EE16A Lab: Acoustic Positioning System (APS) 1

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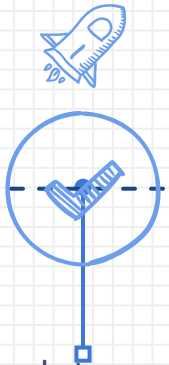
Lab Assistants: Cam, Ed, Ryan

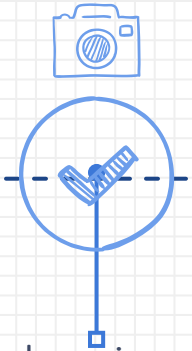
Announcements

- Lab Grades on Gradescope
  - Just email me~ no problem

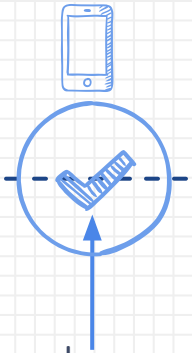
Where Are We Now?



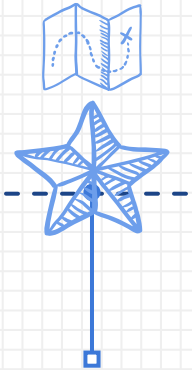
~~Intro Module~~



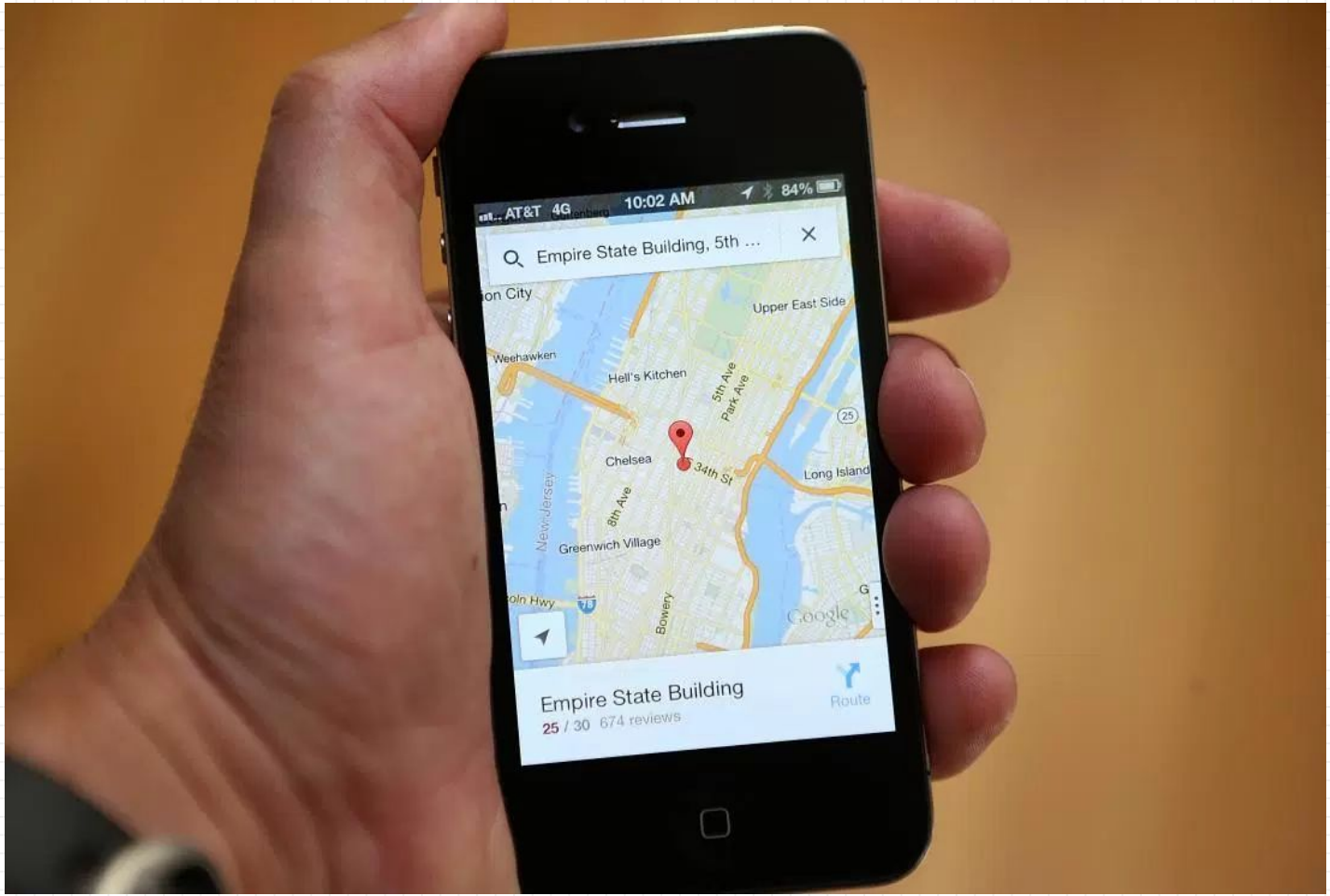
~~Imaging Module~~



~~Touchscreen Module~~



APS Module


AT&T 4G
10:02 AM
84%
Empire State Building, 5th ...
Upper East Side
Weehawken
Hell's Kitchen
5th Ave
Park Ave
25
Chelsea
34th St
Long Island
New Jersey
8th Ave
Greenwich Village
Bowery
Google
Empire State Building
25 / 30 674 reviews
Route

