ICUAS 2026

From Language to Logic (FL2L)

A Theoretical Architecture for VLM-Grounded Safe Navigation

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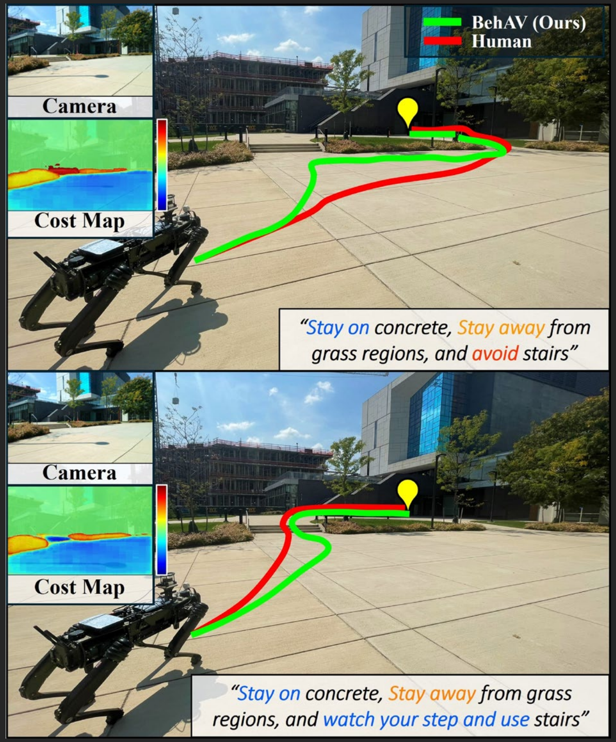
Vision + Mobile Robots = Robots That Can See AND Navigate!

Current technology supports vision-guided navigation of fixed-wing aircrafts, quadcopters, and more.

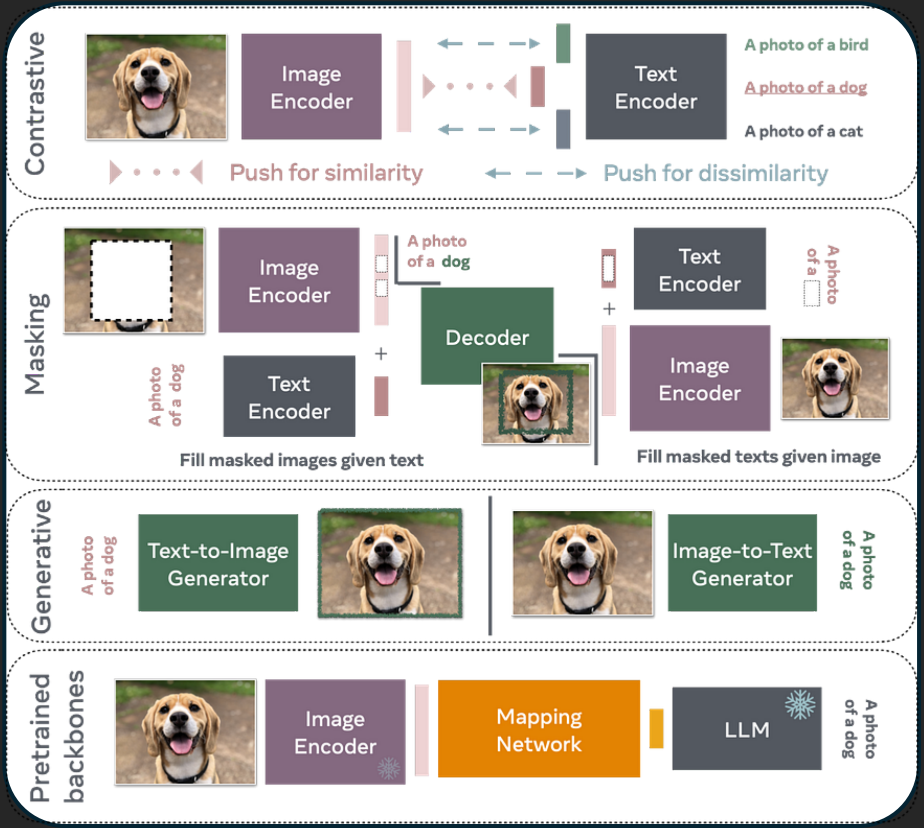
Song et al. (2024)



