Glottis Center of Gravity Position During Phonation

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| Introduction

The vocal cords kinematics is examined using a High Speed Video (HSV) camera. The recording enables observing slowed down real movement of the vocal cords. In order to analyze the phonation quality accurately, as many as possible parameters should be acquired. Therefore, our goal is to extend the set of these parameters for further analysis and evaluation.

This paper deals with calculating position of the center of gravity in the glottal gap area and the border and its movement during phonation. These parameters are not commonly used in commercial software for HSV.

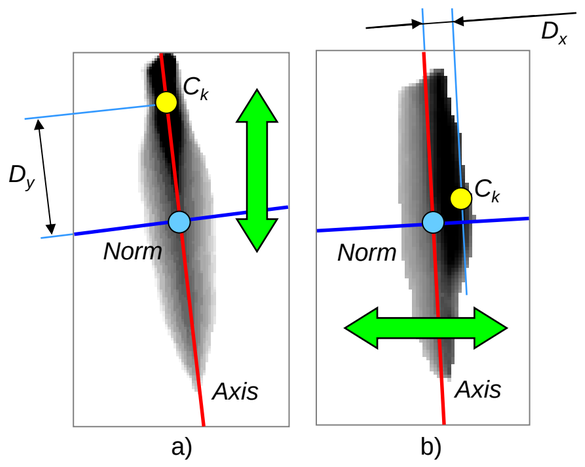
| Methods

At first, glottal gap area has to be detected by segmentation methods in all frames of video recordings. The axis system based on the symmetry axis and its normal can be used to avoid inconsistency of the data caused by movement of the camera.

The parameters of the glottal gap center of gravity C_k in the frame k of video sequence are:

D_x – the distance between the center of gravity and the axis of symmetry

D_y – the distance between the center of gravity and the normal



Principal diagram of D_x and D_y center of gravity development during one vocal cord vibration.
a) symmetric vocal cords
b) asymmetric vocal cords

For these parameters, following formulas apply:

$$D_x = \frac{a\,x_C + b\,y_C + c}{\sqrt{a^2 + b^2}}, \quad D_y = \frac{a_{norm}\,x_C + b_{norm}\,y_C + c_{norm}}{\sqrt{a_{norm}^2 + b_{norm}^2}},$$

where x_c and y_c are coordinates of the center of gravity according to its type:

1) Center point of the area S_k:

$$x_C^{(S)} = \frac{1}{A_k}\sum_{x_S \in S_k}\sum_{y_S \in S_k} x_S\,, \quad y_C^{(S)} = \frac{1}{A_k}\sum_{x_S \in S_k}\sum_{y_S \in S_k} y_S\,,$$

2) Center point of the border H_k of the area S_k:

$$x_C^{(H)} = \frac{1}{L_k}\sum_{x_H \in H_k}\sum_{y_H \in H_k} x_H\,, \quad y_C^{(H)} = \frac{1}{L_k}\sum_{x_H \in H_k}\sum_{y_H \in H_k} y_H\,.$$

For used formulas applies:

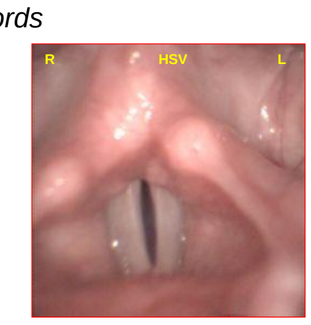
A_k	… area of segmented glottal gap [*px*]
x_S, y_S	… coordinates of pixel $\in S_k$
L_k	… length of glottal gap border [*px*]
x_H, y_H	… coordinates of pixel $\in H_k$.

| Results

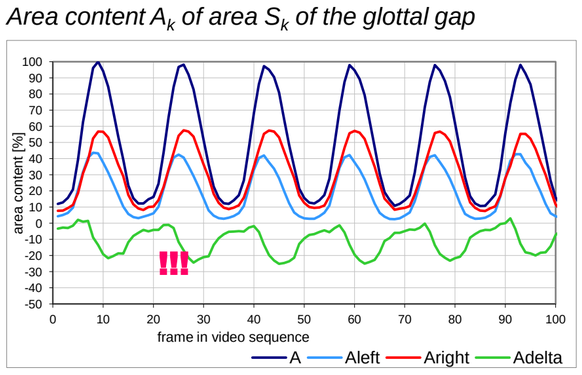
About 400 video sequences of HSV examinations were served as the data for parameters extraction. Based on the results, parameters of the glottal symmetry can be deduced from the center of gravity position in the area and border. Several casuistries are presented as an example of *symmetric* an *asymmetric* vocal cords.