Today's Lab: APS

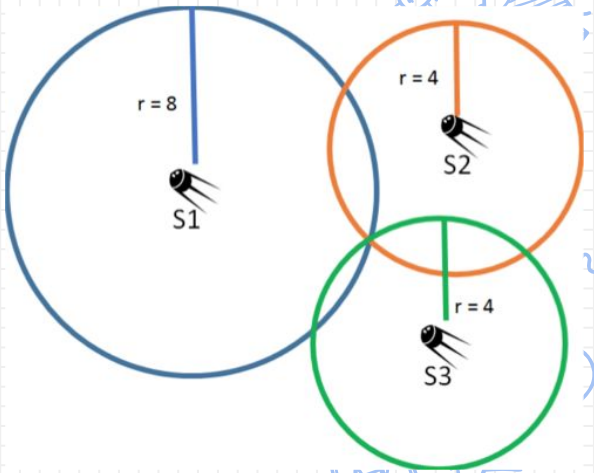
- ✘ Global Positioning System (GPS)
- ✘ Understanding mathematical tools used for sifting and detecting signals (cross-correlation)

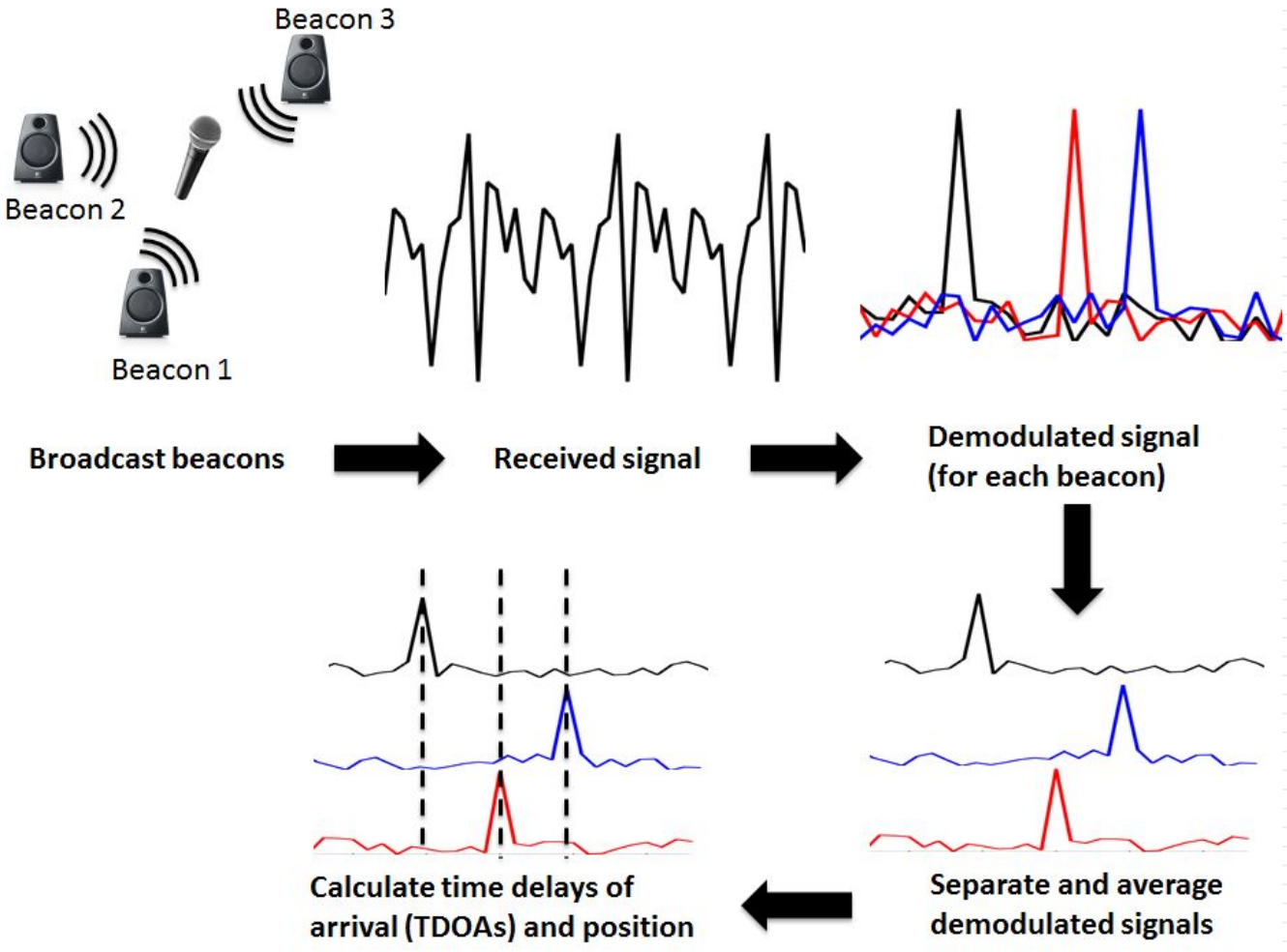
Topics From Class:

- ✘ Correlation
- ✘ Lateration (Week 2)
- ✘ Least Squares (Week 3)

GPS?

- ✘ There are satellites in the sky (beacons)
- ✘ Satellites send signals at known times (beacons are synchronized)
- ✘ Receiver gets these signals
- ✘ From **time-delay** of a beacon signal, receiver calculates **distance** to the beacon
- ✘ From **distances** to satellites, **position** is determined by **lateration**




Beacon 3
Beacon 2
Beacon 1
Broadcast beacons
Received signal
Demodulated signal
(for each beacon)
Separate and average
demodulated signals
Calculate time delays of
arrival (TDOAs) and position

Time of Flight

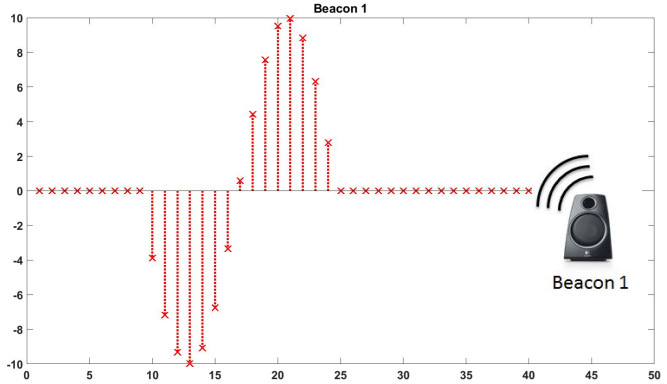
- ✘ Receiver gets signals from multiple satellites at the same time (“raw” signals)
- ✘ Each satellite sends a particular beacon waveform
- ✘ Receiver determines when this beacon is received, with reference to when other beacons are received