Weerakoon et al. (2024)

Vision-Language Models (VLMs)

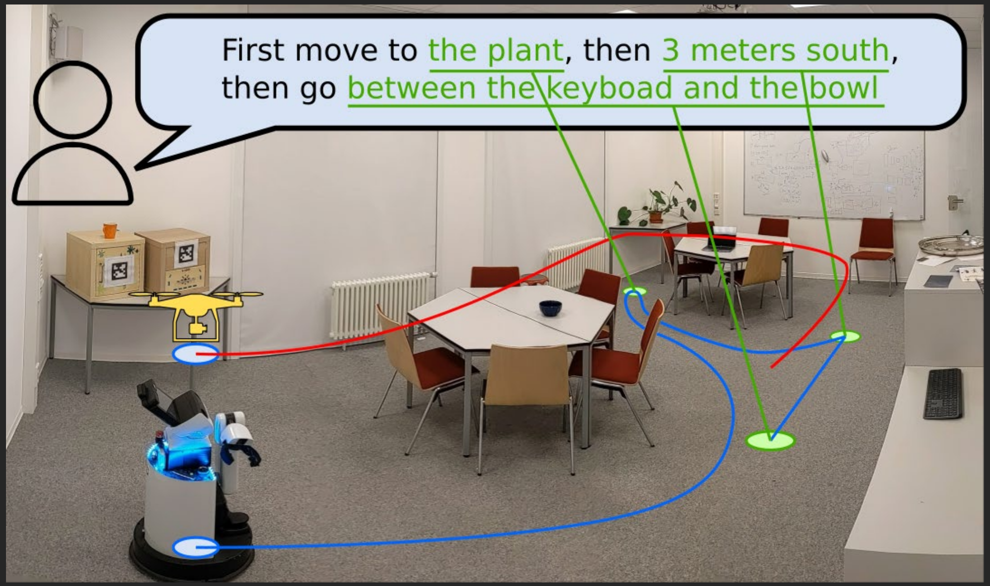
Multi-modal AI that can process, understand, and reason about visual data (image and videos) and text.



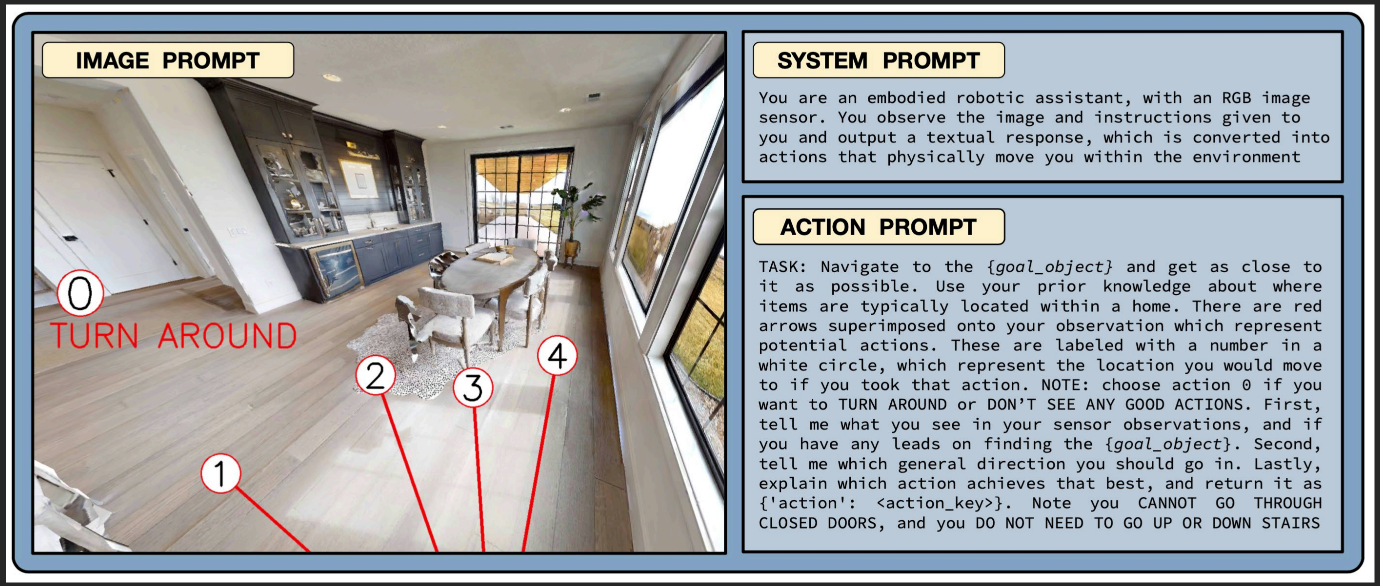
Bordes et al. (2024)

