User guide for VocalTractLab3D

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Contents

1 Introduction

VocalTractLab3D is a special version of the articulatory synthesizer VocalTractLab 2.3 [1] (`www.vocaltractlab.de`) which integrates a module that performs 3D acoustic simulations. The other modules are, to some very little differences, the same as the original VocalTractLab 2.3 and the reader is referred to the manual of VocalTractLab 2.3 to learn how to use them. The 3D acoustic simulations are performed with a frequency domain multimodal method which has been designed to be particularly fast and accurate. The details of this simulation method are provided in Blandin et al. [4].

1.1 What are 3D acoustic simulations?

What are vocal tract acoustic simulations?

It consists in describing how acoustic waves travel inside the vocal tract volume, are reflected at the discontinuities, such as changes of cross-section or the mouth opening and create resonances. This allows one to compute transfer

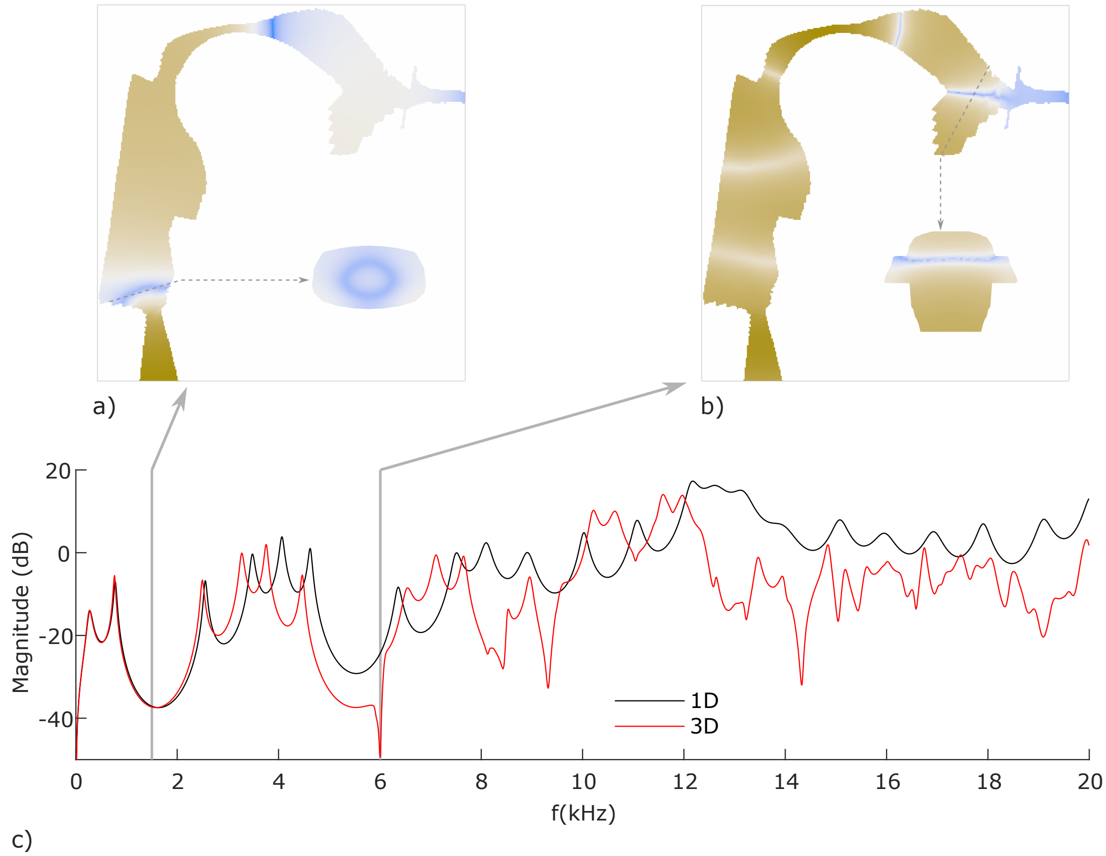

Figure 1: Transfer function and acoustic fields computed for the vowel /u/. The transfer function has been computed with a 1D and a 3D simulation. The acoustic fields have been computed at frequencies shown on the transfer function with arrows. They are shown in the sagittal plane and some selected transverse planes indicated with dashed lines.

functions, as an example, between the acoustic volume flow created at the vocal folds and the acoustic pressure radiated in front of the lips. It can also be used to compute the acoustic field, which describes the variations of the acoustic pressure and the particle velocity over space.

