Flute Sound Synthesis and Real Time Play

Zejin Li, Wen Huang, Department of Biomedical Engineering, University of Rochester

Abstracts

Flute sounds can be synthesized with given parameters such as fundamental frequency (pitch), harmonics, amplitudes and phases. In this project, we synthesized three flute octaves with both non-vibrato and vibrato sound effects. The parameters were extracted from the real flute samples notes by using MatLab. With these sound feature parameters, sounds could be synthesized. Comparison between real sound and synthesized sound will be displayed.

C# is being used to create a GUI interface to achieve real time playing. Options like playing demonstration pieces, non-vibrato and vibrato sound effects could be heard by switch between the radius buttons and drag down menu.

Introduction

- Flute can make sounds when the air hits the tube at flute's resonant frequency.
- Mezzo-forte (*mf*), forte (*f*) and piano (*p*) is the intensity of sound, when playing flute, these sound effect could be changed with volume and speed of blow.
- Vibrato could be generated by musician vibrate the abdomen, which causes the air vibrates. This vibrating frequency is much lower than the resonant frequency of flute.
- Vibrato could be easily distinguished from the non-vibrato sound is because the frequency of vibrating is low.
- C# created user interface to achieve real time control

Methods

- Flute samples are referenced to University of Iowa Electronic Music Studio [1].
- MatLab Analysis
  - Basically, the sounds are synthesized by pooling all frequency components together.
  - **Equation1**. $\mathrm{y(t)} = \sum_{k=1}^{N} \sin(2\pi f_k t + \emptyset_k) + airblow$
  - **Equation2.** $\mathrm{y(t)} = A_1(t)\cos[(\omega_1 + A_2(t)\cos(\omega_2 t))t]$ [2]
  - Equation1 and equation 2 show how we derived different notes and vibratos. K refers to the index of harmonics, N is the total number of harmonics that we collected. Here we made N = 5. f_k, $\emptyset_k$ are the frequency and phase of the K_{th} harmonic.

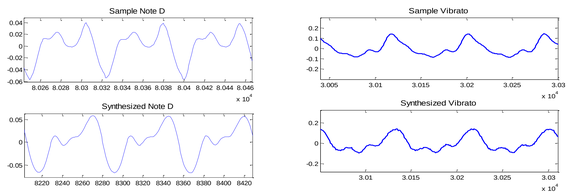
- C# interface designs
  - Key event handler: key up and key down events
  - Media player: system sound player being used to play sounds
  - Label and menu: allow users to hear synthesized demonstration piece
  - Different octave notes are color coded
  - Diatonic scale played by 36 different keys

Results

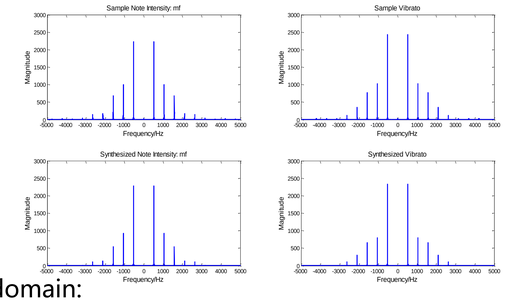
- Extracted parameters of the middle octave:

	Pitch (Hz)	Harmonics (Hz)	Amplitude (no unit)	Phase (degree)
C	526.205	1051.5, 1579.7 2103.2, 2633.1	1522.4, 611.3, 412.6 195.7, 66.1	-110.194, 122.091,-142, -160.32, -17.5336
C#	558.039	1115.9, 1674.5 2232.3, 2786.4	1086.9, 438.5, 243.4, 69.7, 54.7	-101.24, -124.59, -39.76 175.142, 149.439
D	589.977	1176.9, 1765.6 2360.1, 2942.7	809.6,646.39, 177.55 104.92, 56.93	-86.14, 60.59, 49.29 50.79, -65.445
D#	624.512	1248.8,1873.9 2494.2	1108.1, 467.8, 219.7 85.6	155.295, -141.48, 169.528 23.577
E	662.061	1324.3, 1986.6	1358.2, 404.9, 345.9	-40.598, 60.433, -5.727
F	700.045	1399.5, 2099	2137.4, 504.1 392.4	16.463, 144.473,54.86
F#	747.028	1493.4, 2239	1876.7, 482, 216	134.864, 19.184, 75.995
G	786.977	1573.4, 2360.2	1649.2, 228.8, 184.2	111.556, -561.7, -70.358
G#	833.219	1666.3, 2489.6	1328.3, 501.3, 38.6	131.78, 91.116, 120.36
A	886.658	1326.6, 1772.5	2150.2, 171.1, 35.6	-80.525, -163.703, 36.81
A#	943.029	1886.2, 2829.1	2893.2, 230.8, 90	170.928, -66.58, -123
B	998.325	1995.5, 2993.7	1716.6, 225.9, 120.1	-20.607, 29.063, -41.767

- Comparison between real sound and synthesis results
  - Time Domain (waveform)



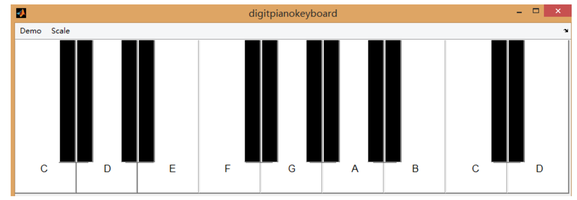
  - Frequency Domain (spectrum)



- Time domain:
  - **Left** :Waveform of sample flute note of middle D (top) and synthesized middle D (bottom).
  - **Right**: Waveform of sample flute vibrato middle D (top) and synthesized vibrato middle D (bottom).
- Frequency domain:
  - **Left** :Spectrum of sample flute note of middle D (top) and synthesized middle D (bottom).
  - **Right**: Spectrum of sample flute vibrato middle D (top) and synthesized vibrato middle D (bottom).

Application

- Matlab Keyboard



  - GUI interface allows people to play single notes like playing the piano, besides, people can also play a piece of demo music or a scale.
  - Matlab simulated keyboard can only play the sounds with fixed time length. It cannot detect the hit and release time point of the key and achieve real-time playing.
- C# user interface

  - Synthesis results are close to the original ones.
  - Demo menu allow user play and stop the demo piece
  - Note name will appear while playing
  - Key board control instead of mouse click
  - Synthesis effect change as select

Future Work

- More instruments sounds synthesis
- Non-instruments sounds could be created
- Multi-sound combine and play at same time
- Multi key being pressed to hear two or more tones
- Better designed C# control panel

References

- [1] University of Iowa Electronic Music Studio http://theremin.music.uiowa.edu/MISviolin.html
- [2] S.Rossignol, P.Depalle, J.Soumagne et al, vibrato_detection estimation extraction modification