AMIL: Localizing Neighboring Mobile Devices Through a Simple Gesture

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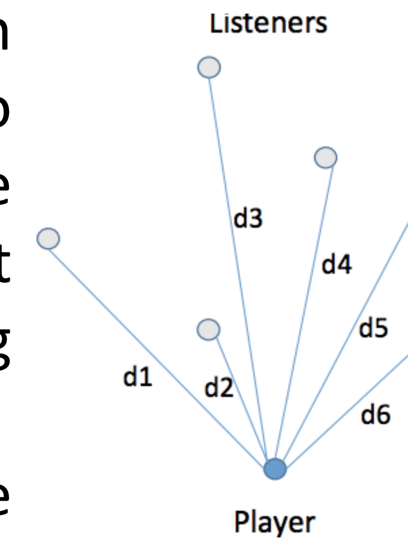
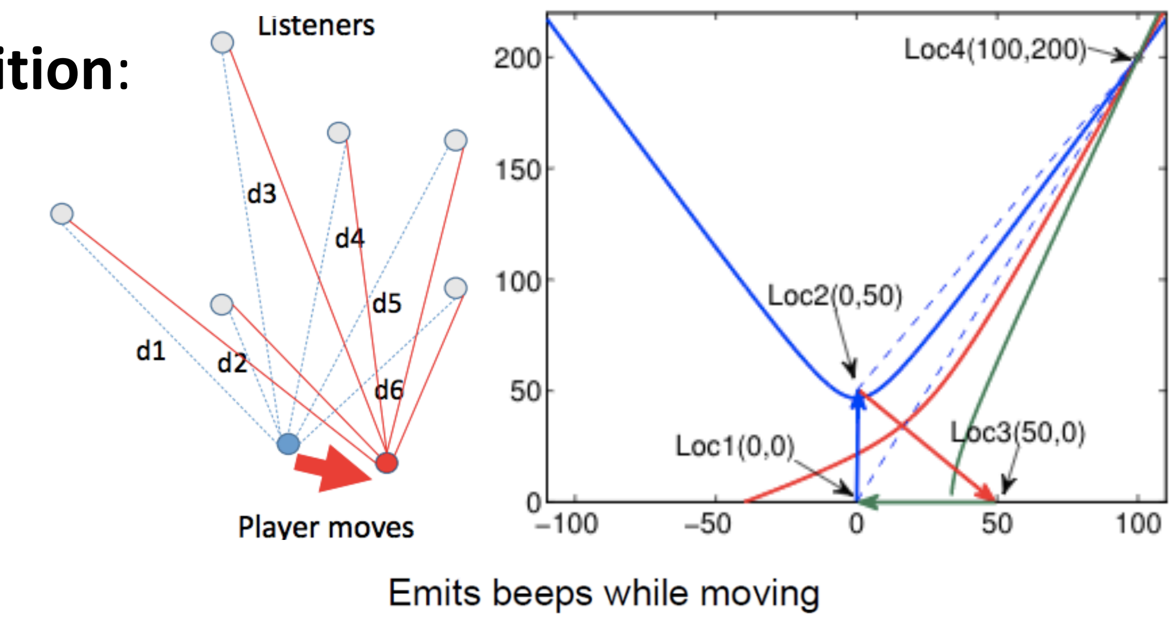
Introduction

