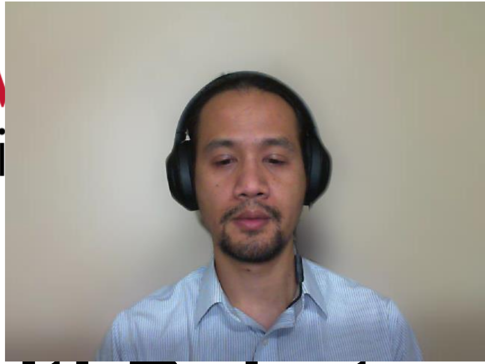


High Throughput Multi-Robot Weed Management for Specialty Crops

PI: Yiannis Ampatzidis, Associate Professor, UF

Co-PIs:

Panos Pardalos, Professor, UF

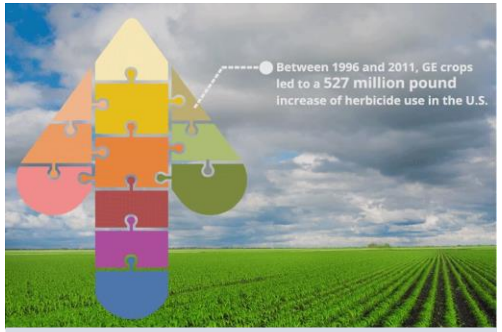
Abhisesh Silwal, Project Scientist, CMU

Award No. 1924925

Need for precision weed management

Conventional sprayers have a lot of limitations but are still used widely throughout the world

Apply agrochemicals uniformly



Consistent increased use of agrochemicals → increased cost

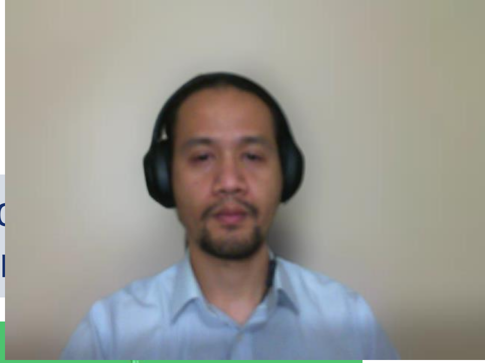
Crop damage risk

Environmental pollution

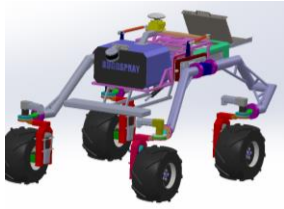
Existing co
weedi

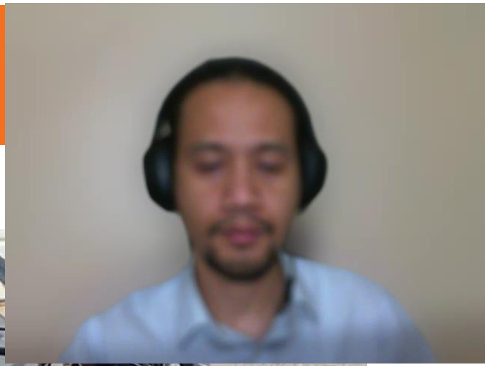
Ecorobotix

Blue River Technologies (John Deere)



Brief introduction to the project





- An autonomous robot for precision weed management is being developed with a low-cost machine vision-based spraying system.
- The machine vision system identifies and detects three types of weeds
- Targeted for vegetable crops like pepper and tomato

Autonomous Robot design

Spraying system

Three types of weeds

Sedge

Broad leaf

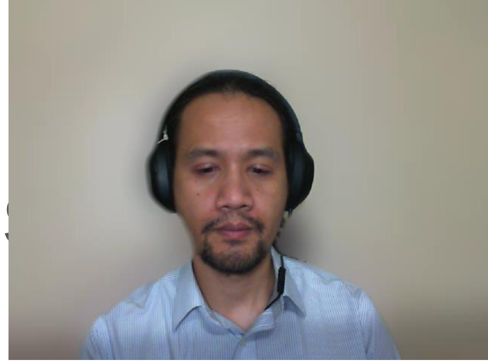
Grass leaf

Target crops

Tomato

Pepper

Overview, Motivation, and Objectives

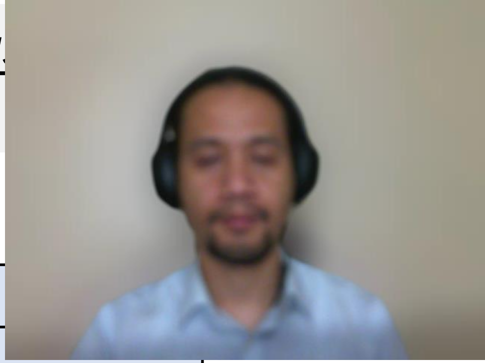


Most conventional sprayers apply agrochemicals uniformly, despite the fact that the distribution of weeds is typically patchy, resulting in increased costs, crop damage risk, pest resistance to chemicals, environmental pollution, and contamination of produce.

Objectives:

- ❖Develop a low-cost, high throughput, and smart technology to simultaneously scout and spray a variety of weeds with different herbicides
- ❖Develop low-cost and multi-crop autonomous robots equipped with the precision spray technology
- ❖Design and develop a high-level task planning and control (fleet optimization)
- ❖Conduct comprehensive economic analyses of the proposed multi-robot system.

