FACULTY
OF APPLIED SCIENCES
UNIVERSITY
OF WEST BOHEMIA

Detection of abnormal vocal fold oscillation

BIOMEDICAL INFORMATICS GROUP

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING
FACULTY OF APPLIED SCIENCES
UNIVERSITY OF WEST BOHEMIA
PILSEN, CZECH REPUBLIC

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_0 in electroglottogram EGG
- Synchronization of MIC and EGG signals
- Detection of F_0 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

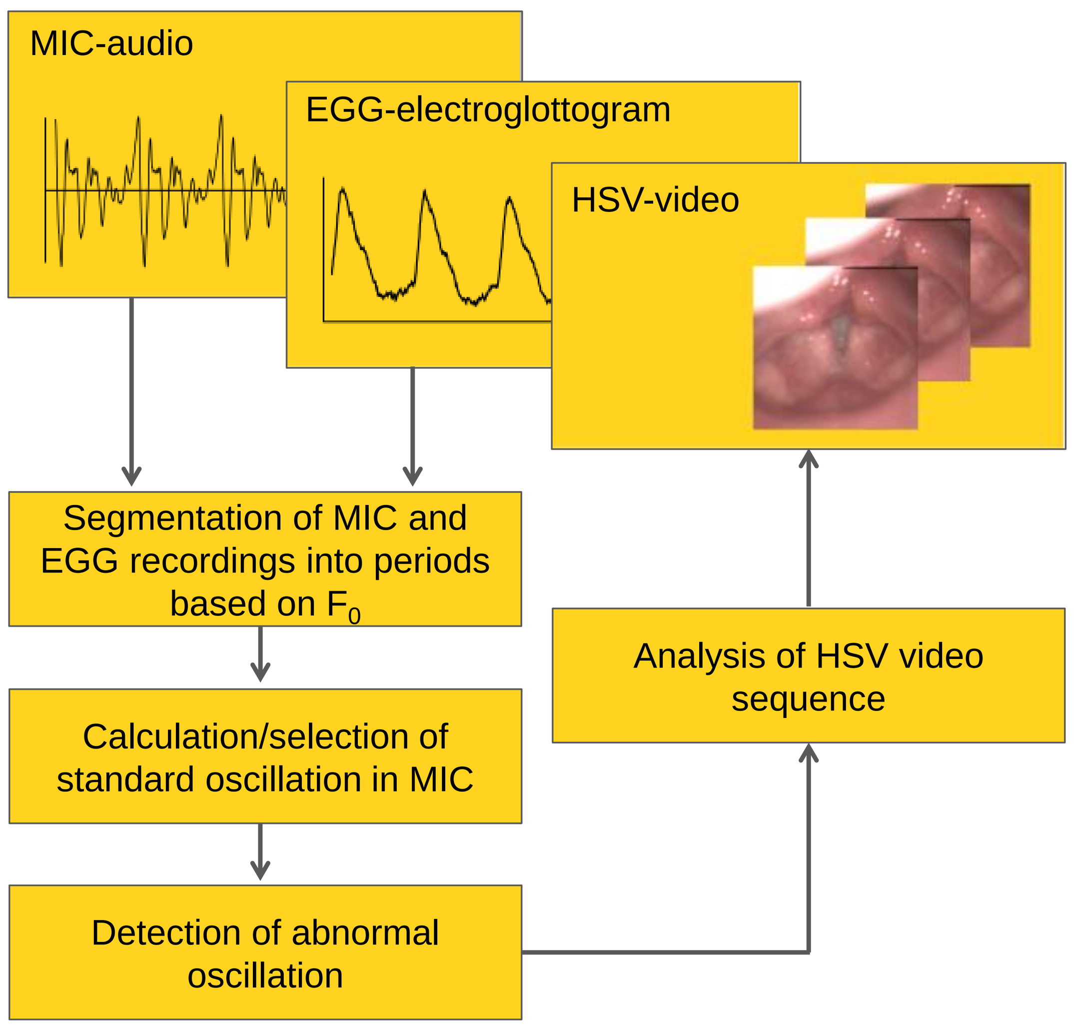


Diagram of detection and analysis of abnormal oscillation.