What is specific to vocal tract acoustics?

The vocal tract has an elongated shape in which the acoustic waves are guided to travel mainly along its length. From the point of view of wave propagation, the vocal tract can be called a *waveguide*. This specificity of the vocal tract makes easy to approximate the propagation of acoustic waves using a single value of the acoustic pressure varying along its length, thus neglecting transverse variations of the acoustic field. This has led to 1D simulation methods and electrical analogies which are very widely used to simulate vocal tract acoustics [9].

What is 3D vocal tract acoustics?

Even though not very important below 4-5 kHz, the acoustic field has transverse variations, and thus, varies in all the three dimensions of space. At low frequency these variations appear as a curvature of the acoustic field related to variations of cross-sectional dimensions (see Fig. 1a). At higher frequency, the 3D nature of the acoustic field is more obvious as transverse resonances can be observed (see Fig. 1b).

What does accounting for the 3D acoustics changes in comparison to using a 1D simplifying assumption?

The impact of accounting for the 3D nature of the acoustic field inside the vocal tract is rather limited up to about 3 kHz. It consists mainly in small changes in the resonance properties (frequency, amplitude and bandwidth). From 3 kHz on, the changes in the resonance properties can be more substantial. Above 4-5 kHz the transverse resonances can induce zeros and additional peaks in the transfer function (see Fig.1c).

What is the multimodal method?

It is a simulation method which relies on the projection on eigen-function basis. Such an approach is very efficient to reduce computation times and memory requirements. In the case of the vocal tract, the 3D geometry is cut in multiple segments in which the local transverse eigen modes are computed and on which the acoustic field is decomposed. The method implemented in VocalTractLab3D is described in details in Blandin et al. [4].

1.2 What VocalTractLab3D can do?

- Compute transfer functions between the volume velocity at the location of the vocal folds and one or several points inside or outside the vocal tract.
- Compute transfer functions between the acoustic pressure on a transverse plane anywhere inside the vocal tract and one or several points inside or outside the vocal tract. This is useful to emulate noise generation by aeroacoustic sound sources.
- Compute the input impedance of the plane mode at the location of the vocal folds.
- Compute and visualize the transverse modes.
- Compute the acoustic field at a specific frequency in the sagittal plane and in transverse planes anywhere inside the vocal tract.
- Compute the above listed quantities for vocal tract geometries generated with the articulatory model implemented in VocalTractLab3D or vocal tract geometries imported from external .csv file coded in a specific format. Note that in this last case any waveguide geometry can be imported and not only vocal tract geometry (e.g. airways of other animals, wind instruments ...). However, the parameters of VocalTractLab3D are optimized for human vocal tracts and may not be optimal for other applications.
- Synthesize vowel and fricative sounds.

1.3 What VocalTractLab3D cannot do?

The simulation method implemented in VocalTractLab3D has been designed primarily to be efficient, and this comes with some limitations regarding the geometries which can be simulated. However, it is to be noted that some of the geometrical simplifications are also used with other simulation methods, such as the finite element method (FEM), in order to reduce the computation time, or simplify the task of describing the geometry.

VocalTractLab3D cannot:

- Simulate continuous cross-sectional shape variations within the segments of the vocal tract geometry. The cross-sectional shape can be scaled to account for area variation, but the shape remains constant.
- Simulate lip shapes. The mouth opening is contained in a plane, and thus, the 3D lip shape cannot be simulated.
- Simulate branches such as piriform sinus or the nasal cavity.
- Simulate the diffraction by the head and the torso outside of the vocal tract.
- Perform time domain simulation.

Some of the limitations listed above may be overcomed with future developments of the simulation method used (3D lip shape, branches and diffraction by the head and torso), and some are inherent to the simulation method used (constant cross-sectional shape in the segments, and frequency domain simulations).

