Foes or Friends: Embracing Ground Effect for Edge Detection on Lightweight Drones

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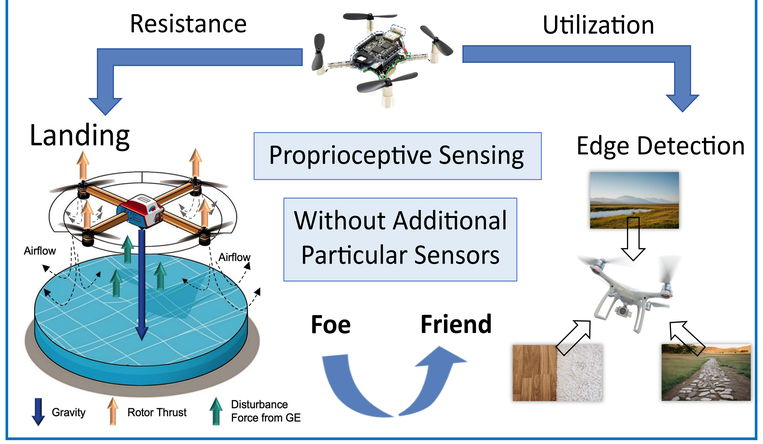
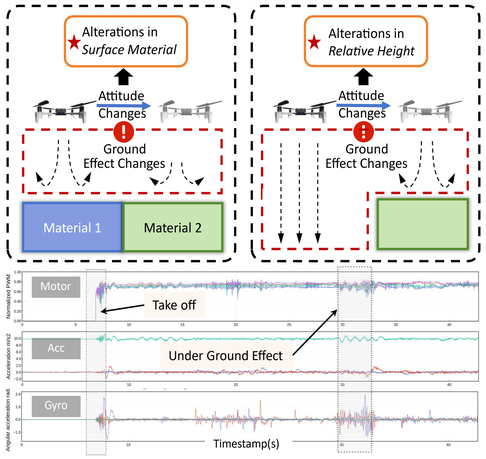
Abstract

- **Goal:** Develop a new sensing modality for light-weight drone for rapid and accurate edge detection with minimum number and lowest-level sensors, for delivery precise landing, mobile terrain mapping in agriculture, etc.
- **Research Question:** How can ground effect be turned into a new sensing modality for accurate edge detection?
- **Challenge:** Target discrepancy between sensing and flight control complicates ground effect profiling. Noisy sensing data overwhelms vital feedback related to ground effect.
- **Novelty:** Transforming a "foe" to a "friend": a new sensing modality for edge detection. Implementing the system with a light-weight model on edge computing device.

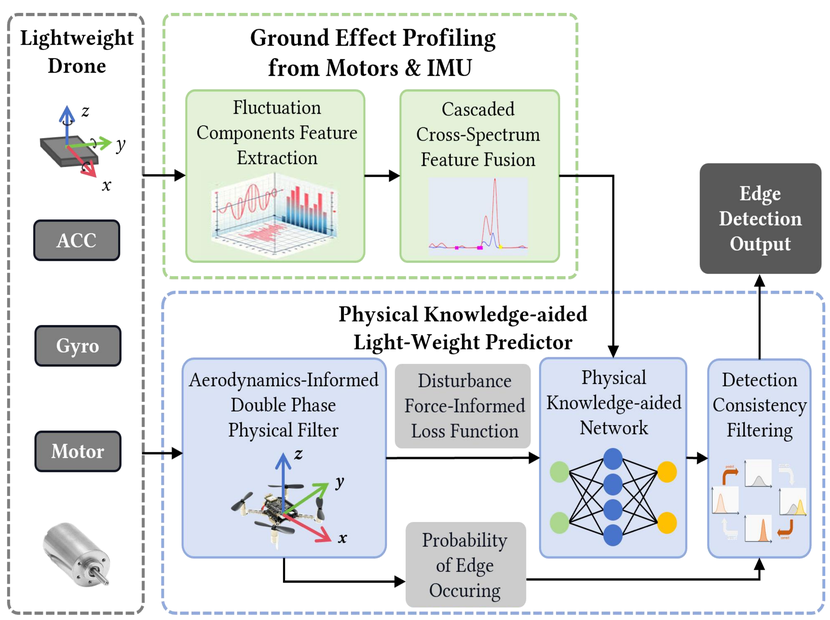
Motivation



Insight

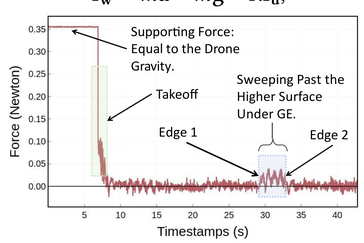


System Design

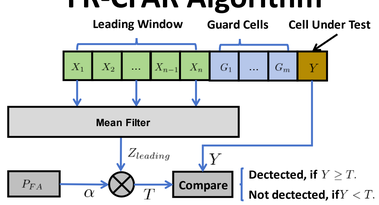


Disturbance Force

$$f_w = ma - mg - Rf_u,$$



FR-CFAR Algorithm

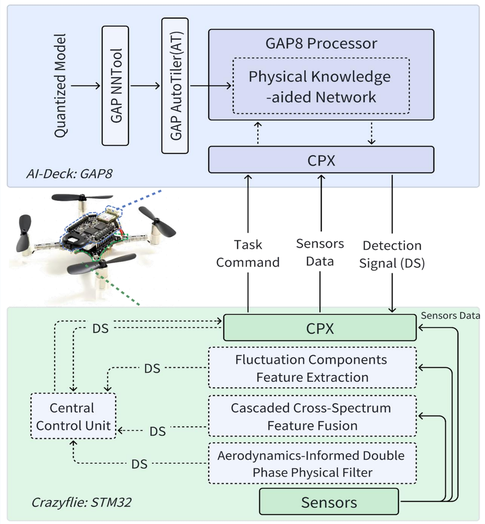


CCS-Feature Fusion

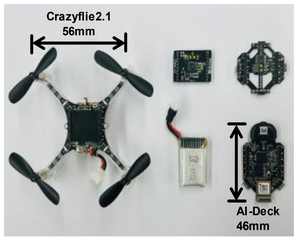
$$|P_{ccs}(f)| = \prod_{i=1}^{n-1} |G_{x_i x_{i+1}}(f)|$$
$$= |G_{x_1 x_1}(f)||G_{x_2 x_2}(f)|...|G_{x_n x_n}(f)|.$$