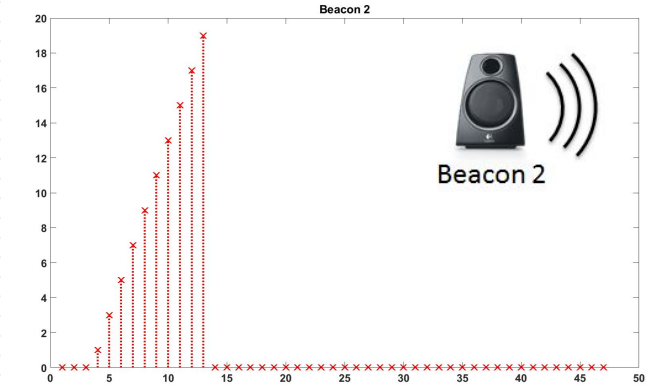
Cross-correlation

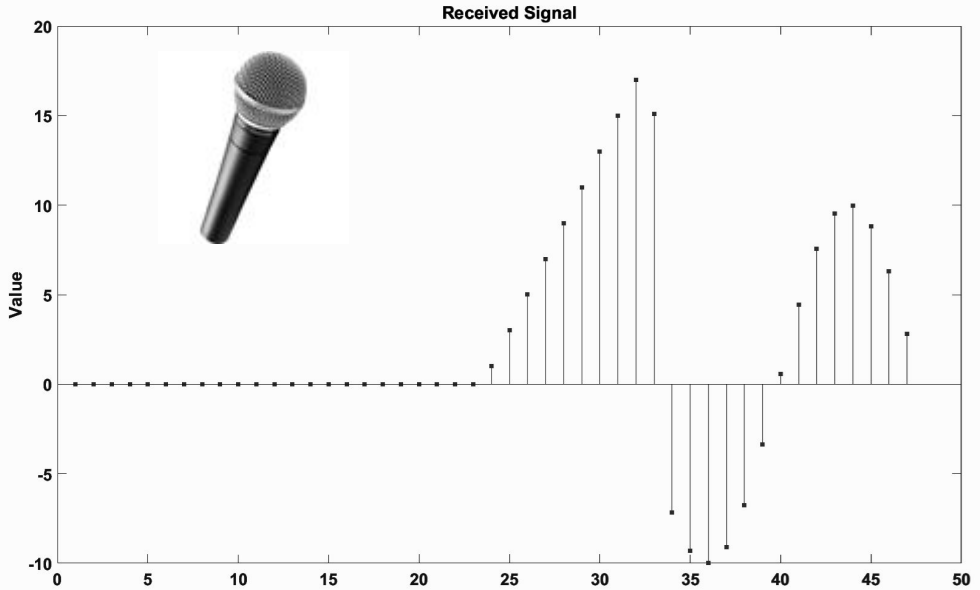
$$\text{corr}(f, g)[n] = \sum_k f[k]g[k-n]$$

- ✘ Mathematical tool for finding similarities between signals
- ✘ **Cross-correlation**: Take *g* and slide over *f*, find area of product for different sliding amount
  - ✘ Sliding Dot Product
- ✘ Cross-correlation is plotted over sliding amount
- ✘ Peak of cross-correlation → sliding amount that makes *g* "most similar" to *f*

Cross-Correlation: How We'll Use It

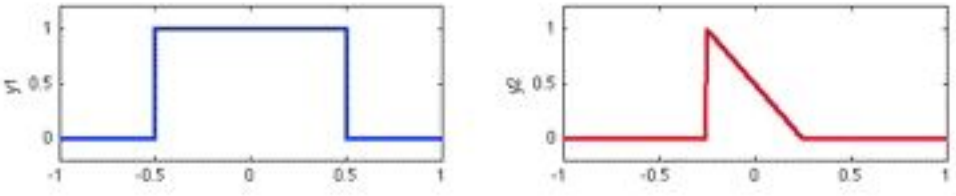






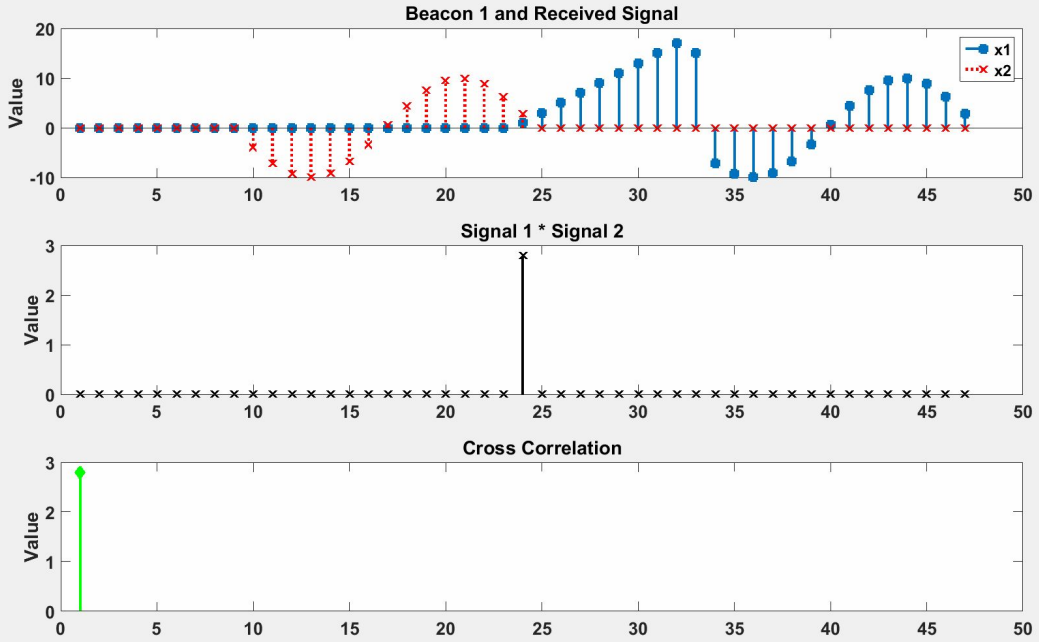
Cross-correlation

"Sliding Dot Product"



