T-Pain on a Chip: Real-time Pitch Correction

6.111 Final Design Project

Trevor Walker and Ishwarya Ananthabhotla

Autotuning

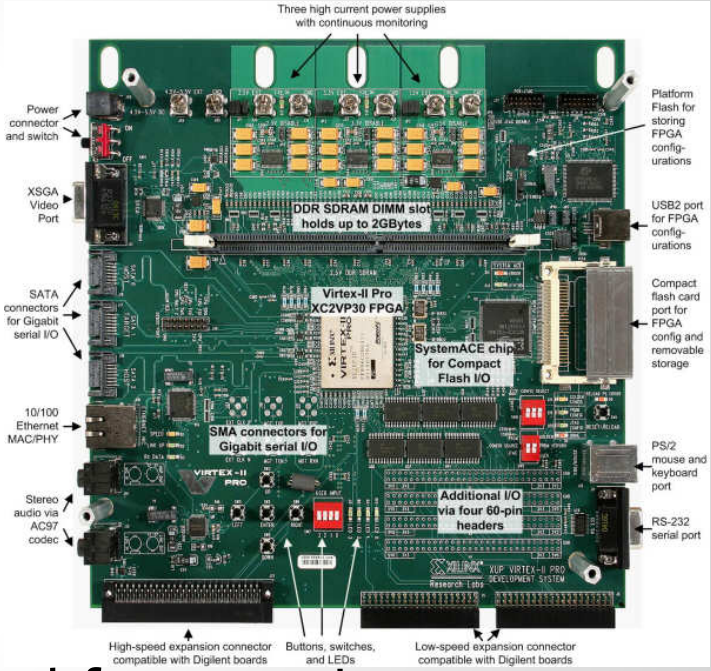
- Pitch correction-
  - Fixing intonation of audio signal
  - Without changing other features
  - Post-processed
- Everywhere!
  - Contemporary vocal artists
  - Auto-generation of harmonies
  - Interesting effects in instrumentals

Motivation

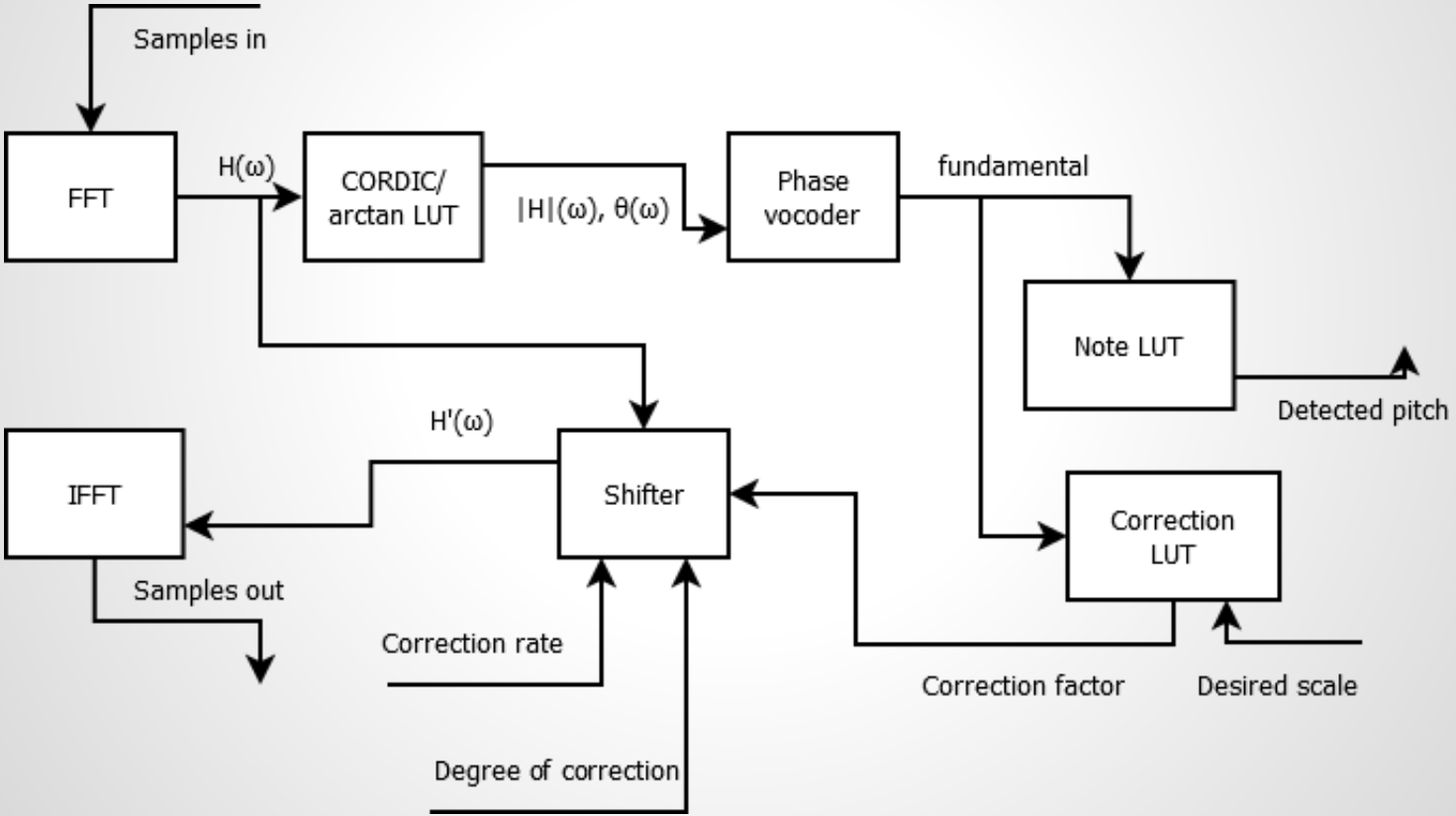
- Signal processing in frequency shifting?
- Investigate challenges: sampling, resolution, quality of sound, “naturalness”
- Limitations of a hardware?
- **Realtime?**

