An Improved Digital Waveguide Model of a Flute - Implementation Issues

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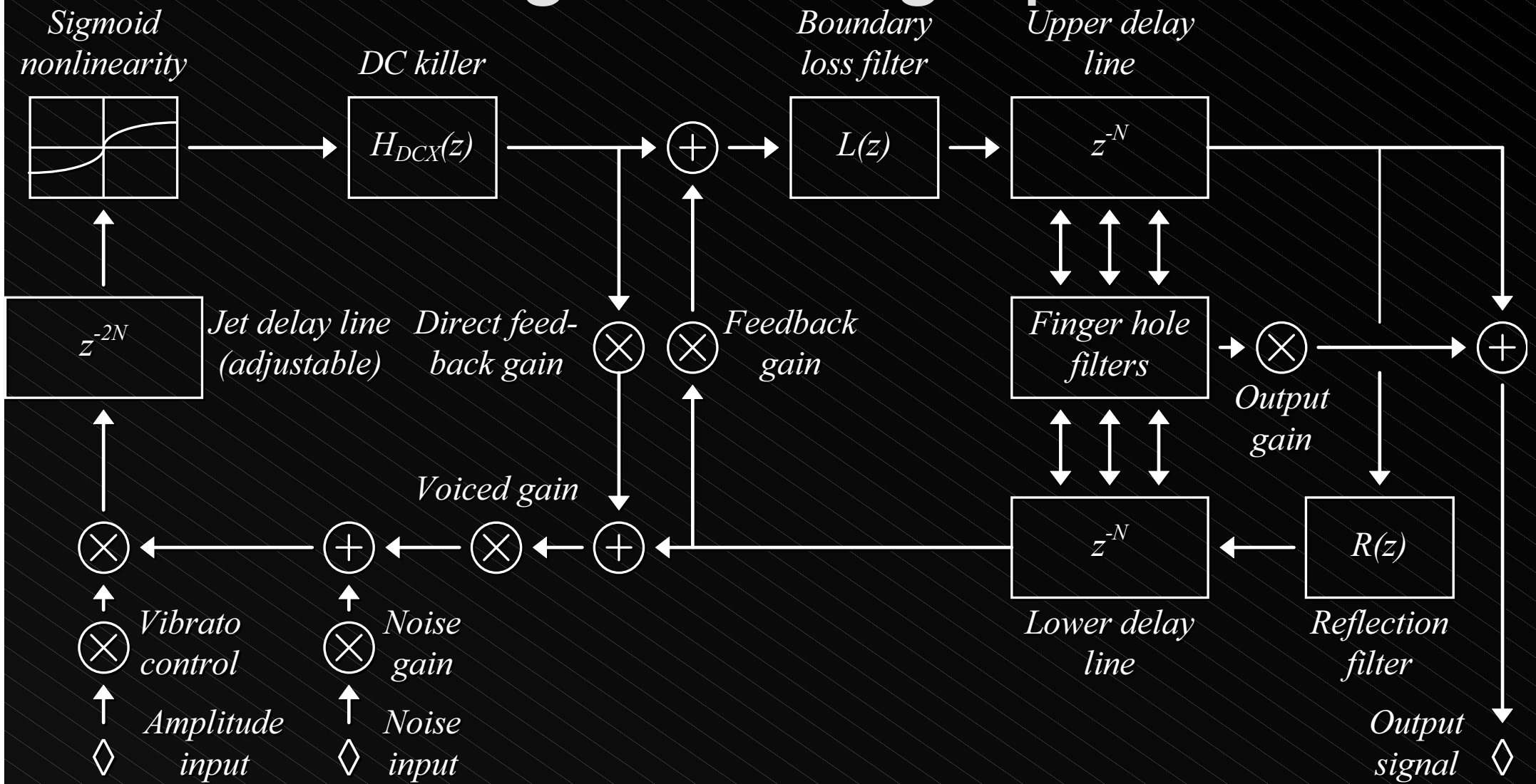
Introduction

- Physical modeling of musical instruments has become a popular approach to digital sound synthesis
- Digital waveguide modeling is one of the most important methods of the many modeling techniques
- Basic theory of digital waveguide modeling developed by J. O. Smith (CCRMA, Stanford Univ.) in the 1980's
- The first real-time waveguide flute model at the Acoustics Lab of HUT was built in 1991-1992 (Karjalainen et al., 1991; Välimäki et al., 1992)
- Recently, physical modeling of the flute has been a target of active research (Coltman, 1992; Chafe 1995; Cook, 1995; Verge, 1995; Magalotti et al., 1995)

