

DATA MINING FOR ALTERNATE FINGERINGS AND MULTIPHONICS OF THE MODERN FLUTE



Andrew M. Botros BE MBiomedE

The University of New South Wales

School of Computer Science & Engineering • Music Acoustics, School of Physics

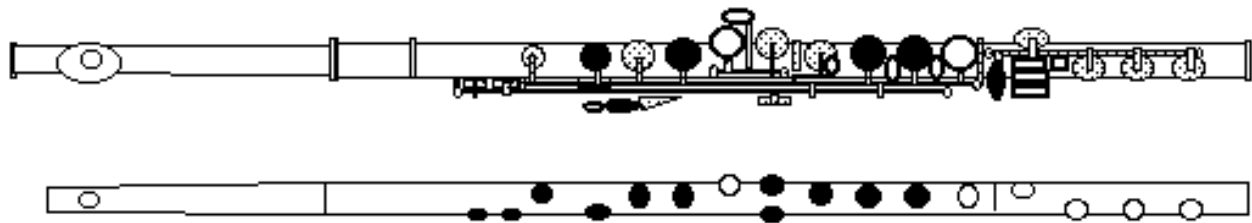
... and Jane!

(Expert flutist – recruited from the UNSW Orchestra)

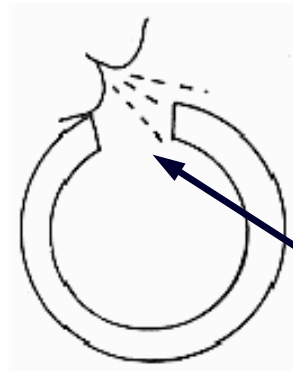
FLUTES AND FLUTE PLAYING

tapered head

cylindrical body and foot

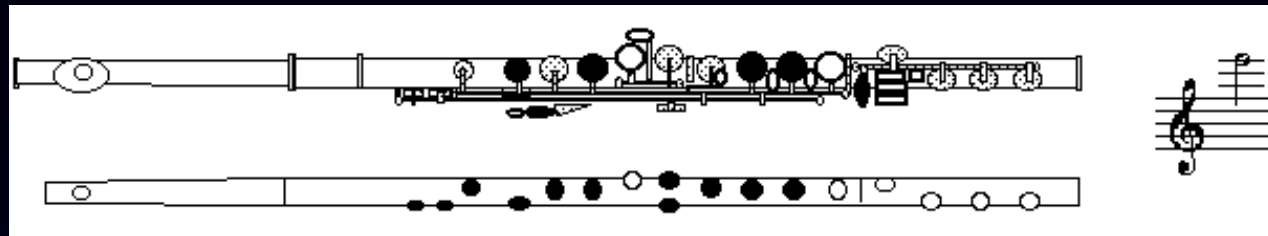


16 or 17 holes



embouchure hole

STANDARD & ALTERNATE FINGERINGS



- A standard fingering is known for each of the flute's 44 standard notes.
- There are in fact 39,744 unique fingerings! Each note therefore has a number of **alternate fingerings**.



WHY ALTERNATE FINGERINGS?

- Better **intonation** in different circumstances.
- Easier to play in different contexts, such as fast or awkward passages, and **trills**.
- **Microtones**.

MULTIPHONICS

- Flutes can also play more than one note at a time.
- Multiphonics are increasingly written for modern flute solos.



- Most multiphonics are unknown. Musicians do not have a large source of multiphonics.



PROJECT GOALS

- Only **several hundred** alternate fingerings and multiphonics are known, though in reality there are **hundreds of thousands**.
- The main aim is to predict as many alternate fingerings and multiphonics as possible, and to make them available to musicians.
- For 150 years, the entire musical response of the flute has not been known... Until now.



ACOUSTIC IMPEDANCE

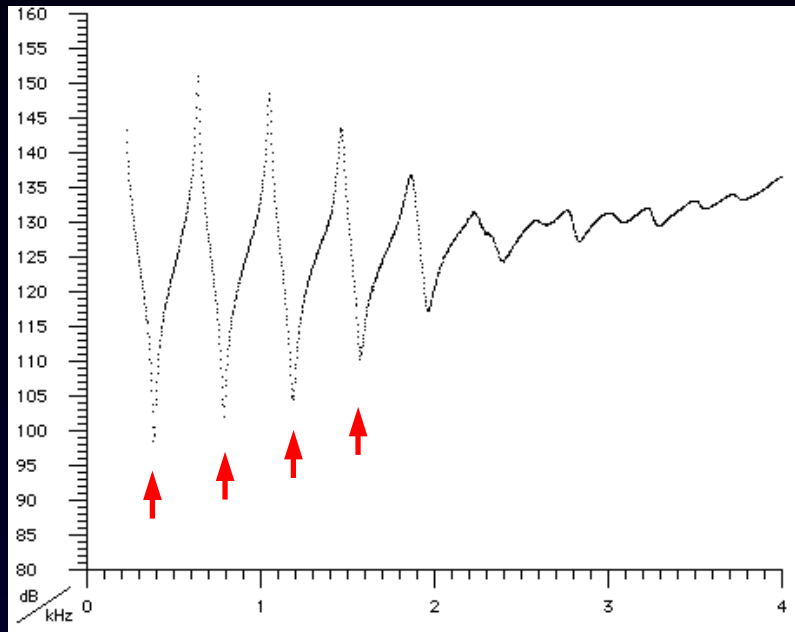
$$Z = \frac{\text{Acoustic pressure}}{\text{Air flow}}$$