Symmetric vocal cords

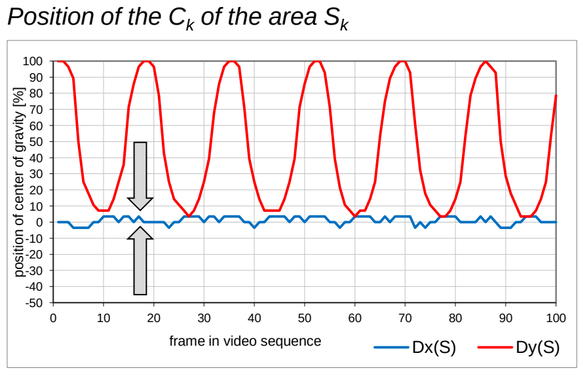
dg.: non
female (ID 415)
20 years
MIC-HSV:
SPL_{min} = 64 dB
SPL_{max} = 83 dB
F_0 = 236 Hz



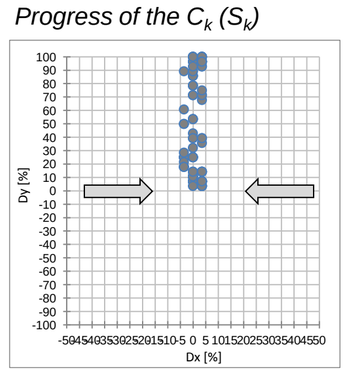
Area content A_k of area S_k of the glottal gap



Position of the C_k of the area S_k



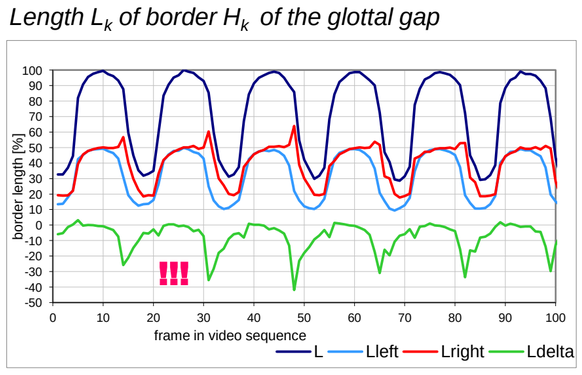
Progress of the C_k (S_k)



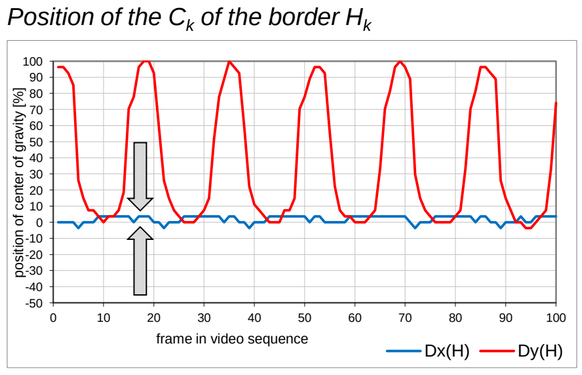
comment:

- healthy vocal cords
- analysis of area A_k shows asymmetry, see parameter A_{delta}
- also analysis of border length L_k shows asymmetry, see parameter L_{delta}
- progress of position of center points *Dx(S)* and *Dx(H)* shows behavior of healthy symmetric vocal cords, i.e. maximum movement of *Dy(S)* and *Dy(H)* in the axis direction and minimal movement of *Dx(S)* and *Dx(H)* in normal direction
- difference between the center of gravity of the area D_S and the border D_H during phonation is minimal

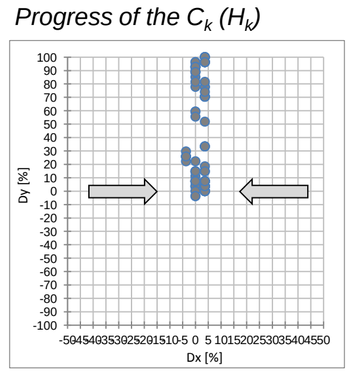
Length L_k of border H_k of the glottal gap

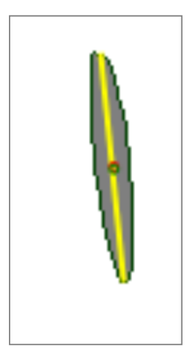


Position of the C_k of the border H_k



Progress of the C_k (H_k)





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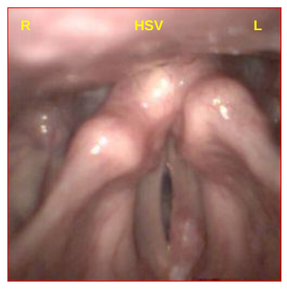
| Results

Asymmetric vocal cords

dg.: **carcinoma** left
male (ID 470)
82 years
MIC-HSV:

