Source Modelling

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- Topics:

- Filtering (Waveguide)
- Physical Modelling

- Emulation of the functioning of musical instruments

- Classic method: systems of equations describing the acoustic behaviour of an instrument

- Not very practical: equations are too complex

- Very demanding in terms of computational resources

- Alternatives: encapsulate the equations into modular blocks; then one use these blocks to implement the synthesisers

- Interesting “surreal” instruments; e.g., change the material of the instrument during the sound production; change the shape, etc.

- Electrical circuits can be used to study mechanic-acoustic models

- Various electrical models of musical instruments were created in 1930's at RCA Labs

- But progress on turning these models into usable synthesisers for music was slow until computer technology became available

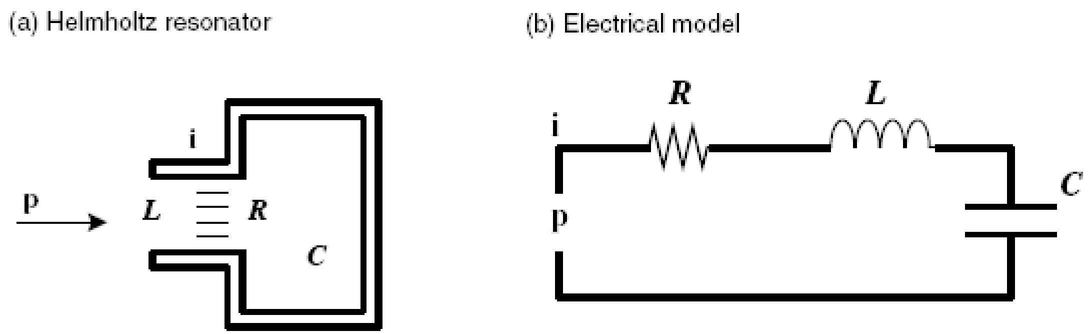


Figure 4.1 Electrical circuitry (b) may be used to model mechanico–acoustic systems (a)

Subtractive Synthesis

- Source-filter paradigm can be considered as a simple case of physical modelling
- Approach to modelling the instrument, rather than the sound

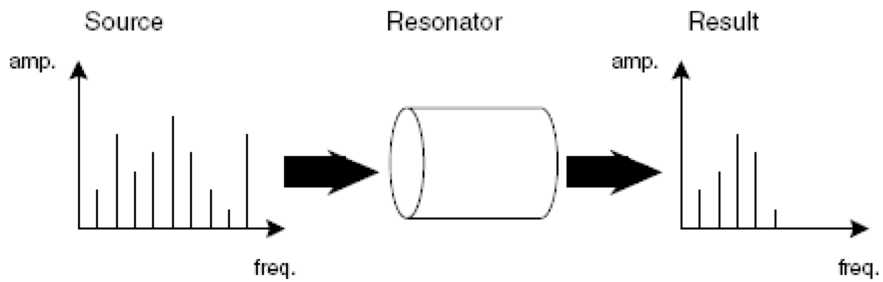


Figure 4.2 A variety of spectra can be obtained by varying the acoustic properties of the resonator

Filters

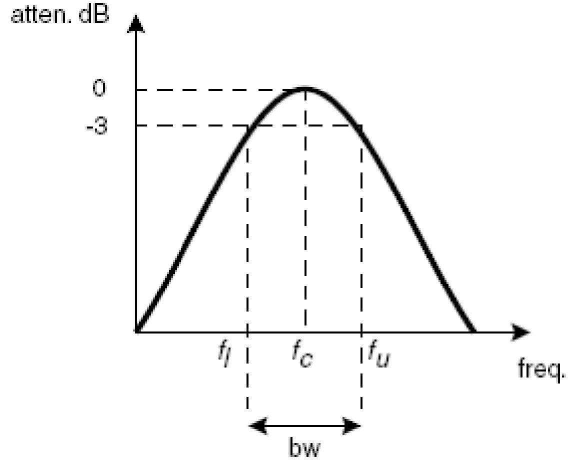


Figure 4.3 The basic building block of subtractive synthesis is the band-pass filter (BPF)

Waveguide Filtering

- Similar to subtractive synthesis, but it is based on the feedback interaction between the source of excitation and the resonator

- This feedback interaction enables to model resonating media other than acoustic chambers, such as strings

- A waveguide filter comprises a variety of signal processing units, mostly delay lines and LPFs