*Objective 1: **Develop** a low-cost, high throughput, and smart technology to simultaneou a variety of weeds with different herbicides*

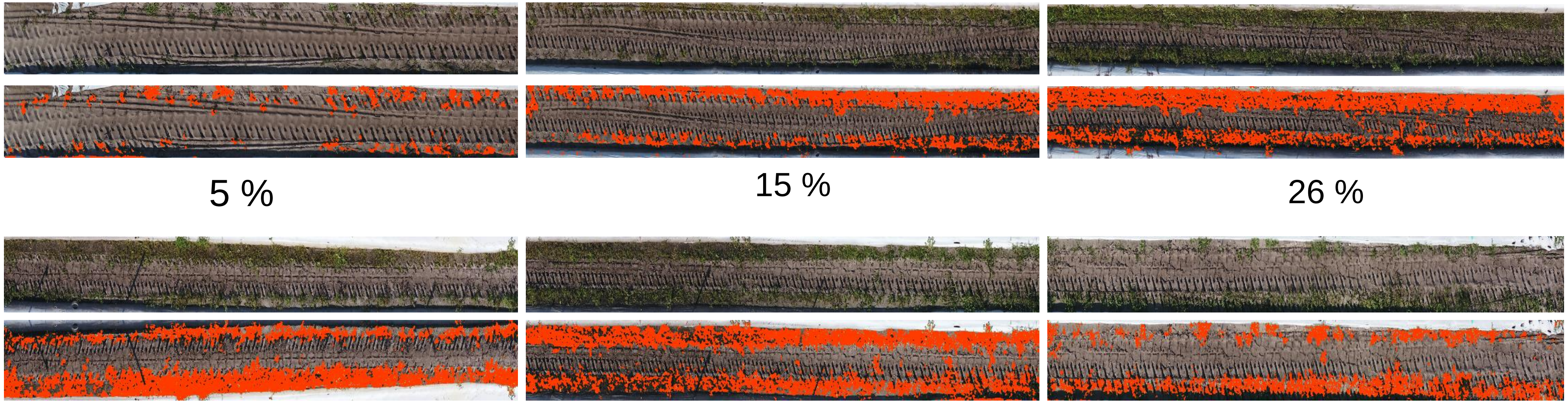


Weed pattern and percentages for a single strip of space between two rows in a block of the vegetable field farm at the SWFREC, Immokalee.

Length of bed ~250 ft

Flight altitude (ft)	Percentage of weed		
	Between blocks (A)	Between blocks (B)	Between rows
35 ft	16 %	23 %	18 %
100 ft	16 %	27 %	14 %

35 ft :: 18 %



Original Images

Weed highlighted Images

5 % 15 % 26 %

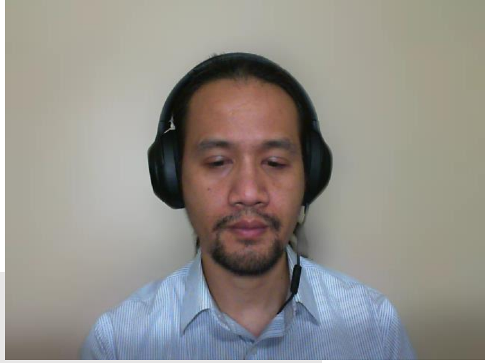
Original Images

Weed highlighted Images

21 % 25 % 13 %

Green weed pixels identified and colored in orange. Percentage refers to the percentage of weeds in that picture

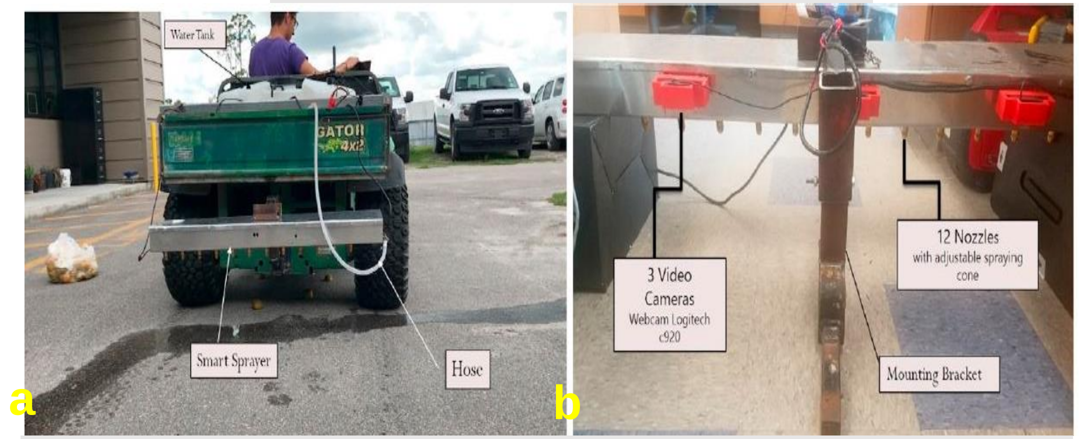
Smart spraying prototypes 1 & 2



- Preliminary prototype consisted of:
- 12 nozzles with an adjustable spraying cone
- Real-time kinematic GPS (RTK-GPS)
- Three webcam Logitech video cameras
- Smart controller (Arduino)
- A computational unit (NVIDIA Jetson TX2 GPU)

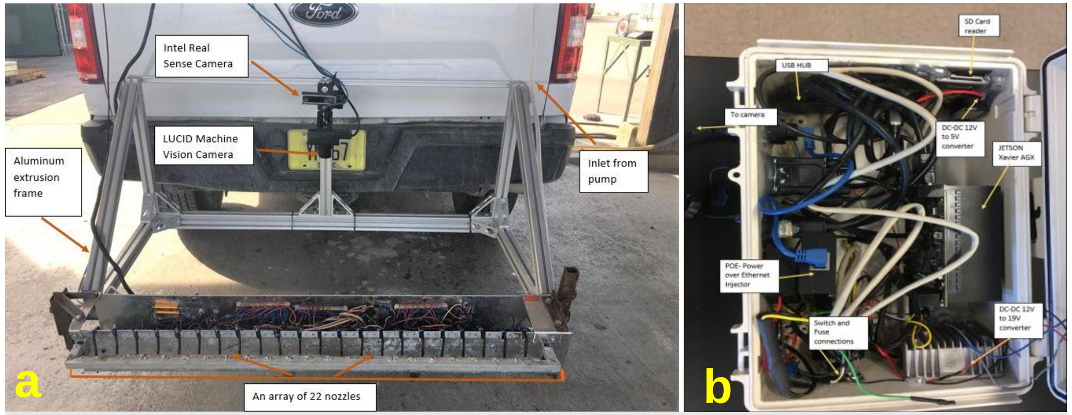
- The current prototype consists of:
- 22 nozzles
- Swift RTK-GPS
- One Lucid RGB camera
- Smart controller (Arduino)
- A computational unit (NVIDIA Jetson Xavier GPU)