VLMs for Mobile Robot Navigation

Navigating an environment with a RGB camera, while parsing instructional text from a human.



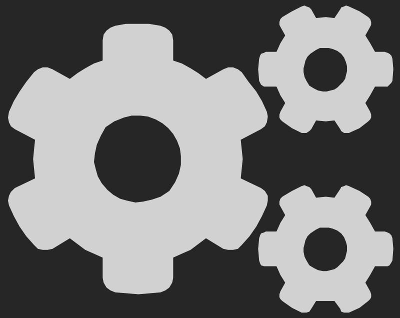
Huang et al. (2023)



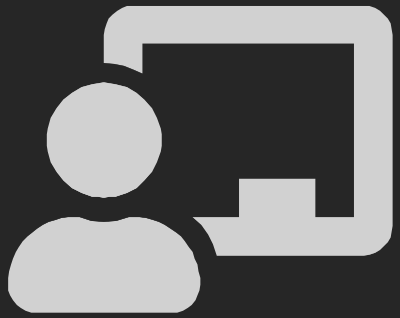
Goetting et al. (2024)

Verification and Validation (V&V) of Mobile Robots

How do we ensure that autonomous mobile robots are safe and following the rules?



Empirical Testing
demonstrations
scenarios
high-fidelity simulations



Safety Heuristics
time-to-collision
near-misses
minimum separating distance

Formal Logic & Rules
finite state machines
hard-coded rules
formal specifications

Bridging Human Intent with Mathematical Guarantees

FL2L blends the adaptability of VLM-based navigation with the mathematical rigor of Formal Methods.

