

2022 NRI-FRR PI Meeting

# Learning-Aided Integrated Control and Semantic Perception Architecture for Legged Robot Locomotion and Navigation in the Wild #2118818 (FRR)

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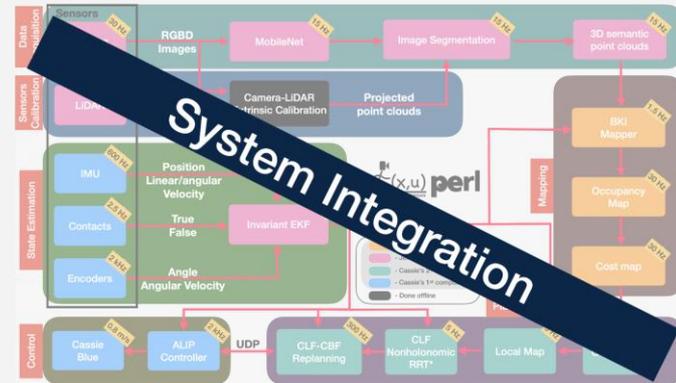
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Robotics Institute

University of Michigan

# Key Features of this Project

- Full-stack autonomy pipeline is addressed instead of pieces in isolation.
- Results are tested on **multiple platforms**: 2 legs, 4 legs, wheels
- Industry partners are in tune with NSF project objectives
- **Industry sees present and future benefits in**
  - Learning-enhanced perception & planning
  - Multi-layer mapping
  - Semantic MPC
  - CLF-RRT\* Reactive Planning

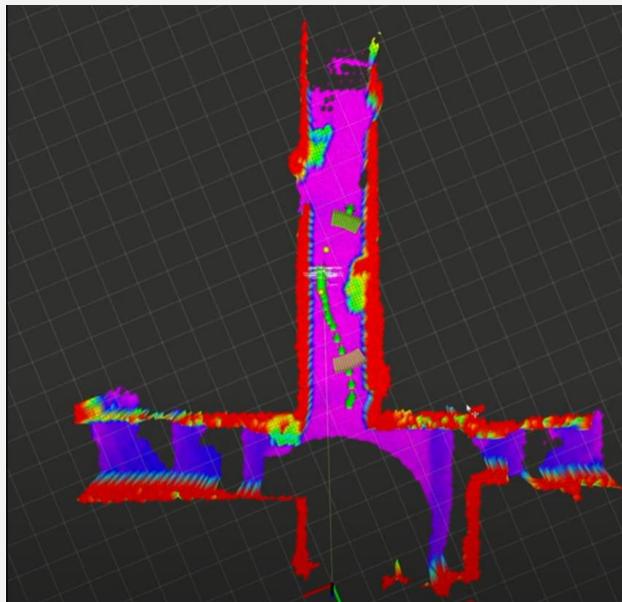


# Killer App: Autonomously Navigate within an Unmapped Forest

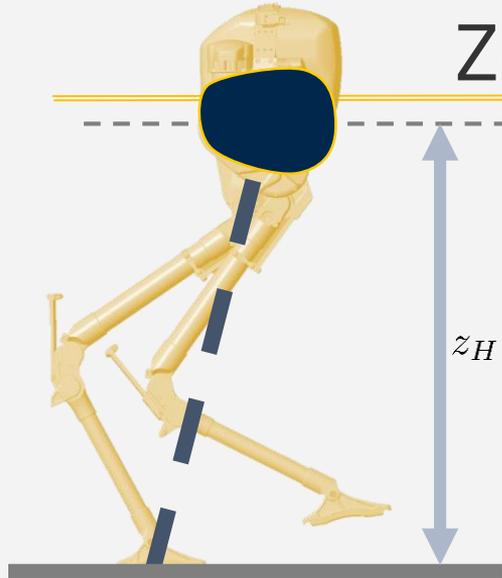
Goal



Can do now: hallways with obstacles and the **UM North Campus Wave Field**

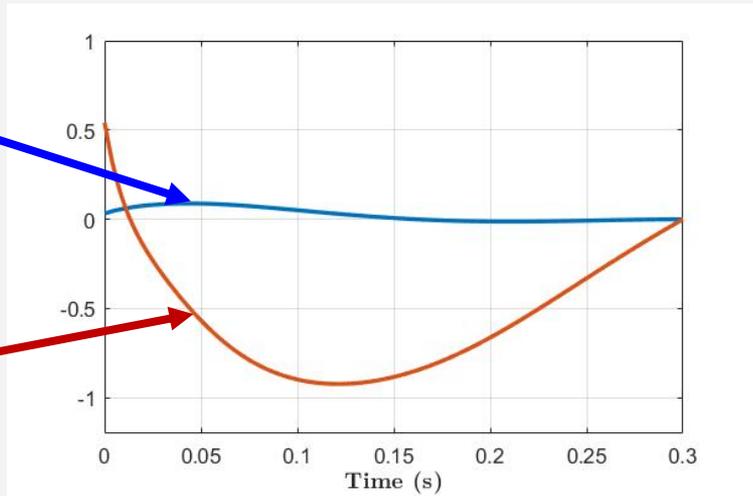


# Zero Dynamics: appropriate theory



Our approx error

Baseline approx error with competing LIP model



True Zero Dynamics

$$\begin{cases} \dot{x} = \frac{L - \kappa_1(x, L, \tau)}{\kappa_2(x, L, \tau)} \\ \dot{L} = \kappa_3(x) \end{cases}$$