Preliminary prototype



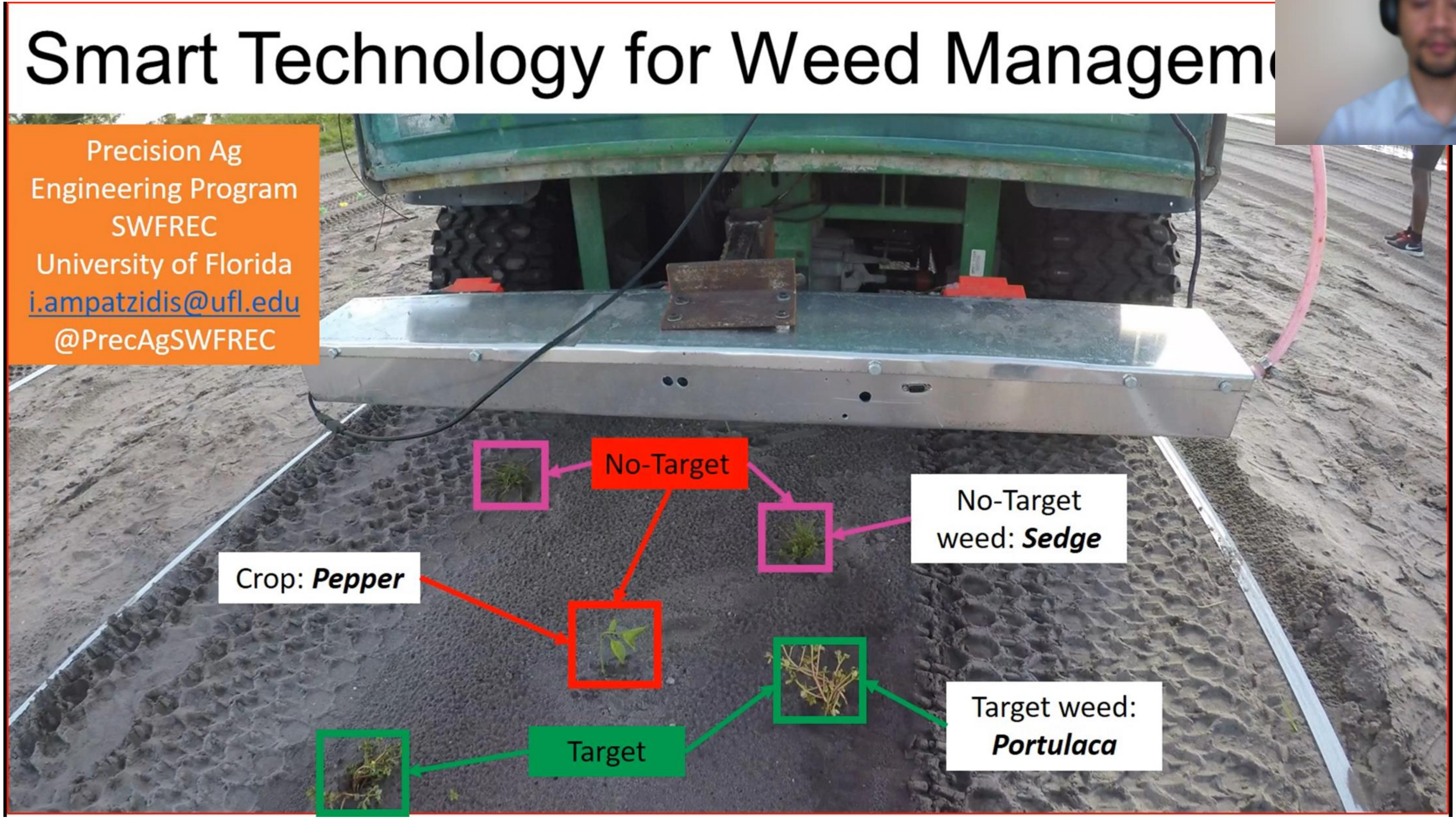
a) Smart sprayer mounted on an ATV; b) Main components of smart sprayer