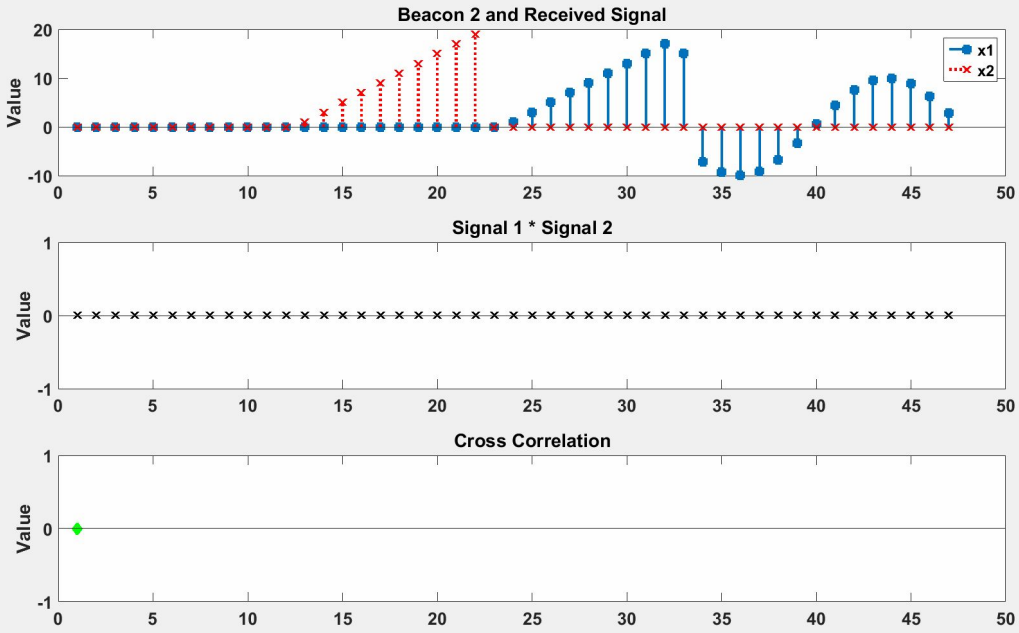
Cross-Correlation: Beacon 1

- ✘ Find the index at which the maximum occurs (25)



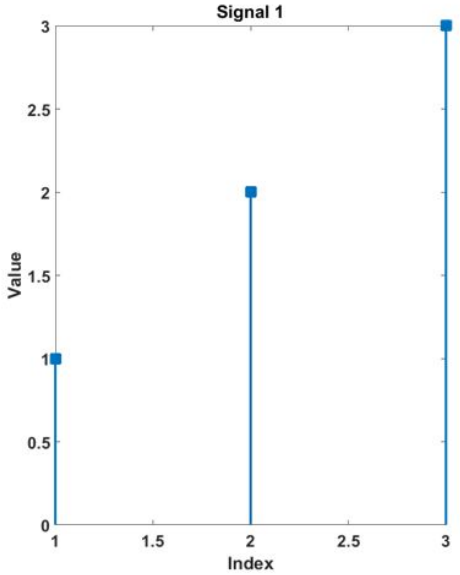
Cross-Correlation: Beacon 2

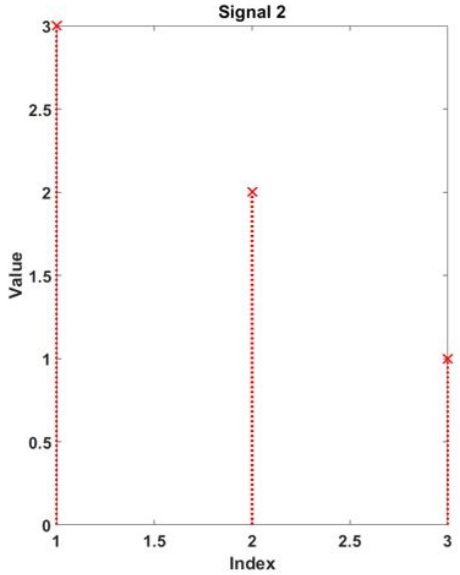
- ✘ Find the index at which the maximum occurs (12)



Cross-Correlation: An Example

1. Pad signals with zeros
2. Align last index of X2 with first index of X1
3. Multiply signals and sum (dot product)
4. Shift X2 to the right by one
5. Repeat 3 + 4 until the first index of X2 reaches the last index of X1





X1 = [1 2 3]

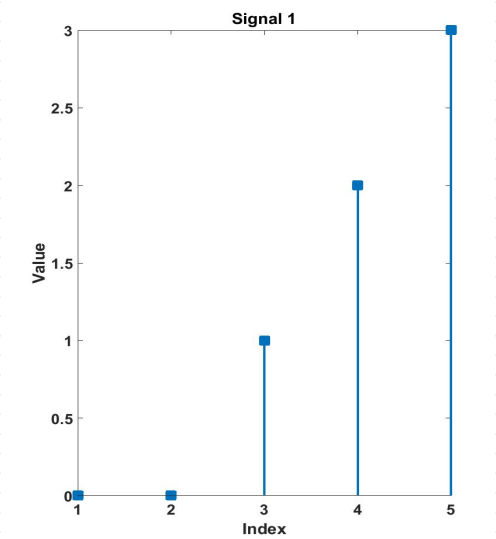
X2 = [3 2 1]