Features of the New Flute Model

- Digital waveguide model
- Full set of finger holes (also introduced by Cook (ICMC'95), using a different approach)
- Fractionally delayed finger hole filters using FIR interpolation and deinterpolation
- Overblowing, vibrato, real flute finger tables
- Smooth note transition
- Real-time C++ implementation on a fast Unix-workstation (16 kHz)

Signal Flowgraph



Implementation

Matlab

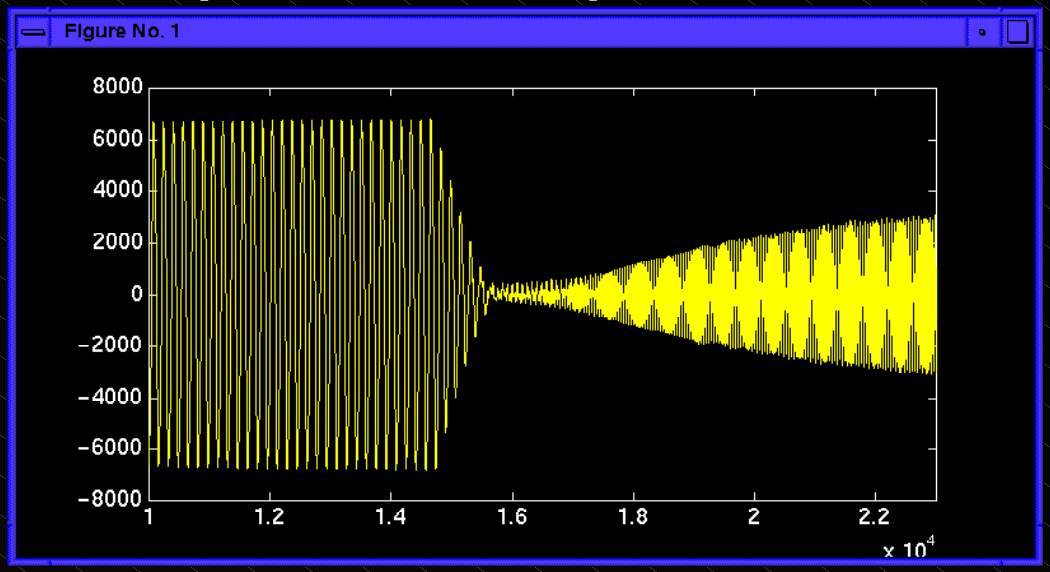
- Linear vectorized delay line
- Finger hole filtering vectorized with matrix operations
- Easy to analyze
- Portable

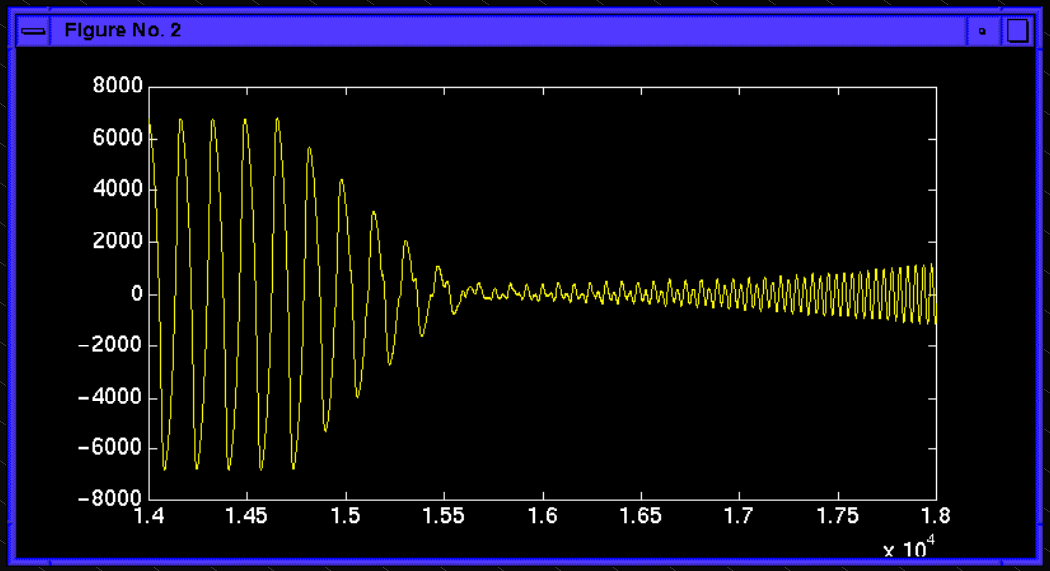
C++

- Traditional ring-buffered delay line
- Each finger hole filter is an C++ object instance
- Fast
- Portable

Simulation (Matlab)