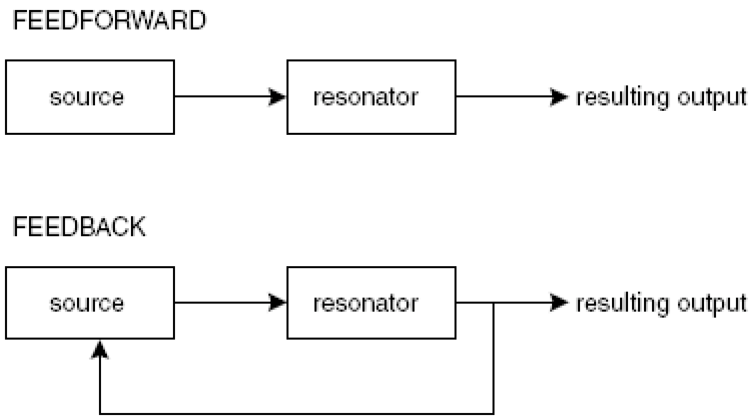


Figure 4.6 The feedback interaction between the source and the resonator is an important aspect of the waveguide technique

- A good way to visualise the technique: imagine what happens when the string of a monochord is struck at a specific point

- Two waves travel in opposite directions and when they reach a bridge, some of their energy is absorbed and some is reflected back to the point of impact, causing resonance and interference

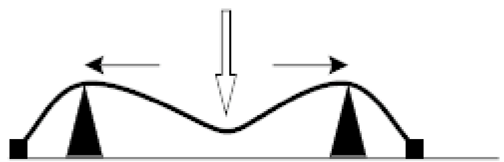


Figure 4.7 When the string of a monochord is struck at a specific point, two waves travel in opposite directions. When they reach a bridge, some of their energy is absorbed, and some is reflected back to the point of impact, causing resonances and interferences

• A source signal – e.g. noise – is input into a bi-directional delay line and travels until it reaches a filter (Filter A)

• The filter passes some of the signal’s energy through and bounces some energy back

• This models the effect of a scattering junction, such as the whole in a cylindrical tube or a finger pressing a string

• Filter B at the end of the chain is intended to model the output radiation type (e.g., the bell of a clarinet)

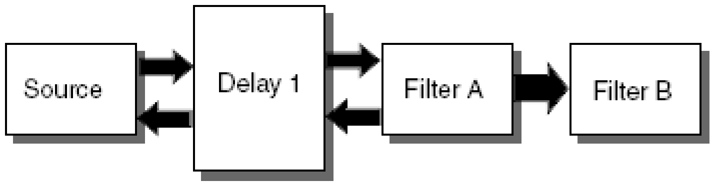


Figure 4.8 A generic waveguide filter instrument

Classic Physical Modelling

- Emulation of the behaviour of an acoustic device using a network of interconnected mechanical units: mass-spring-damping (MSD units)

- Implemented as a set of differential equations, whose solution describes the waves produces by the model in operation

- Sound samples result from the computation of these operations

- Ability to capture 2 essential properties of vibrating media: mass density and elasticity

- A single string can be modelled as a series of masses connected by spring-damping units

Figure 4.13 A string can be modelled as a series of masses connected by spring-damping units

• If force is applied to a certain portion of the string ("striking it"), masses are displaced from their initial positions

• Generate wave motion, forcing other masses to move away form equilibrium

• Mass density and elasticity define speed of propagation, resistance to disturbance and time it takes to restore its equilibrium