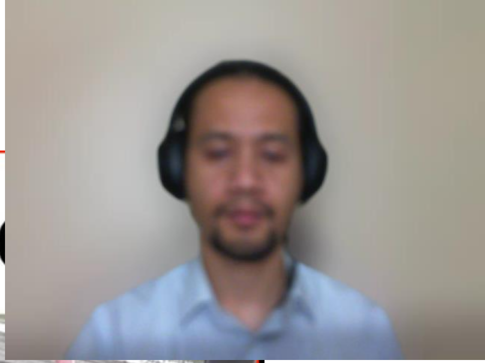
Current prototype



a) Smart sprayer mounted on a truck; b) Main components of control box

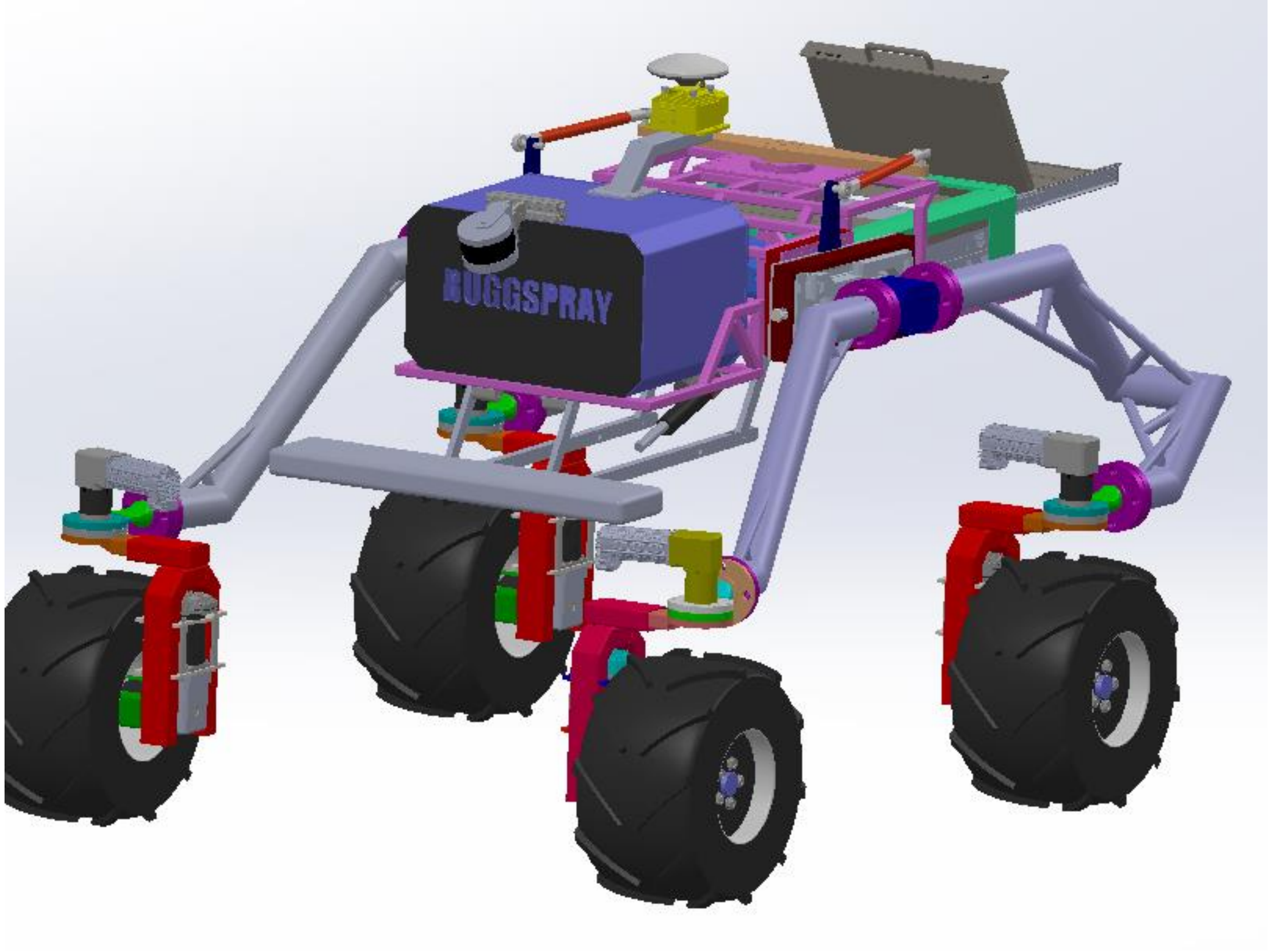
Demo of prototype 1

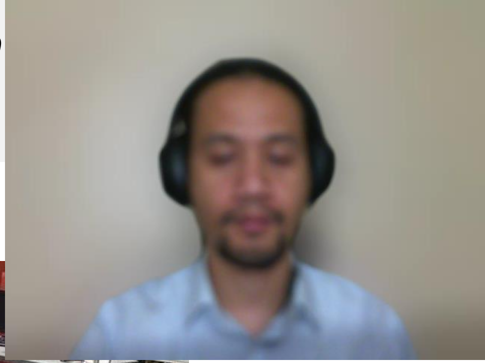




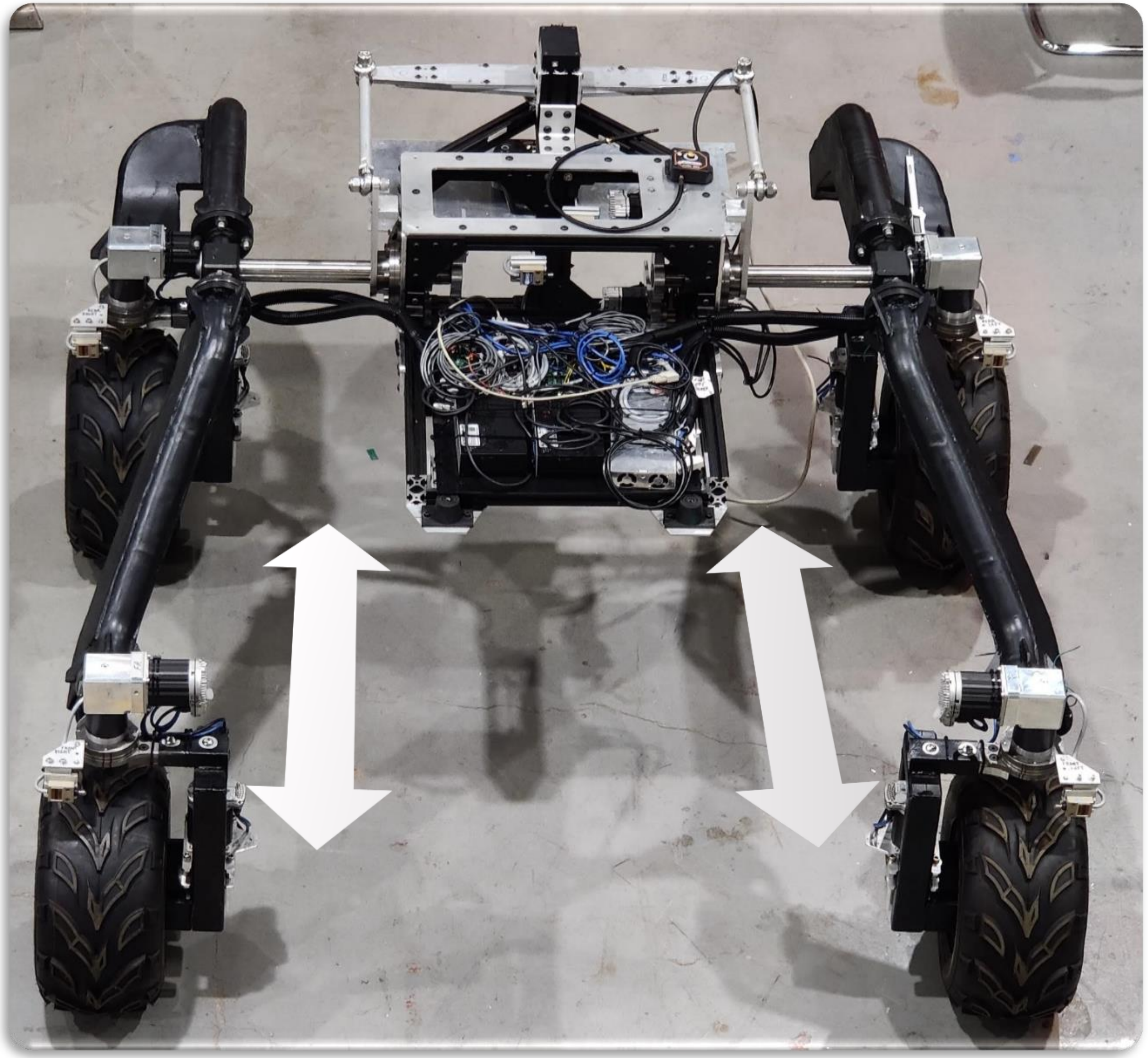
https://twitter.com/i/status/1045013127593644032

