Indoor Follow Me Drone

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Background

Drones are becoming cheaper and popular

Motivation: videotaping + tracking

- Modification of outdoor drone videotaping

Challenges:

- No GPS
- Controlling small follow-me distances

Tracking

Indoor methods (no GPS):

- Computer Vision -- too inaccurate, expensive
- RF Localization -- too finicky, static anchors
- Coarse Movement Tracking -- too many sensors, expensive
- Acoustic -- our goldilocks, just right

Acoustics

Challenges:

Environment noise -> multiple paths from drone to mobile

-> similar-path-length interference

Dynamic pathing -- drone and mobile are moving

Drone propellers are loud -> acoustic signal noise

Computational efficiency

Rabbit

Robust Acoustic Based Indoor Tracking

Modifies/combines existing work on FMCW, MUSIC, and Kalman filtering

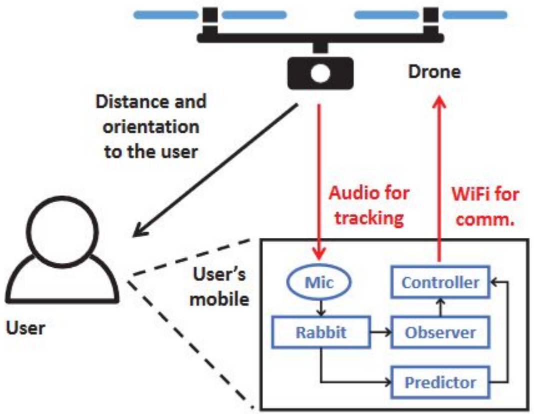


Figure 1: System diagram.

FMCW (Frequency Modulated Continuous Wave)

Estimates distance between audio signal source and sink based on FFT peaks

Issue:

multiple paths => multiple peaks => merged FFT peak => higher error

Solution: MUSIC

$$v_m(t) = \alpha \cos\left(2\pi f_{min} t_d + \frac{\pi B (2t' t_d - t_d^2)}{T}\right). \quad (1)$$

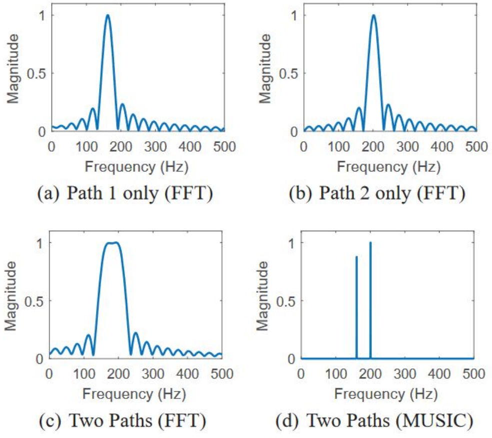


Figure 2: Peak merging in FFT-based FMCW.

MUSIC (MUltiple SIgnal Classification)

Improves multi-path resolution and enhances distance estimation

Issues:

sensitive to distortion -> flatten frequency amplitude in speakers

false peak interference -> further apply filtering

eigenvalue decomposition -> use subsampling

$$v_n = \sum_{i=1}^{M_p} \cos(2\pi f_i n t_s + \phi_i), \quad (2)$$

Thus, the resolution of our approach is 5 cm.