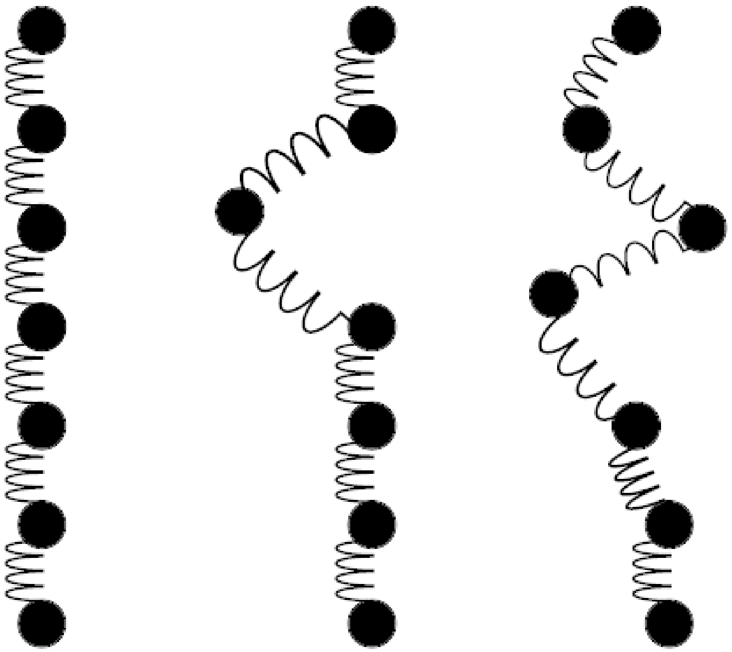


Figure 4.14 Disturbed mass units propagate the disturbance and generate wave motion by forcing adjacent masses to move away from their point of equilibrium (Note that this is only a schematic represention of the mass movements)

• Surfaces (e.g., skin of drum) and volumes can be modelled as a network of masses connected by more than one spring

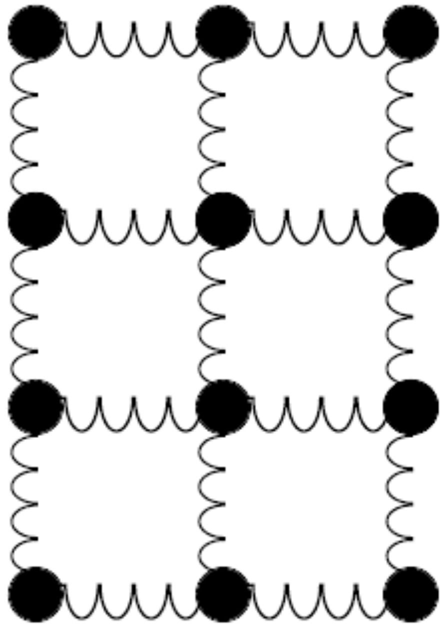


Figure 4.15 A membrane can be modelled as a matrix of masses connected by spring-damping units

Types of physical modelling systems available to musicians

- Generic:
  - PM tools not originally designed for music, but for mechanical simulations.
  - They are very flexible in terms of what can be done, but may lack specific requirements for audio simulations (e.g. built-in routines for generating high-quality sounds.
  - Example: *Bond Graphs*

- Dedicated:
  - Specially designed for modelling musical instruments.
  - Lack of generality is compensated by specially designed functions for audio, etc.
  - Example: *Cordis*

- Specific:
  - Provide a ready-made instruments furnished with the means to control their parameters.
  - One cannot program other the instruments with it.
  - Example: *Praat's vocal synthesiser*

Genesis and Cordis

- Genesis is a visual interface for Cordis-Anima, a programming language developed at ACROE (Grenoble) for implementing simulations of sounds (Cordis) and animated objects (Anima)

- Cordis instruments are built using two types of 'atoms': matter and links

- "Atom" = the smallest unit of Cordis

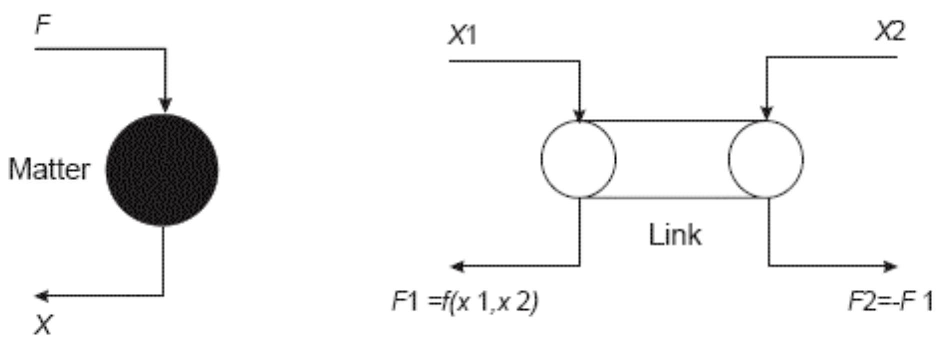


Figure 4.26 Matter and links are the two atoms of the Cordis universe

• Matter: exists in a 3D space and its state is computer according to forces exerted by the surrounding environment

• Link: connects pieces of matter; acts as a mechanical bridge between 2 pieces of matter; it does not take physical space

• Matter and link atoms are connected by 2-channel ports

• 1 channel is used to communicate force vectors *F*
• 1 channel is used to communicate displacement vectors (or positions) *X*