Objective 2: Develop low-cost and multi-crop autonomous robots equipped with spray technology

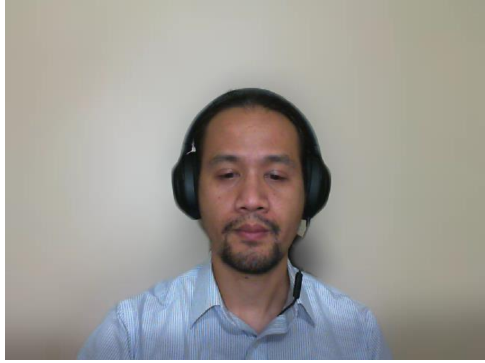




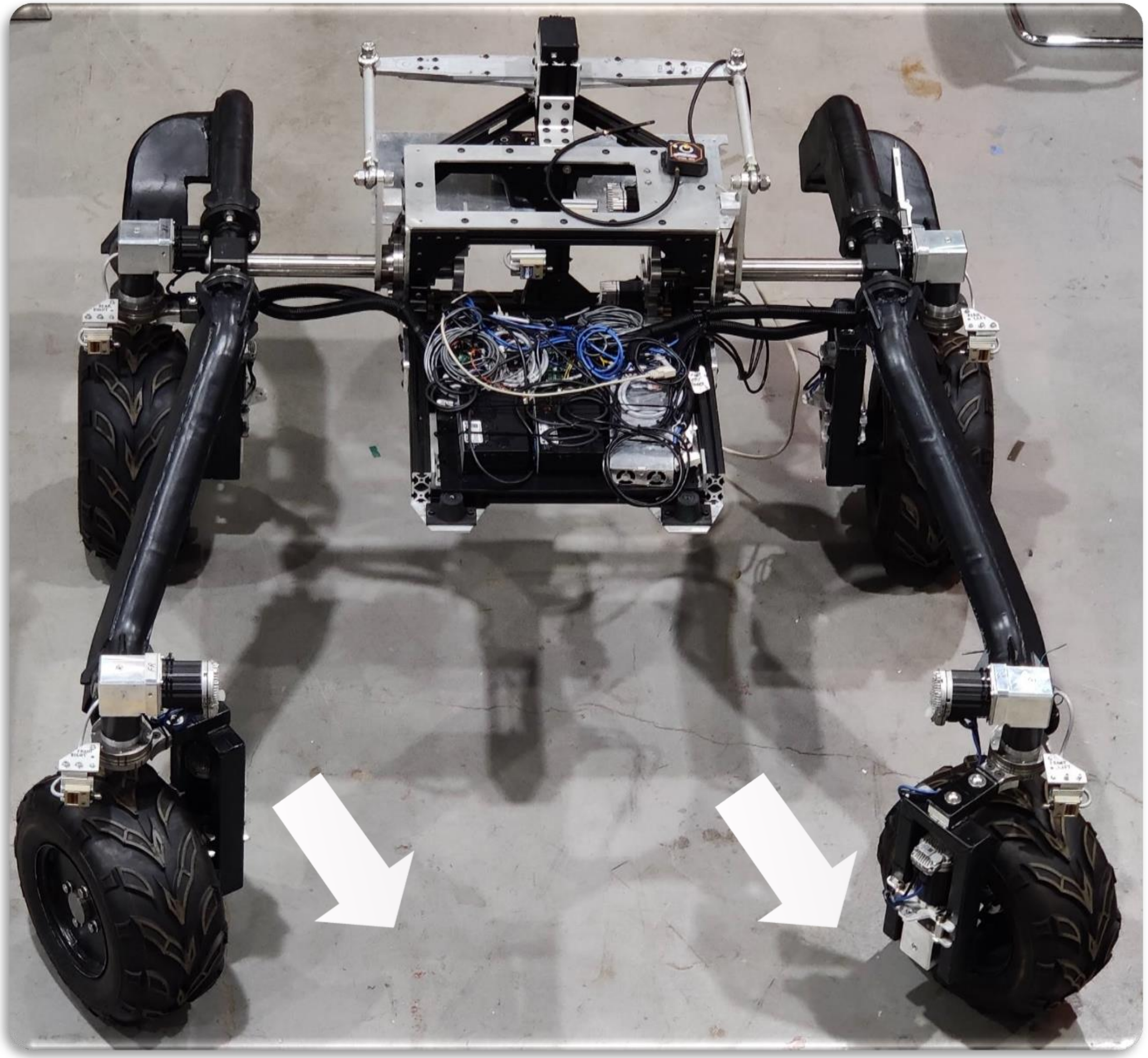
Objective 2 …

