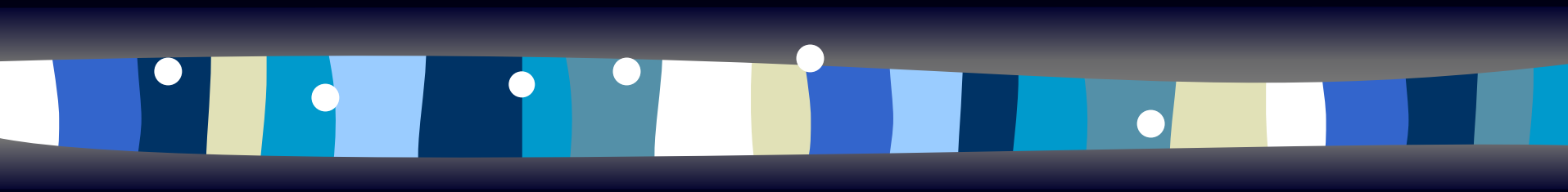
"THE VIRTUAL FLUTE": ACOUSTIC MODELLING AT THE SERVICE OF PLAYERS AND COMPOSERS



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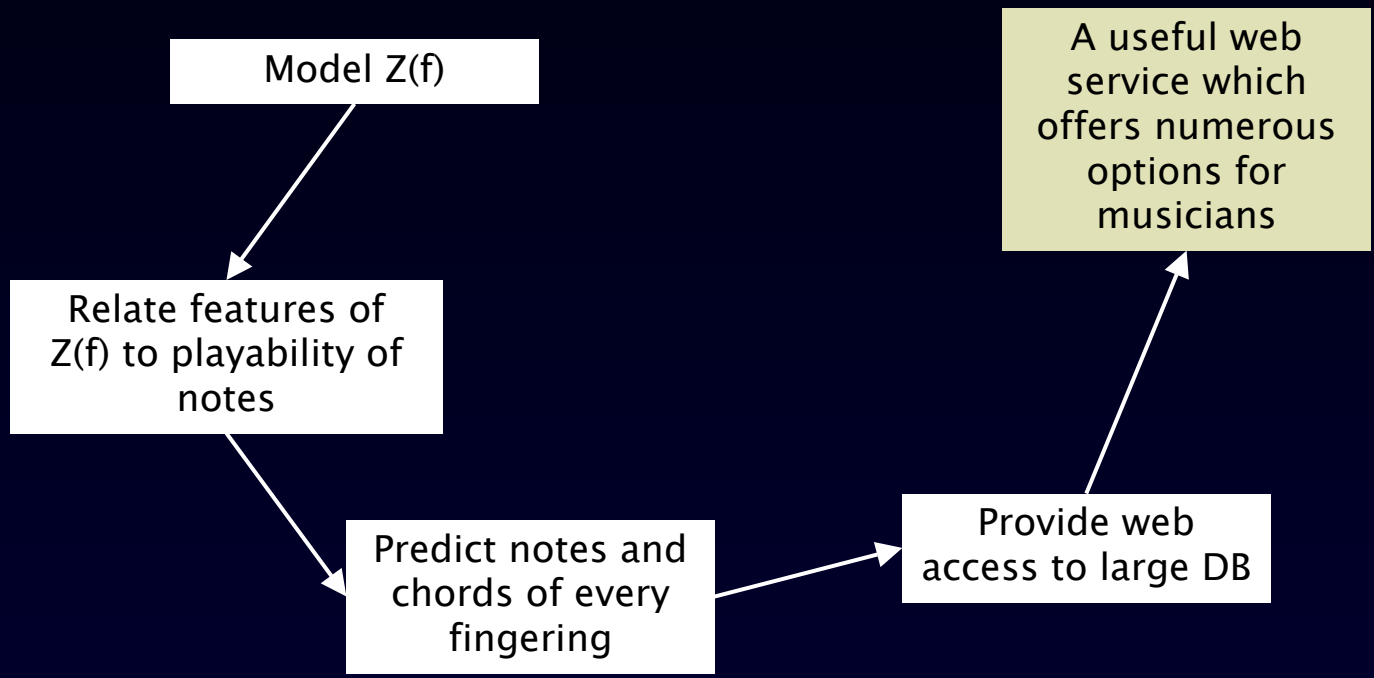
INTRODUCTION