$$Z = \frac{V}{I}$$

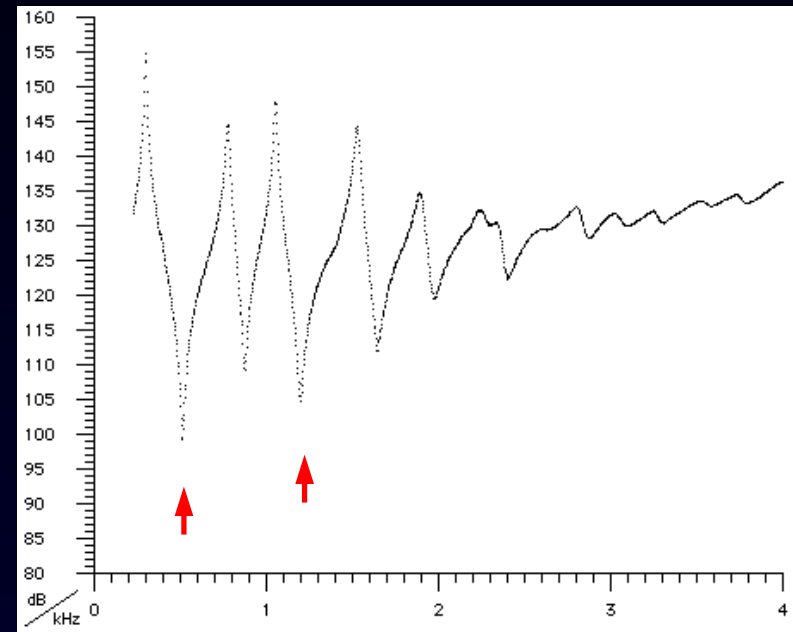
- The impedance spectrum at the embouchure hole of a flute tells a lot about the musical response of the flute.
- Low impedances give rise to high resonances - i.e. the flute sounds at impedance **minima**.

IMPEDANCE SPECTRA

G4/G5



D6, C5&D6





SIMULATING ACOUSTIC IMPEDANCE

- Researchers in the past have attempted to simulate flute impedances without accurate measurements.
- Two possible approaches: a 3D model, or a 1D model with measured corrections for 3D effects.
- The method here is to model the flute with a network of cylinders and truncated cones.

TRANSMISSION LINE CALCULATION





MEASURING 3D TO 1D CORRECTIONS

- A number of physical parameters must be minutely adjusted for an accurate 1D model.
- Adjustments were made in an incremental fashion by investigating simpler systems first.



SIMULATION EVALUATION

- The result? The most accurate flute impedance simulation ever developed.
- Presented at a Musical Acoustics conference in Italy 2001, and being prepared for publishing in 2002.



EVALUATING IMPEDANCE MINIMA

- We need to get from impedance minimum (physical quantity) to playability (player assessment).
- Jane tested the playability of 957 minima from 76 different fingerings on a scale of 3 (most playable) to 0 (not playable).
- Her results form the training set of an expert system, using decision trees.



FLUTE PLAYABILITY EXPERT SYSTEM

- An innovation: separate the discrete and continuous aspects of the problem domain.
- Use C5.0 to predict whether an impedance minimum is playable or not. (Well behaved, 5% error rate.)
- Use Cubist to rank playable minima on a continuous scale of 0 to 3. (Quite approximate but very useful.)

DATA MINING MUSICAL DATA

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



Calculate impedance spectrum
using transmission line model

Extract minima

Predict harmonically unrelated
notes as multiphonics

Predict playable notes

Correct pitches of playable
notes for playing conditions



THE VIRTUAL FLUTE

<http://www.phys.unsw.edu.au/music/flute/virtual/>



THE VIRTUAL FLUTE EVALUATION

"I've been to your site - bravo! It's beautifully done in a musician friendly way."

Robert Dick, U.S.A.

"The Virtual Flute is GREAT. It's fantastic to see this work being done. We talk about it quite a bit here."

Ann Cecil Sterman, New York City

"Wow. This is the greatest thing I have seen in all my flute playing. I will totally use this."

Frank Davis, Saudi Arabia



POTENTIAL AND FUTURE RESEARCH

- Become the defining source on flute fingerings, replacing current sources. (e.g. the elusive G7.)
- Consider that Yamaha's flute sales in Australia are \$3M per year. If we can design the "ideal" flute...
- Now consider that we're doing the same research for the clarinet, oboe, bassoon.....



QUESTIONS?