1.4 Download, intallation and requirements

VoocalTractLab3D is distributed as a free and open source software under the GNU General Public Licence (GPL). It is written in C++ and developed for both Windows and Linux platforms. Adaptation to MacOS should be easy as cross-platform libraries are used. The software is free of charge and available for download as a ZIP file from `www.vocaltractlab.de`. It needs no special installation: just unzip the achive and run the executable "VocalTractLab.exe" for Windows, or "VocalTractLab" for Linux. contained in the folder. VoocalTractLab3D was tested on Windows 10 and Ubuntu 20.04.4 LTS, but can probably run on other versions of Windows and Linux. A fast computer and a high screen resolution are strongly recommended. Tablet computers and netbooks are generally not suited to work with VTL. On some Windows systems it could be necessary to explicitly install OpenGL. Without OpenGL, the 3D model of the vocal tract will not be displayed properly.

Since the simulation method requires to solve complex problems it was necessary to rely on external libraries for specific issues:

- wxWidgets 3.1.5 (`https://www.wxwidgets.org`) is used for the graphical interface.
- boost 1.71.0 (`https://www.boost.org/`) is used for Bessel functions and Gauss integration.
- The Computational Geometry Algorithms Library (CGAL 5.0) (`https://www.cgal.org`) is used for the generation of mesh and other geometry problems.
- Eigen 3.3.9 (`http://eigen.tuxfamily.org`) for solving linear algebra problems, in particular eigenvalue decomposition for the computation of the transverse modes.

Note that VoocalTractLab3D comes with no warranty of any kind.

1.5 How to cite VocalTractLab3D?

R Blandin et al. "Efficient 3D acoustic simulation of the vocal tract by combining the multimodal method and finite elements". In: *IEEE Access* (2022), pp. 69922 –69938. DOI: `10.1109/ACCESS.2022.3187424`

1.6 Troubleshooting

For any issue, bug report or question related to VocalTractLab3D, please write to remi.blandin@tu-dresden.de or peter.birkholz@tu-dresden.de.