Mission Operator

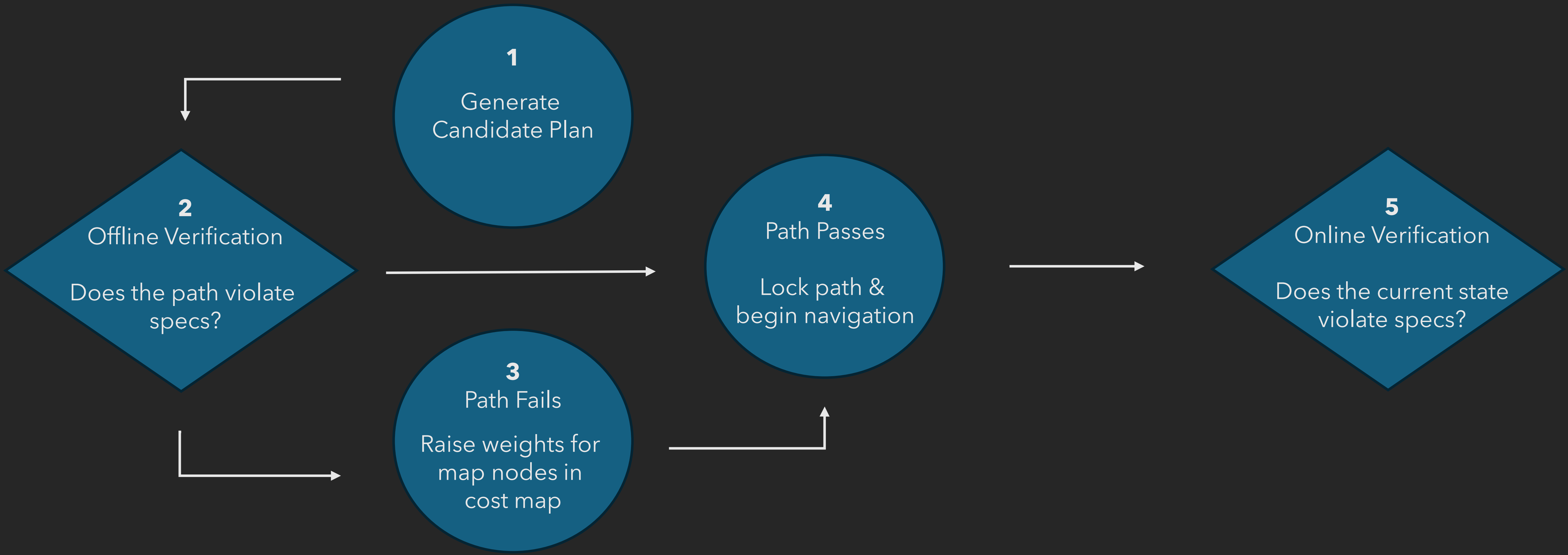
"If you go into the grass area, then eventually (within 3 secs), you must come out of the grass and stay above the sidewalk for at least 5 secs."