propeller noise -> Kalman filter the resulting distance and velocity measures

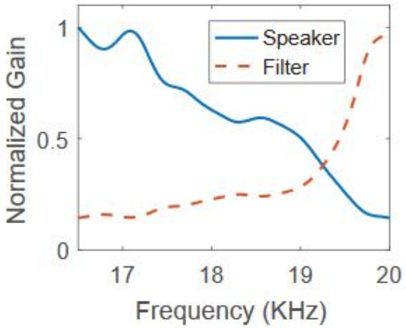
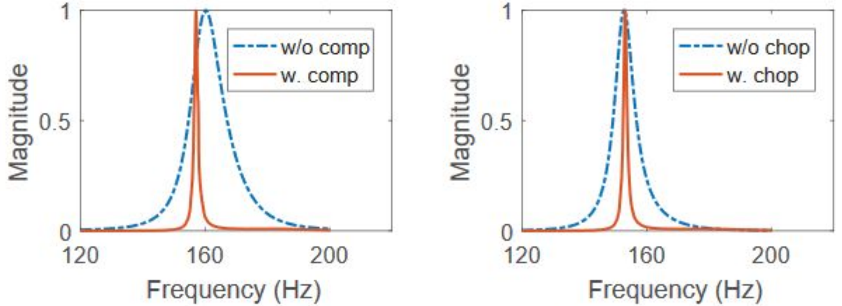


Figure 3: The frequency response of the speaker and filter.



(a) Compensation (b) Chopping

Figure 4: The sharpness of peaks: (a) applying signal chopping and comparing the performance with/without frequency response compensation; (b) applying response compensation and comparing the performance with/without signal chopping.

Kalman Filter

Drone propeller noise -> distance estimation error

Solution:

Apply a Kalman filter to distance and velocity to reduce error

Control

Q: How to get drone to follow agent once localized?

Control Theory

MPC and PID for autonomous control

Doppler shifts can be predictive of the user

DroneTack

MPC and PID

What we know: distance and orientation

We need to convert to drone parameters

MPC for Yaw and Pitch -> distance and orientation

Needs a N_p and w_u

PID for roll -> lateral velocity

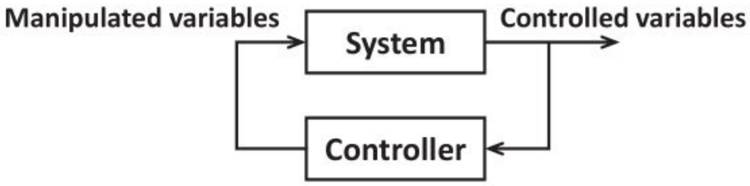
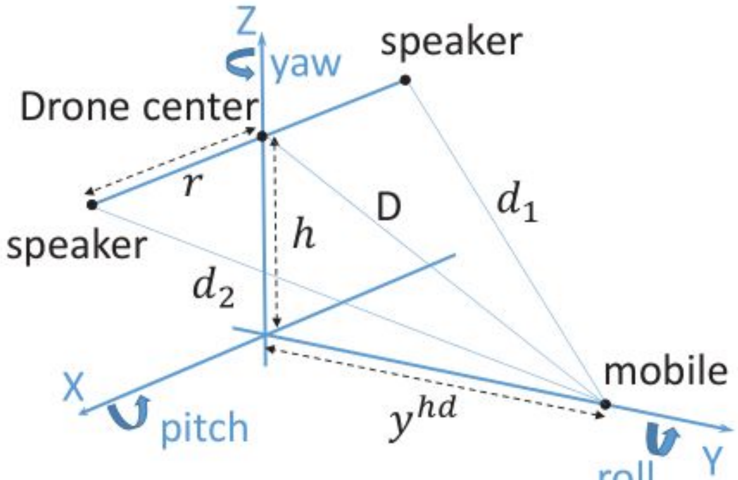