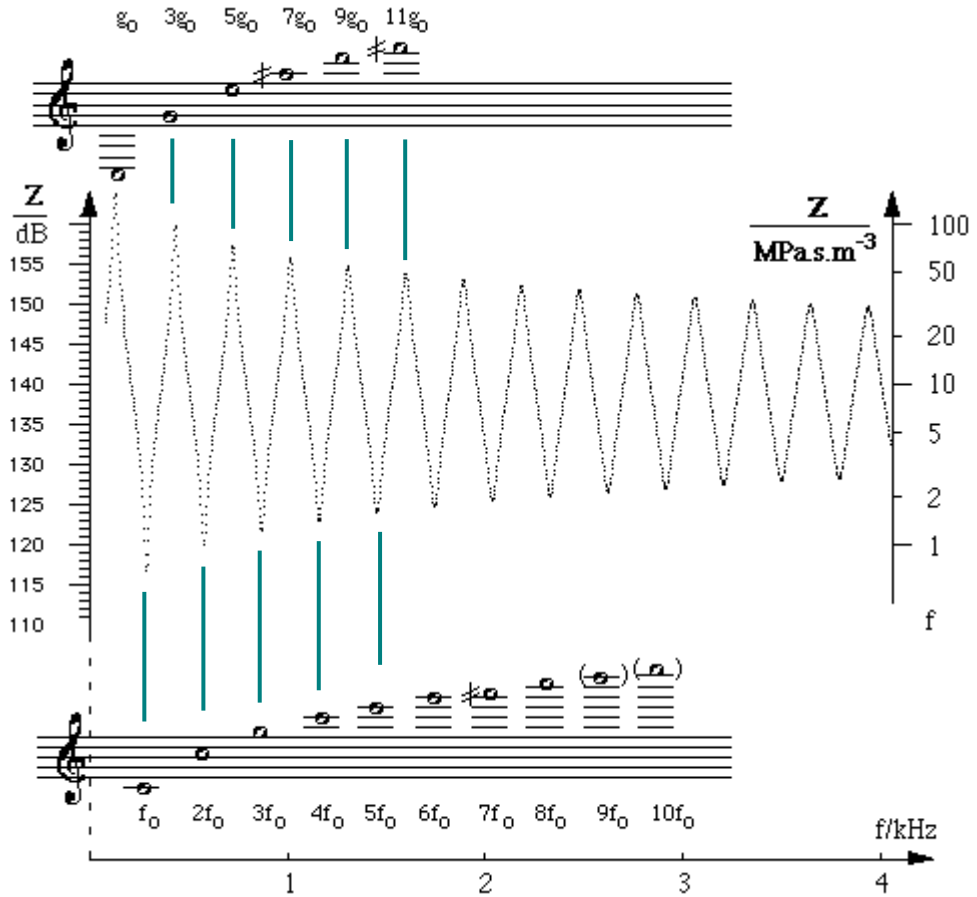
- Why are wind instruments difficult to play?
  - Pitches may need to be corrected
  - Loudness and stability can be difficult to control
  - Timbre may be inhomogeneous
  - Fingering transitions can be awkward
- What are flutists and composers requesting?
  - Alternate fingerings
  - Microtones
  - Multiphonics
  - Technical ease so they can concentrate on the music!

INTRODUCTION

- How can music acoustics help? Acoustic Impedance (Z(f)) tells a lot about a flute's musical response.