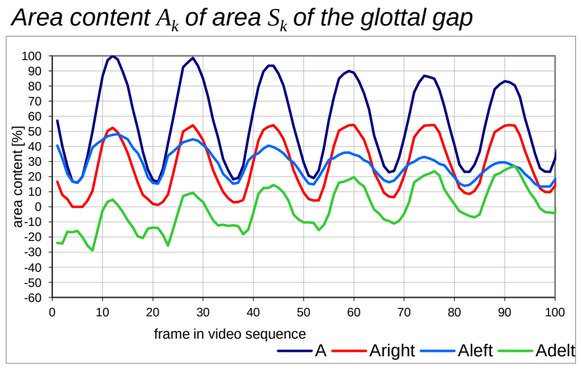
SPL_{min}	=	77 dB
SPL_{max}	=	81 dB
F_0	=	298 Hz



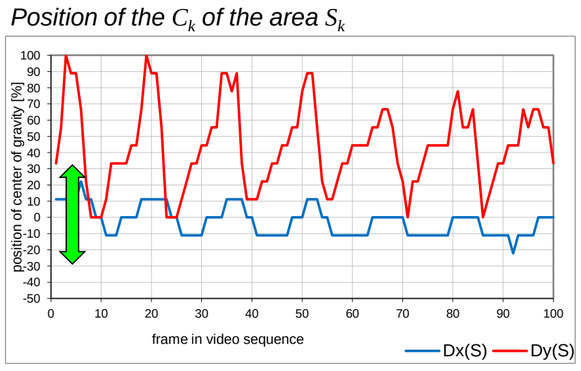
comment:

- asymmetric vocal cords, movement limitation on the left side
- analysis of area A_k and border length L_k shows asymmetry, see parameters A_{delt} and L_{delt}
- progress of position of center points $Dx(S)$ and $Dx(H)$ confirms a behavior of non-symmetric vocal cords, significant movement of $Dx(S)$ and $Dx(H)$ in normal direction
- difference between position of area center point and border center point is increased

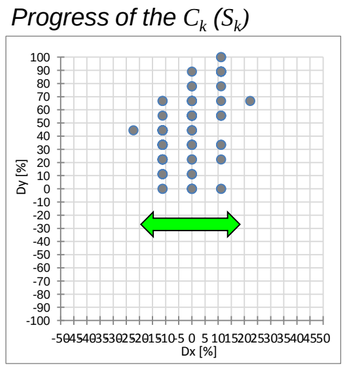
Area content A_k of area S_k of the glottal gap

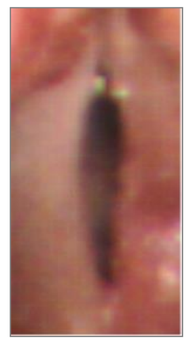


Position of the C_k of the area S_k

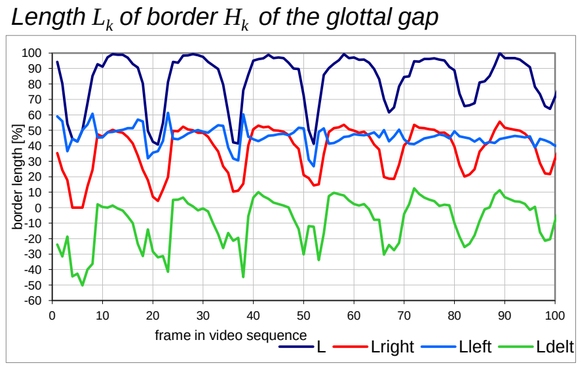


Progress of the C_k (S_k)

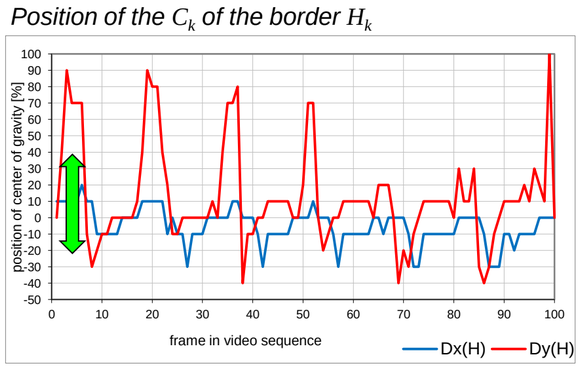




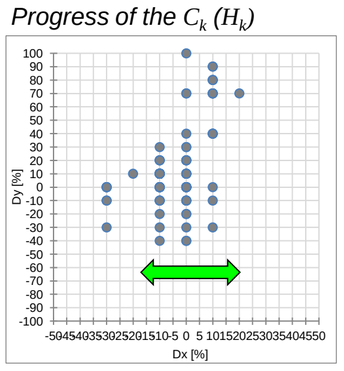
Length L_k of border H_k of the glottal gap