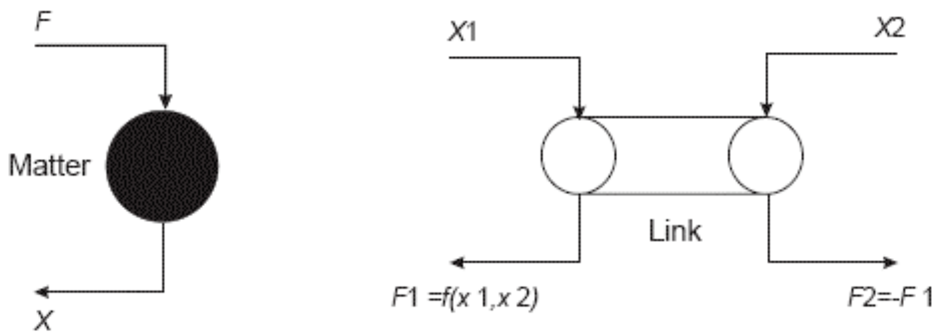


Figure 4.26 Matter and links are the two atoms of the Cordis universe

- 3 types of links: spring, friction and conditional
- Spring and friction = spring & damping elements
- Conditional = a combination of spring and friction; allows for non-linear interactions

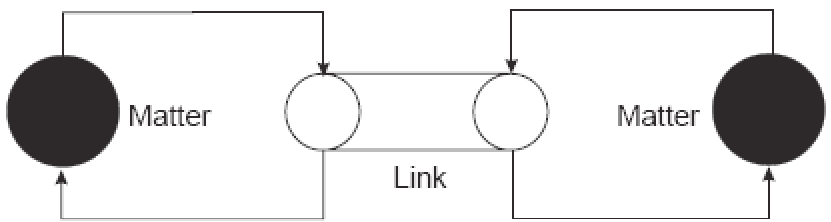


Figure 4.27 A Cordis instrument consists of a network of pieces of matter and links

Genesis

• A ‘canvas’ and a menu for atoms

• Matter is represented by a circle
• Link is represented by a wire

• A network is built by dragging the respective atoms from the menu onto the canvas and connecting them

• Each atom has a number of attributes that can be edited via a pop-up menu

• 2 types of atoms: MAT (matter) and LIA (link)

• 2 types of MAT: MAS (mass) and SOL (ground; to represent a fixed support)

• MAS has 3 parameters: inertia (M), initial position (X_0), speed (V_0)

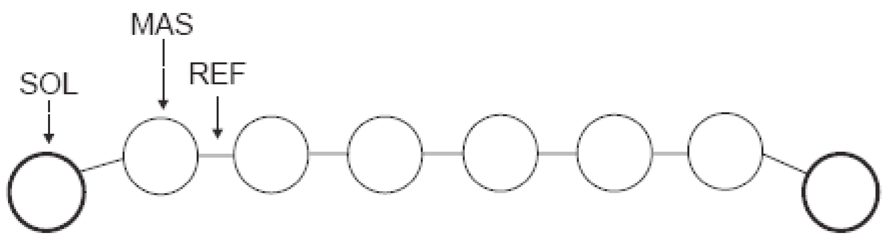


Figure 4.28 An example of a string represented in Genesis

• 5 types of LIA: RES (spring), FRO (friction; or damping), REF (spring-damping), BUT (block), LNL (non-linear link)

• LIA defines the nature of the bridge between 2 MATs

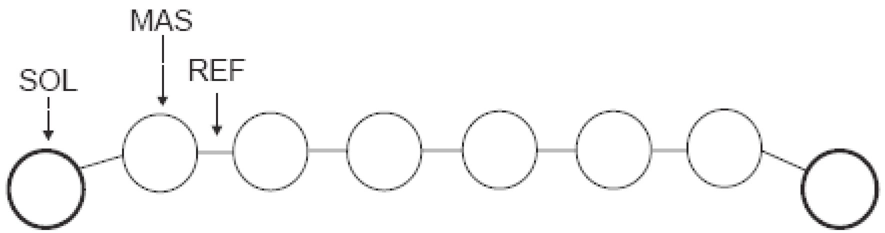


Figure 4.28 An example of a string represented in Genesis

• This string could be set into vibration by pulling out some of its masses; e.g., by changing the initial position (X_0) of a MAS

