Developing a Microtonal Clarinet via Wind Controller and 3D Printing

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Precedents

Early harpsichords (before the adoption of well-tempered tuning systems) were sometimes built with "black" keys split front-to-back.

This javascript demo compares three different EDO keyboards: a Modern disposition 19-tone keyboard, a standard 12-tone keyboard, and a third 19-tone keyboard with the ancient keyboard layout.

More details at
Why 19-EDO?

Graham Hair:
Vocalise for 19EDO Clarinet/Breath Controller and Digital Ensemble

Neo-Riemannian harmony: chords share constant and moving notes across

Enharmonically Equivalent in 19-EDO
Hyperchromatic Step in 19-EDO
Specialist Instruments

- Players of “un-fretted” (strings, but also voice, trombone etc) instruments obviously need only modify their technique to produce non-standard intonation.

- Variants of standard instruments have been constructed, for example the 19-tone trumpet with an extra valve to produce a hyperchromatic step.

- The following video is a work originally for two women's voices and organ obbligato with one part performed on the 19-tone trumpet (recorded at Animusic 2014, Braga).
Graham Hair: Turkish Duets.
3. Azrail
Acoustic Instrument with Alternative Fingerings

• Presents a huge challenge to expert performer, who has to play with non-standard fingerings “It was like being 15 years old again” (Alex South)

• Attempted by Alex South (SCQ), and Ingrid Pearson (RCM, London; period instrument specialist). Period instruments normally require more exaggerated intonation adjustment.

• The “Ill-tempered clavier”, a scordatura
Electroacoustic Instrument with Custom Interface

- An alternative approach is to give the performer a familiar interface in some way augmented to permit microtonal inflexion.
- The WX5 breath controller was connected to a patch written in PureData. Additional input was acquired from a two pedals which could raise and lower the standard pitches to achieve the desired microtonal inflexion.
- The synthesis algorithm was that of the STK (Scavone et al) which dates back many decades.
Using the Augmented WX5
Alex South explains some challenges of performing with pedal augmentation.
Studio Recording at Manchester Metropolitan University, UK
with Katrina Nimmo (soprano) and Graham Hair (continuo).
Using a 3d-markup language such as OpenSCAD makes possible the
Traveling-wave Acoustical Model

Smith modelled the clarinet as a propagating plane-wave in the 1990s.

- A pressure wave travels from the reed to the bell where it is inverted and reflected. The reflected rarefaction interacts with the reed to produce the oscillatory behaviour.

- Tone holes are modelled as scattering functions.

- The model was acoustically satisfactory, but does it produce accurate pitch estimates?
C++ Programing

Original simulator (Robertson & Scavone) refactored in a more object-oriented fashion to permit easier definition of arbitrary instrument geometries

```cpp
LowDWhistle::LowDWhistle()
{
    const double bore {0.011};

    elements = new const Element*[16] {
        new Butterfly,
        new ToneHole(0.005, bore),
        new ToneHole(0.005, bore),
        new ToneHole(0.005, bore),
        new ToneHole(0.005, bore),
        new ToneHole(0.003, bore),
        new ToneHole(0.0045, bore),
        new ToneHole(0.005, bore),
        new OpenEnd(bore),
        nullptr
    };

    parse_elements();
}
```
Applying Evolutionary Computation to Instrument Specification

- Choose what to optimise
  - Tone hole placement
  - Tone hole size
  - ...to minimise maximum and average deviation from 19-EDO

- Construct instrument from specification and try all possible fingerings
  - 9 holes: 512 fingerings
  - Ramp breath pressure from 0 to “a lot”
  - Find fundamental frequency of resulting tone
DEAP Programming

In this initial study, evolutionary techniques are used to produce a set of tone hole sizes and positions which best match the 19-EDO scale with an arbitrary fingering.
Internal representation

- Parameters are normalised in the range [0, 1.0) to keep DEAP happy.
- A 9-hole instrument has a reed, 9 ToneHoles, 10 Pipes and a Termination.
- The ToneHole diameters are proportions of the bore width.
- The Pipe lengths are multiples on 0.5m.
The BLX-α algorithm

C++ program ends up being invoked like this:

./hotair 0.3617473085502436 0.004492622692911909 0.36546847137480726 0.0045551146322185465 0.25133359603790495 0.013490554296424793 0.3853430271667548 0.006161814134620142 0.03459440899334253 0.007133613067089454 0.3086680273386964 0.01750736934150487 0.3468471013558714 0.009253493363501453 0.3503389630336043 0.013991840063922786 0.2815331036362345 0.013620265929286474 0.3939958437763

Evolutionary Step:

- Select the two parents
- Their separation is \(d\)
- Offspring has value
  - between them
  - or up to \(ad\) outside them

- Mutation: add normally-distributed random variable to individual
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Did it work?

• Yes!
• Well, mostly.
• Fingerings are so arbitrary that they would have to be applied electromechanically for a real performance.
• 3D-printed keys were not air-tight and wore out very quickly.
• The model does not take overblown tuning into account, which is a major factor in the design of a modern instrument (and introduces some key conflicts of interest).
What next?

- Construction of proof-of-concept instrument successful — you can print useful instruments.
- Need more sophisticated model including bore contour to get overblown twelfth in tune.
- Evolutionary Algorithm should take fingering considerations into account.
- Keywork on a “final” instrument should probably be built by an instrument maker. Meanwhile, using early instruments (with...
Pedro Rubio, Clarinettist
Bassus Ediciones, Madrid