Add one constraint to gait

No approx. yet

$$\begin{cases} \dot{x} = \frac{L}{mH} - \frac{L_c}{mH} \\ \dot{L} = mgx \end{cases}$$

Drop one term!

$$\begin{cases} \dot{x} = \frac{L}{mH} \text{ (ALIP)} \\ \dot{L} = mgx \end{cases}$$



CURLY  
Explore the Unknown

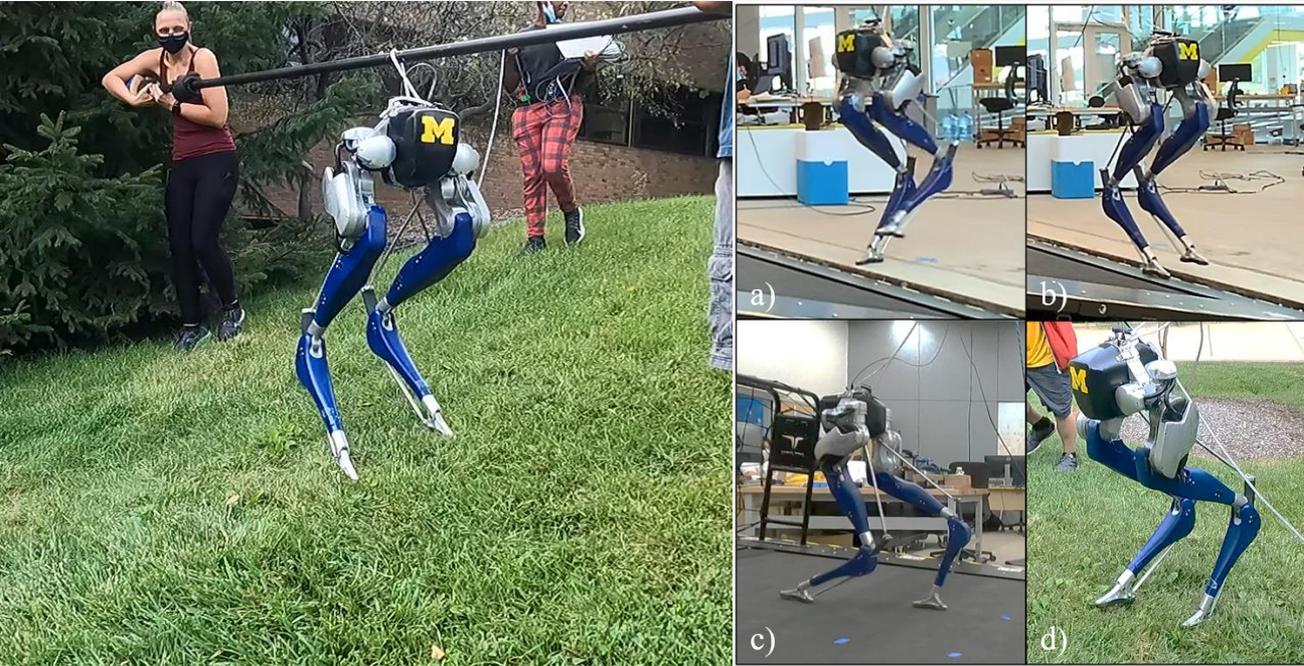


Foundational  
Research in  
Robotics

# MPC has Constraints to Avoid Self Collisions and Respects Friction Cone

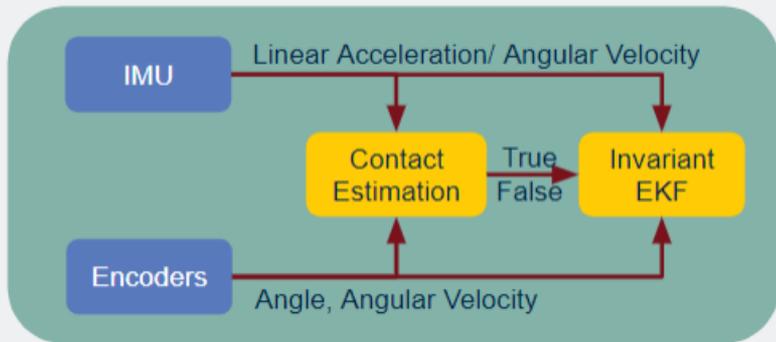