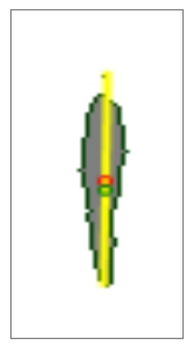


Position of the C_k of the border H_k



Progress of the C_k (H_k)

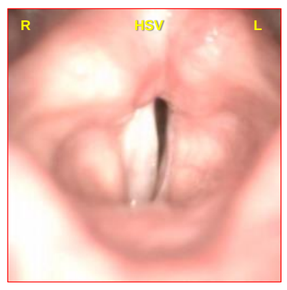




Asymmetric vocal cords

dg.: **chordectomie** left
female (ID 337)
57 years
MIC-HSV:

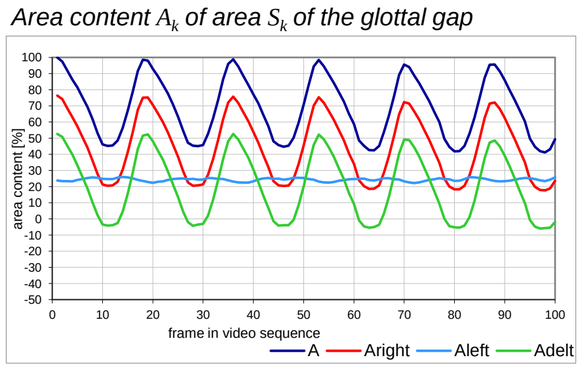
SPL_{min}	=	74 dB
SPL_{max}	=	84 dB
F_0	=	230 Hz



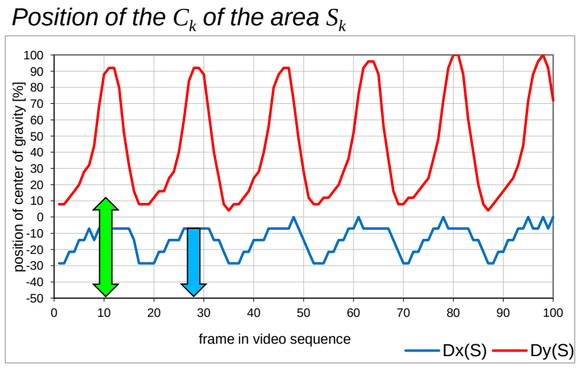
comment:

- asymmetric vocal cords, after removal of left cord
- analysis of area A_k and border length L_k shows asymmetry, see parameters A_{delt} and L_{delt}, left cord is not moving
- progress of position of center points $Dx(S)$ and $Dx(H)$ confirms a behavior of non-symmetric vocal cords, significant one sided movement of $Dx(S)$ and $Dx(H)$ in normal direction
- difference between position of area center point and border center point is minimal

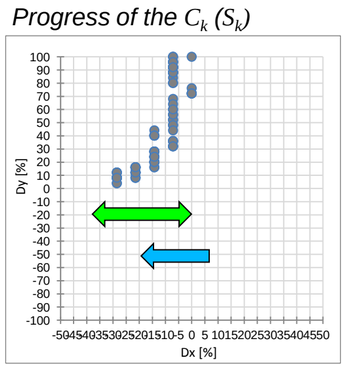
Area content A_k of area S_k of the glottal gap

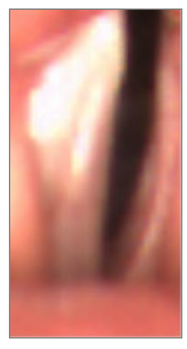


Position of the C_k of the area S_k

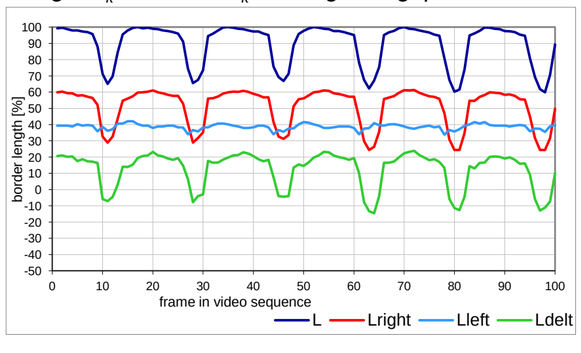


Progress of the C_k (S_k)