Figure 5: The system with a controller



Predictive users

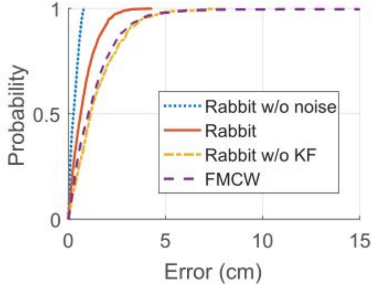
MPC and PID need more to predict

We need user’s movement

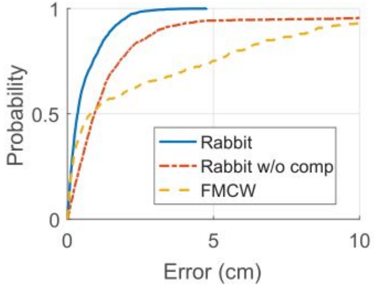
Doppler shifts give relative velocity

Evaluation

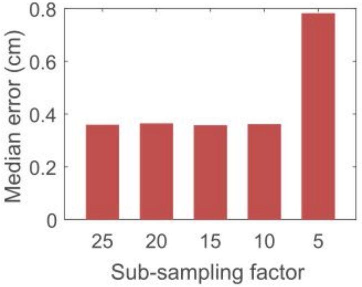
Conditions to consider for Rabbit:



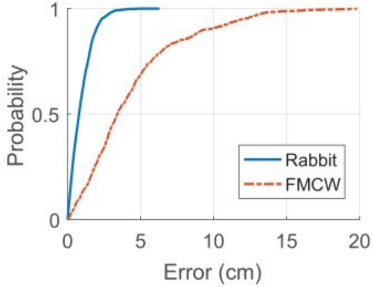
(a) Propeller noise



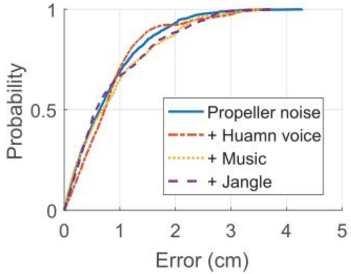
(b) Multipath



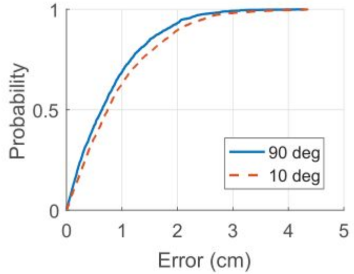
(c) Sub-sampling



(d) Noise & multipath



(e) Environment noise



(f) Mic orientation

Evaluation

Things to consider for DroneTrack

- Different MPC parameters
- Different user speeds
- Convergence time
- User prediction
- Varying drone-to-user Distance
- Location of phone

Evaluation

- Different MPC parameters
- Different user speeds
- Convergence time

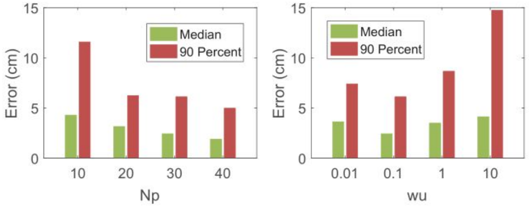


Figure 12: Errors on drone-to-user distance.

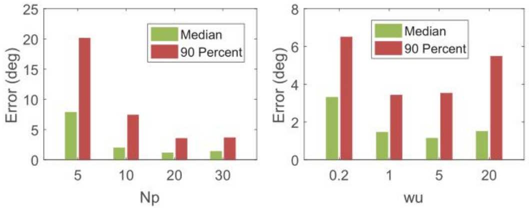
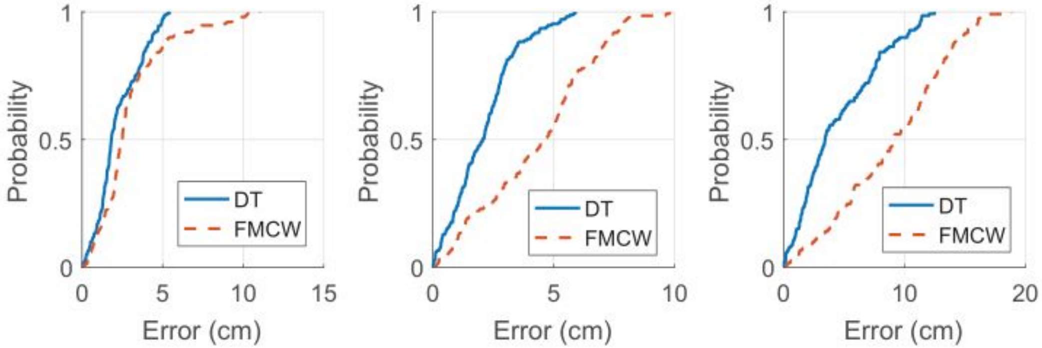
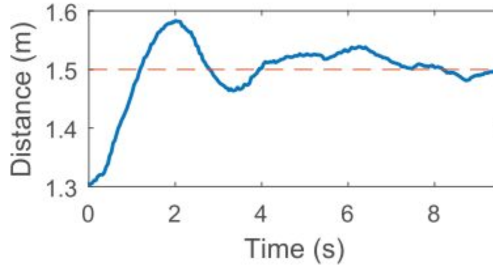