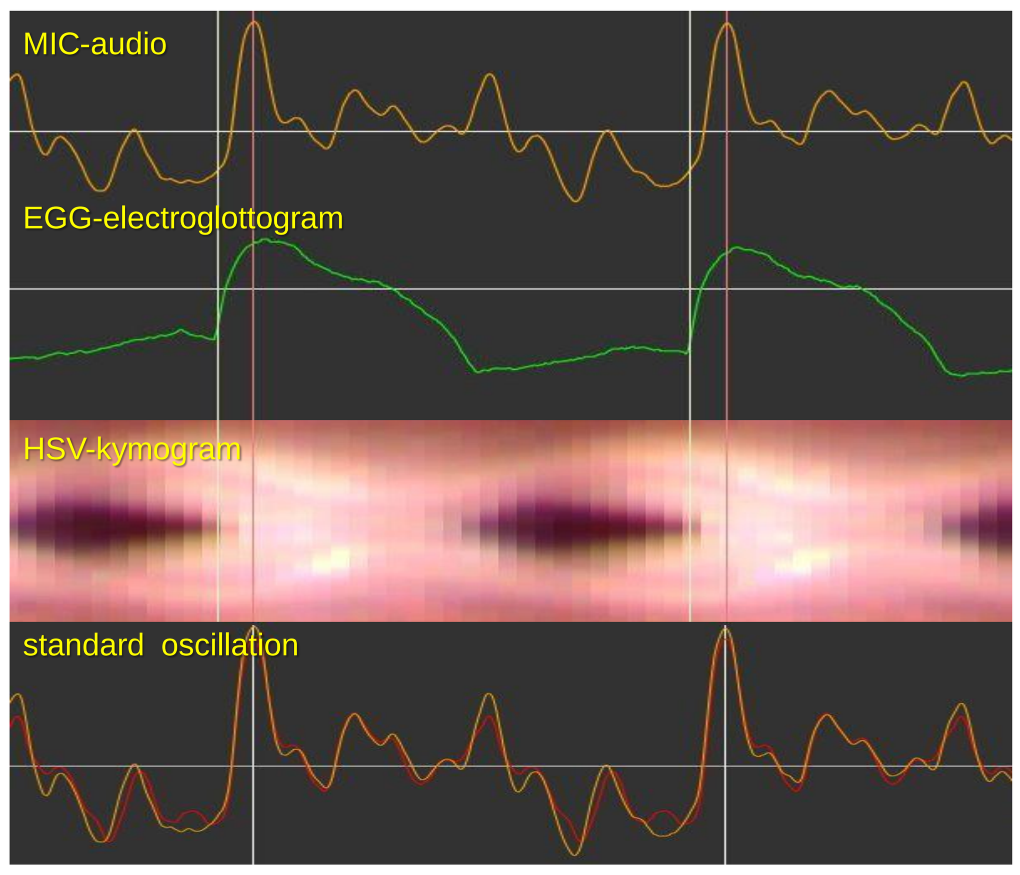
Methods of *standard* oscillation estimation:

time domain (generated standard oscillation)
based on resampling of oscillations to match F_0

- 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



Visualization of audio recording MIC, EGG signal, video recording HSV in form of kymogram and generated estimate of standard oscillation (healthy vocal cords).

Methods of **abnormal** oscillation detection:

(relative to standard oscillation)

time domain

- average deviation D_s of samples of single oscillation
- Euclidean distance D_{sd} of samples of single oscillation
- score D_σ of samples of single oscillation out of σ, 2σ, 3σ strip

$$D_s[k] = \frac{1}{L}\sum_{i=0}^{L} |x_s[i] - x_k[i]|,\ pro\ \forall\ k = 1, \dots, N$$

$$D_{sd}[k] = \sqrt{\sum_{i=0}^{L} (x_s[i] - x_k[i])^2},\ pro\ \forall\ k = 1, \dots, N$$

$$D_\sigma[k] = \frac{1}{L}\sum_{i=0}^{L} y_k[i],\ pro\ \forall\ k = 1, \dots, N$$

where $y_k[i]$ denotes degree of sample difference from σ, 2σ and 3σ strip

frequency domain

- Fourier development, amplitude spectrum
- The method of maximal Euclidean distance D_{sAA} of amplitude spectra of oscillations
- The method of maximal Euclidean distance D_{fd} of Fourier Descriptors

$$D_{AA}[k] = \sqrt{\sum_{i=0}^{HARM} (AA_{ss}[i] - AA_{kk}[i])^2},\ pro\ \forall\ k = 1, \dots, N$$