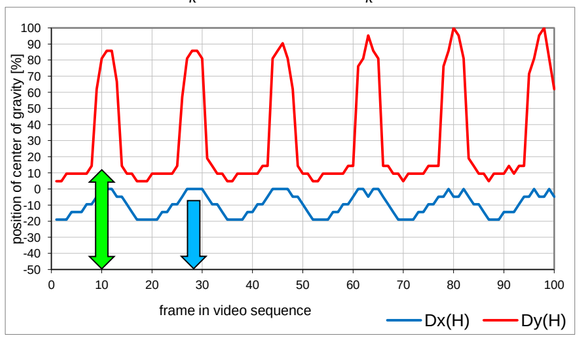




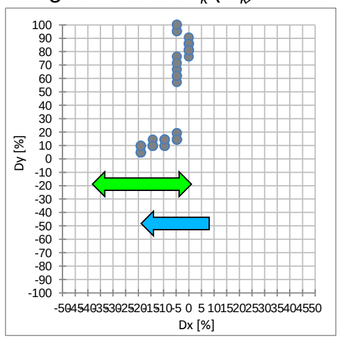
Length L_k of border H_k of the glottal gap

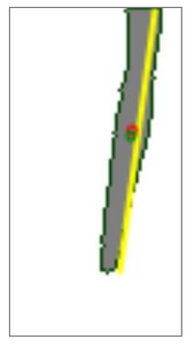


Position of the C_k of the border H_k



Progress of the C_k (H_k)

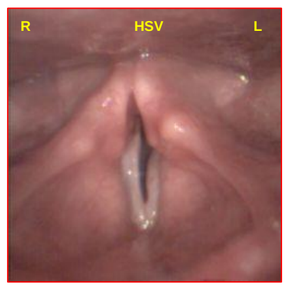




Asymmetric vocal cords

dg.: **paresis** left
female (ID 343)
29 years
MIC-HSV:

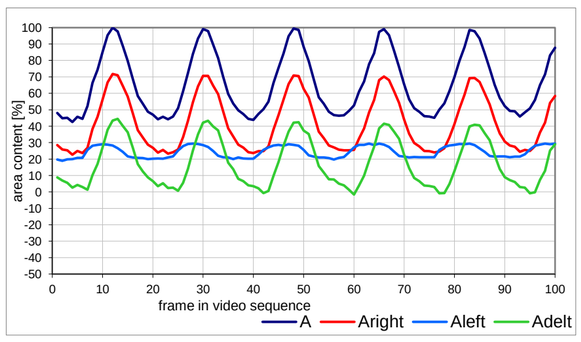
SPL_{min}	=	53 dB
SPL_{max}	=	78 dB
F_0	=	240 Hz



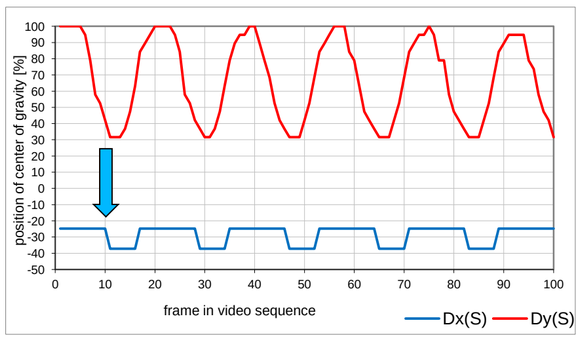
comment:

- asymmetric vocal cords
- analysis of area A_k and border length L_k shows asymmetry, see parameters A_{delt} and L_{delt}
- progress of position of center points *Dx(S)* and *Dx(H)* confirms a behavior of non-symmetric vocal cords, center points *Dx(S)* and *Dx(H)* are deflected to the one side
- difference between position of area center point and border center point is minimal

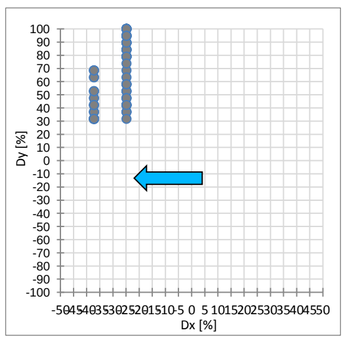
Area content A_k of area S_k of the glottal gap

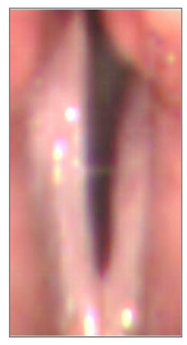


Position of the C_k of the area S_k

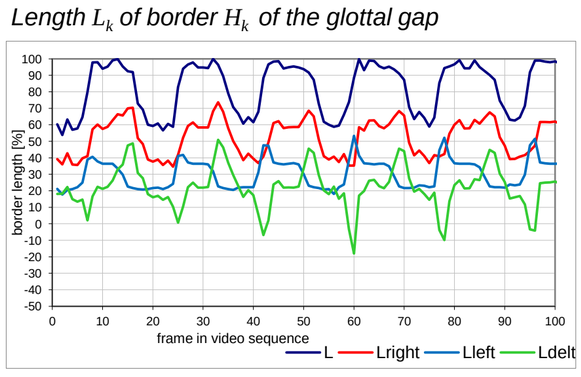


Progress of the C_k (S_k)

