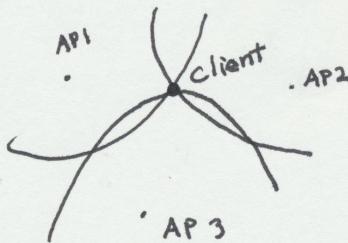


9/29/16

## Lecture 12 : Localization II



- Localization techniques discussed previously
- trilateration : compute distances via RSSI
    - sensitive to noise & multipath
  - triangulate : AoA → multiple antennas
    - works well when Line of Sight is not blocked

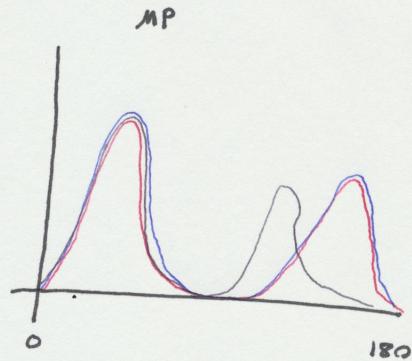
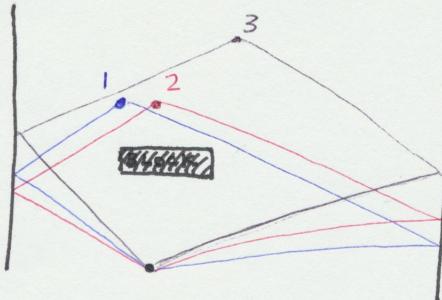
### Description of Papers

Pin It → 2 devices close together will see same multipath profile (MP)

- Similar to fingerprinting → MP instead of RSSI
- Measure MP on the fly
  - RFIDs are cheap, deploy everywhere
  - Find nearest RFID

### Example

- tag 3 (ref2)
- tag 2 (desired)
- tag 1 (ref1)



If 1 and 3 are known, since 2 and 1 are so close together in terms of MP, 2 is closest in distance to 1

### Application Spaces

- checkout lines
- really any localization problem
- books / libraries
- smart homes

How do we measure how close the MP is to another MP?

### Distance Metrics :

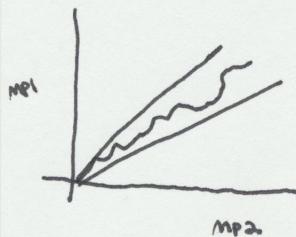
Correlation? → shifting, scaling issue  
Norm of difference? → scale issue

1

Metric used: DTW  $\rightarrow$  Dynamic Time Warping

- calculates the cost of warping signal 1 to signal 2
- $\rightarrow$  scaling issue is taken care of by taking derivative of DTW
- $\rightarrow$  can: computational cost

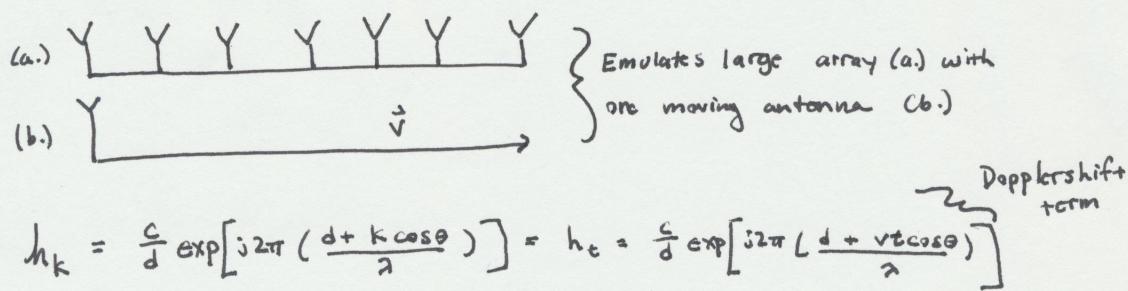
Example DTW graph



- DTW graphs are commonly used in speech signal processing

How to get a large antenna?

A) - SAR  $\rightarrow$  Synthetic Aperture Radar



Can we use SAR w/ WiFi?

- Note that simple!  $\rightarrow$  always has CFO
- RFID  $\Rightarrow$  synchronized

Array { 
$$h_k = \exp\left[j\left(\frac{2\pi d + k\cos\theta}{\lambda} + 2\pi\Delta f_c t\right)\right]$$

$$P(\theta) = \left| \sum_{k \in \mathbb{Z}} h_k e^{-j2\pi k\cos\theta/\lambda} \right|^2$$

$$= \left| e^{j\phi} \sum \frac{c}{\lambda} e^{j2\pi d/\lambda} \right|^2$$

$\nearrow$  still contains CFO for array!