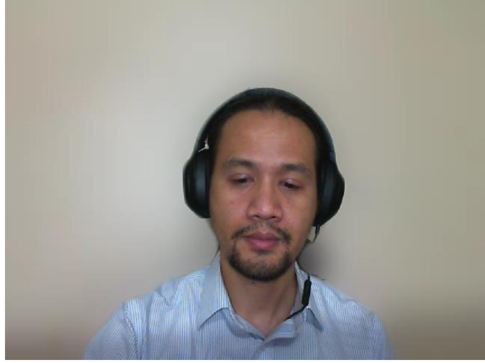


Skid Steering



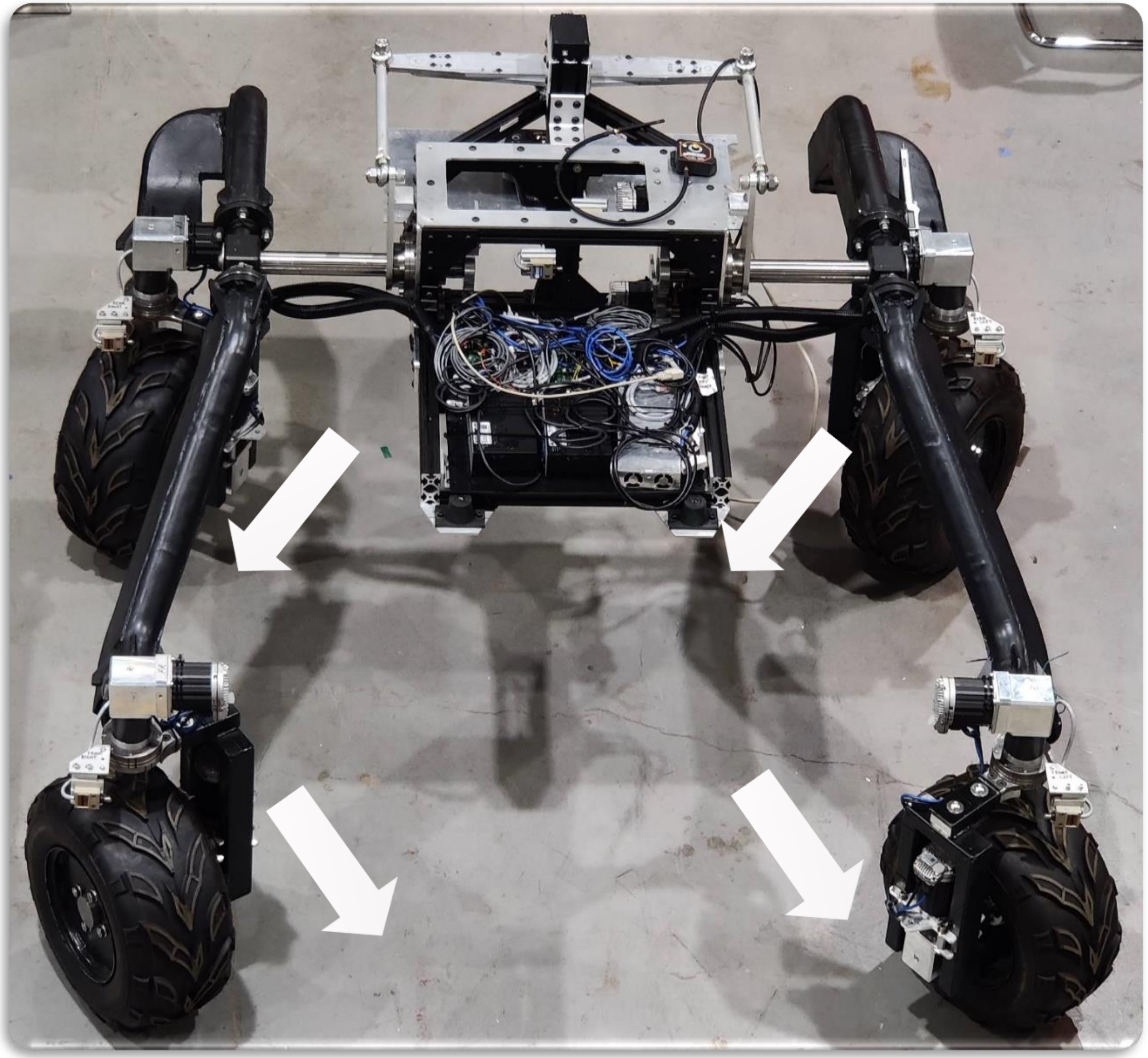
Objective 2 …



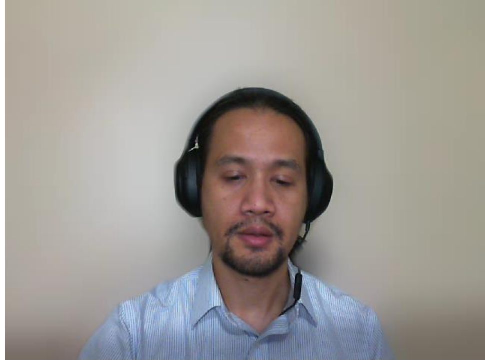


Ackermann Steering

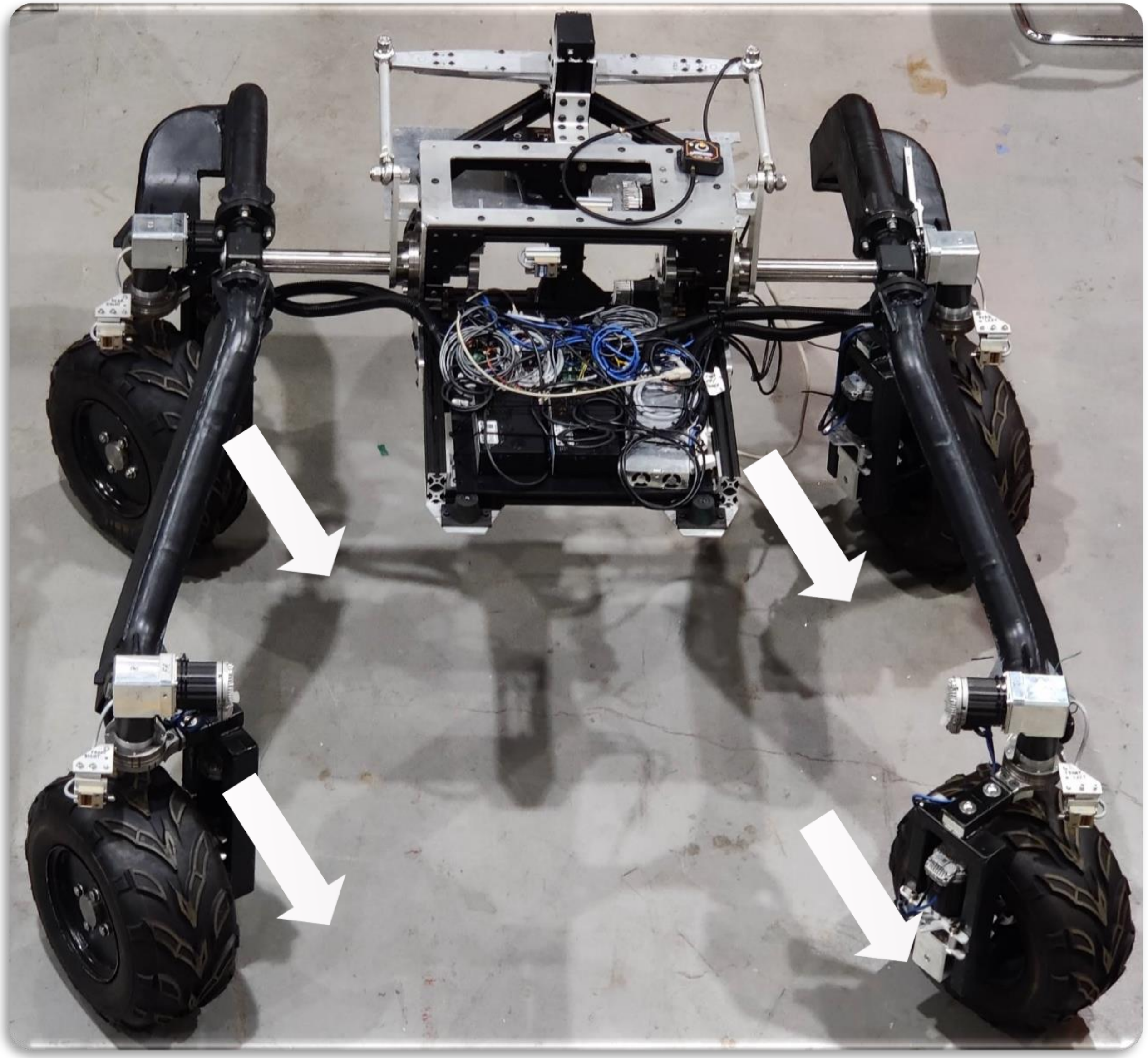