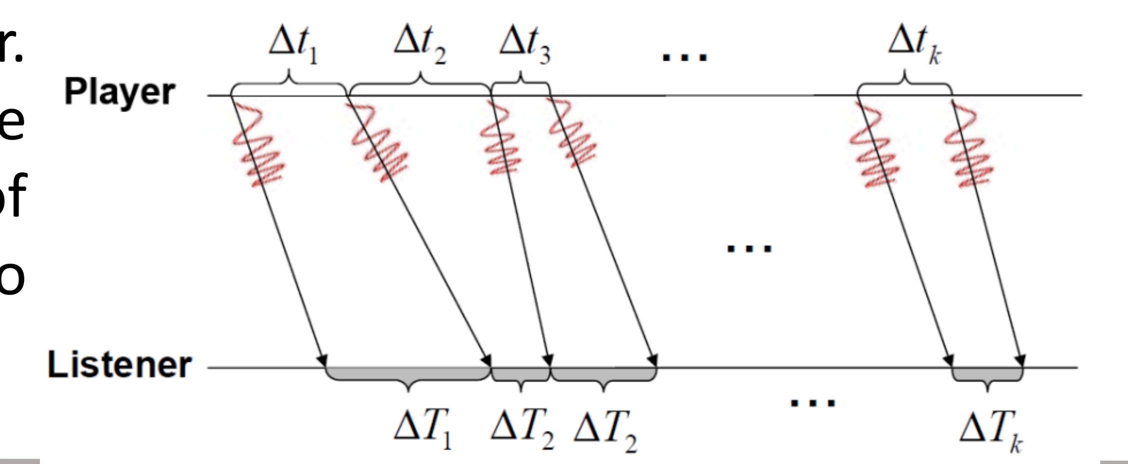
Smartphone users are often grouped to exchange files when meeting together. They may not know each other in advance. This ad hoc pattern increases the demand for more intuitive methods to identify communication parties. Yet the user may not easily link the name to individuals, because of the perception gap between the digital and the physical world. We argue that location info can bridge this gap. We build AMIL: an Acoustic Mobility Induced Localization scheme for smart device to provide such location information. The user only needs to hold the phone drawing a simple gesture in the air and she will get relative locations of all neighboring devices at the same time.

In order to do localization, we move the device to create multiple virtual anchor and use inertial sensor to estimate the displacements. We send out beep during the movements and rely on counting audio samplings to get the time different between beeps from both player and listener. Then we can use Time Delay of Arrival technique to localize all listener.

Intuition:







System Design and Algorithms

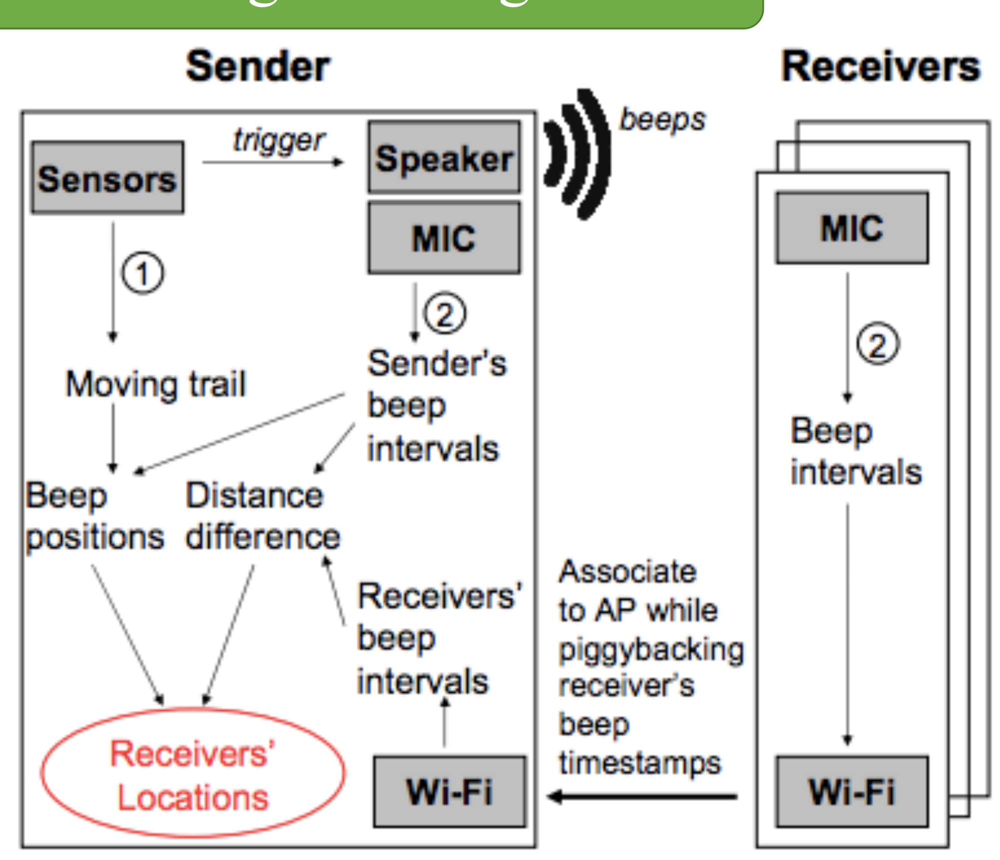


Fig. 2 System Architecture

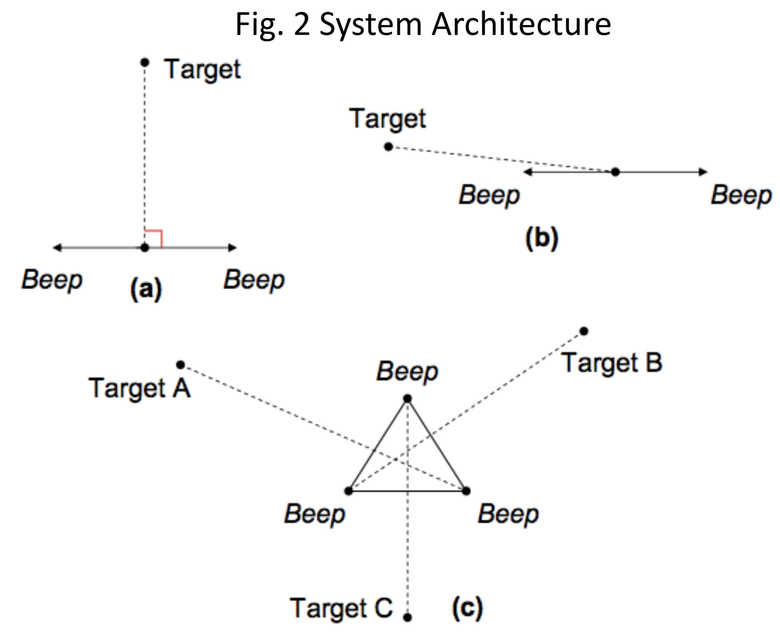


Fig. 3 Moving strategies

Movement tracking algorithm:

- integral: acceleration -> speed -> distance, angle acceleration -> angle.
- noise canceling:
  - only integrate chunks when motion is detected
  - using gyroscope to rotate the phone's frame to initial orientation
  - leverage natural pauses in gestures (e.g. triangle), compensate the velocity at pause to 0.

Interval calculation algorithm :

- linear chirp, FFT-based filter + cross correlation (reduce finishing time by more than 90%)
- 'self-recording'
  - sender records the beep as well
  - count audio samples differences in two consecutive beeps. (TDoA)

$$\Delta d_i = c \cdot (\Delta T_i - \Delta t_i)$$

Positioning algorithm :

- Three beeps: one, two or zero solutions
- More beeps
  - select a set of three beeps and solve it.
  - filter out impossible solution
  - get the centroid of all candidate solutions.

$$\Delta d_i = \sqrt{(x-x_i)^2 + (y-y_i)^2} - \sqrt{x^2+y^2}$$

$$\begin{bmatrix} A_1 & B_1 \\ A_2 & B_2 \\ \cdots & \\ A_{n-2} & B_{n-2} \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} C_1 \\ C_2 \\ \cdots \\ C_{n-2} \end{bmatrix}.$$

Moving strategy:

- if the location is known, draw a perpendicular line is the best
- if the location is not known, a triangle would achieve good result on average

Evaluation

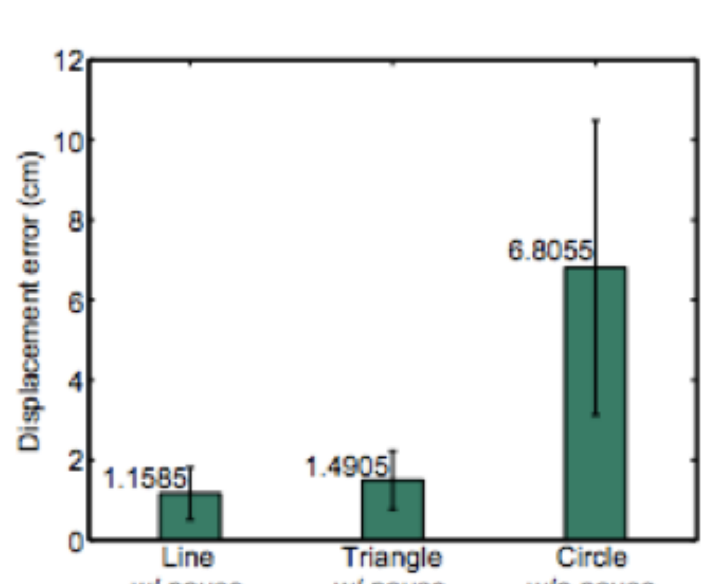


Fig. 4 Displacement error. Comparison of different gestures with or without pauses.