2 Interface

2.1 Overview

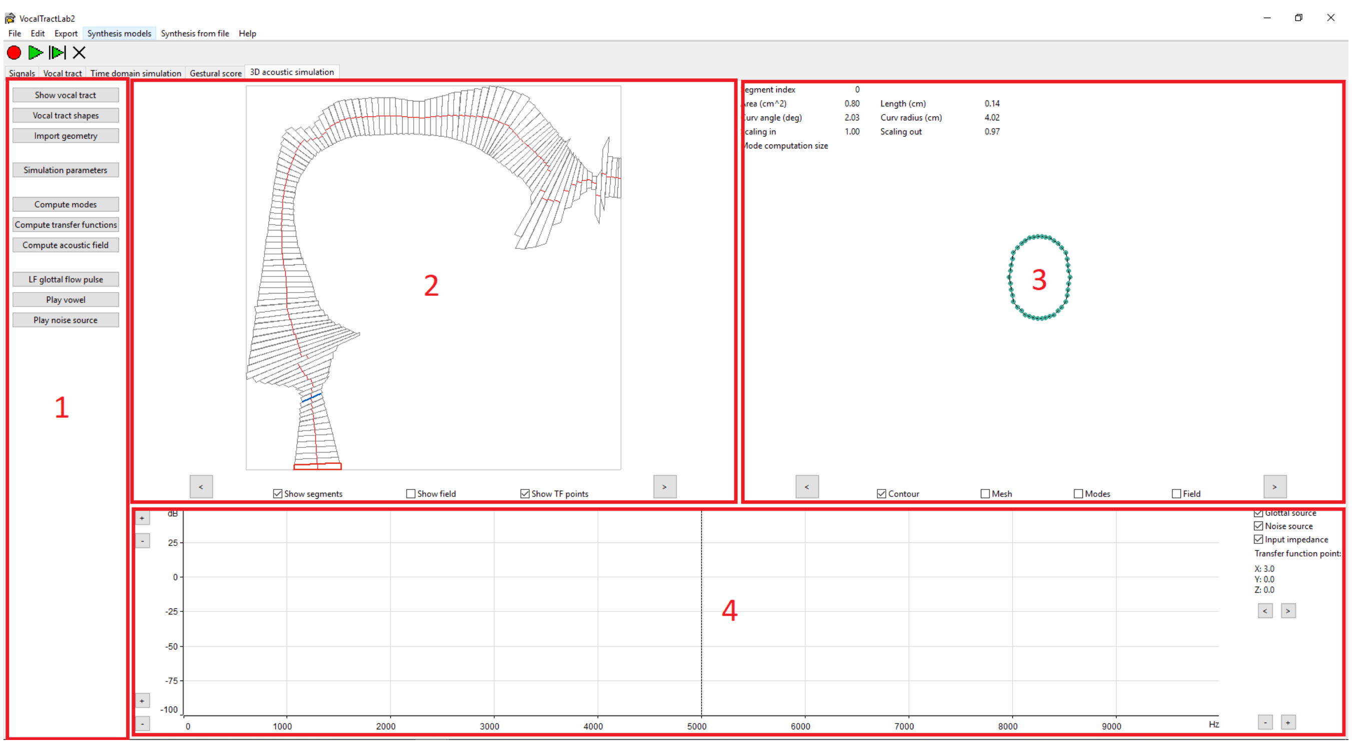

Figure 2: The different panels of the "3D acoustic simulation" page.

When VocalTractLab3D is started, it shows by default two windows:

- The main window showing the "3d acoustic simulation" page.
- A small window showing the 3D geometry corresponding to the articulatory model (called the vocal tract dialog). The user can interact with the articulatory model using the control points to move the articulators. When closed, this window can be shown again by clicking on the button "Show vocal tract".

The "3d acoustic simulation" page is divided into 4 panels (see Fig. 2):

1. the left panel contains buttons to manage the geometries, launch the simulations and synthesize phonemes.
2. The middle panel shows a sagittal cut of the geometry simulated.
3. The right panel shows a transverse cut of the geometry corresponding to a specific segment.
4. The bottom panel shows the transfer functions and input impedance computed.

2.2 Vocal tract geometry

2.2.1 Defining a vocal tract geometry

When VocalTractLab3D is started, the default geometry of the articulatory model is already loaded and ready to use for simulations. However, the geometry can be defined or modified in several ways:

- It can be simply defined by moving the control points in the vocal tract dialog (shown by clicking on "Show vocal tract" in the left panel). When doing so, one can see the updates of the segmented geometry in the central panel.
- If a speaker file containing predefined geometries is loaded, a geometry can be selected using the dialog shown by clicking on the button "Vocal tract shapes" of the left panel.
- An external geometry can be loaded as a `.csv` file formatted in a specific way detailed hereafter.

Csv format for externally defined geometries:
The file describes a list of segments by specifying

- a centerline point,
- a normal,
- input and output scaling factors,
- and a contour.

`Centerline` x	`Normal` x	`Input scaling`	`Contour point 1` y	`Contour point 2` y	...	`Contour point N` y
`Centerline` y	`Normal` y	`Output scaling`	`Contour point 1` z	`Contour point 2` z	...	`Contour point N` z

Table 1: Csv file format to encode segmented vocal tract geometries.

One segment is defined on two lines: the first one describes the first coordinates (x or y) and the input scaling factor, the second one the second coordinates (y or z) and the output scaling factor. This is summarized in the Tab. 1. The columns must be separated by semi-columns ";". An example of such `.csv` file encoding a simple waveguide geometry is provided in Tab. 2. Note that in this example the normal of the second segment is not normalized. In this case the normalization is done when the file is imported, otherwise this would be equivalent to applying a scaling factor. The length and curvature of a segment are defined by its centerline point and normal and the centerline point and normal of the following segment. Thus, a minimal number of two segments must be provided. The before-last and the last segment are defined by computing an intermediate centerline point and normal between the last and before last centerline points and normals provided.

-2.;	-1.;	0.5;	-1.;	-1.;	1.;	1.;
0.;	0.;	1.;	-1.;	1.;	1.;	-1.;
-1.4142;	-0.5;	1.;	-1.;	-1.;	1.;	1.;
1.4142;	0.5;	1.5;	-1.;	1.;	1.;	-1.;

Table 2: Example of `.csv` file which can be imported to generate a waveguide geometry.