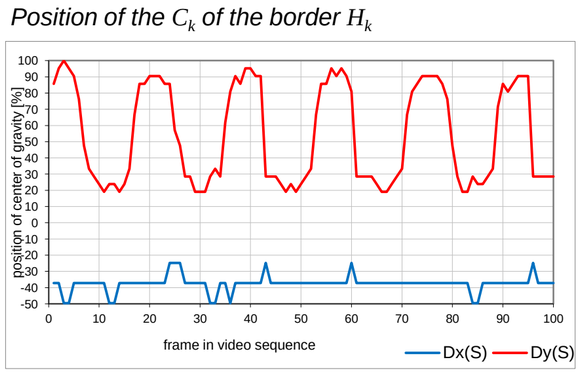




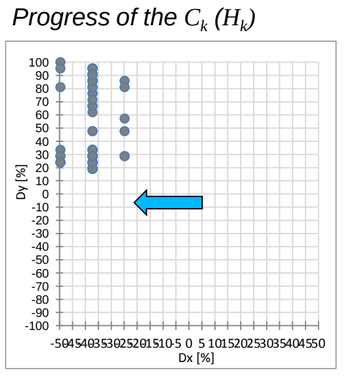
Length L_k of border H_k of the glottal gap

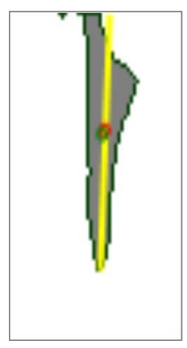


Position of the C_k of the border H_k



Progress of the C_k (H_k)





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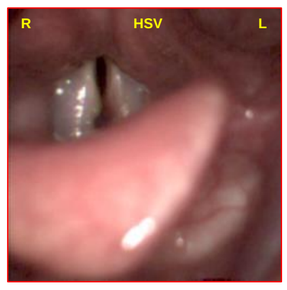
| Results

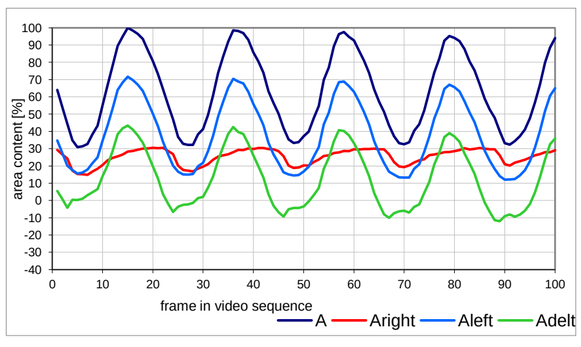
Asymmetric vocal cords

dg.: **nodule** right
female (ID 431)
48 years
condition
before surgery
MIC-HSV:

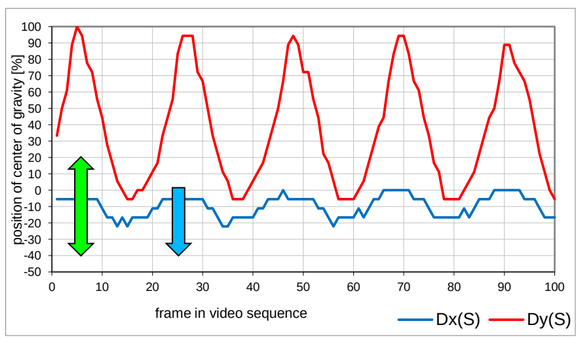
SPL_{min} = 78 dB
SPL_{max} = 87 dB
F_0 = 192 Hz



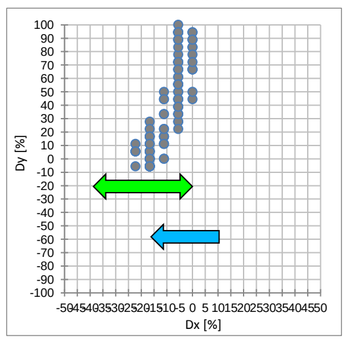
Area content A_k of area S_k of the glottal gap