Performance

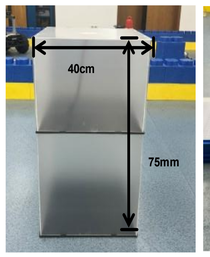
Experiment Setup



(a) Implementation Framework and Modules

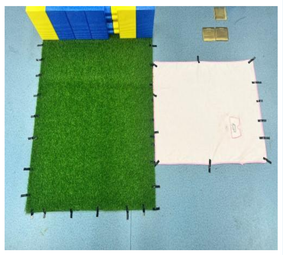


(b) Lightweight Drone

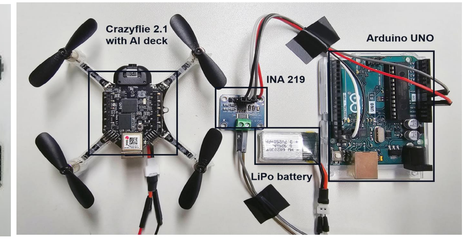


(c) Height Detection Platform

(d) Water and Cement

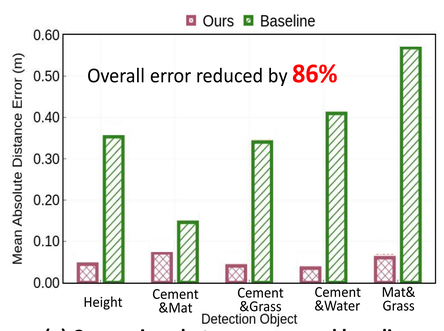


(e) Grass and Mat



(f) Power Measurement Equipment

Evaluations Results

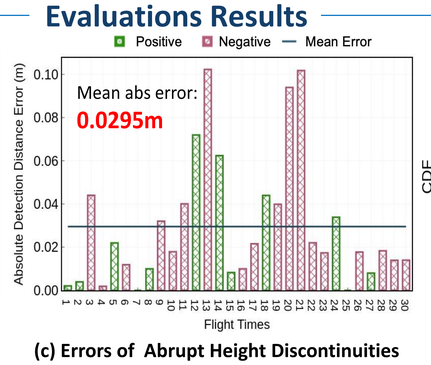


(a) Comparison between ours and baseline

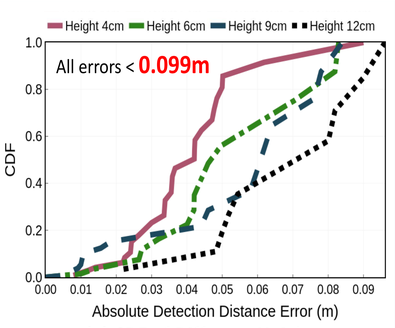
Module	Power (mW)
Basic drone module power	78
Fluctuation Components Feature Extraction	6
Cascaded Cross-Spectrum Feature Fusion	2
Aerodynamics-Informed Double Phase Physical Filter	2
Physical Knowledge-aided Network	33
Total Power	121

43mW

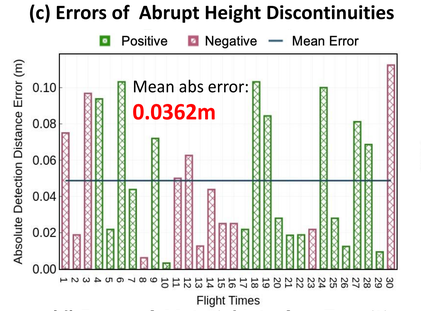
(b) System power consumption



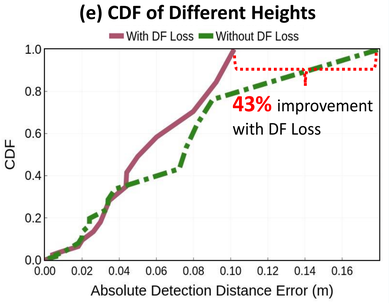
(c) Errors of Abrupt Height Discontinuities



(e) CDF of Different Heights



(d) Errors of Material Interface Transitions



(f) Efficiency of Disturbance Force Loss

Conclusion

- **AirTouch:** Transform ground effect into a positive sensing modality for precise edge detection on lightweight drones, enhancing drone capabilities across diverse environments.
- **Future Work:** Extend edge detection to mobile platforms for enhanced air-ground coordination and collaboration.

Reference

[1] H. Wang, J. Xu, C. Zhao, Z. Lu, Y. Cheng, X. Chen, X.-P. Zhang, Y. Liu, X. Chen. Transformloc: Transforming mavs into mobile localization infrastructures in heterogeneous swarms. In Proceedings of IEEE INFOCOM, 2024.

[2] C. Zhao, H. Wang, Jiaqi Li, F. Man, S. Mu, W. Ding, X.-P. Zhang, X. Chen. SmoothLander: A quadrotor landing control system with smooth trajectory guarantee based on reinforcement learning. In Adjunct Proceedings of ACM UbiComp/ISWC, 2023