Objective 2 …



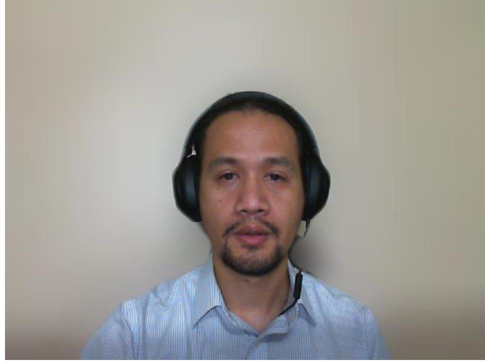
Dual Ackermann Steering



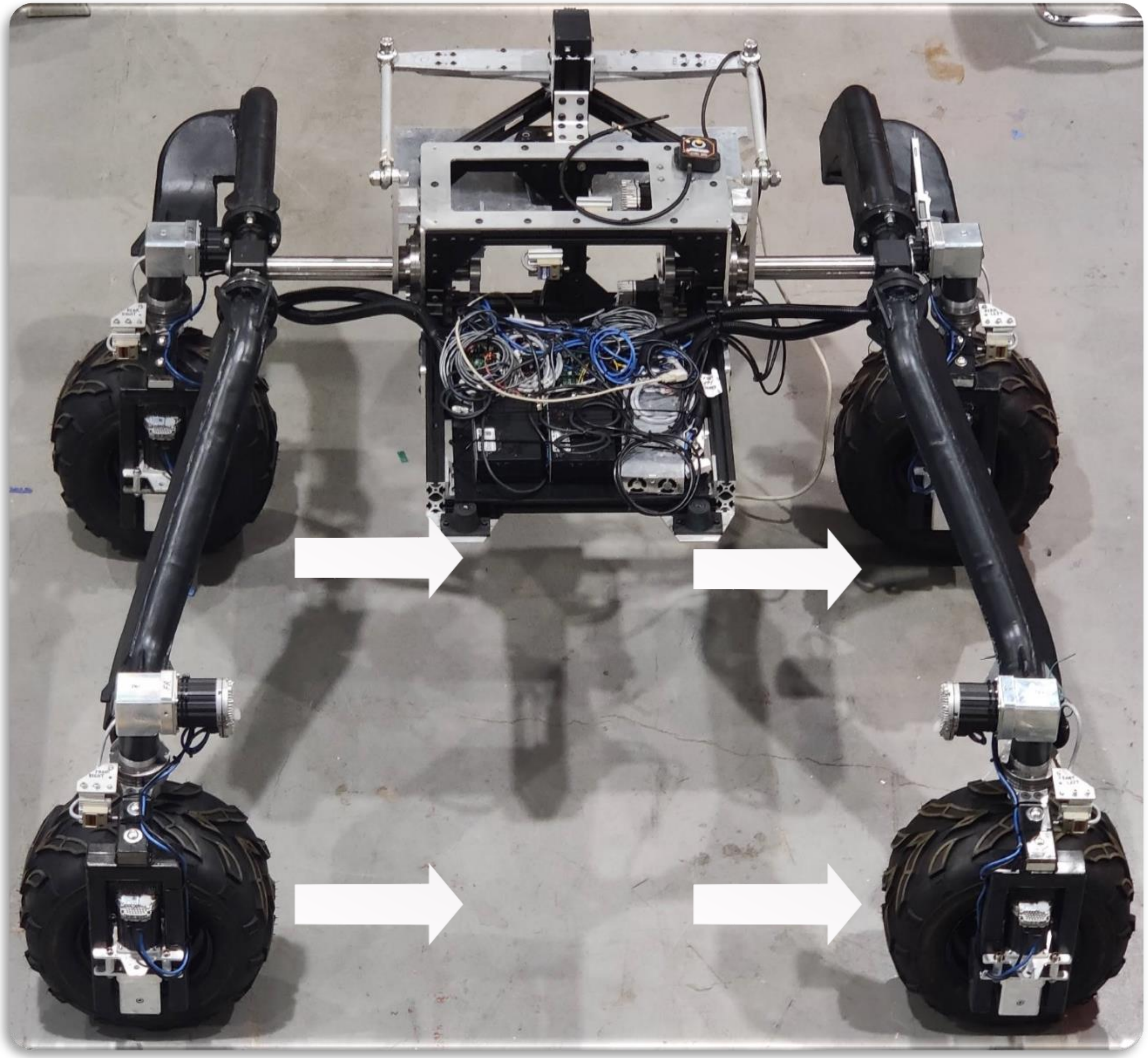
Objective 2 …



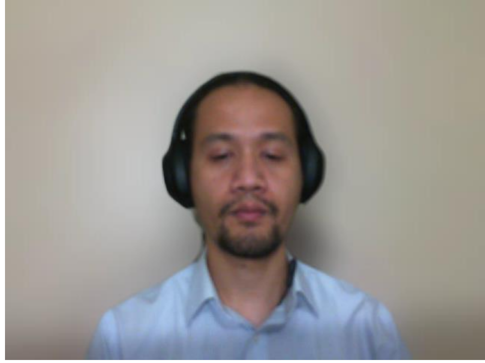
