Detection of abnormal vocal fold oscillation

Introduction
Examination of the vocal cords is performed using integrated system consisting of high speed video (HSV) camera, electroglottograph (EGG) and module for recording audio signal of the vocal phonation by microphone (MIC). Recording of the HSV examination allows to observe real motion of the vocal folds in time. To assess the quality of vocal cords kinematics and the quality of the glottis closure by observing the video recording without some kind of supporting tools might not be sufficient. That’s why we focused our attention in development of early diagnosis method for severe laryngeal disease on detection of vocal cords kinematic anomalies. These anomalies of vocal cords behavior are detected using method based on estimation of standard oscillation determined from MIC audio recording obtained during HSV examination. Non standard oscillation is detected using estimated standard reference oscillation and system of criterion functions. These non standard oscillations may indicate anomaly of vocal cords motion. With synchronized EGG, HSV video and MIC audio signals we are able to analyze video frames corresponding to non standard oscillation.

Approach and Methods

To detect abnormal oscillations the process consisting of the following steps of preprocessing and analysis of input data from MIC/EGG was devised and tested:
- Detection of \( F_g \) in electroglottograph EGG
- Synchronization of MIC and EGG signals
- Detection of \( F_g \) in audio recording MIC
- Detection of vocal fold oscillations in MIC
- Calculation of standard oscillation estimate
- Detection of anomaly/non standard oscillation
- Visualization and analysis of video frames corresponding to non standard oscillation

Methods of standard oscillation estimation:

**Time domain** (generated standard oscillation) based on resampling of oscillations to match \( F_g \):
- The method of arithmetic average of samples
- The method of median values of samples

**Frequency domain** (selected representative oscillation) Based on calculation of Fourier development and amplitude spectrum
- The method of minimal Euclidean distance from median of amplitude spectrum
- The method of score of occurrence frequency of amplitude spectrum values

Methods of abnormal oscillation detection:

- **Time domain**: average deviation \( D_e \) of samples of single oscillation
- \( D_e \) of samples of single oscillation score \( D_e \) of samples of single oscillation out of \( \alpha, 2\alpha \) and \( 3\alpha \) strip
  \[
  D_e[k] = \frac{1}{N} \sum_{i=1}^{N} |x_i[k] - y_i[k]|, \quad \forall \propto k = 1, \ldots, N
  \]
- \( D_{eg} \) of samples of single oscillation
  \[
  D_{eg}[k] = \frac{1}{N} \sum_{i=1}^{N} |x_i[k] - y_i[k]|, \quad \forall \propto k = 1, \ldots, N
  \]
- \( D_{eg} \) of samples of single oscillation
  \[
  D_{eg}[k] = \frac{1}{N} \sum_{i=1}^{N} |x_i[k] - y_i[k]|, \quad \forall \propto k = 1, \ldots, N
  \]

**Frequency domain**
- Fourier development, amplitude spectrum
- The method of maximal Euclidean distance \( D_{eg} \) of amplitude spectra of oscillations
- \( D_{eg} \) of Fourier Descriptors

\[
D_{eg}[k] = \sum_{i=1}^{N} A_i[k], \quad \forall \propto k = 1, \ldots, N
\]

where \( A_i[k] \) and \( D_i[k] \) are Fourier descriptor.

Conclusion
Detection of abnormal oscillation was tested on number of casuistry from HSV examination database. Results are presented on selected casuistry (mucus on vocal cord at the beginning of phonation 1...–16 oscillation):