Examples of such files generated for vowel geometries measured on magnetic resonance image (MRI) are provided in the archive in the folder "geometries_from_MRI". They have been generated with VocalTractTransferFunction from MRI provided in the Dresden Vocal Tract Dataset [2]. The software VocalTractTransferFunction can be downloaded at `www.vocaltractlab.de` and used to load a surface mesh and save it in the `.csv` format specified above (Not yet though).

The geometry can also be exported in the same format through the context menu which appears with a right click on the central panel "Export geometry in a csv file".

Geometry options:
When a geometry is loaded, it can be chosen to take into account or not the curvature and the area variations in the segments. This is done using the simulation parameters dialog displayed by clicking on the button "Simulation parameters" in the left panel. These options are found in the "Geometry options" section. When "Varying area" is checked, the variation of area is taken into account through the scaling factor which is set to vary linearly from the entrance to the exit of the segments. The entrance and exit scaling factors are displayed in the information text of the right panel. The variations of the scaling factor can be computed in two different ways, or directly provided by the user when the geometry is loaded as a `.csv` file. These options can be selected in the "Geometry options" as well. One scaling factor computation method, "Area", consists simply in linearly interpolating the cross-sectional area. The other one, "Bounding box", interpolates the largest dimension of the bounding box of the contour of the segments, provided that the resulting scaled contour does not exceed the area of the following contour, in which case it is set to interpolate the area. Finally, one can specify that the scaling factors provided in the input `.csv` file must be used by selecting "From file".

2.2.2 Visualizing the vocal tract geometry

The geometry is visualized both in the central and the right panels. The central panel shows a sagittal cut of the bounding box of the segments. This bounding box is a rectangle whose dimensions are the maximal and minimal dimensions of the cross-sectional contour. The center of the segment is shown as a red line.

This sagittal cut of the segments can be exported as a list of coordinates in a text file using the context menu of the central panel "Export segment picture". This can be used to plot the same picture with other softwares such as Matlab. This can be easily done with this kind of Matlab code:

```
load("segment_picture.txt");
plot(segment_picture(:,1), segment_picture(:,2));
```

When clicking on a segment, its outline becomes red to confirm that it has been selected, and the contour and some information regarding the segment are displayed in the right panel. It is also possible to move to the previous and next segments using the buttons "<" and ">" at the bottom of the central panel. Note that this is the only way to visualize the junction segments which have a zero length. When the geometry is provided by the articulatory model, it is possible to identify the type of surfaces which constitutes the edges of the contour (tongue, teeth, lips, openings on the sides of the lips, uvula, epiglottis and other walls). The color code for these different surfaces is given in Fig. 3. By clicking on the arrows "<" and ">" at the bottom of the right panel, one can display the contour with its original dimensions ("Mode computation size") and scaled at the entrance and exit of the segment.

Figure 3: Correspondence between the colors of the contour and the anatomical parts to which the walls corresponds.

The coordinates of the points of the contour can also be exported into a text file through the context menu of the right panel obtained with a right click "Export contour in text file". Note that the contour exported has the scaling with which it is displayed: if at the entrance the scaling is 0.5 and the entrance contour is displayed, the coordinate of the exported contour will be the ones of the original contour multiplied by 0.5. The exported contour can easily be plotted using another software in the same way as the segment picture.

2.3 Transverse modes

2.3.1 Computation

The transverse modes can be computed by clicking the button "Compute modes" of the left panel. This can be useful if one is interested in analyzing the transverse modes without computing the acoustic field or the transfer functions.

The computation of the transverse modes is parametrized by:

- the density of the mesh which is used to solve with 2D FEM the eigenvalue problem giving the transverse modes and their associated cutoff frequencies. This is related to the average side length of the elements through the relationship $average\ side\ length = \frac{\sqrt{cross-sectional\ area}}{mesh\ density}$. Thus, the mesh density is an estimation of the number of elements per characteristic length.
- The maximal cutoff frequency. It is an upper limit to the cutoff frequency of the transverse modes included in the simulations: for a given segment, only the modes having a cutoff frequency lower than this value are kept. Thus, segments having a small cross-section have less transverse modes than the ones having a bigger one. This is done to increase the efficiency of the simulations.