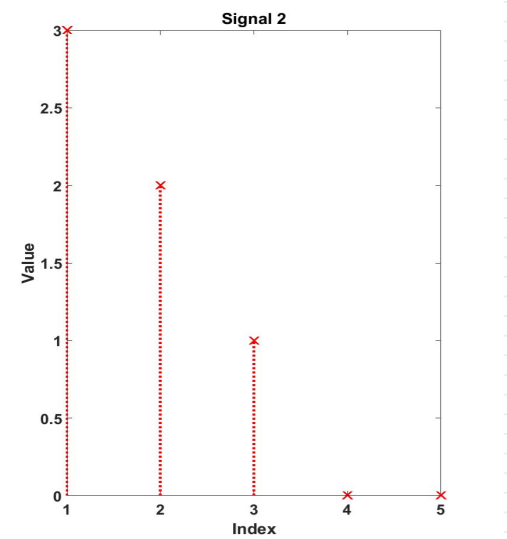
Cross-Correlation: An Example

1. Pad signals with zeros

X1 = [0 0 1 2 3]

X2 = [3 2 1 0 0]



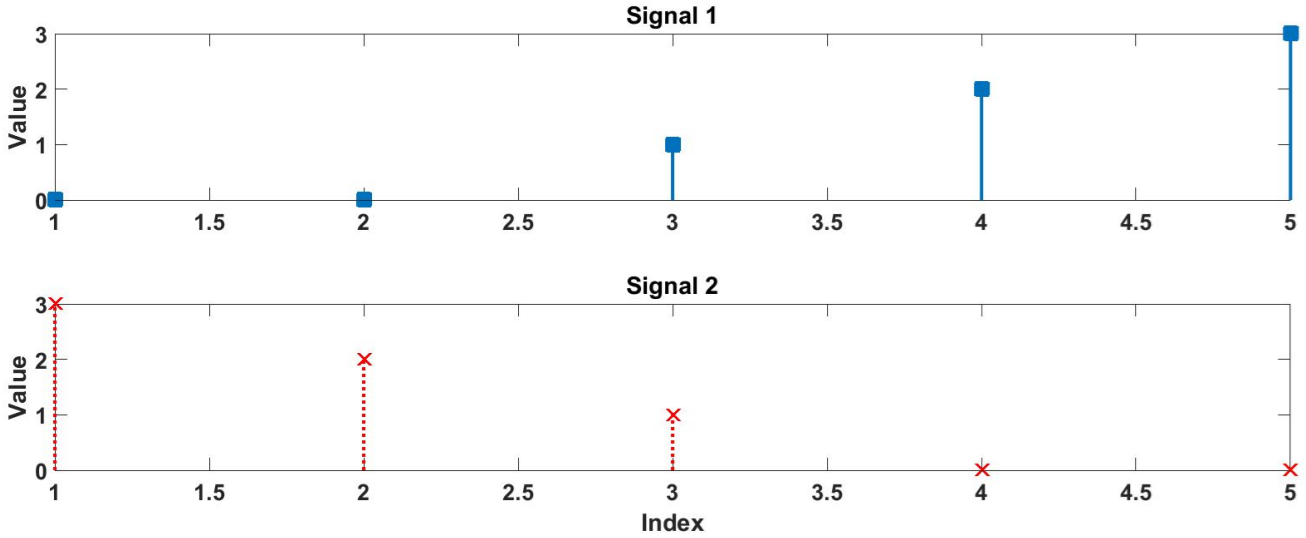


Cross-Correlation: An Example

2. Align last index of X2 with first index of X1

X1 = [0 0 1 2 3]

X2 = [3 2 1 0 0]



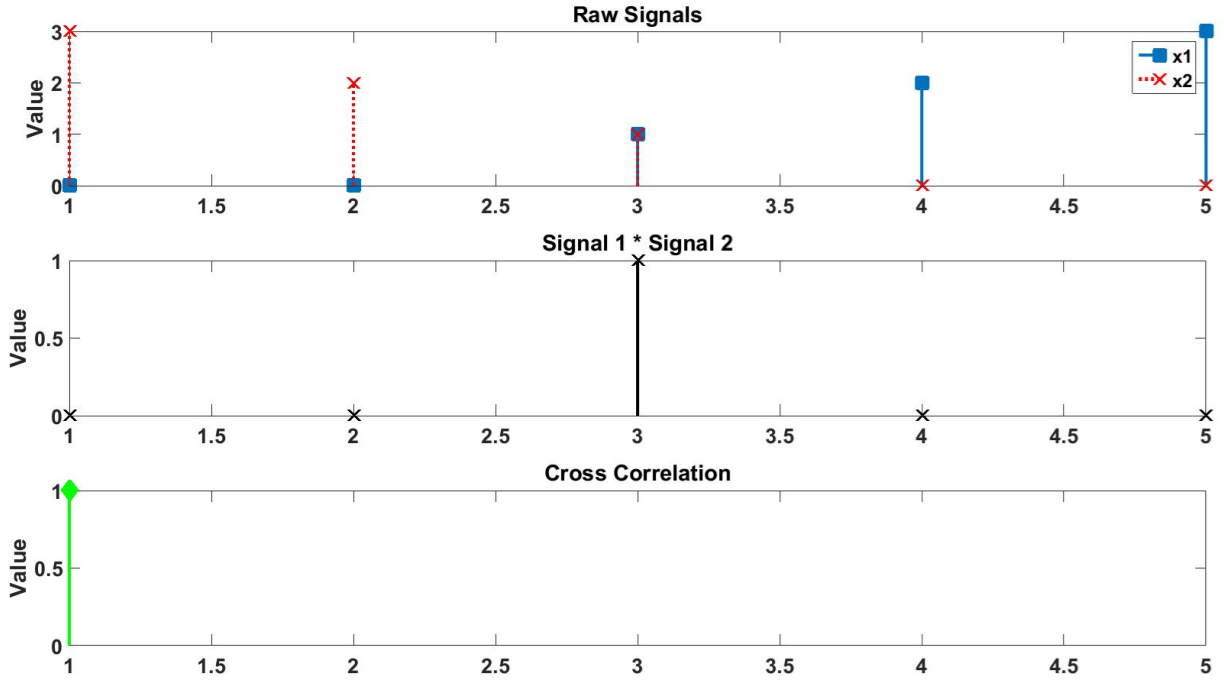
Cross-Correlation: An Example

3. Multiply signals and sum (dot product)

X1 = [0 0 1 2 3]
X2 = [3 2 1 0 0]