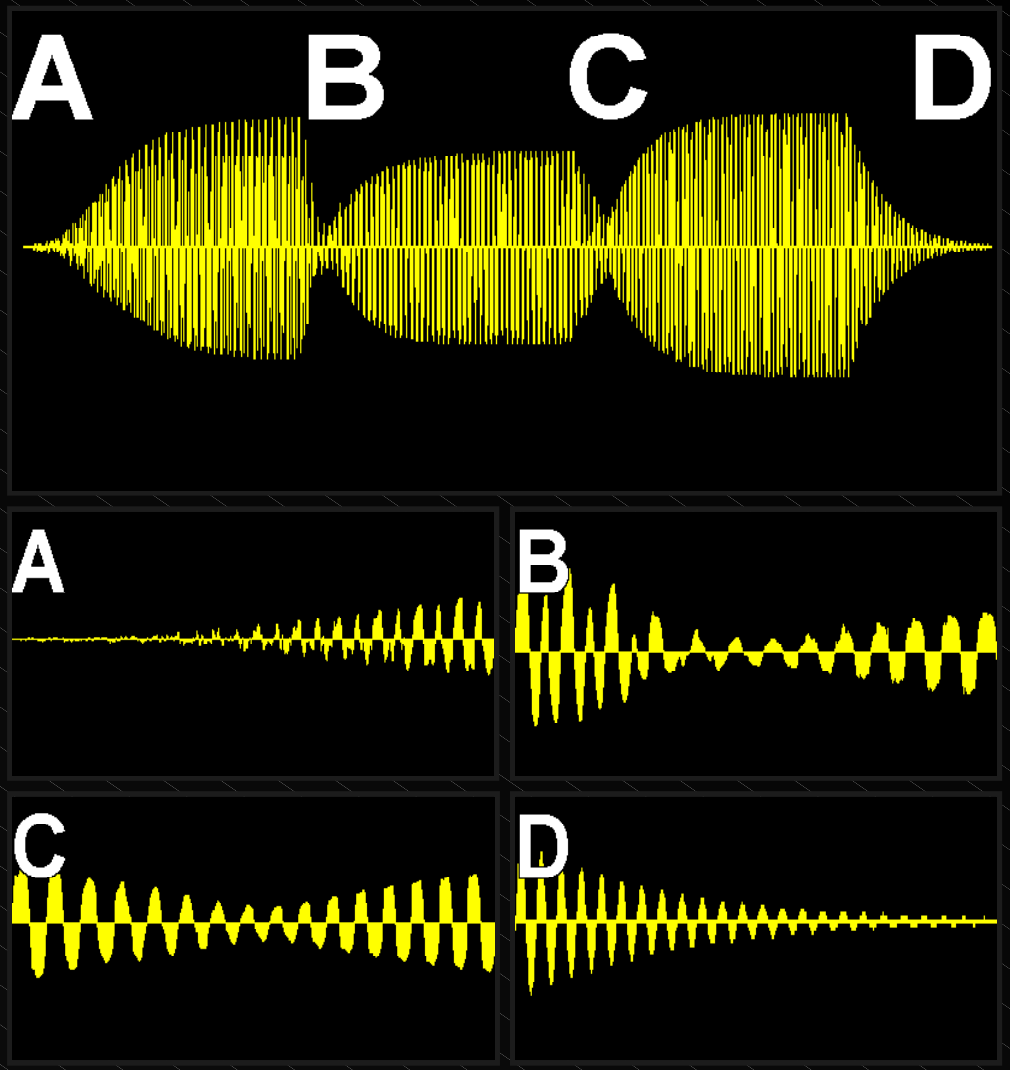
- Simulated on a 60 MHz HP 9000/712
- Matlab 4.2a
- Sample rate 44.1 kHz
- With 1 finger hole, computes about 230 samples/s
- With 10 finger holes, computes about 200 samples/s
- Tools to experiment with different finger hole configurations





Simulation (C++)

- Simulated on a 200 MHz SGI IP19/Mips
- Compiled with gcc 2.7.2
- Sample rate 44.1 kHz
- Computes about 18.000 samples/s
- Implemented as an easy-to-use C++ object
- Tools include a MIDI-player and manual flute parameter adjuster



Observed Behaviour

- The exact parameter values to reach a certain overblow level depend on the current state of the flute model
- With constant input signal amplitude, the output amplitude depends on the current overblow level and finger hole configuration
- A real flutist must learn how to compensate these effects. A well-implemented flute model MIDI controller should do this, too.

Future Work

- A good parametrization method is required to fine-tune the numerous (>100) parameters:
  - geometrical measurements of the locations and sizes of finger holes
  - measurement and estimation using sophisticated DSP methods (e.g., Karjalainen et al.,1995)
  - automatic learning system, such as a genetic algorithm (e.g.,Vuori and Välimäki, 1993)
- Many parameters depend on sample rate, currently only 44.1 kHz is supported
- Air turbulence in input air flow should be incorporated into the model