Offline Verification

Online Verification

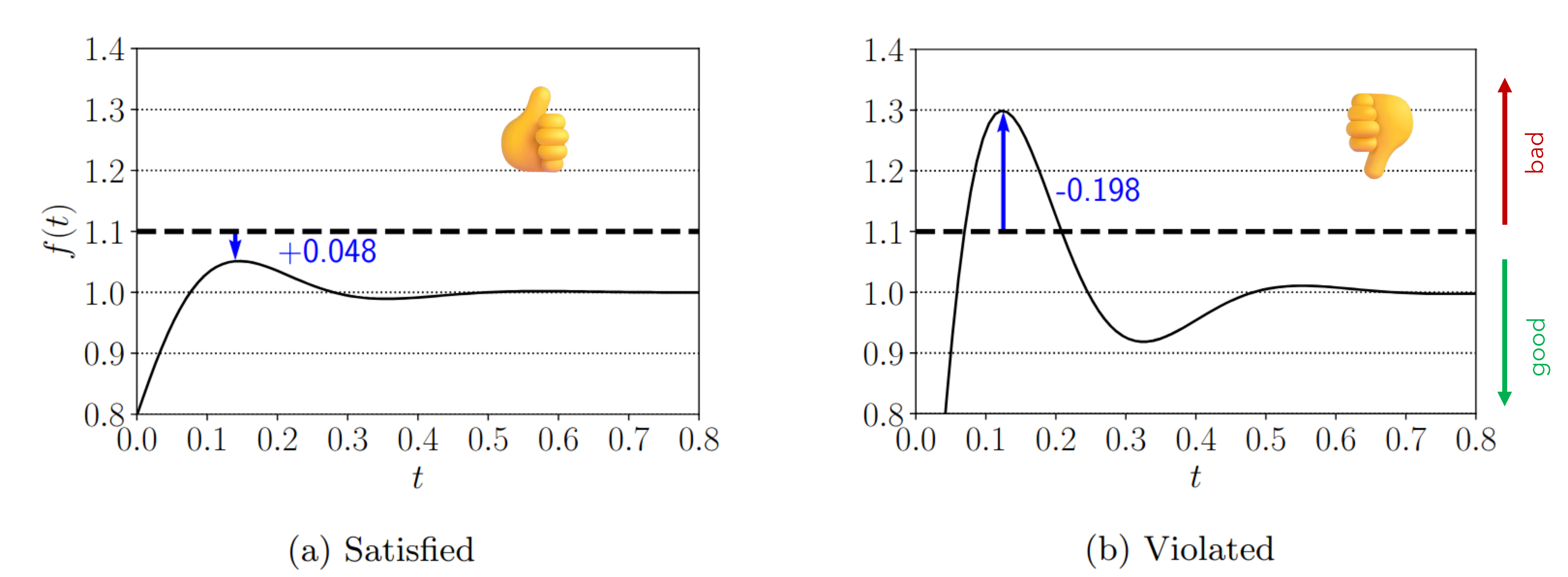
The Formal Evaluation Loop

The system maintains a mathematically proven, safe path to the goal.



Quantifying Safety with Signal Temporal Logic

The core concept: moving beyond safety as a "true" and "false" concept for dense-time signal.



Yamaguchi, Hoxha, and Nickovic (2025)

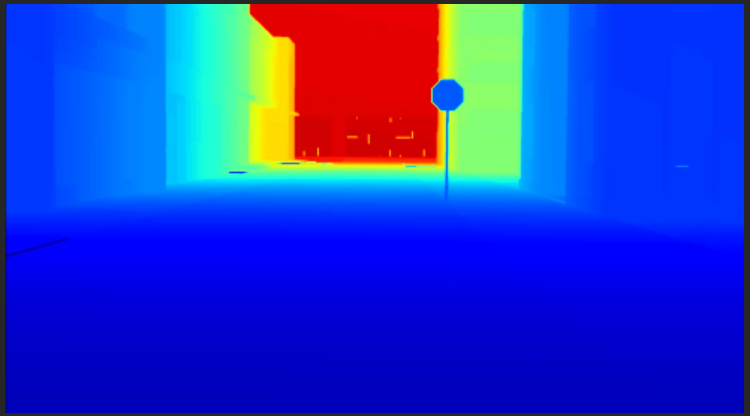
Example rule: *"Always stay below 1.1"* → G[0,∞] f(t) ≤ 1.1

Virtual Proving Ground: Verifying Our Approach in Simulation

Combining Blender (environment modeling), IsaacSim (robot sim), and CLIPSeg (VLM)

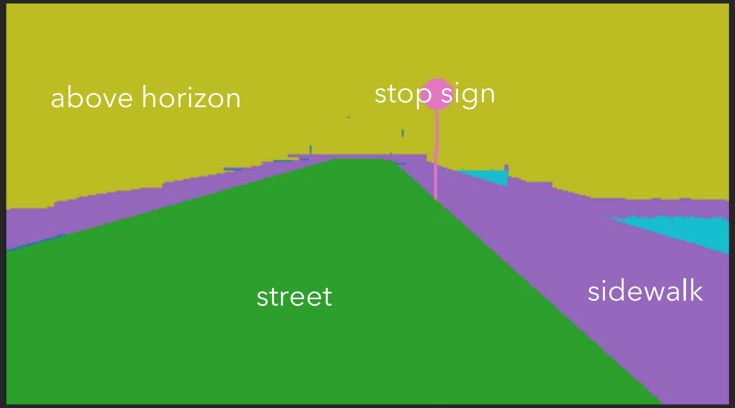
RGB Image
(simulated in Blender)

