

Pitch Detector

ISPR - Midterm 1
Assignment 3

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Autocorrelogram

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

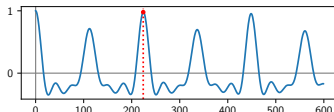
$$\text{Auto}_y[\tau] = \frac{1}{\|y\|^2} \sum_{t=0}^{N-\tau-1} y[t] \cdot y[t + \tau].$$

- ▶ 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)
```

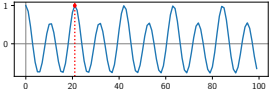
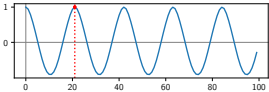
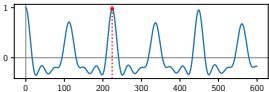
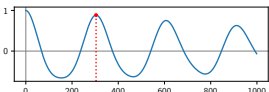
Finding the Pitch

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



```
def find_pitch(y, sr):  
    a = autocorrelogram(y)  
    peaks = np.array([], dtype = int)  
    for b in np.split(np.arange(a.size),  
        np.nonzero(a < 0)[0])[1 :]:  
        if np.any(a[b] > .01):  
            peaks.append(b[np.argmax(a[b])])  
    highest_peak = max(a[peaks])  
    f = peaks[a[peaks] > .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	 The autocorrelogram for the Oboe C6 shows a periodic waveform with a period of approximately 20 samples. The x-axis ranges from 0 to 100, and the y-axis ranges from -1 to 1. A red dashed vertical line marks the first peak at x=20.	1046 Hz	0.03 %
Clarinet	C6	 The autocorrelogram for the Clarinet C6 shows a periodic waveform with a period of approximately 20 samples. The x-axis ranges from 0 to 100, and the y-axis ranges from -1 to 1. A red dashed vertical line marks the first peak at x=20.	1049 Hz	0.3 %
Keyboard (homemade)	G3	 The autocorrelogram for the Keyboard G3 shows a periodic waveform with a period of approximately 200 samples. The x-axis ranges from 0 to 600, and the y-axis ranges from -1 to 1. A red dashed vertical line marks the first peak at x=200.	196.7 Hz	0.3 %
Voice (homemade)	D3	 The autocorrelogram for the Voice D3 shows a periodic waveform with a period of approximately 300 samples. The x-axis ranges from 0 to 1000, and the y-axis ranges from -1 to 1. A red dashed vertical line marks the first peak at x=300.	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!