M = [0 0 1 0 0]

CC[1] = 1

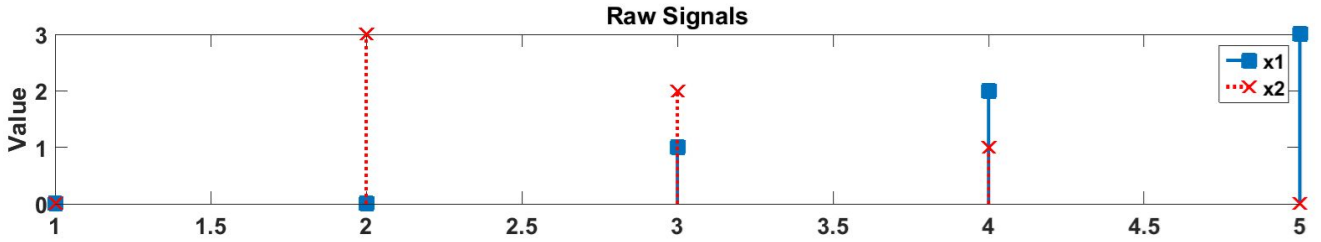


Cross-Correlation: An Example

4. Shift X2 to the right by one

X1 = [0 0 1 2 3]

X2 = [0 3 2 1 0]



Cross-Correlation: An Example

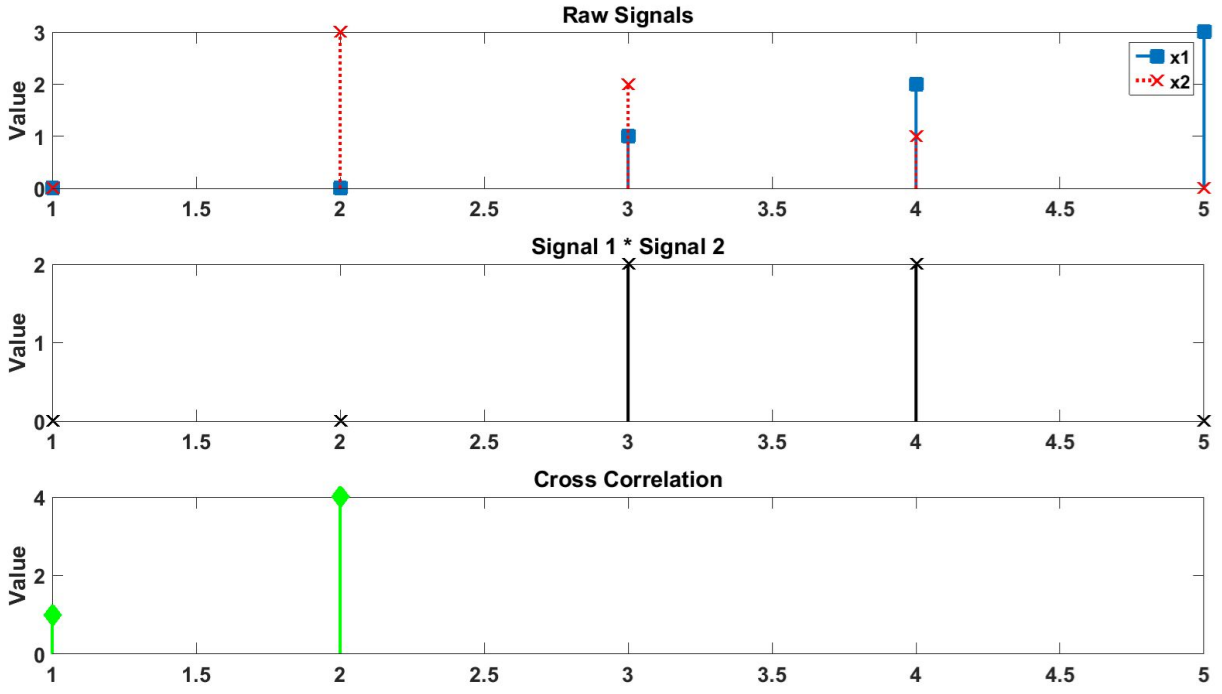
5. Repeat 3 + 4 until the first index of X2 reaches the last index of X1

X1 = [0 0 1 2 3]

X2 = [0 3 2 1 0]

M = [0 0 2 2 0]