Using gestures with pauses can improve the displacement estimation

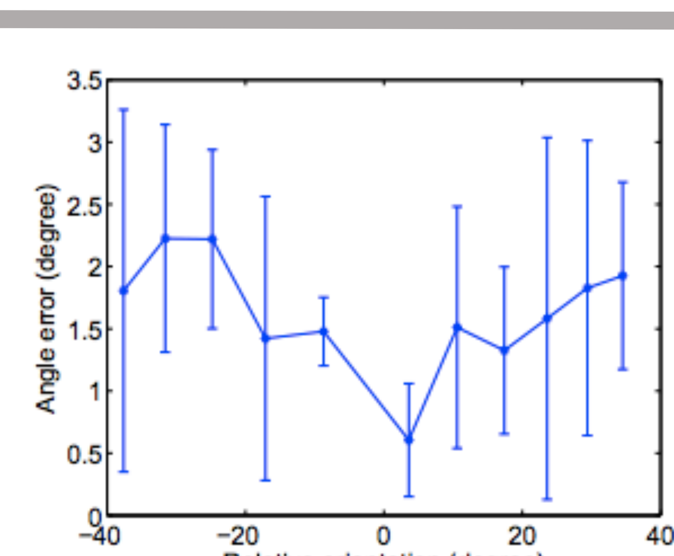


Fig. 4 Angle errors with line gesture.

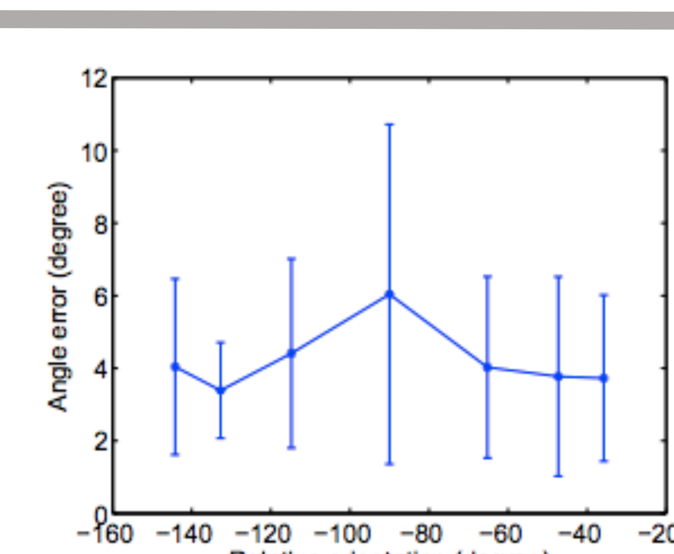


Fig. 5 Angle errors with triangle gesture.

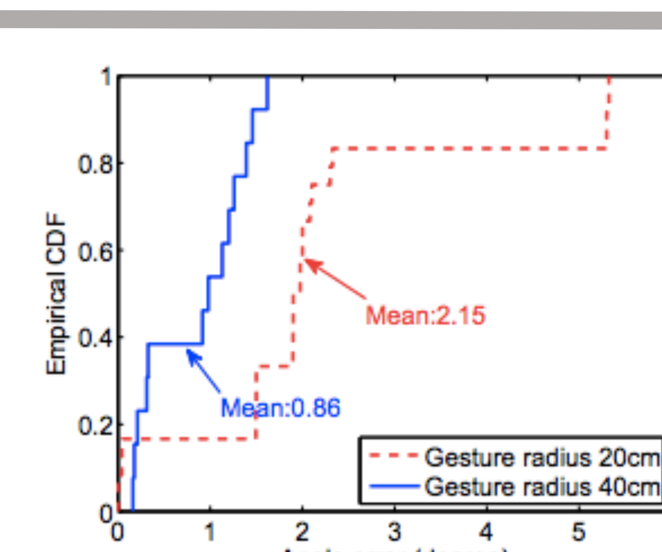


Fig. 6 Angle errors with different moving radius.

Average direction errors were 2.5 ° using a ling gesture, less than 6 ° using a triangle gesture. Larger radius has better accuracy.

Both error of sensor and beep detection contribute to the localization error. Displacement error adds more variation. By combining three triangles, we can limit the error to less than 50cm.