The cutoff frequency is related to the sound speed, which itself is related to the temperature. Both the sound speed and the temperature can be set in the "Physical constants" section of the "Simulation parameters" dialog. Since both quantities are related, they cannot be modified independently: changing the temperature will change the sound speed and conversely.

2.3.2 Visualization

The mesh used to compute the transverse modes can be visualized in the right panel by selecting "Mesh" in the bottom. The transverse modes can be visualized by selecting "Modes" at the bottom. One can browse the different modes using the arrows "$<$" and "$>$". The amplitude variation of the modes is displayed as a color scale, and their cutoff frequency is given in the text information.

2.4 Transfer functions

2.4.1 Computation

The transfer functions can be computed by clicking on the button "Compute transfer functions" in the left panel.

The computation of the transfer function requires to solve the walve problem. In this purpose, the simulation of wave propagation can be achieved either with an analytical solution [3] or a numerical Magnus-Möbius scheme [8]. This can be selected in the section "Numerical scheme options" of the "Simulation parameters" dialog. The analytical solution is enabled by selecting "Straight". However, this solution has strong limitations: it cannot take into account the curvature, cross-sectional area variations and wall losses. The numerical scheme is enabled by selecting "Magnus". In this case a number of integration steps is given and can be modified if necessary. This number is the same for each segment. Note that since the segmentation generally used for vocal tract geometries gives segments having approximately the same length, this parameter is expected to affect the accuracy in a similar way for each segment. However, if the segment length is made inhomogeneous (e.g. in an imported geometry), this parameter needs to be considered more carefully.

The boundary conditions can be set in the "Boundary conditions options" section of the "Simulation parameters" dialog. It includes the mouth boundary condition which can be described with a radiation boundary condition computed following Blandin et al. [5], or a zero pressure condition. Several types of wall losses can be selected:

- "Visco-thermal losses" includes frequency dependent visco-thermal losses implemented according to Bruneau et al. [6].
- "Soft Walls" includes frequency dependent losses corresponding to soft walls using the same model as the one implemented in VocalTractLab 2.3.
- "Constant wall admittance" includes a frequency independent wall admittance whose real and imaginary parts can be set by the user.

The index of the segment in which the noise source is integrated can be set either in the "Transfer functions options" section of the "Simulation parameters" dialog, or through the context menu of the central panel by selecting "Define current segment as noise source location". The noise source segment is highlighted in blue (or green when selected) in the central panel. When the segment has a non-zero length, the noise source is implemented at the end of the segment which is closer to the mouth exit. The noise source implemented is uniform over the cross-sectional surface, which is equivalent to excite the vocal tract with a plane wave at the specified location. The transfer function computed for the noise source is a pressure-pressure transfer function, contrarily to the glottal transfer function which is a velocity-pressure transfer function.

The upper frequency limit for the transfer function computation can be set in the "Transfer functions options" section of the "Simulation parameters" dialog. The frequency step size can be selected in a list. The proposed values correspond to divisions of the sampling frequency by powers of 2 to make the synthesis which can be done afterward faster.

The coordinates of the reception point of the transfer functions can also be set in the "Transfer functions options" section of the "Simulation parameters" dialog. It can be chosen either to use a single point whose coordinates can be directly set, or to use several points whose coordinates can be loaded from a `.csv` file. The origin of the landmark in which the coordinates of the reception points are expressed is the center of the mouth exit. The $\boldsymbol{n_y}$ unit vector of this landmark is the normal to the centerline at the mouth exit. The reception points can be placed anywhere. However, if it is located in the half-space behind the mouth exit and not inside the vocal tract, the returned value will be "nan".

When point coordinates are loaded from a `.csv` file, they must be given in 3 columns corresponding to the x, y and z coordinates. This functionality can be useful to compute the directivity patterns of the radiated sound, or the acoustic field at multiple frequencies.

2.4.2 Visualization

The transfer function points are visualized as "+" on the middle panel. It is possible to hide them by unchecking "Show TF points" on the bottom of the panel. This can be useful if many points are used and their visualization disturbs the visualization of the other elements. Note that if the point is located outside of the area of the sagittal cut displayed, it will not be visible.