# MPC has Constraints to Avoid Self Collisions and Respects Friction Cone

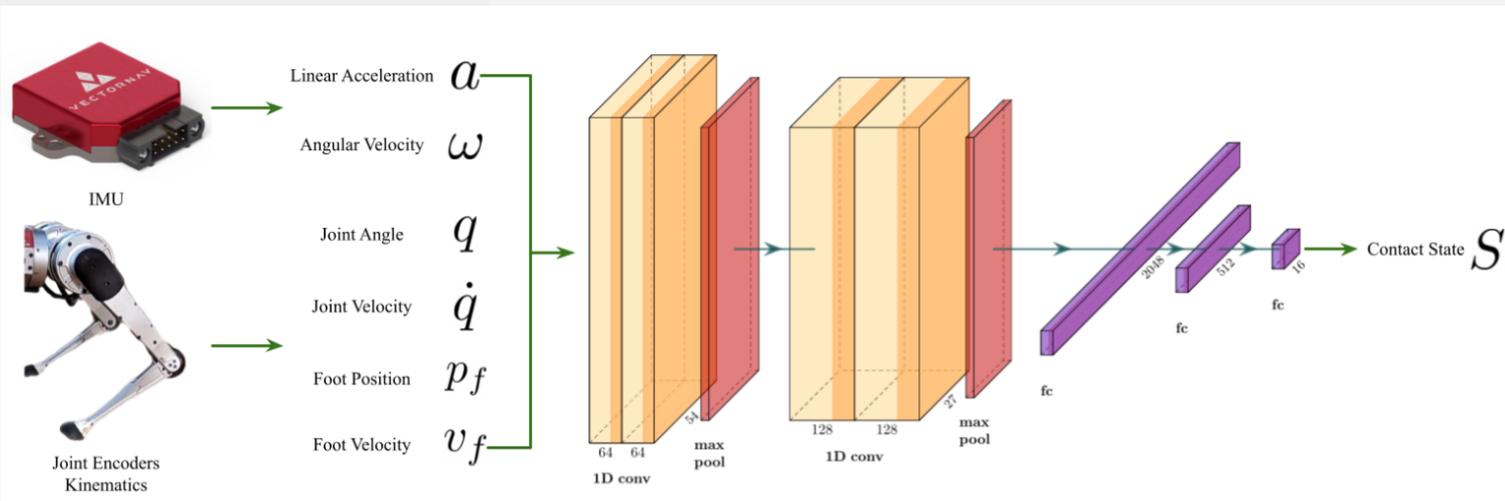


cool videos

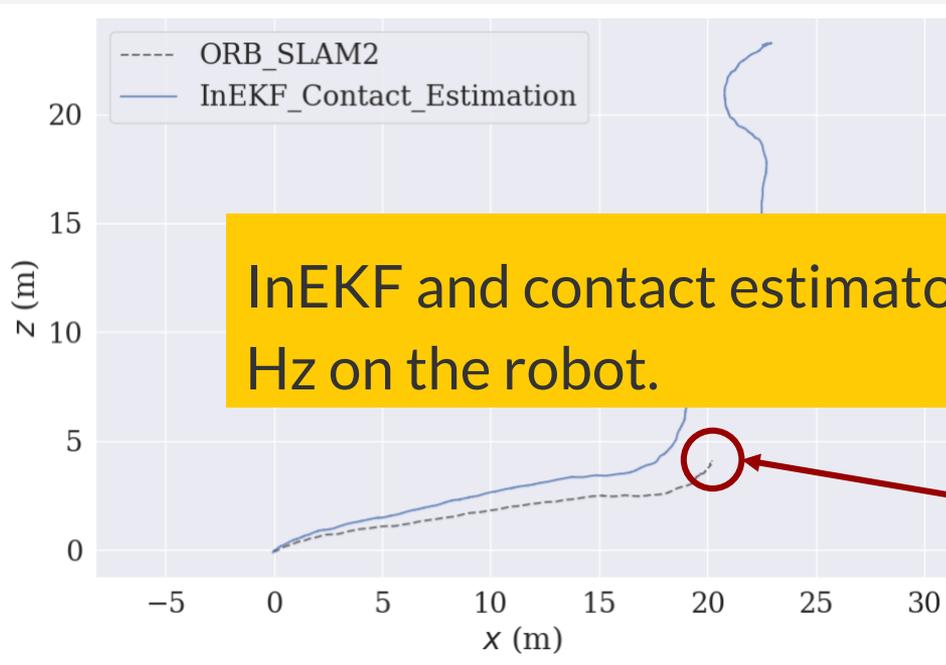
# Learning-Aided Invariant EKF on Mini Cheetah



- Deep Multi-Modal Contact Estimation
- Lightweight convolutional neural network for classification



# Learning-Aided Invariant EKF on Mini Cheetah



InEKF and contact estimator run **real-time** at 500 Hz on the robot.

ORB SLAM2 failed

