

Pitch Detector

ISPR - Midterm 1
Assignment 3

Filippo Baroni

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Autocorrelogram

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

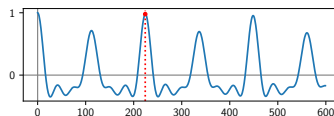
$$\text{Auto}_y[\tau] = \frac{1}{\|y\|^2} \sum_{t=0}^{N-\tau-1} y[t] \cdot y[t + \tau].$$

- ▶ It can be computed as the convolution between y and $\text{reverse}(y)$.

```
def autocorrelogram(y):  
    a = np.convolve(y, y[::-1], 'same')  
    a = a[a.size // 2 :]  
    return a / np.dot(y, y)
```

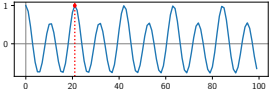
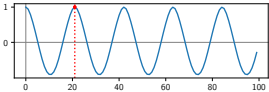
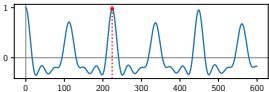
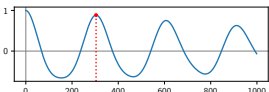
Finding the Pitch

- ▶ 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):  
    a = autocorrelogram(y)  
    peaks = []  
    for b in np.split(np.arange(a.size),  
                      np.nonzero(a < 0)[0].tolist())[1 :]:  
        if b := [i for i in b if a[i] > .01]:  
            peaks.append(max(b, key = lambda i: a[i]))  
    highest_peak = max(a[p] for p in peaks)  
    f = np.array([p for p in peaks  
                  if a[p] >= .95 * highest_peak][: 10])  
    tau = np.average(f / np.arange(1, f.size + 1), 0, a[f])  
    return sr / tau
```

Results

Instrument	Note	Autocorrelogram	Pitch	Error
Oboe	C6	 An autocorrelogram plot for Oboe C6. The x-axis ranges from 0 to 100, and the y-axis ranges from 0 to 1. A blue curve shows periodic peaks. A red dashed vertical line is at x=20, with a red dot at the peak (20, 1).	1046 Hz	0.03 %
Clarinet	C6	 An autocorrelogram plot for Clarinet C6. The x-axis ranges from 0 to 100, and the y-axis ranges from 0 to 1. A blue curve shows periodic peaks. A red dashed vertical line is at x=20, with a red dot at the peak (20, 1).	1049 Hz	0.3 %
Keyboard (homemade)	G3	 An autocorrelogram plot for Keyboard G3. The x-axis ranges from 0 to 600, and the y-axis ranges from 0 to 1. A blue curve shows periodic peaks. A red dashed vertical line is at x=200, with a red dot at the peak (200, 1).	196.7 Hz	0.3 %
Voice (homemade)	D3	 An autocorrelogram plot for Voice D3. The x-axis ranges from 0 to 1000, and the y-axis ranges from 0 to 1. A blue curve shows periodic peaks. A red dashed vertical line is at x=300, with a red dot at the peak (300, 1).	145.1 Hz	1 %

Real-time Pitch Detection

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