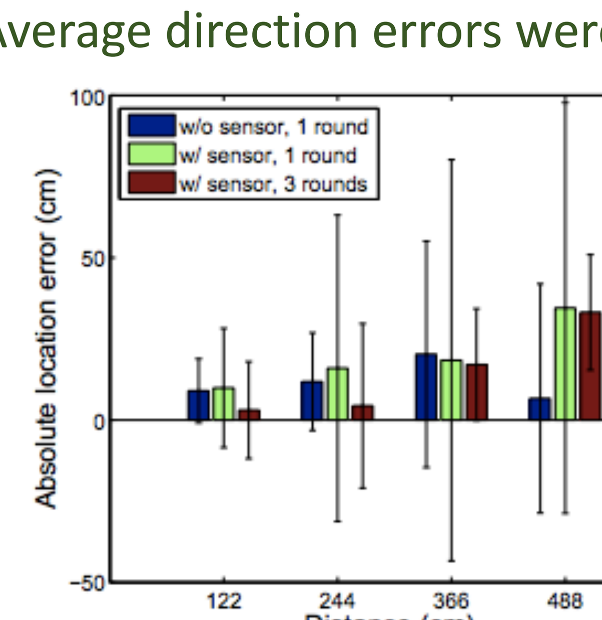


Fig. 5 Localization errors with triangle gesture (30.5cm radius). w/: using sensor to estimate displacement, w/o: accurate moving distance is supplied.

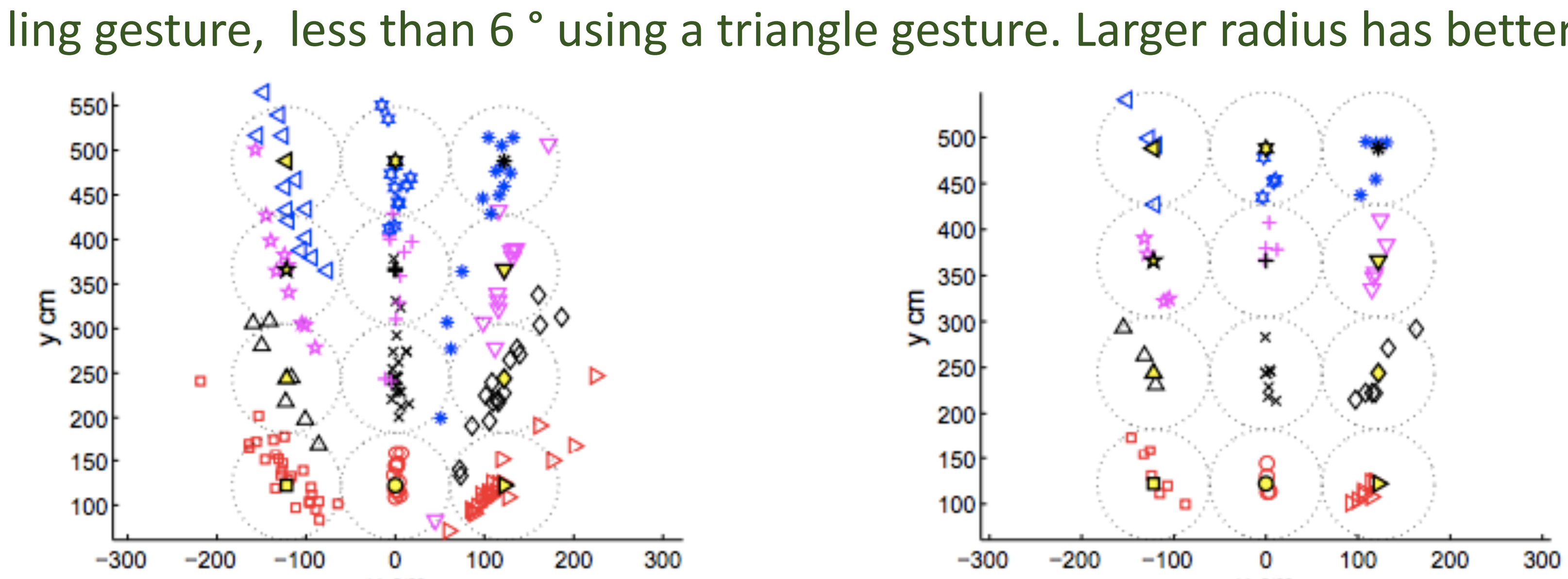


Fig. 6 Field test with triangle gesture (61 cm radius). Left is using single triangle and right is combining three.

Have good result when target is near the sender. Confirm the accuracy of direction and multiple rounds can reduce errors.

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Please refer the paper for more information and references

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