DATA MINING FOR 
ALTERNATE FINGERINGS AND MULTIPHONICS 
OF THE MODERN FLUTE

Andrew M. Botros 
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)
A fingering map for virtual virtuosos

Jeremy Roberts

A FLUTE has 17 holes and can play 44 notes — from a semitone below middle C to F sharp, three octaves above. But in theory there are more than 25,000 different combinations for playing the notes — and an engineering student has mapped them all.

Andrew Botros of the University of NSW has won the $25,000 Siemens Prize for Innovation for his flute simulator and Internet site that analyses the thousands of alternative fingerings available to experienced flautists.

The virtual flute gives alternative fingerings, a ranking of the difficulty of playing the note and predicts special acoustic properties such as multiphonics or chords.

Mr Botros worked with UNSW Orchestra principal flautist Jane Cavanagh, who verified many of the new fingerings suggested by the virtual flute and also found many were physically impossible to play.

Ms Cavanagh was on hand when Mr Botros received his prize at NSW Parliament House on Friday to demonstrate some new ways of playing old notes.

"From a musician's point of view the website is an amazing resource for players and composers," Ms Cavanagh said.

Experienced flautists were able to select new fingerings to suit their musical purpose.

‘Winning this prize may enable me to design the ideal flute’
Andrew Botros
Winner, Siemens Prize for Innovation

Cavanagh, who verified many of the new fingerings suggested by the virtual flute and also found many were physically impossible to play.

Ms Cavanagh was on hand when Mr Botros received his prize at NSW Parliament House on Friday to demonstrate some new ways of playing old notes.

"From a musician's point of view the website is an amazing resource for players and composers," Ms Cavanagh said.

Experienced flautists were able to select new fingerings to suit their musical purpose.

For example, Ms Cavanagh said the rapid change between A and F in the third octave above middle C was made easier by using new fingerings suggested by the virtual flute.

And composers could find new chords, Mr Botros said.

"Winning this prize may enable me to design the ideal flute in the near future."

Ms Cavanagh has played — or attempted to play — several hundred new fingering configurations and ranked them according to difficulty and the stability of the notes...

Mr Botros won from seven state and territory finalists who competed for $50,000 in prizes.

Watch for The Australian’s special report on education in Science, Engineering and Technology with Higher Education next week.
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

\[ Z = \frac{\text{Acoustic pressure}}{\text{Air flow}} \quad Z = \frac{V}{I} \]

- 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.
IMPEDEANCE 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.
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.
EVALUATING IMPEDANCE MINIMA

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

Alan Turing, 1950.
ARTIFICIAL INTELLIGENCE

HAL9000, 1969.
Age = 41
Sex = Female
Sick = False
Thyroid surgery = False
TSH = 1.3
T3 = 2.5
TT4 = 125
Hypothyroidism = Negative
DECISION TREES (C5.0)

Guess Who? - Determine if person is male or female

- Earrings? (Yes/No)
  - No: Red cheeks? (Yes/No)
    - Yes: FEMALE
    - No: Bald
      - Bald: Short
        - Short: MALE
        - Long: FEMALE
      - Hair length: Long
        - Long: FEMALE

- Yes: FEMALE

- MALE
FLUTE PLAYABILITY EXPERT SYSTEM

- Jane tested the playability of 957 minima from 76 different fingerings.

- Predict whether an impedance minimum is playable or not. (Well behaved, 5% error rate.)
DATA MINING MUSICAL DATA

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

Calculate impedance spectrum using transmission line model

Extract minima

Predict playable notes

Predict harmonically unrelated notes as multiphonics

Correct pitches of playable notes for playing conditions
THE VIRTUAL FLUTE


http://www.phys.unsw.edu.au/music/flute/virtual/
“Gee, look at all the little black dots.”
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.....
ASTOR PIAZZOLLA

Tango Etude No. 6
for Solo Flute
QUESTIONS?