Project Goals and Expectations

- Realtime vocal autotuning system
- Corrects pitches so that they match user entered scale – i.e. "C Major"
- Features
  - Degree of correction
  - Rate of correction
  - Range of upper male to female vocal frequencies
  - Preserve reasonable output quality

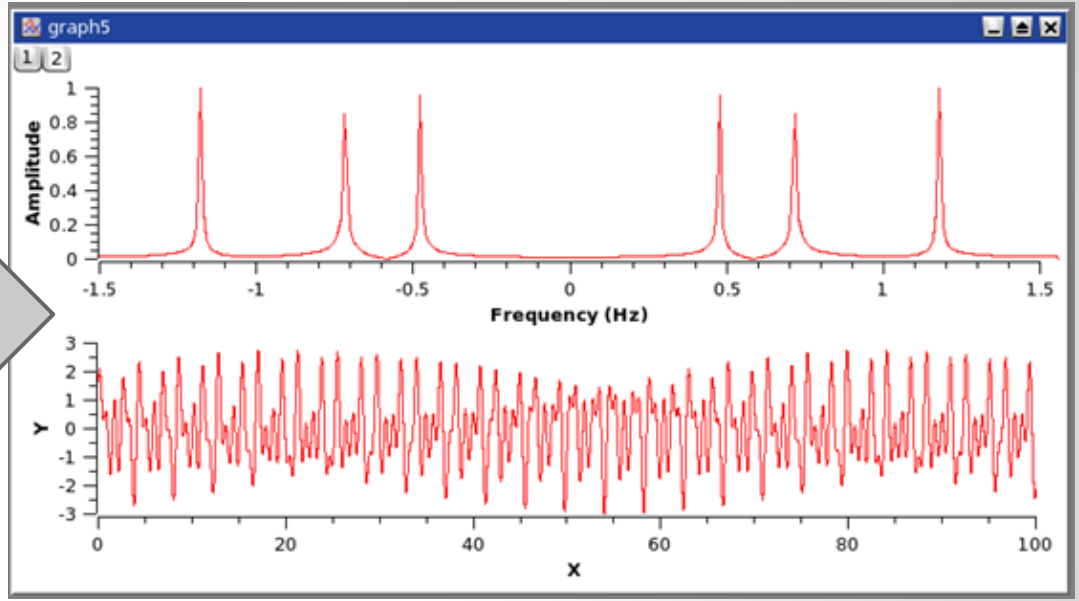


Block diagram



FFT

Audio Codec



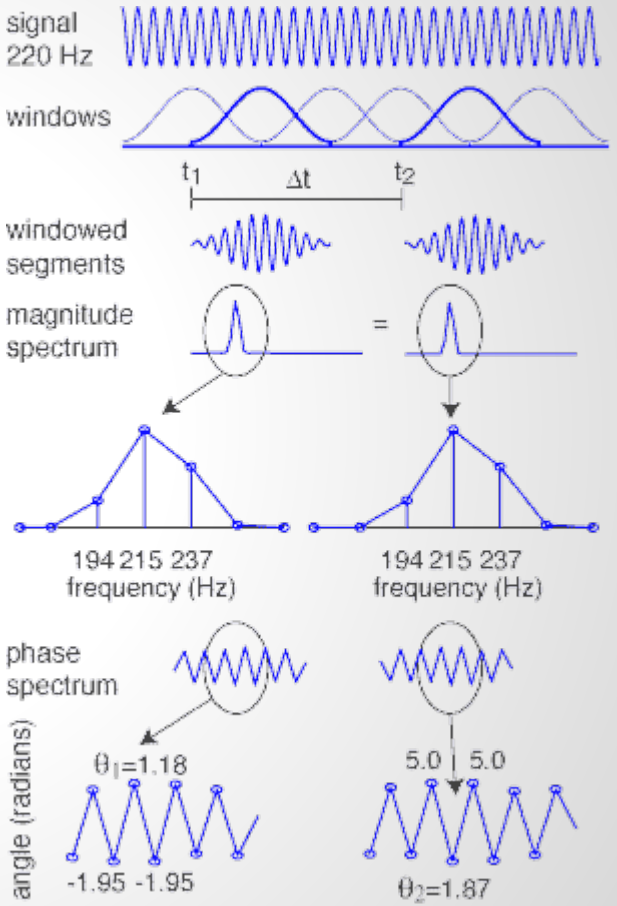
- Window audio signal
- Sampling rates meet minimum frequency specs

- Fixed point, low-speed FFT
- 18 bit precision, up to 27Mhz, 4% consumption of FPGA
- Read and Write across SRAM-like interface

Phase vocoder

FFT bins are too wide to determine frequency accurately

Exploit phase information in FFT to drastically increase resolution



http://sethares.engr.wisc.edu/vocoders/phasevocoder.html

Phase vocoder, continued

Phase is related to frequency: $f \propto d\theta/dt$

Resolution of phase comes from precision of arctan, not number of FFT bins