The transfer function and the input impedance computed are displayed in the bottom panel. The glottal transfer function, the noise source transfer function and the input impedance are plotted in black, blue and green respectively. It is possible to show or hide each of them by checking or unchecking "Glottal transfer function", "Noise transfer function" or "Input impedance" on the right of the bottom panel.

In case several points are used, the transfer functions corresponding to the different reception points can be visualized by clicking on the "<" and ">" buttons on the right of the bottom panel. The coordinates of the point corresponding to the transfer function plotted appear above these buttons, and the corresponding point is displayed as a red "+" in the middle panel. Note that the input impedance does not depend on a reception point location, and hence it will be the same for each point.

The transfer functions and the input impedance can be exported using the context menu which is displayed by a right click on the bottom panel. They are saved in a text file in which the first column gives the frequency, the second and third the magnitude and phase of the first point, and the following columns the magnitude and phase of the other points, if other points have been included. Such text files can easily be loaded in another software such as Matlab to plot and analyse the data. This can be done easily with Matlab with the following code:

```
load transfer_function.txt
figure
subplot 211
plot(transfer_function(:,1), 20*log10(transfer_function(:,2)))
xlabel("f (Hz)")
ylabel("Magnitude (dB)")
subplot 212
plot(transfer_function(:,1), transfer_function(:,3))
xlabel("f (Hz)")
ylabel("Phase (rad)")
```

2.5 Acoustic field

2.5.1 Computation

The acoustic pressure field can be computed in the sagittal plane and the transverse planes by clicking the button "Compute acoustic field". It corresponds to a sound source located at the glottis. The frequency at which it is computed can be set by moving the vertical dashed line in the transfer function plot in the bottom panel. A precise frequency can also be set in the section "Acoustic field options" of the "Simulation parameters" dialog.

In the sagittal plane the acoustic field is computed in a rectangular area displayed as a gray rectangle in the middle panel. By default, this rectangle is the bounding box of the geometry outline. The dimensions of this rectangle can be modified by clicking "Define bounding box lower corner" or "Define bounding box upper corner" in the context menu which is displayed by right clicking on the middle panel. In this case, the location of the right click is attributed to the lower left corner or the upper right corner of the rectangular area respectively. This functionality is useful for looking in more details at a specific area. Alternatively the dimensions of this rectangular area can be manually set in the "Acoustic field options" of the "Simulation parameters" dialog. This can be useful if one wants to visualize the radiated field as well. In this case, the maximal value of x can be increased to extend the area to the radiated field. The original dimension of the acoustic field area can be restored by double clicking on the middle panel, or clicking "Reset bounding box" in the context menu of the middle panel.

The resolution of the grid of points used to compute the sagittal plane acoustic field can be set in the "Acoustic field options". In the transverse plane the resolution of the field corresponds to the resolution of the image displayed on the screen.

The computation of the radiated field takes a bit more time than the internal field, so it is possible to avoid computing the radiated field by unchecking the option "Compute radiated field" in the "Acoustic field options".

2.5.2 Visualization

Once computed, the acoustic field is displayed as a logarithmic color scale in the middle and right panels. For a better visualization, the segments and/or the transfer function points can be hidden by unchecking the options "Show segments" and "Show TF points" in the middle panel. Alternatively, the acoustic field can also be hidden by unchecking the option "Show field". This can be useful if the acoustic field disturbs the visualization of the segments and/or transfer function points. In the transverse plane the acoustic field corresponds to the exit plane of the segments.

