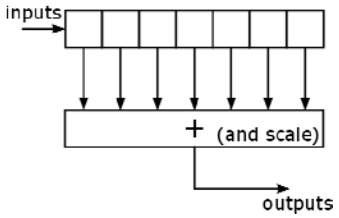
Signal Processing

CSE 132

Inputs from Physical World

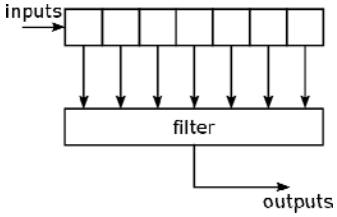
- Temperature
  - Noisy signal → average to smooth signal
- Pushbutton input
  - Bouncing contacts → de-bounce software
- Accelerometer
  - Gives acceleration, but we want steps → perform peak detection
- Pulse oximeter
  - Very noisy signal, smoothing could suppress pulse information → better filter

Temperature Averaging



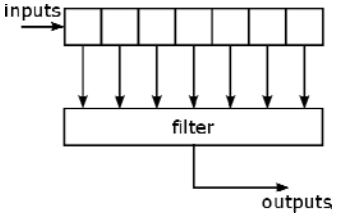
- Operation is summation and multiplication (which can happen in either order)

Digital Discrete-time Filter



- Replace summation with general computation

Pushbutton Debounce as a Filter



- Filter:

  if last two inputs are equal

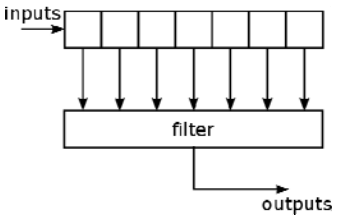
  output last input value and save

  else output saved value

Types of Filters

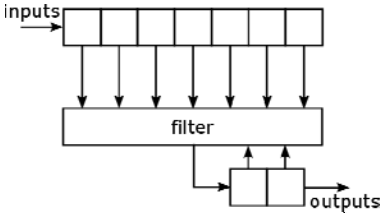
- Linear vs. Non-linear
  - Does input doubling equal output doubling?
- Analog vs. Digital
  - Are values continuous or discrete?
- Discrete-time vs. Continuous-time
  - Is time sampled?
- Finite impulse response (FIR) vs. Infinite impulse response (IIR)
  - Is response to a pulse bounded in time?

Finite Impulse Response (FIR) Filter



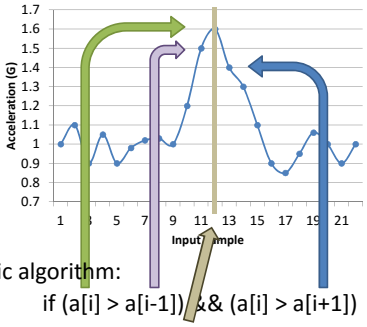
- Output is function of last N inputs only
- Temperature average is FIR filter
- Pushbutton debounce is not!

Infinite Impulse Response (IIR) Filter



- Save past output values
- They are fed back into filter computation
  - E.g., saved output value in debounce algorithm

Peak Detection

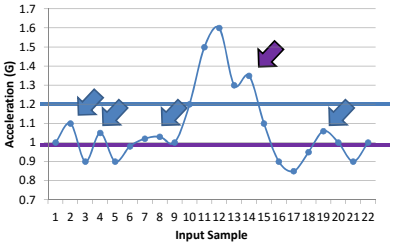


- Classic algorithm:

  if (a[i] > a[i-1]) && (a[i] > a[i+1])

  sample i is a peak

Peak Detection Improvements

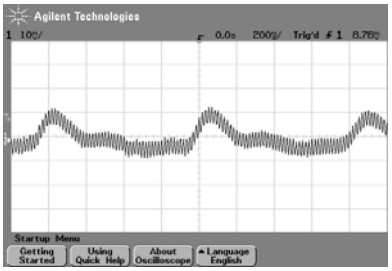


- Zero-crossing (actually mean-crossing)
- Minimum value for peaks

Peak Detection Filter

- Linear vs. **Non-linear**
- Analog vs. **Digital**
- **Discrete-time** vs. Continuous-time
- **Finite impulse response (FIR)** vs. Infinite impulse response (IIR)

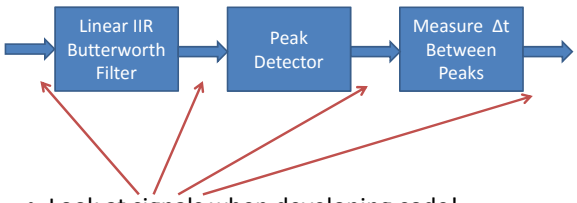
Pulse-Ox Signal



- Peaks 800 ms apart (= 75 beats per min)
- Lots of noise

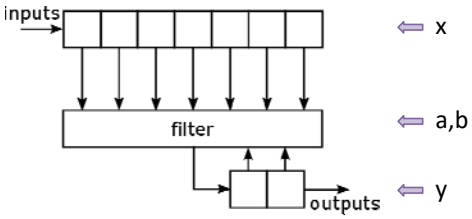
Measuring Pulse

- Filter pipeline:



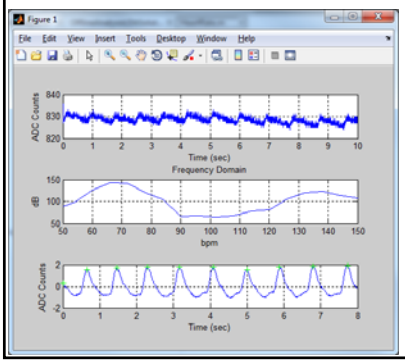
- Look at signals when developing code!

Butterworth IIR Filter



- $y[i] = b_1 \cdot x[i] + b_2 \cdot x[i-1] + b_3 \cdot x[i-2] - a_2 \cdot y[i-1] - a_3 \cdot y[i-2]$
- Bandpass between 50 bpm and 150 bpm

Filter Operation



⇦ x

⇦ frequency domain

⇦ y

Butterworth Filter

- **Linear** vs. Non-linear
- Analog vs. **Digital**
- **Discrete-time** vs. Continuous-time
- Finite impulse response (FIR) vs. **Infinite impulse response (IIR)**

Upcoming Schedule

- This week:
  - Studio – experiment with accelerometer and work on peak detection algorithms
  - Lab – continue with assignment 7 (due next week)
- Next week:
  - Lecture – introduction to computer architecture
  - Studio – experiment with pulse oximeter and work on Butterworth filter
  - Lab – demo assignment 7 and start on FitBit assignment (steps and pulse and comm w/ PC)