- A more sophisticated way would be to implement a hammer to strike the string

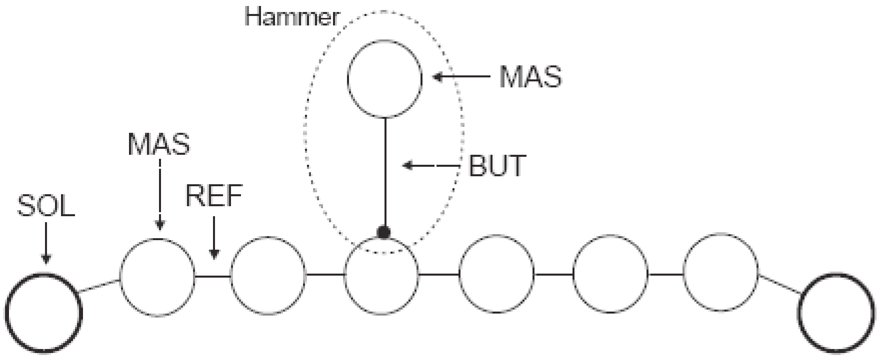


Figure 4.29 An example of an instrument consisting of a string and a hammer to strike it

- The ability to build hierarchical vibrating structures, whereby the behaviour of one can control the behaviour of another

- 3-level structure
- Musician: controls the hammer
- Genesis encourages composers to think in terms of a unified physical modelling framework for composing musical structures

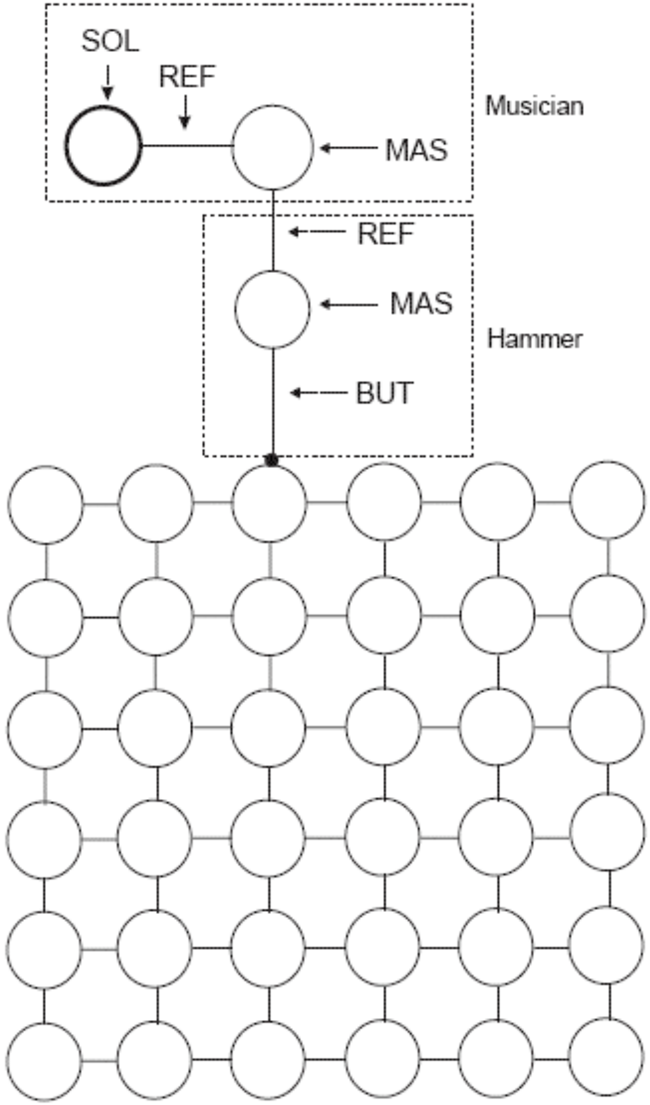
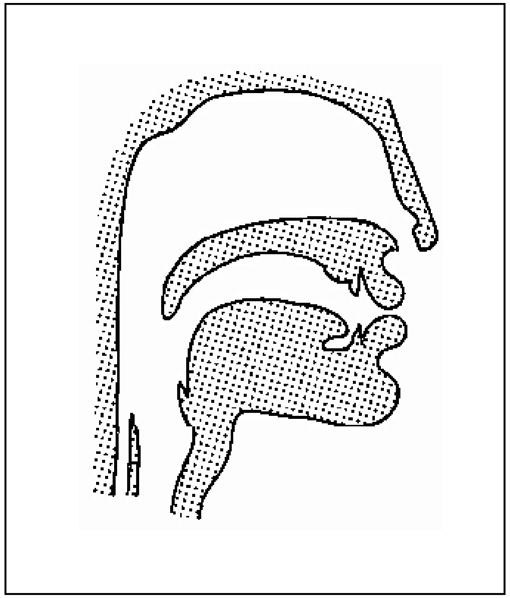