→



Monocular Depth Estimation

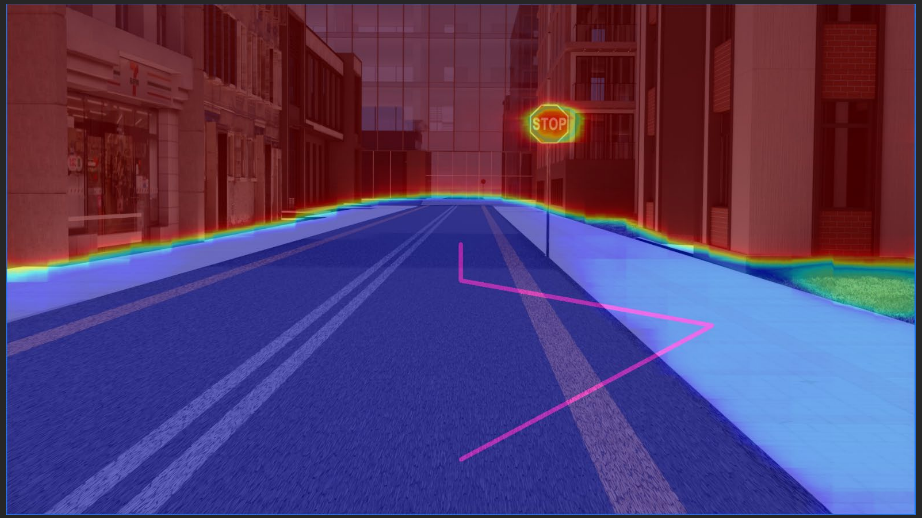
+



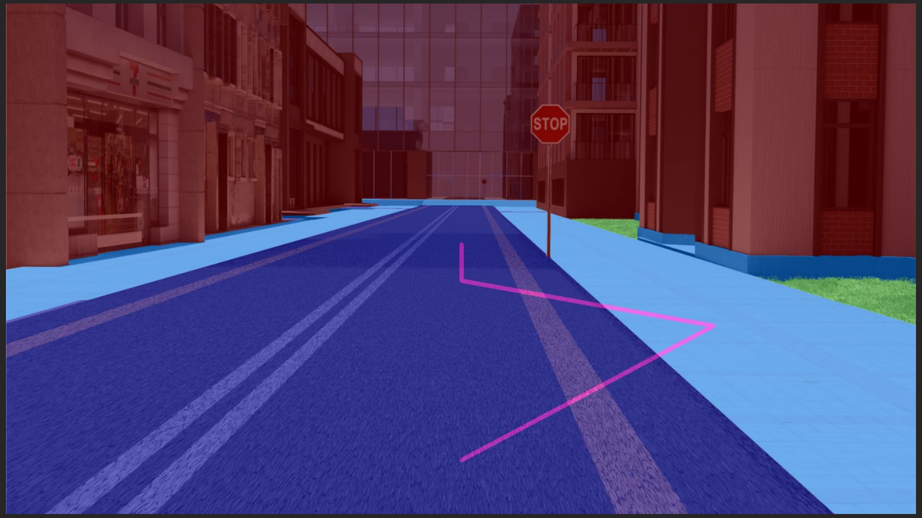
Object Segmentation

Virtual Proving Ground: Verifying Our Approach in Simulation

Combining Blender (environment modeling), IsaacSim (robot sim), and CLIPSeg (VLM)



Predicted Cost Map
(CLIPSeg)