By observing the change in phase between successive FFTs, we can figure out the true frequency

LUTs

Note LUT converts frequency (440Hz) into human language (A_4)

Shift LUT takes fundamental, produces:

- Closest note in specified scale
- Ratio $f_{\text{desired}}/f_{\text{actual}}$

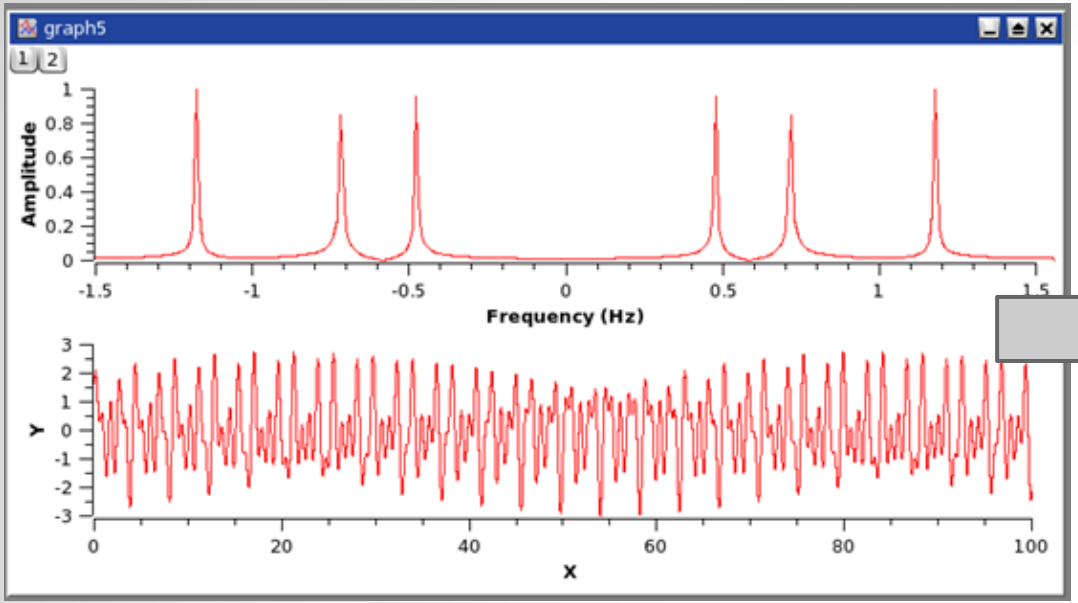
Shifter

Shifts FFT based on LUT result (multiplication)

Rate of change of pitch shift limited by correction speed

Degree of correction controls magnitude of shift

IFFT



Audio Codec

- Entire spectrum shifted based on scaling of fundamental frequency
- Non-normalized, manually scale

- Convert back to audio waveform
- For output through speakers

Timeline

	Week 1 (Nov 12)	Week 2 (Nov 17)	Week 3 (Nov 24)	Week 4 (Dec 1)	Week 5 (Dec 8)
FFT/ IFFT	**Ishwarya**				
Vocoder					
LUTs		**Trevor**			
Shifter					
Interfacing			**Both**		
Final Report/ Adjustments					