

FAR - Fast, Accurate, and Robust localization

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SwordFight

<http://research.microsoft.com/apps/video/default.aspx?id=162808>

Premise

Most multiplayer mobile games still involve staring at the screen

Wii/Playstation Move/Kinect controll-style with phones

What is necessary?

- Phones only
- Low latency
- High accuracy
- User mobility
- Practical in most environments

Acoustic Distance Measuring

- Phone A emits tone
- Phone A records own tone at time t_{A1}
- Phone B records at time t_{B1}
- Phone B emits tone
- Phone B records own tone at time t_{B2}
- Phone A records at time t_{A2}
- distance = $\frac{1}{2} * c * [(t_{A2} - t_{A1}) - (t_{B2} - t_{B1})]$

Process

Play/Record -> Compute -> Exchange

Cross-Correlation

Indicates a match between two sound samples as a sharp peak

Runs in $O(B*L)$ for B samples of length L

Limitations

- Basically takes way too much time - ~800ms
- Phones need to be stationary

FAR

Addresses all points of delay:

- Tone Length - 512 samples, ~46.4ms
- Audio Playing Lag - continuous stream
- Sound Propagation Delay
- Buffering Delay - pipelined stream, ~46.4ms
- Computation Time - autocorrelation
- Measurement Exchange - UDP, 2-4ms

Autocorrelation

1. Each phone sends a pseudorandom sequence twice for its tone ($X(t)$)
2. The other phone takes the sequence it hears and generates a copy ($Y(t)$)
3. Formula Magic (Section 5.1, p5)

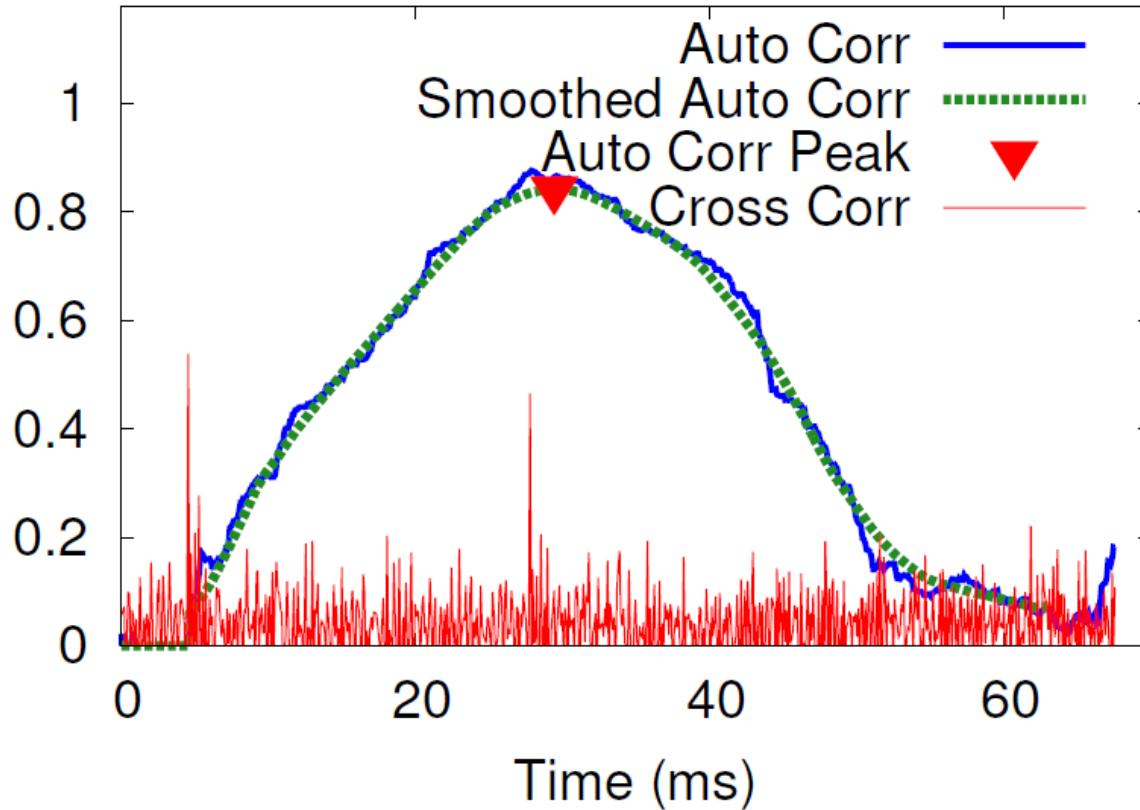
$$R(L/2, t_0) = \frac{\sum_{t \in W} [X(t) - \overline{X(t)}][Y(t) - \overline{Y(t)}]}{\sqrt{\sum_{t \in W} [X(t) - \overline{X(t)}]^2 \sum_{t \in W} [Y(t) - \overline{Y(t)}]^2}}$$

Basically...