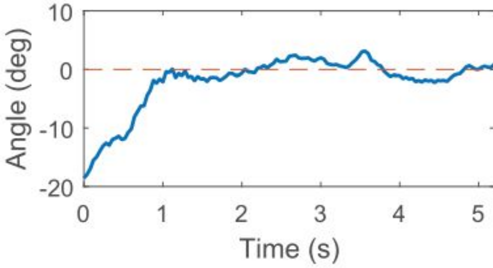
Figure 13: Errors on drone orientation.



(a) Slow speed (b) Normal speed (c) Fast speed



(a) Drone-to-user distance



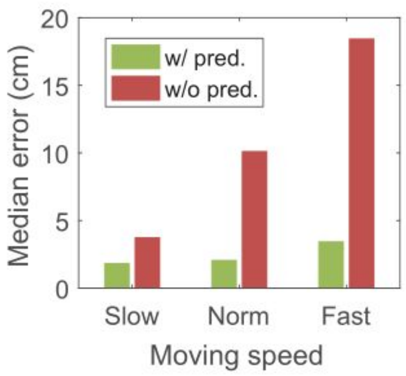
(b) Drone orientation

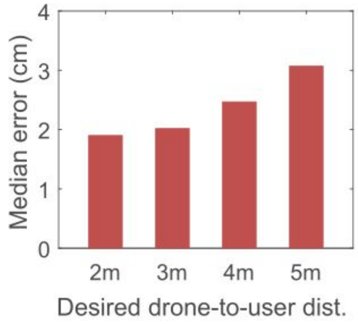
Evaluation

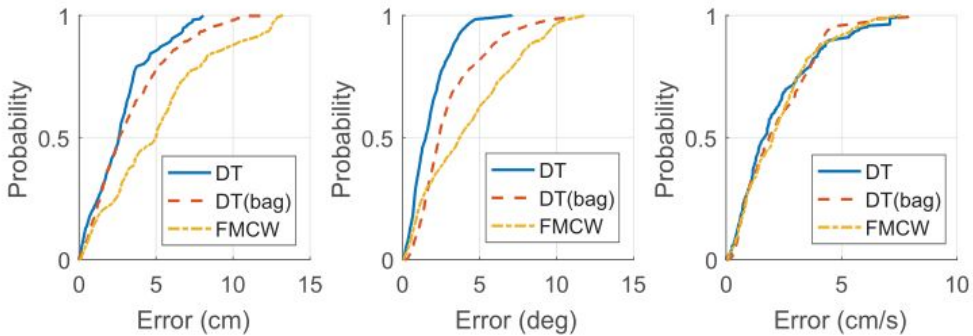
User prediction

Varying drone-to-user Distance

Location of phone







(a) Drone-user dist. (b) Drone orientation (c) Lateral velocity

Evaluation

Computation Cost

Tracking Time and overall time and percentage of cpu used

Battery Life

10 minute period on a galaxy s7 (3000 mAh)

	CPU Usage (%)	Delay (ms)
Tracking	13	9
Overall	42	13

Limitations

Audio signal physical constraints

Microphone direction

Possible sound annoyance

https://www.youtube.com/watch?v=YHI4016v4IY

^ video demonstration