Increasing the Level of Autonomy for Agricultural Robots:
Effective Interaction and Programming Paradigms

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We aim to enable agbots to autonomously operate with minimal interventions from human supervisors. These robots will be resilient on the field through improved contextual awareness and runtime monitoring, allowing users to command large fleets. Our work will be evaluated on the Illinois Autonomous Farm (an experimental farm testbed) and we will work closely with farmers and collaborators to remove barriers to adoption.

Improved Abstractions for Programmers

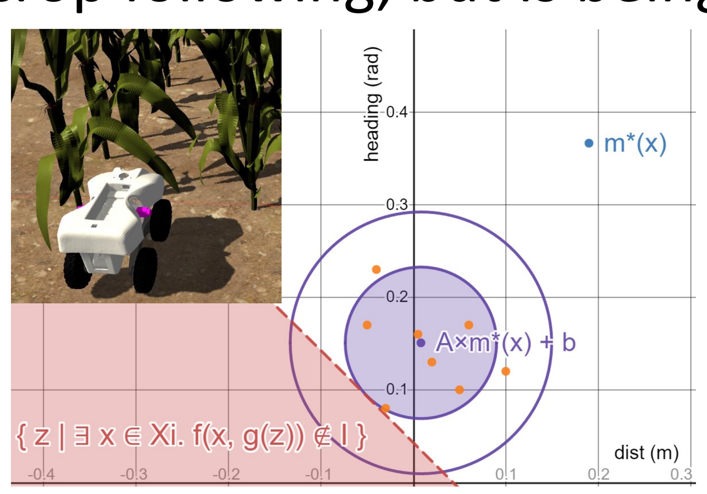
Agbots consist of complicated modules (e.g., perception) that are challenging to verify, especially for non-experts.

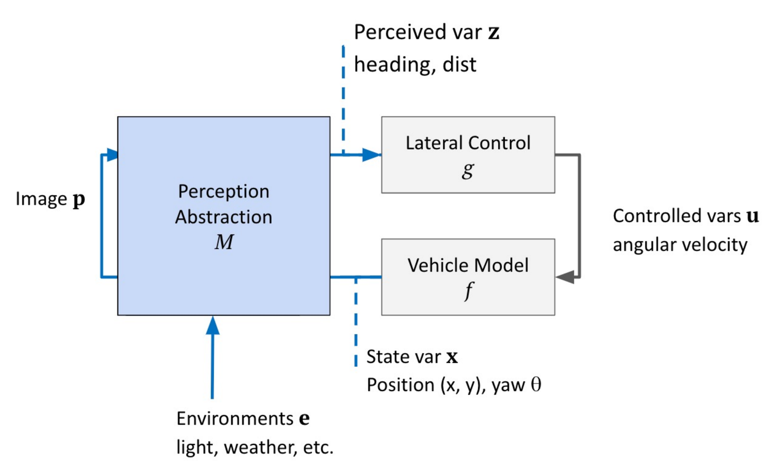
Goal: Find a simple, representative abstraction from sampled perception output in varying environments, $\mathbf{z} = \mathbf{A} \times m^*(\mathbf{x}) + \mathbf{b}$, along with a radius to capture uncertainty