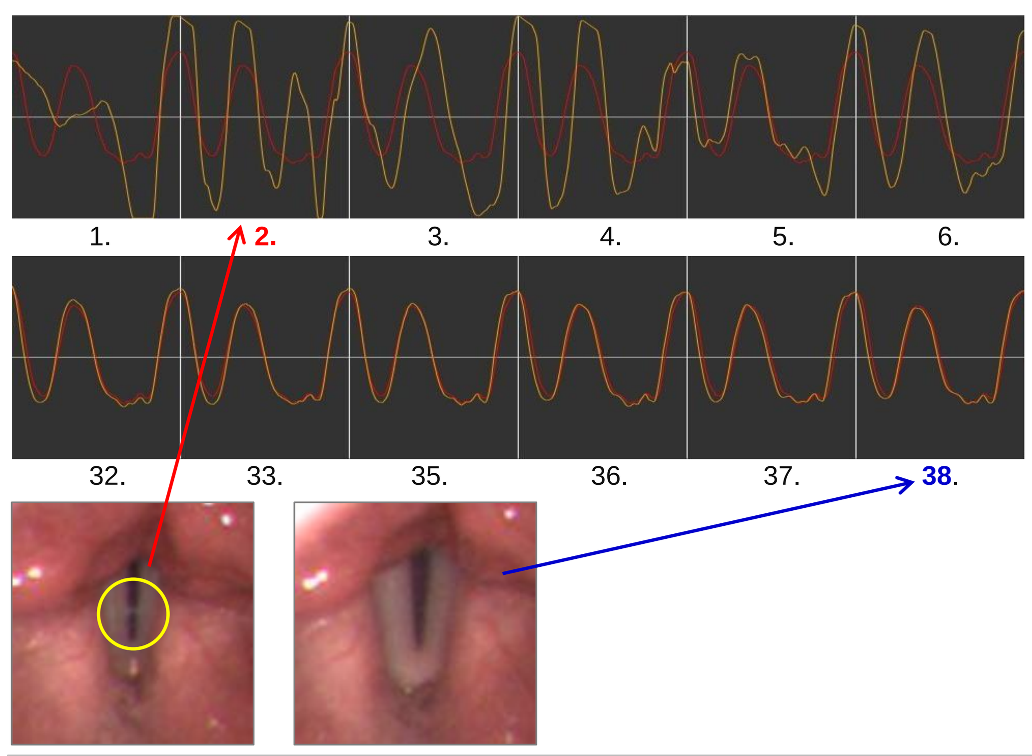
$$D_{fd}[k] = \sqrt{\sum_{i=0}^{HARM} (D_s[i] - D_k[i])^2},\ pro\ \forall\ k = 1, \dots, N$$

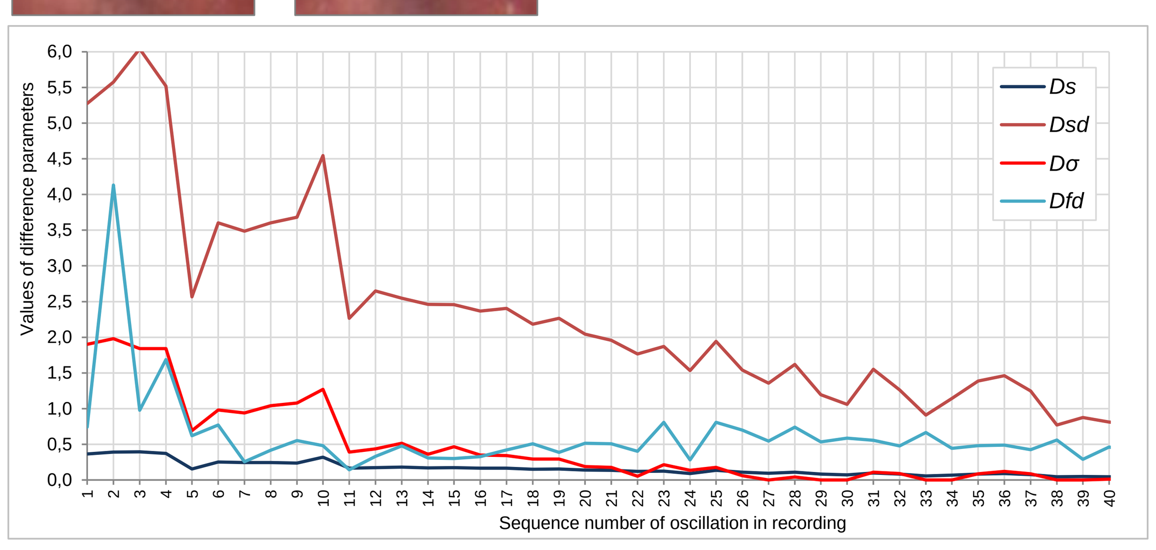
where $D_s[i]$ and $D_k[i]$ are Fourier descriptor.

Conclusion

Detection of abnormal oscillation was tested on number of casuistries from HSV examination database.

Results are presented on selected casuistry
(mucus on vocal cord at the beginning of phonation
1. – 10. oscillation):



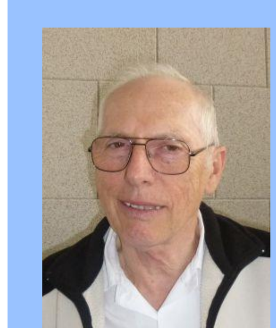


Pavel Nový
novyp@kiv.zcu.cz
Senior Researcher
Research areas:
- Signal and image processing
- Biomedical data analysis
- Audiology and phoniatry

Tomáš Ettler
thritton@kiv.zcu.cz
Junior Researcher
Research areas:
- Signal and image processing
- Medical data processig and analysis
- Database systems

Lukáš Kroupa
kroupal@students.zcu.cz
Student
Research areas:
- Signal and image processing
- Database systems

František Vávra
vavra@kma.zcu.cz
Senior Researcher
Research areas:
- Statistical methods and analysis
- Application of information and cybernetics theory in biomedical areas



Jiří Pešta
pestaj@fnplzen.cz
Expert of Otorhinolaryngology
Research areas:
- Audiology and phoniatry
- Signal processig

<KIV> KATEDRA INFORMATIKY A VÝPOČETNÍ TECHNIKY
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