Figure 4.30 A three-level structure instrument consisting of a membrane, a hammer and a device that controls the hammer, or 'musician'

Praat's vocal synthesiser



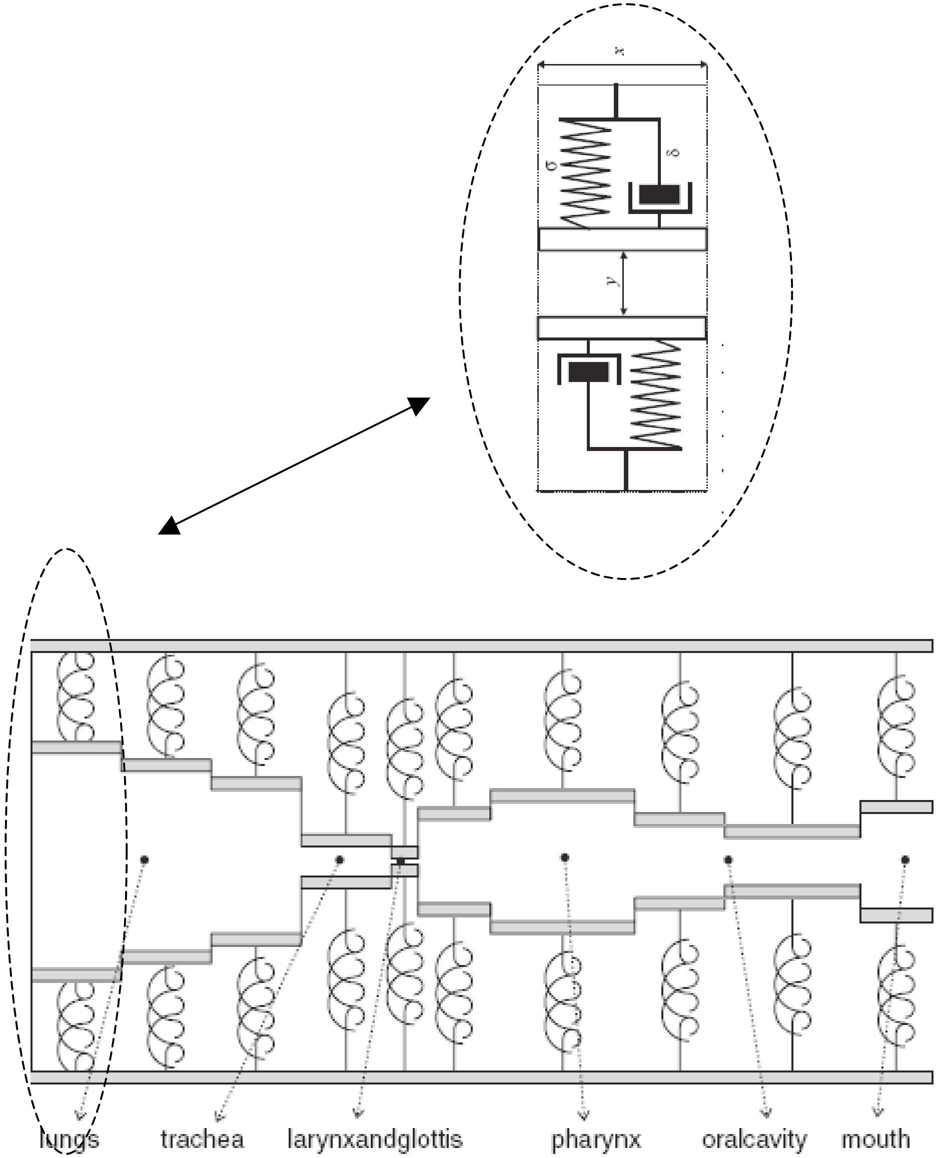


Figure 4.32 Schematic representation of the vocal system. Each sub-pipe has four walls, but for the sake of clarity, the third dimension is not represented in this figure. Also not represented here is the branching for the nose at the boundary between the pharynx and oral cavity