IMPEDANCE SPECTRA

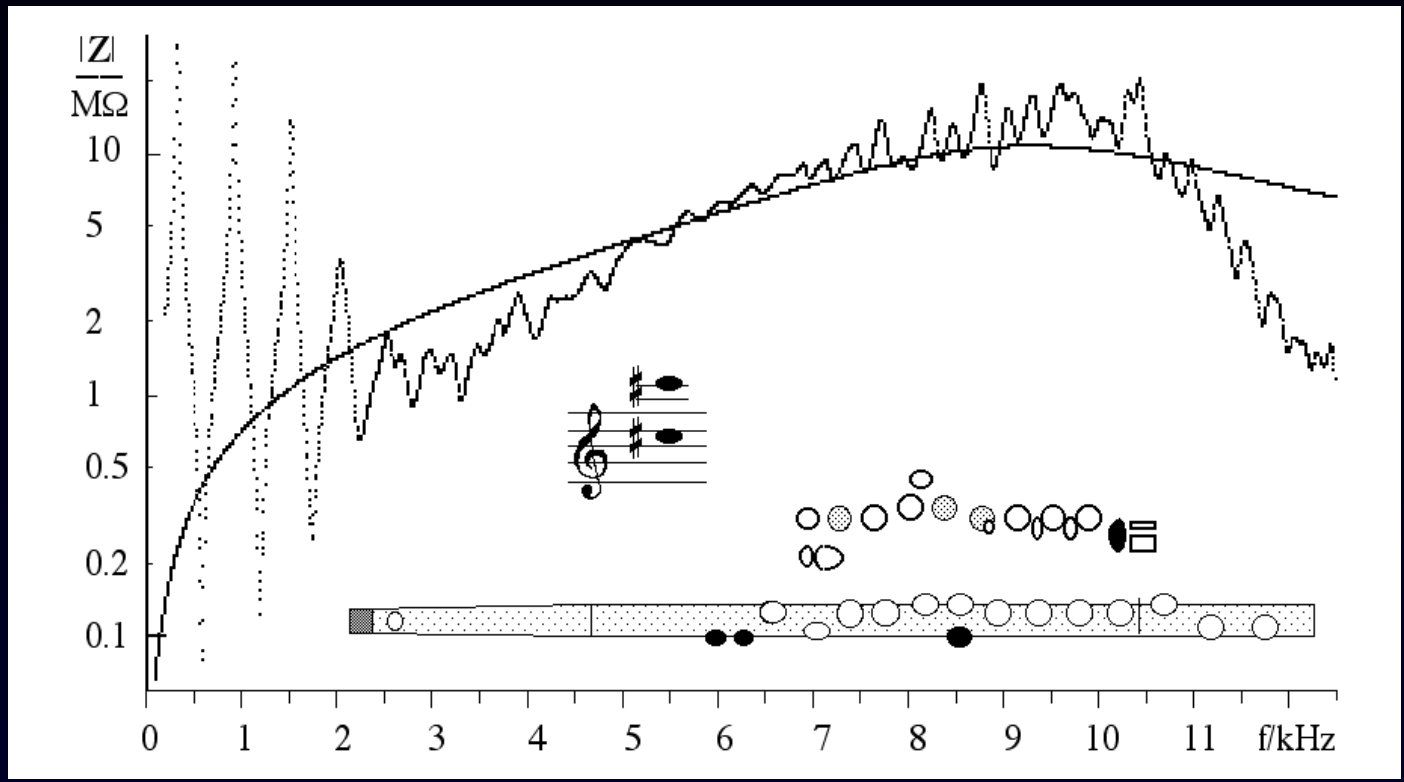


Clarinets play at maxima

Measured Z(f) of 600 mm cylinder

Flutes play at minima

IMPEDANCE SPECTRA



modern B flute acoustics - D6 - Microsoft Internet Explorer

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Acoustics of baroque, classical and modern flutes

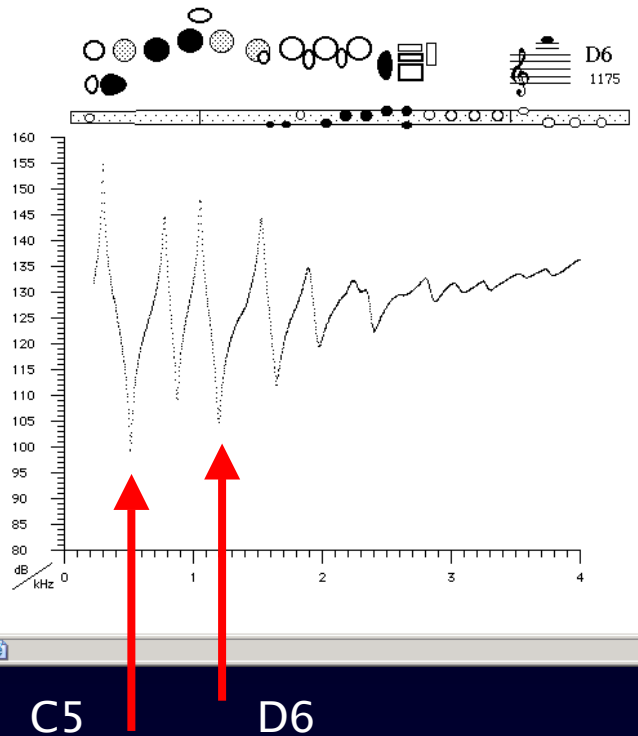
modern flute
B foot

D6

Music Acoustics
UNSW

modern B	modern C	classical C	classical D	classical flared	baroque	B3
C4	C#4	D4	D#4	E4	F4	F#4	G4	G#4	A4	A#4	B4
C5	C#5	D5	D#5	E5	F5	F#5	G5	G#5	A5	A#5	B5
C6	C#6	D6	D#6	E6	F6	F#6	G6	G#6	A6	A#6	B6
C7	C#7	D7	D#7	E7	F7	F#7	multiphonics				

Impedance



Fingering

- a key depressed
- a key not depressed
- a part of the mechanism that is not normally touched

Details in fingering legend.