Autocorrelation detects correlation of a signal to itself

Since phones send two identical sequences, something in $X(t)$ will match $Y(t)$.

Issues with Autocorrelate



How FAR Works

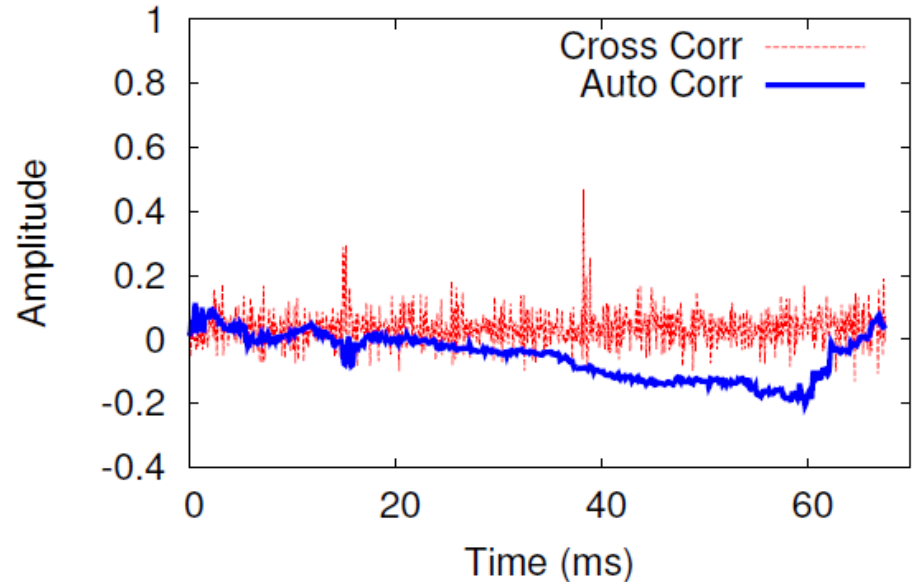
The entire process:

Filter out Ambient Noise

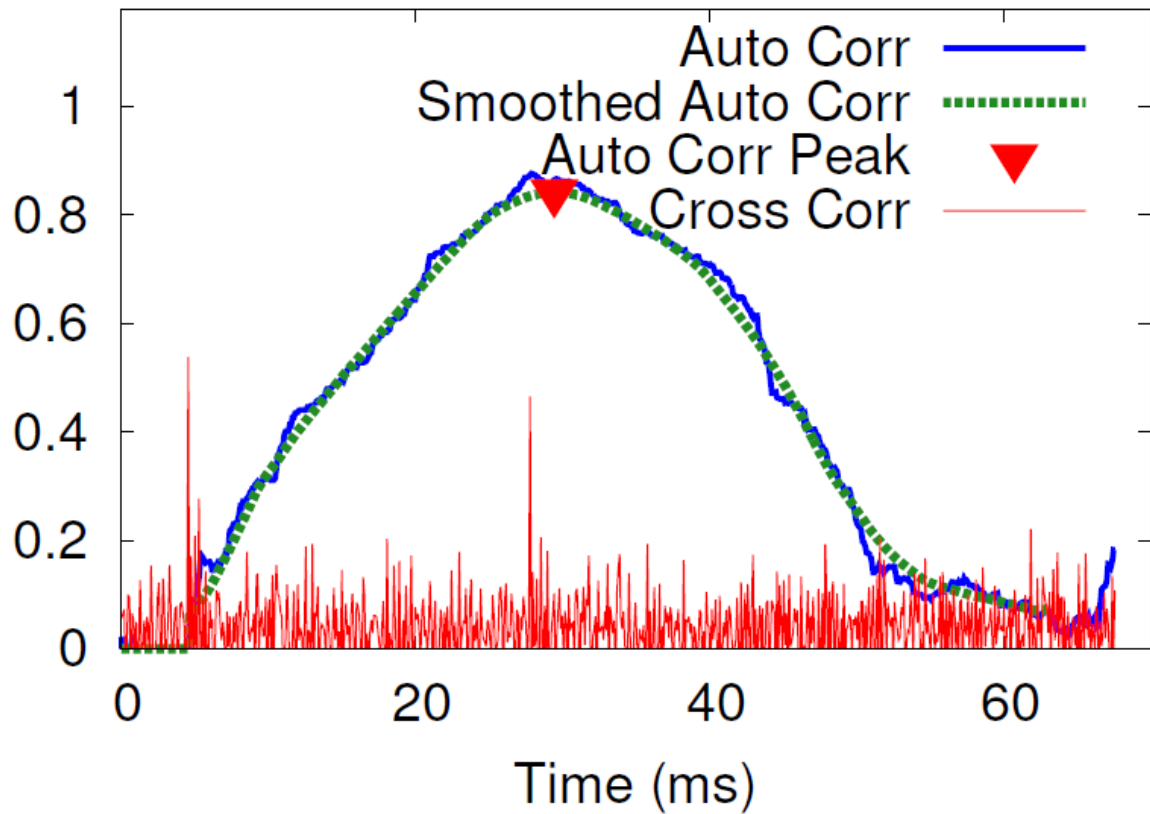
- Allows for easier location of tone signatures
- Identifies multipath readings

