

Pitch Detector

ISPR - Midterm 1
Assignment 3

Filippo Baroni

March 30, 2021

Autocorrelogram

- ▶ The autocorrelogram Auto_y measures the correlation of a signal y with itself at different time lags:

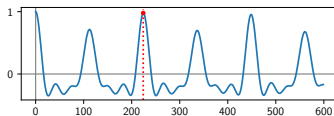
$$\text{Auto}_y[\tau] = \frac{1}{\|y\|^2} \sum_{t=0}^{N-\tau-1} y[t] \cdot y[t + \tau].$$

- ▶ It can be computed by convolution, but for a small set of time lags (window) the naive implementation is more efficient.

```
def autocorrelogram(y, window):  
    b, e = window  
    a = np.array([np.dot(y[0 : y.size - tau], y[tau :])  
                  for tau in range(b, e)])  
    return a / a[0]
```

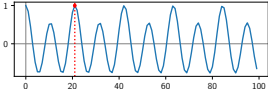
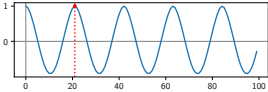
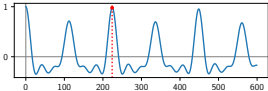
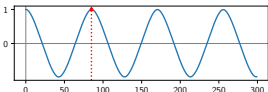
Finding the Pitch

- ▶ Peaks in the autocorrelogram correspond to periods of the signal y .
- ▶ The minimal period τ_0 of y is the smallest maximum point of the autocorrelogram **after 0**.



```
def find_pitch(y, sr, lowest_freq = 80.):
    cor = autocorrelogram(y, [0, int(sr / lowest_freq)])
    peaks = []
    for a in np.split(np.arange(cor.size),
                      np.nonzero(cor < 0)[0].tolist())[1 :]:
        u = [i for i in a if cor[i] > .01]
        if u:
            peaks.append(max(u, key = lambda i: cor[i]))
    highest_peak = max(cor[p] for p in peaks)
    f = np.array([p for p in peaks
                  if cor[p] > .95 * highest_peak])
    d = np.average(f / np.arange(1, f.size + 1), 0, cor[f])
    return sr / d
```

Results

Instrument	Note	Autocorrelogram	Pitch	Error
Oboe	C6	 The autocorrelogram for the Oboe C6 shows a periodic waveform with a period of approximately 20 units. The x-axis ranges from 0 to 100, and the y-axis ranges from -1 to 1. A red dashed vertical line is drawn at x=20, indicating the period of the waveform.	1046 Hz	0.01 %
Clarinet	C6	 The autocorrelogram for the Clarinet C6 shows a periodic waveform with a period of approximately 20 units. The x-axis ranges from 0 to 100, and the y-axis ranges from -1 to 1. A red dashed vertical line is drawn at x=20, indicating the period of the waveform.	1049 Hz	0.2 %
Keyboard (homemade)	G3	 The autocorrelogram for the Keyboard G3 shows a periodic waveform with a period of approximately 200 units. The x-axis ranges from 0 to 600, and the y-axis ranges from -1 to 1. A red dashed vertical line is drawn at x=200, indicating the period of the waveform.	196.7 Hz	0.3 %
Voice (homemade)	D3	 The autocorrelogram for the Voice D3 shows a periodic waveform with a period of approximately 100 units. The x-axis ranges from 0 to 300, and the y-axis ranges from -1 to 1. A red dashed vertical line is drawn at x=100, indicating the period of the waveform.	145.1 Hz	1 %

Real-time Pitch Detection

- ▶ This algorithm is fast enough to run in real-time.
- ▶ pyaudio for microphone input, pyglet for graphics.
- ▶ And now, a live demonstration!