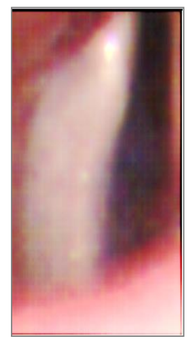


Position of the C_k of the area S_k

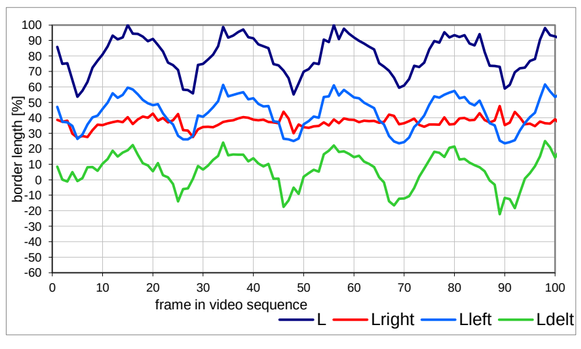


Progress of the C_k (S_k)

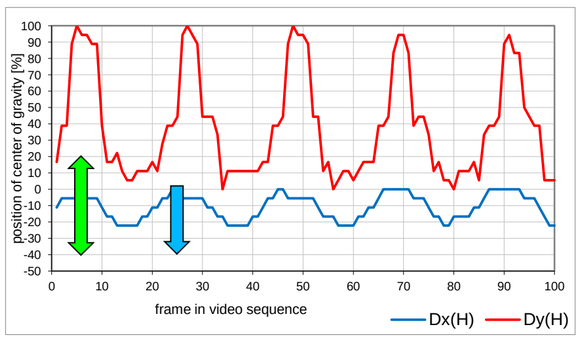




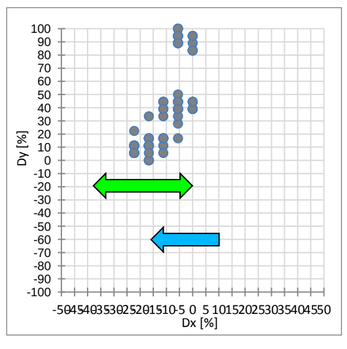
Length L_k of border H_k of the glottal gap

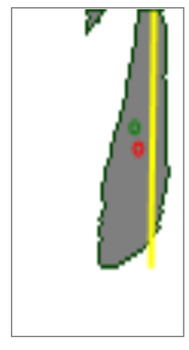


Position of the C_k of the border H_k



Progress of the C_k (H_k)



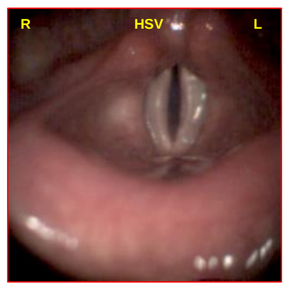


comment:

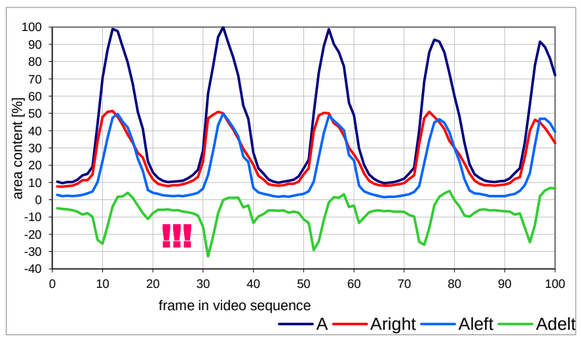
- asymmetric vocal cords
- analysis of area A_k and border length L_k shows significant limitation in movement and asymmetry on the right side, see parameters A_{delt}, A_{right} and L_{delt} , L_{right}
- progress of position of center points $Dx(S)$ and $Dx(H)$ shows behavior of healthy symmetric vocal cords, i.e. maximum movement of $Dy(S)$ and $Dy(H)$ in the axis direction and also movement of $Dx(S)$ and $Dx(H)$ in normal direction
- center points D_S and D_H are deflected to the right side from the axis of symmetry

condition after surgery
MIC-HSV:

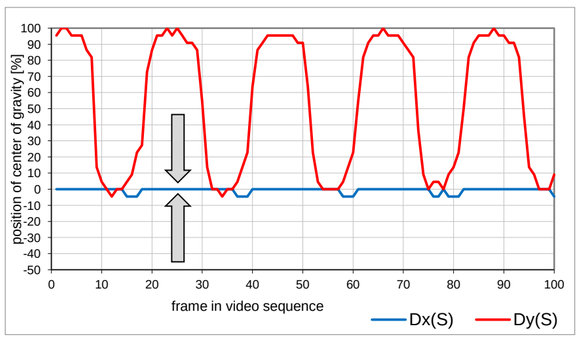
SPL_{min} = 82 dB
SPL_{max} = 84 dB
F_0 = 191 Hz