Run Multiple Autocorrelators

- Necessary to counter Doppler Effect
- No more than 3
(In most cases)

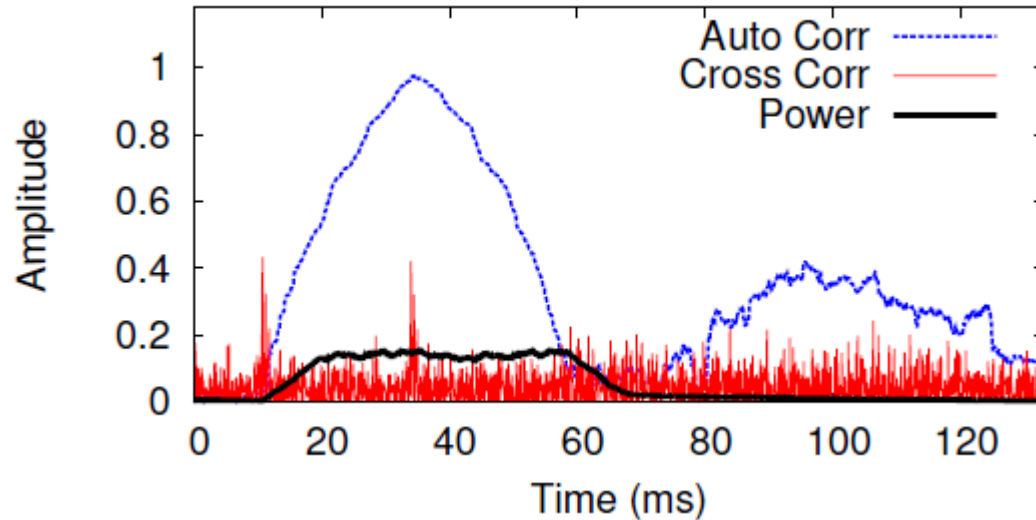


Smoothing



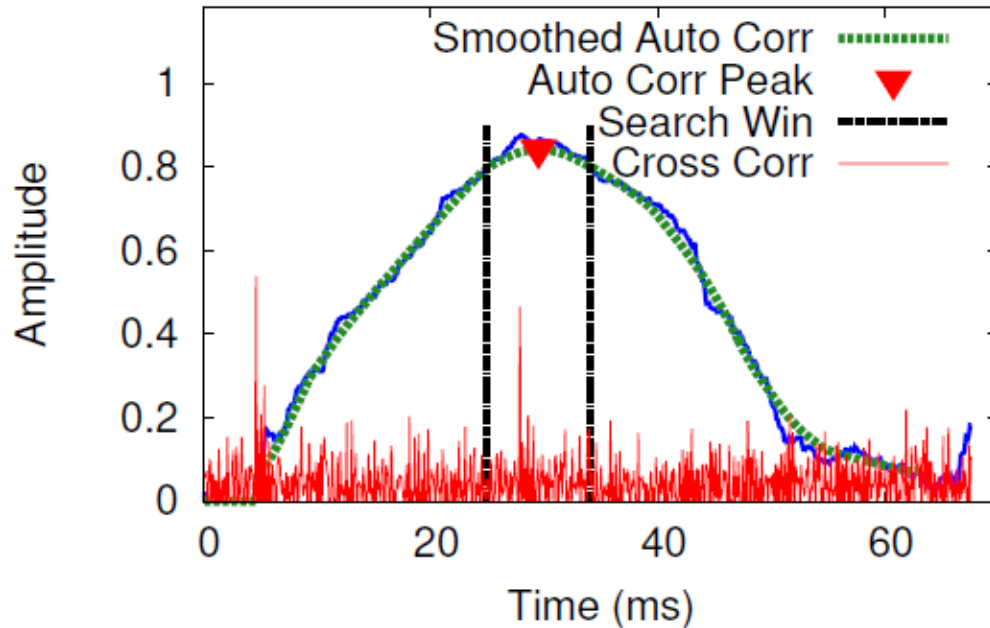
Remove Multipath Readings

Set power threshold to .02, peak level threshold to 0.4



Use focused Cross-Correlator

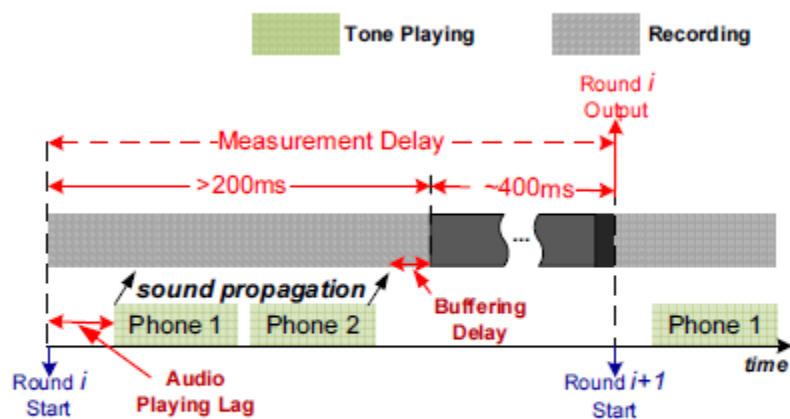
Search window of 100 samples (-80 to +20)



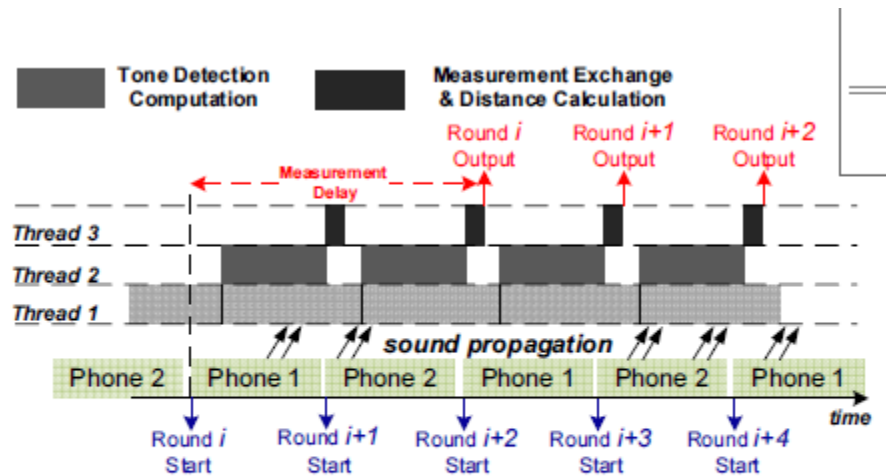
The Rest

- Exchange Data over WiFi (UDP)
 - If it fails, readjust calculations - can tell from pattern
 - If fails multiple times, use longer tone to recalibrate
- Calculate Distance
 - Adjust Doppler predictor
- Final Low Pass Filter

Overall



(a) Traditional Execution Strategy



(b) FAR Execution Strategy

SwordFight and ChaseCat

Demonstrated with Android 2.3.4 on Nexus One and Windows Phone 7.5 on Samsung Focus

Median Error: 2cm

Expected effects are neutralized