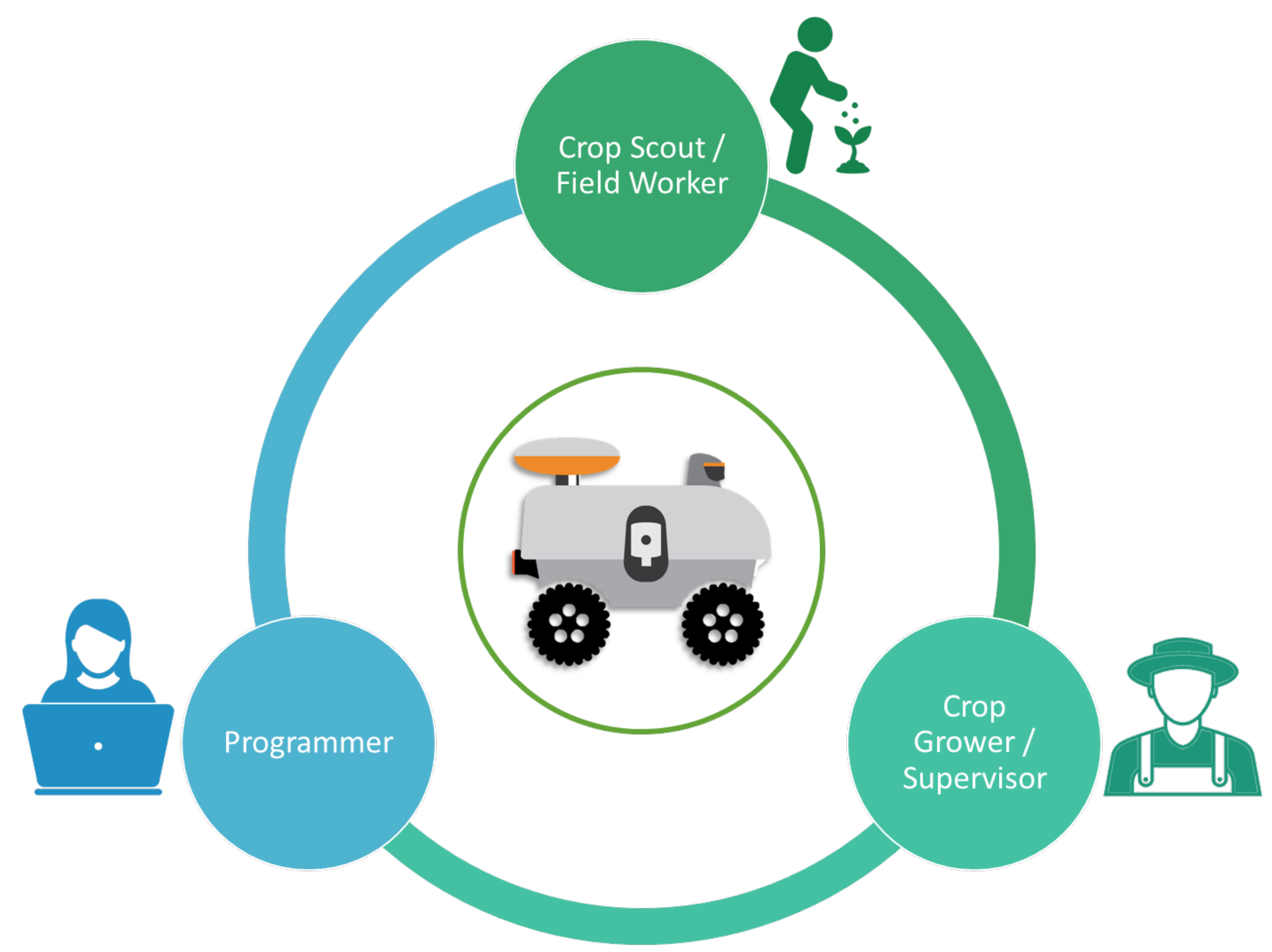
What is a reasonable radius r around the mean value **z?**

- Preserve safety invariant ***I(x)*** when within **r**
- Solve with constrained optimization

Currently this provide offline analysis of perception and control for crop following, but is being extended for online monitoring.





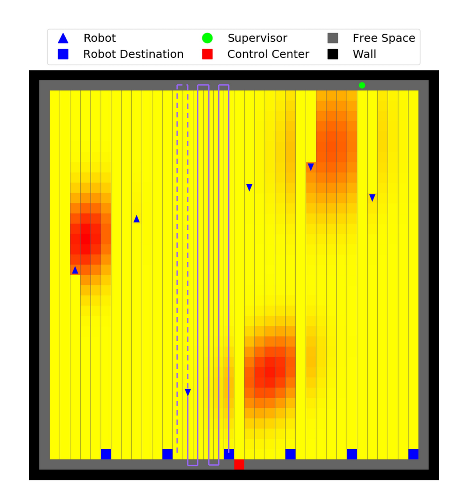


Tools for Fleet Management

When a supervisor is commanding a fleet of agbots, failures in the field are bound to happen. Our goal is to help a supervisor decide which robots to assist.