/ 2

How about for a moving antenna?

$$h(t) = \frac{C}{d} e^{j2\pi(\frac{d}{\lambda} + \frac{vt\cos\theta}{\lambda}) + j2\pi\Delta f_c t}$$

$$h_K = \frac{C}{d} e^{j2\pi(\frac{d}{\lambda} + \frac{vk\cos\theta}{\lambda}) + j2\pi\Delta f_c k/v}$$

Still CFO? → solution: use a fixed and moving antenna

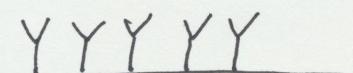
$$h_1(t) = \frac{C}{d} \exp[j2\pi(\frac{d}{\lambda} + \frac{vt\cos\theta}{\lambda}) + j2\pi\Delta f_c t]$$

$$h_2(t) = \frac{C}{d} \exp[j2\pi(\frac{d}{\lambda}) + j2\pi\Delta f_c t]$$

$$\Rightarrow \frac{h_1(t)}{h_2(t)} = e^{j2\pi v t \cos\theta / \lambda}, \text{ we can get rid of CFO}$$

### Some Array Math

there are



linear arrays

&



circular arrays

$$\begin{aligned}
 h_K &= \sum_{z \in L} d_z e^{j(2\pi \frac{d}{\lambda} + \frac{2\pi k z \cos\theta}{\lambda})} \\
 &= \sum_{k=1}^L P(\cos\theta_k) e^{j2\pi k z \cos\theta / \lambda} \\
 &= \sum_{k \in S} P(\cos\theta) e^{j2\pi k f_l / \lambda} \\
 &= \sum_f P(f) e^{j2\pi \frac{f}{\lambda} k \cos\theta} \\
 \Rightarrow h[k] &= \sum_f P(f) e^{j2\pi kf / \lambda} \rightarrow \text{Fourier Transform}
 \end{aligned}$$

Fourier Transform

Time  $\xrightarrow{\text{FT}}$  Frequency

Antenna Pos  $\xrightarrow{\text{FT}}$  Direction

Signal Samples for Window T

$\Rightarrow$  Resolution  $\frac{1}{T}$  where  $N = f_s T$

$\Rightarrow$  Resolution  $f_s$ , separation  $= \frac{1}{f_s}$

$\Rightarrow$  BW =  $f_s \rightarrow$  sample 2x highest freq.

- For a larger antenna array, higher resolution of angles
- Better beamsteering w/ more elements
- Large array, expensive

3

Increase separation w/ small antenna  $\rightarrow$  aliasing

Direction became indistinguishable

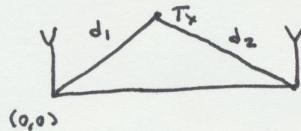
- trade off - separate by  $\lambda/2$   $\begin{cases} \rightarrow \text{bad resolution} \\ \rightarrow \text{no ambiguity} \end{cases}$

separate by  $>\lambda/2$   $\begin{cases} \rightarrow \text{good resolution} \\ \rightarrow \text{ambiguity exists} \end{cases}$

$\Rightarrow$  Use both features, spread properly and with proper # of elements

### Points to wrap up

- Assumes  $+x$  is far away from  $r_x$



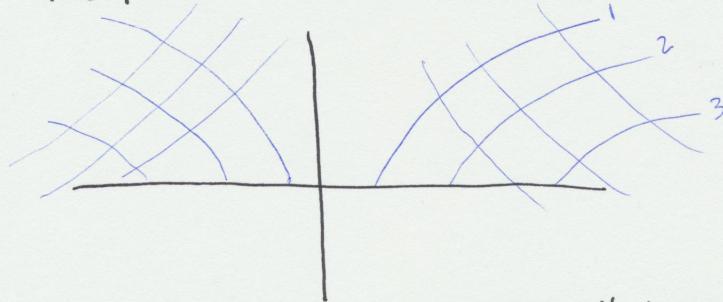
- go back to basic equation if assumption is wrong

- map in terms of  $\cos\theta$

$$e^{j2\pi d_1/\lambda}, e^{j2\pi d_2/\lambda}, \Delta\phi = \frac{2\pi(d_1-d_2)}{\lambda} = \sqrt{\lambda^2+y^2} - \sqrt{(x-s)^2+y^2} = K, \text{ a constant}$$

This takes the form:  $\frac{x^2}{a^2} + \frac{y^2}{b^2} = c^2$

Find points that match hyperbola to localize:



- creates a lot of computation that cannot be avoided