The acoustic field can be exported in text files and easily loaded in other softwares such as Matlab for further analysis or different visualization. This can be done by clicking "Export acoustic field as text file" in the context menu shown by right clicking on the middle and right panels. The acoustic field can be easily loaded and plotted with Matlab with the following code:

```
load "acoustic_field.txt"
figure
imagesc(20*log10(acoustic_field));
axis xy
axis equal
```

2.6 Default parameters

Default simulation parameters can be set by clicking the buttons "Default (fast)" and "Default (accurate)" at the bottom of the "Simulation parameters" dialog. The fast default parameters are set by default when VocalTract-Lab3D is started. They ensure fast simulation with computation times of the order of a few minutes only, but give inacurate results. Thus, they should not be considered as reliable. This can be useful to test the software or to test quickly a simulation before runing a more accurate one. The accurate default parameters have been optimized to offer a good compromise between accuracy and computation time (see Blandin et al. [4]). With these parameters, the computation time for a 1000 frequencies transfer function is of the order of one hour. However, these computation times depend on the geometry simulated and obviously on the computer used.

2.7 Phoneme synthesis

Once the transfer functions have been computed, it is possible to synthesize static phonemes with the buttons "Play vowel" and "Play noise source" on the left panel. The button "Play vowel" synthesize a vowel sound by convolving a glottal pulse synthetic signal with the impulse response computed from the glottal transfer function displayed in the bottom panel. The glottal pulses are generated with a Liljencrants-Fant model [7] whose parameters can be defined using the dialog shown by clicking on the button "LF glottal flow pulse" in the left panel.

The noise synthesis can be useful to synthesize fricative consonants. A synthetic noise signal corresponding to a white noise filtered with a first order low-pass filter having a cutoff frequency of 5 kHz is convolved with the impulse response of the noise source transfer function displayed in the bottom panel.

The synthetic sound generated correspond to the point at which the transfer functions displayed have been computed. Thus, it is possible to listen to the synthetic vowel generated at various locations. This can be useful to study directivity effects. However, note that phenomena important for directivity such as the head and torso diffraction are not simulated. Thus, the directivity effects which can be studied are only due to the mouth opening dimension and the influence of the vocal tract on the acoustic field at the mouth exit.

The synthesized sounds can be visualized and analyzed in the "Signal" page. It is also possible to export them as `.wav` files by clicking "Save WAV" or "Save WAV as TXT" in the "File" menu of the main window.

3 Log file

The parameters used for each simulation and information regarding the evolution of the simulation process are given in a log file. An example of such file is given below:

```
Wed Jul 20 15:06:09 2022

Geometry is from VocalTractLab

PHYSICAL PARAMETERS:
Temperature 31.4266 C
Volumic mass: 0.00115771 g/cm^3
Sound speed: 35000 cm/s

BOUNDARY CONDITIONS:
Percentage losses 100 %
Visco-thermal losses included
viscous boundary specific admittance (2.02984e-05,2.02984e-05) g.cm^-2 .s^-1
thermal boundary specific admittance (4.84832e-05,4.84832e-05) g.cm^-2 .s^-1
Wall losse included
glottis boundary condition: IFINITE_WAVGUIDE
mouth boundary condition: ZERO_PRESSURE

MODE COMPUTATION PARAMETERS:
Mesh density: 5
Max cut-on frequency: 20000 Hz
Compute modes and junction matrices: NO

INTEGRATION SCHEME PARAMETERS:
Propagation mmethod: MAGNUS order 2
Number of integration steps: 3
Take into account curvature
Area variation within segments taken into account
scaling factor computation method : AREA

TRANSFER FUNCTION COMPUTATION PARAMETERS:
Index of noise source section: 25
Maximal computed frequency: 10000 Hz
Spectrum exponent 10
Frequency steps: 43.0664 Hz
Number of simulated frequencies: 233
Transfer function point (cm):
3 0 0

ACOUSTIC FIELD COMPUTATION PARAMETERS:
Acoustic field computation at 1206.9 Hz with 30 points per cm
Spatial resolution for field picture: 30 points per cm
Bounding box:
min x -3.34796
max x 5.94298
min y -7.95
max y 1.57243
Compute radiated field YES
```

This file, named `log.txt`, is generated and modified automatically in the working directory of VocalTractLab3D. It can be useful to assert which parameters have been used for a specific simulation, or to follow in more details the simulation process. During a simulation, on can follow its updates in real time with an appropriate software. This can be done with Notepad++ by selecting the option "Monitoring" in "View". In Linux this can be done in the command line with

```
tail -f log.txt
```

A copy of the log file can be saved to keep track of the parameters used for a specific simulation.

4 Aknowledgements

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