Acoustic schematic

- a closed tone hole
- an open tone hole

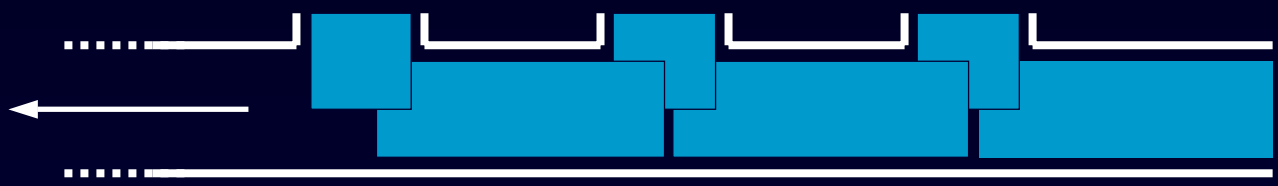
Non-specialist introduction to acoustic impedance
Non-specialist introduction to flute acoustics

Internet

C5 D6

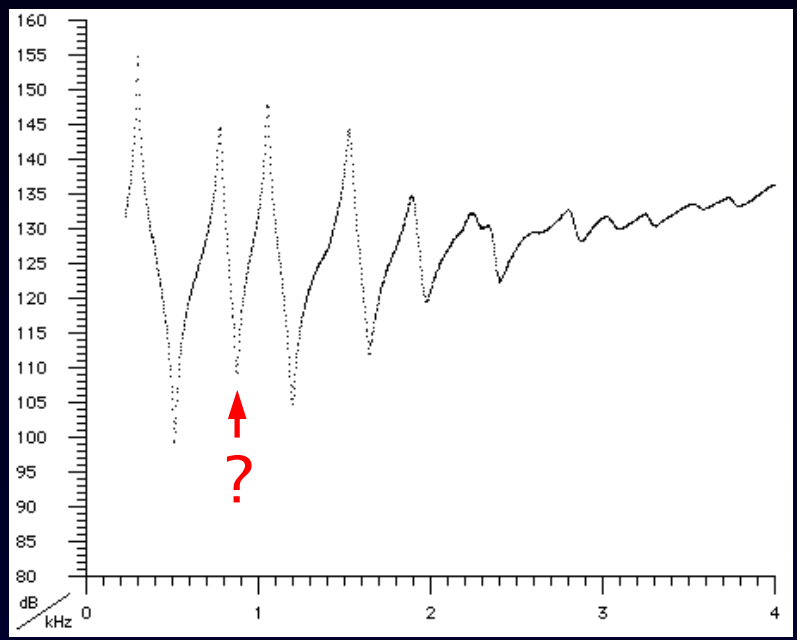
MODELLING IMPEDANCE

- Use a network of one-dimensional cylindrical and conical sections to model flute geometry.
- Use a small number of end corrections and an embouchure attenuation correction.
- Fit model to extensive database of accurate measurements, using progressively more complex systems (from simple tubes to complete flutes).
- Transmission line calculation…



EVALUATING IMPEDANCE MINIMA

- We need to get from characteristics of impedance minimum (physical quantity) to playability (player assessment).

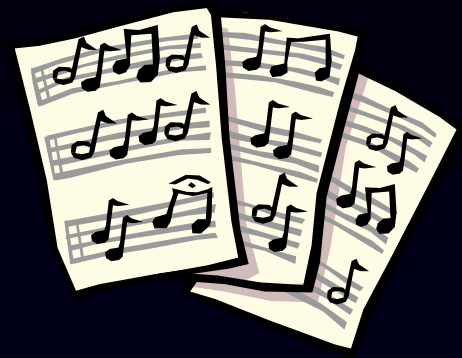


FLUTE PLAYABILITY EXPERT SYSTEM

- The playability of 957 measured minima from 76 different fingerings were evaluated on a scale of 3 (most playable) to 0 (not playable).
- The results form the training set of an expert system, using discrete and continuous decision trees.

DATA MINING MUSICAL DATA

Generate all 39,744 fingerings.
For each fingering...



Calculate impedance spectrum using transmission line model

Extract minima and characterise features (depth, bandwidth, harmonicity, adjacent minima features, etc.)

Predict noncommensurate note combinations as multiphonics

Correct pitches for playing conditions

Predict playable notes

THE VIRTUAL FLUTE EVALUATION

"I am just amazed at the number of fingerings you have provided the flute world with … It's great to see this work being done. We talk about it quite a bit here."

"Simply the most innovative and valuable resource that I have encountered throughout my 25 years as a flute player … Should I have a query about how to play a particular multiphonic or quartertone, I will find the solution on *The Virtual Flute.*"

"Being able to have precise tunings and multiphonic predictions for any given fingering was an incredible time saver … I only wish similar sites were available for other wind instruments!"

THE VIRTUAL FLUTE EVALUATION

"It's the granddaddy of fingering charts."
Seattle Flute Society