- First come, first serve? Closest Robot? Robot with least progress?
- **Goal:** Maximize team performance

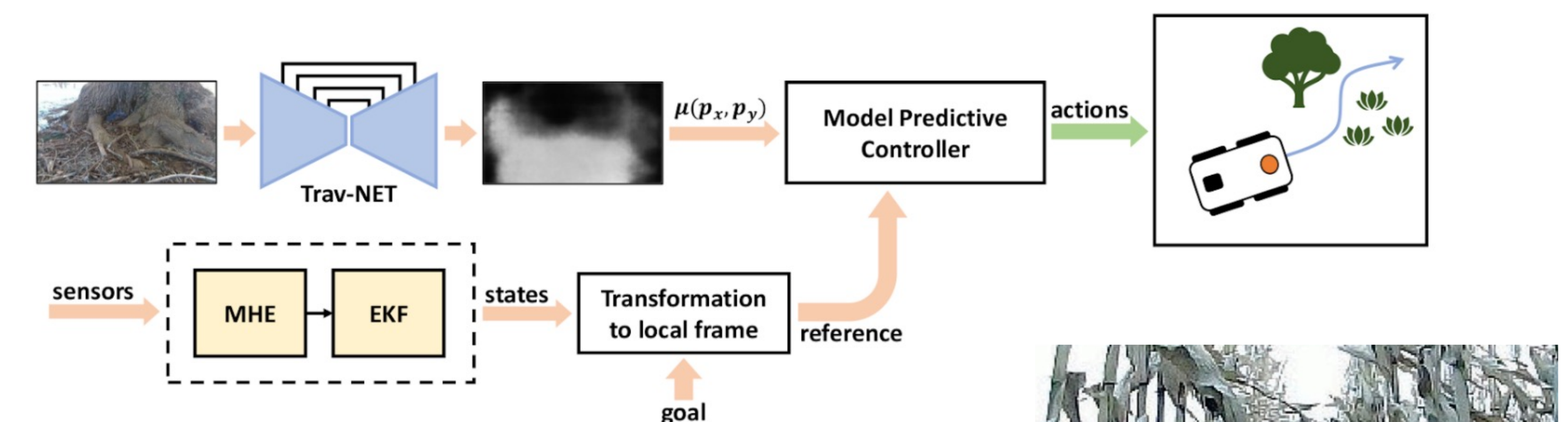
The *traversing supervisor problem (TSP)* for field applications formalizes one-to-many supervision as a dynamic graph. We provide formal with bounds on complexity and optimality for this scheduling problem.



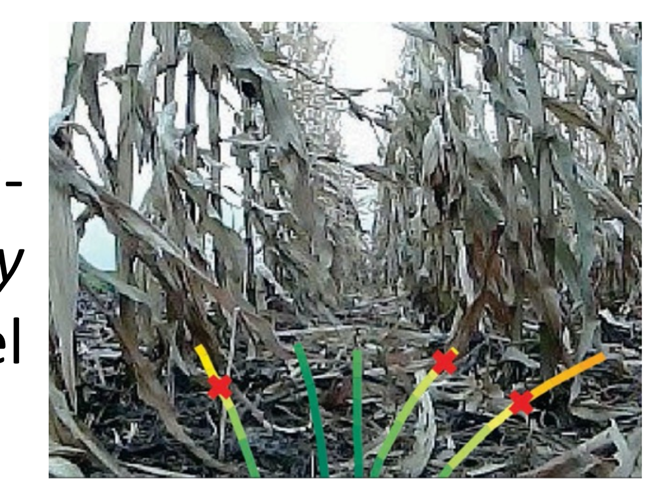
Increased Autonomous Capabilities

To increase the level of autonomy for our agbots, we have improved the navigation stack through improved understanding of the terrain and proactive anomaly detection.

Goal: Defined and modeled *traversability* in terms of a kino-dynamic model. This model can be trained in a self-supervised manner and deployed with MPC to avoid untraversable areas.



Goal: Developed a framework for multi-modal anomaly detection to *proactively* estimate future failures, with novel learning architectures (SVAE).



Broader Impacts

- Our software tools will broadly improve accessibility and deployment of robots
- Insights about users will provide guidelines for modes of interaction in HRI
- The autonomous stack we develop aims to be both robust and generalizable, so it may by used on many different robot systems and settings (e.g., manufacturing)

Potential Impact

- Developing simple, reliable, and usable autonomy will improve agbot adoption by farmers
- Agbots will help alleviate the labor crisis and reduce unsustainable practices
- We are positioned for real-world impact by collaborating with EarthSense Inc, as well as the Illinois Center for Digital Agriculture and our Autonomous Farm testbed

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