Ground Truth Cost Map

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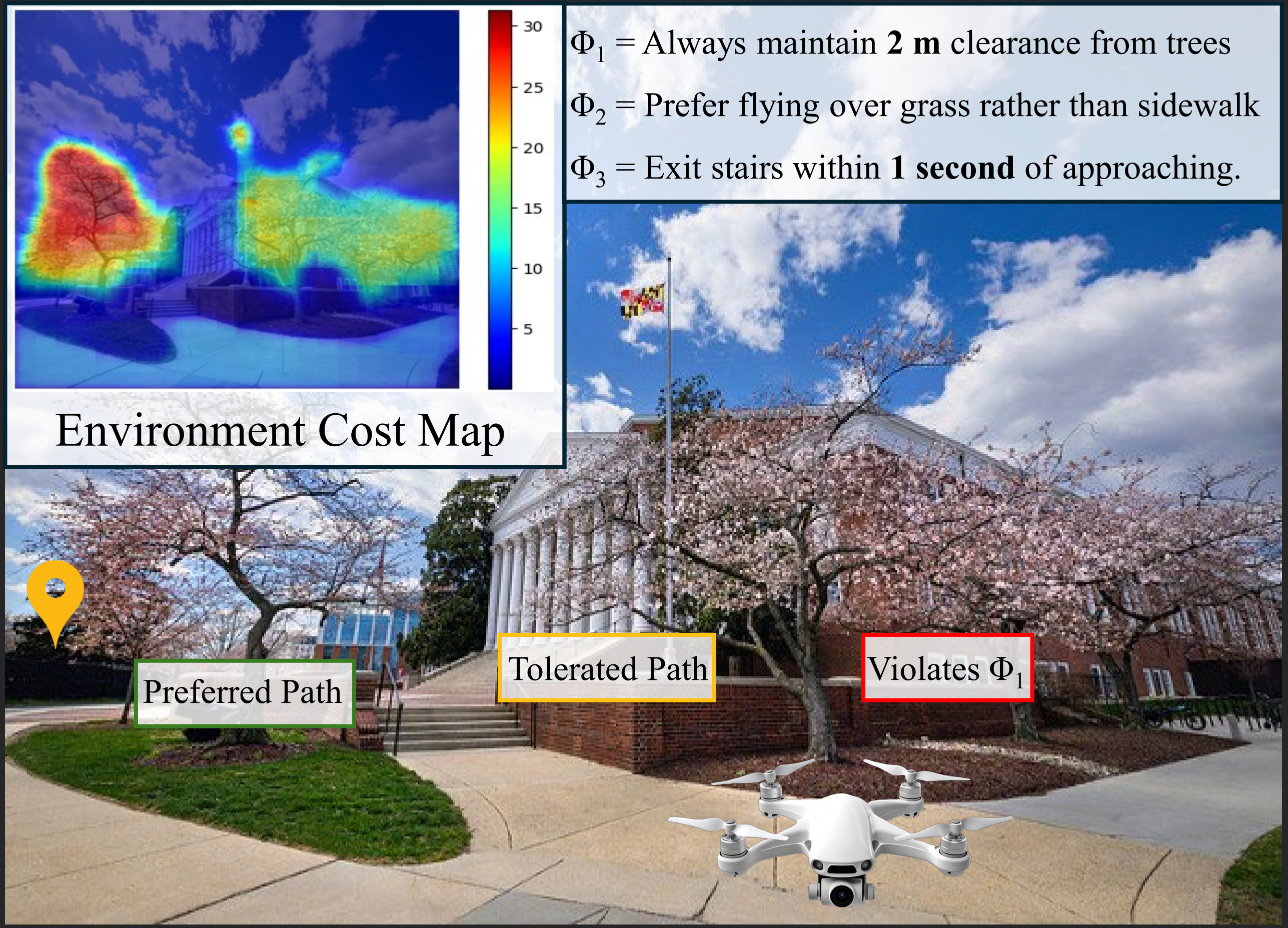

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References in this Talk

Links to references used in this talk.

Slide 2 “Vision + Mobile Robots”: (a) https://arxiv.org/abs/2404.00210 (b) https://arxiv.org/abs/2409.16484
Slide 3 “Vision-Language Models (VLMs)”: https://arxiv.org/abs/2405.17247
Slide 4 “VLMs for Mobile Robot Navigation: (a) https://vlmaps.github.io/ (b) https://jirl-upenn.github.io/VLMnav/
Slide 14 RTAMT https://github.com/nickovic/rtamt

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