CC[2] = 4



Cross-Correlation: An Example

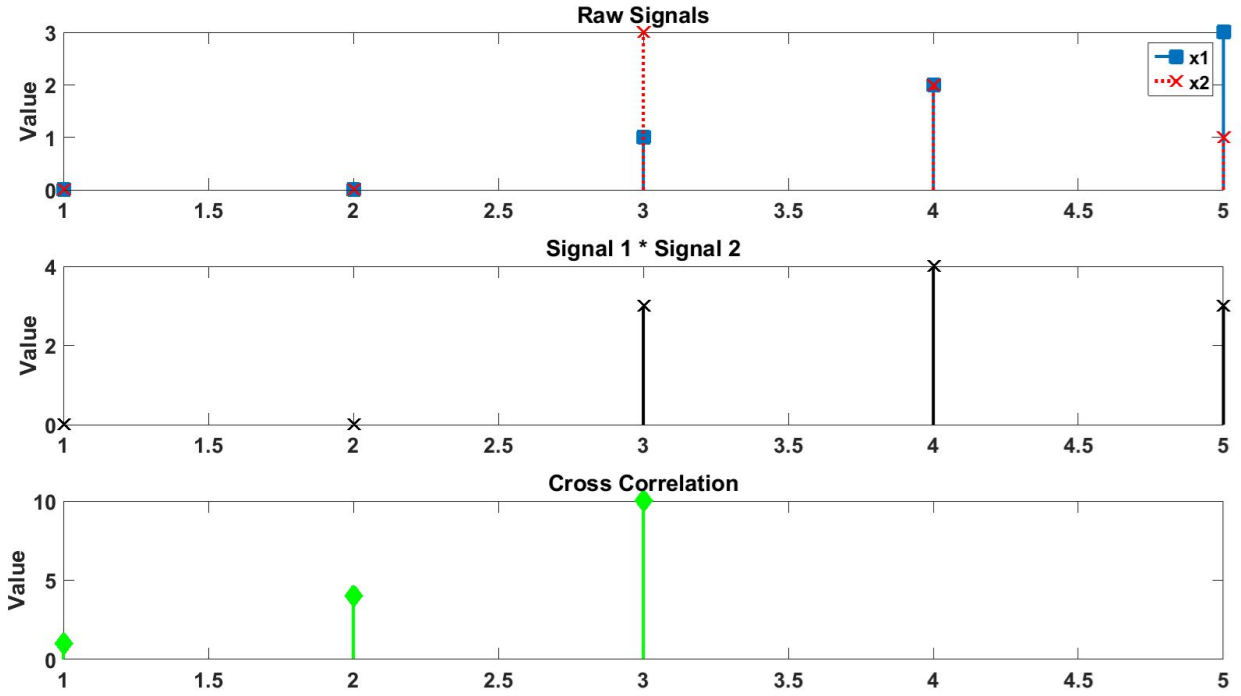
5. Repeat 3 + 4 until the first index of X2 reaches the last index of X1

X1 = [0 0 1 2 3]

X2 = [0 0 3 2 1]

M = [0 0 3 4 3]

CC[3] = 10



Cross-Correlation: An Example

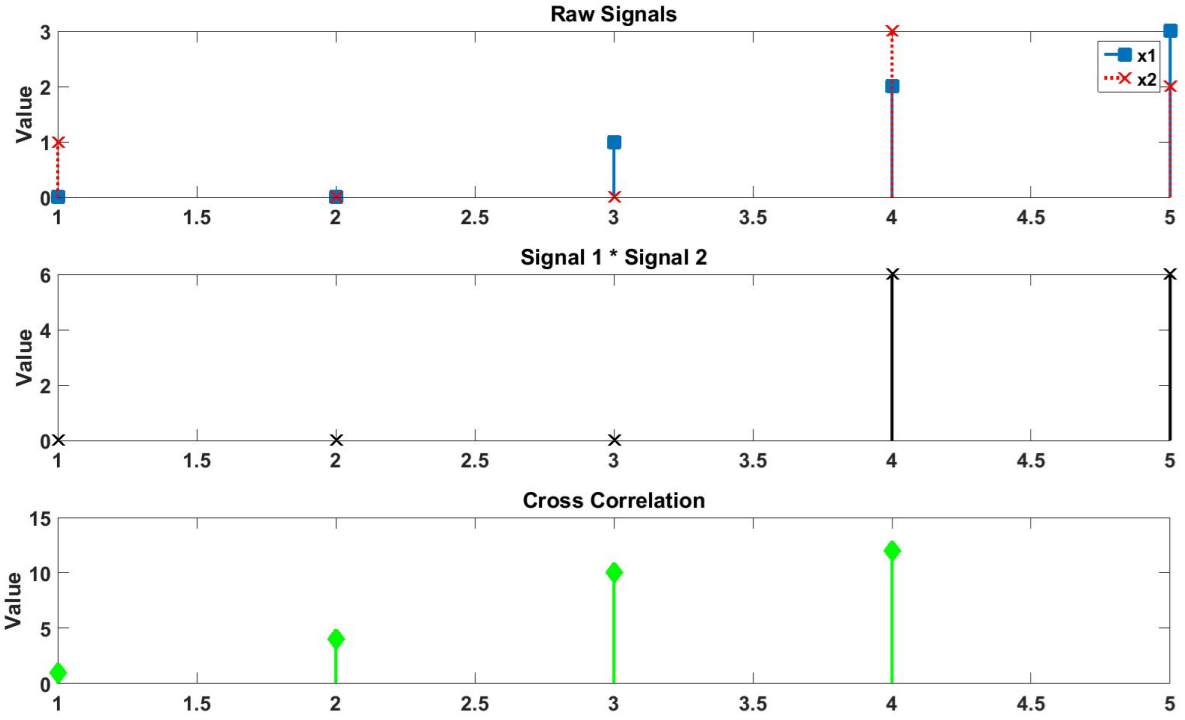
5. Repeat 3 + 4 until the first index of X2 reaches the last index of X1

X1 = [0 0 1 2 3]

X2 = [1 0 0 3 2]

M = [0 0 0 6 6]