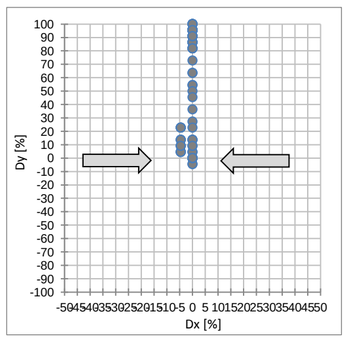
Area content A_k of area S_k of the glottal gap



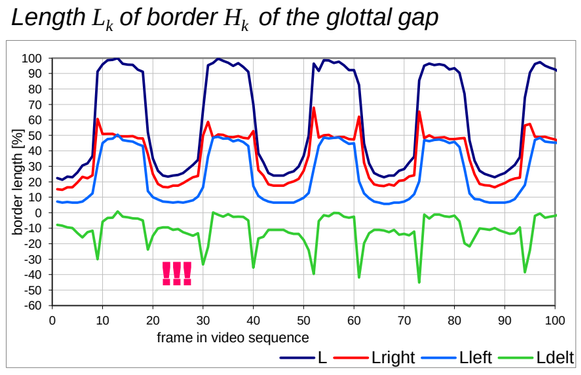
Position of the C_k of the area S_k



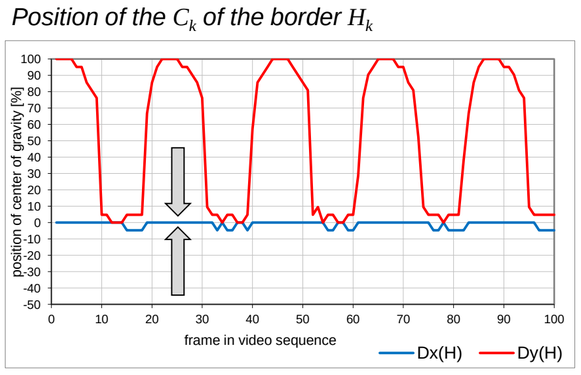
Progress of the C_k (S_k)



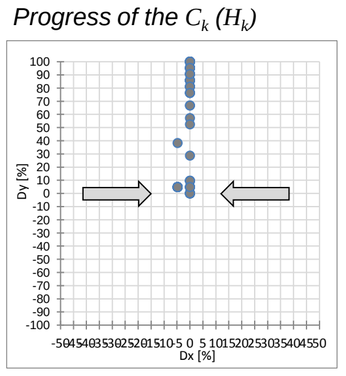
Length L_k of border H_k of the glottal gap

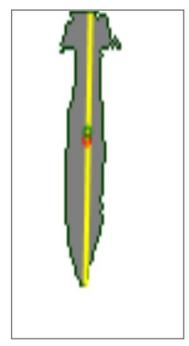


Position of the C_k of the border H_k



Progress of the C_k (H_k)





comment:

- condition after microchirurgical surgery (52 days)
- analysis of area A_k and border length L_k still shows asymmetry, see parameters A_{delt} and L_{delt}, but movement on the right side was significantly increased
- progress of position of center points $Dx(S)$ and $Dx(H)$ shows behavior of healthy symmetric vocal cords, i.e. maximum movement of $Dy(S)$ and $Dy(H)$ in the axis direction and minimal movement of $Dx(S)$ and $Dx(H)$ in normal direction
- both center points are moving near the axis of the symmetry

| Conclusion

The importance of the newly implemented parameters applied to the center of gravity D_S in the glottal area and the center of gravity D_H in the glottal area border may be summarized and compared with the parameters of the area content A_k and border length L_k as follows:

	area A_k , border L_k	*movement D_x and D_y of center points*	*description*
• symmetric vocal cords	symmetry	$D_x \rightarrow$min, $D_y \rightarrow$max	parameters are almost identical
• asymmetric vocal cords	asymmetry	$D_x \rightarrow$min, $D_y \rightarrow$max	parameters of center points shows symmetry
• asymmetric vocal cords	asymmetry	$D_x \rightarrow$max, $D_y \rightarrow$max	movement of center points in normal direction heightens
• asymmetric vocal cords	asymmetry	$D_x \rightarrow$deflection, $D_y \rightarrow$max	one-sided deflection of center points movement

The reliability and accuracy of the area content and border length parameters depend on the quality of the HSV recording, i.e., on the size of glottis in the frame or the angle of the recording.

| Acknowledgement:

We would like to express our thanks to Ing. Jiri Pesta, CSc. and MUDr. Monika Vohlidkova, specialists from the ORL department in the FN Pilsen for long-standing cooperation, giving valuable comments and advice and providing anonymized data from the HSV database.
This study was sustained by the Ministry of Education, Youth and Sports of the Czech Republic within the university project: **SGS-2016-018** Data and Software Engineering for Advanced Applications.