Localization

through

Wireless Access Point

Channel State Information

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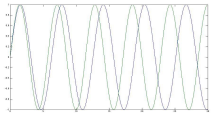
Principle of Operation

- Carriers are synchronized at transmit
- Phase angle between subcarriers encodes Time of Flight (ToF)
- Phase angle between antennas encodes Angle of Attack (AoA)



Data Collection

- Laptop with Intel IWL5300
- Linux 802.11n CSI Tool: custom firmware for accessing channel state information

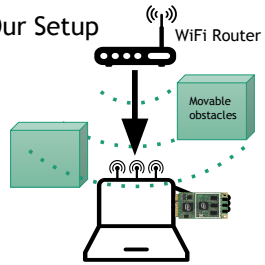
Each of 1 million packets:
3 Antennas
30 Subcarrier Groups
Gain & Phase of Signal
=180 features

Training
2m ~ 20m

Goals

- Estimate distance from WiFi AP at sub-meter accuracy
  - Can triangulate to calculate global coordinates
- Use commodity hardware, no custom equipment
- Software-only solution
- Currently owned technology

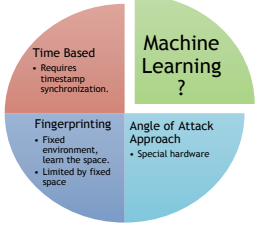
Our Setup



Feature Generation

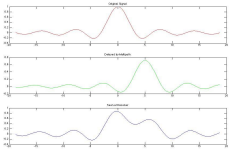
- We chose Kernel Ridge Regression
- Experimented with multiple packets per training sample
- Random sampling from full training set
- Explored pairwise multiplication
- Generalization error obtained through K-Fold Cross Validation

Current Solutions



Multipath

- Multiple reflection paths convolves signal
- Only direct path corresponds to ToF



Results (KRR)

#1 Proof of Concept: Calculated Gaussian Kernel by randomly subsampling 2000 points and computing Mean Squared Distance between the 2000 points for gamma. [Data taken at 2m~4m] → [10 packets]=1800 features per sample.	RMS Error:	0.56m
#2 Expanding Dataset: [Data taken at 2m~15m] → [10 packets]=1800 features per sample.	RMS Error:	2.78m
#3 Reduction in Sampling: [2m~15m] → [10 packets]<Real, Imaginary, Gain, Phase> =3600 features per sample. Limit to 4000 samples per distance.	RMS Error:	3.1m
#4 Experimentation with Gamma: [2m~15m, 4000 Sample/Dist] [10 packets]<Gain, Phase> =1800 features per sample. Conclusion: original gamma is better.		

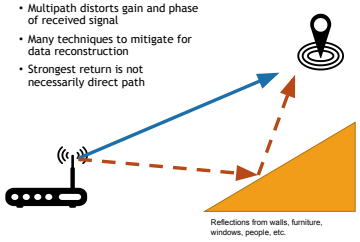
Wi-Fi background

802.11n
2.4 Ghz
11 channels

64 Subcarriers per channel

- OFDM scheme
- Each subcarrier separated by 312.5khz
- Each channel separated by 20/40 Mhz

- Multipath distorts gain and phase of received signal
- Many techniques to mitigate for data reconstruction
- Strongest return is not necessarily direct path



#5 Experimenting with pairwise multiplication: [2m~15m, 4000 Sample per distance] [2 packets + every pairwise multiplication]=65K features/sample.	RMS Error:	1.27m
#6 Trying more packets: [2m~15m, 4000 Sample per distance] [3 packets + pairwise]=146K features/sample.	RMS Error:	1.3m
#7 Trying more packets: [2m~15m, 4000 Sample per distance] [4 packets + pairwise]=260K features/sample.	RMS Error:	1.66m
#7 Self Multiply only [2m~15m, 4000 Sample per distance] [4 packets + pairwise within packet]=65K features/sample.	RMS Error:	2.13m
#7 Self Multiply only [2m~15m, 4000 Sample per distance] [10 packets + pairwise within packet]=161K features/sample.	RMS Error:	2.66m