CC[4] = 12



Cross-Correlation: An Example

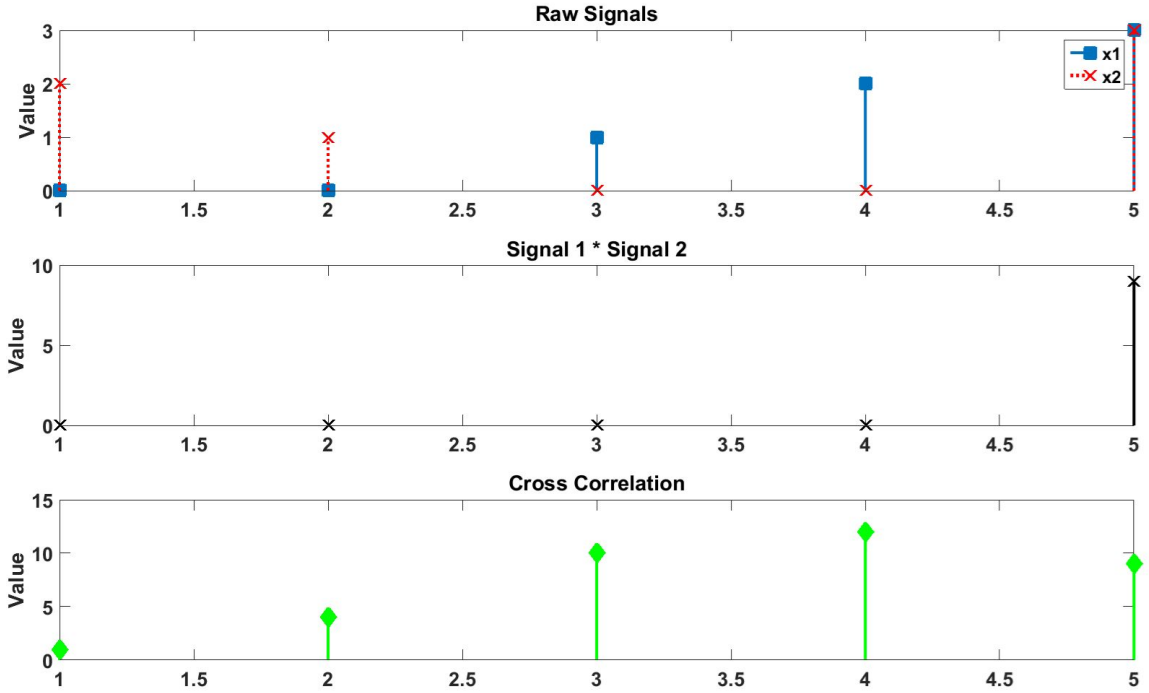
5. Repeat 3 + 4 until the first index of X2 reaches the last index of X1

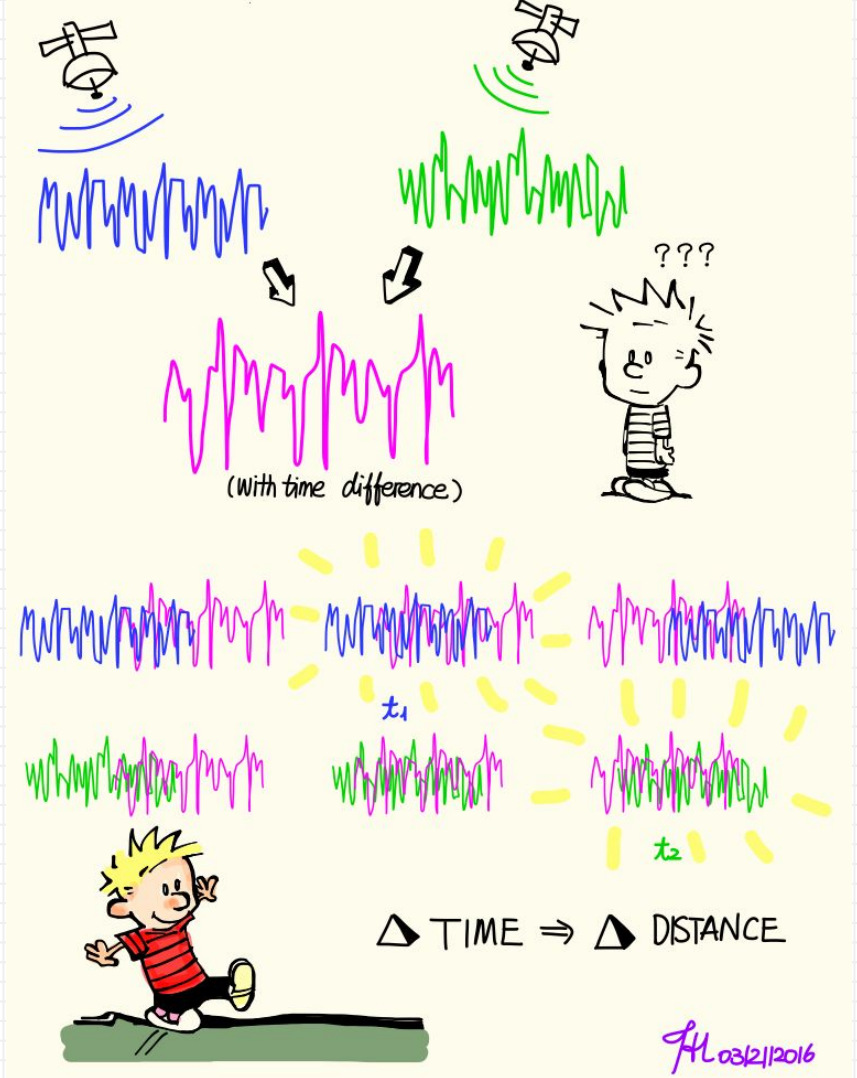
X1 = [0 0 1 2 3]

X2 = [2 1 0 0 3]

M = [0 0 0 0 9]

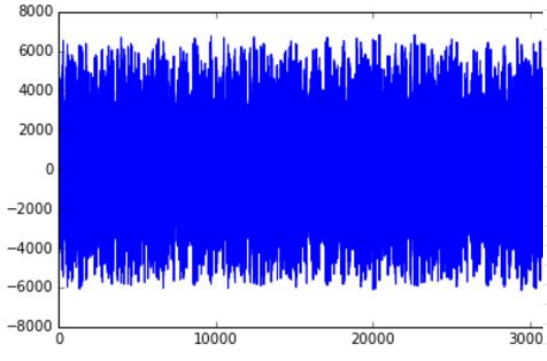
CC[5] = 9




???
(with time difference)
t_1
t_2
Δ TIME ⇒ Δ DISTANCE
JH 03/2/2016

Notes

- ✘ **SAVE THE IPYNB FILE** for the next lab!!
- ✘ Helpful functions:
  - ✘ np.dot, np.array, **np.argmax**....
- ✘ Make sure mic is plugged into the mic port
- ✘ Audio should look like: *[Not a squiggly line]*
- ✘ Return mics at the end!



Check off: tinyurl.com/16a-lab-checkoff
Question Queue: tinyurl.com/lab108-q
Presentation: Check inst website!