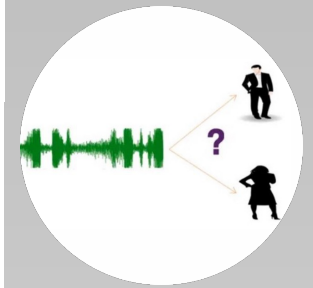
Evaluation

During training stage we found k dominant eigenvectors for both A_f (female) and A_m (male) dataset.
Then distances $D_{f,m}$ between unknown feature vector $x_i \in \mathcal{R}^n$ and eigenvectors $a_{\{f,m\};k}$ of each dataset A_f and A_m is calculated as:

$$D_{\{f,m\}} = \sum_{i=1}^{N} \min_k d(a_{\{f,m\};k}, x_i) \tag{2}$$

$$d(x,y) = 1 - \frac{(x,y)^2}{(x,x)(y,y)} \tag{3}$$

After than we compare D_m and D_f and choose the lowest distance to determine gender of the speaker.



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Results with different sizes of feature vectors

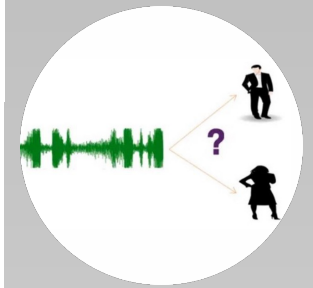
Size	Female accuracy	Male accuracy	Total accuracy
13	0.694	0.897	0.796
20	0.810	0.841	0.825
26	0.828	0.852	0.840

Table: Accuracy on Khanty dataset with 1 eigenvector.

Size	Female accuracy	Male accuracy	Total accuracy
13	0.992	0.777	0.884
20	0.989	0.919	0.954
26	0.989	0.953	0.971

Table: Accuracy on SHRUTI dataset with 1 eigenvector.

Tables are represent dependence of accuracy on size of feature vector.



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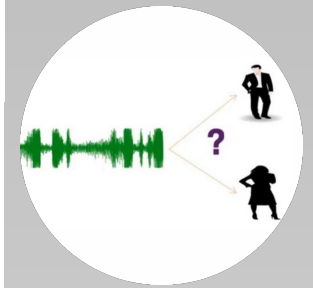
Results with different number of eigenvectors

#	Female accuracy	Male accuracy	Total accuracy
1	0.871	0.822	0.847
2	0.835	0.851	0.843
4	0.828	0.852	0.840

Table: Accuracy on Khanty dataset with 26-size feature vector.

The tables is represent dependence of accuracy on the number of eigenvectors.



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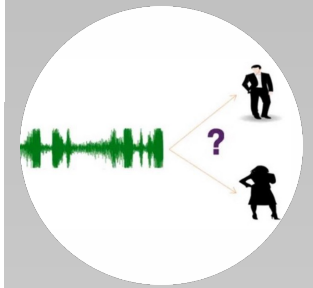
Comparison to other approaches

Method	Female accuracy	Male accuracy	Total accuracy
Article	0.871	0.822	0.847
Naive	0.802	0.856	0.829
GMM	0.968	0.914	0.945

Table: Accuracy on Khanty dataset with the best choice of number of eigenvectors and size of feature vectors



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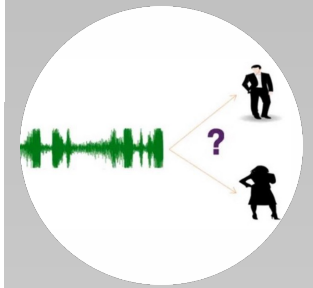
Team Member contribution

- Maxim Brazhnikov: theoretical part, model building, presentation, report
- Maxim Kuznetsov: model testing, results analysis, presentation, report
- Oleg Desheulin: theoretical part, model building, presentation, report
- Denis Rakitin: model building, model testing, presentation, report
- Anita Soloveva: data preprocessing, model testing, presentation, report

Our GitHub repository



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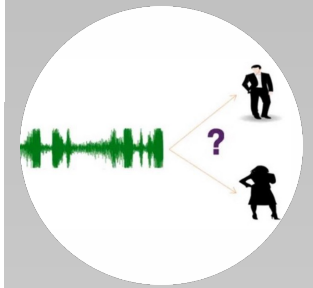

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