Crab Steering



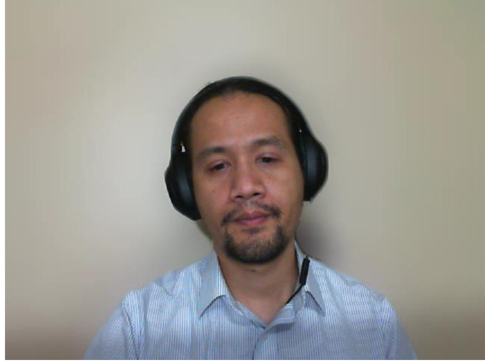
Objective 2 …

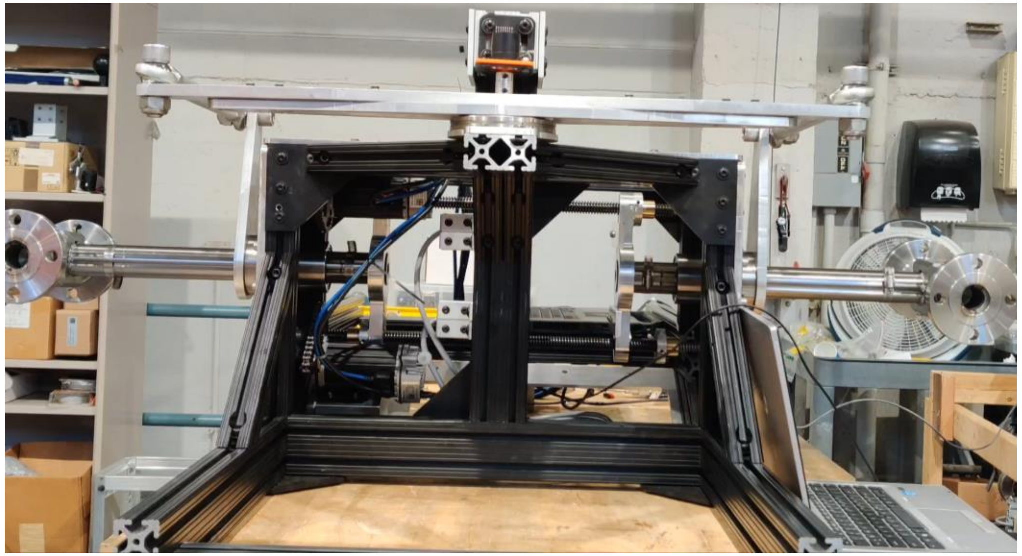


Sideways Steering

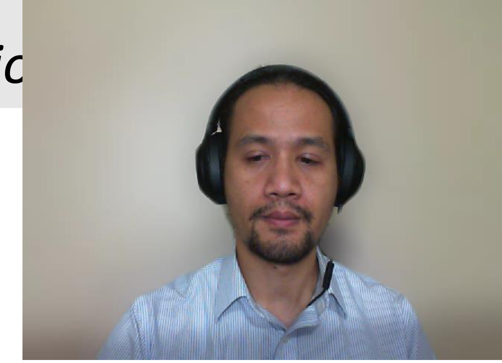


Objective 2 … demo run

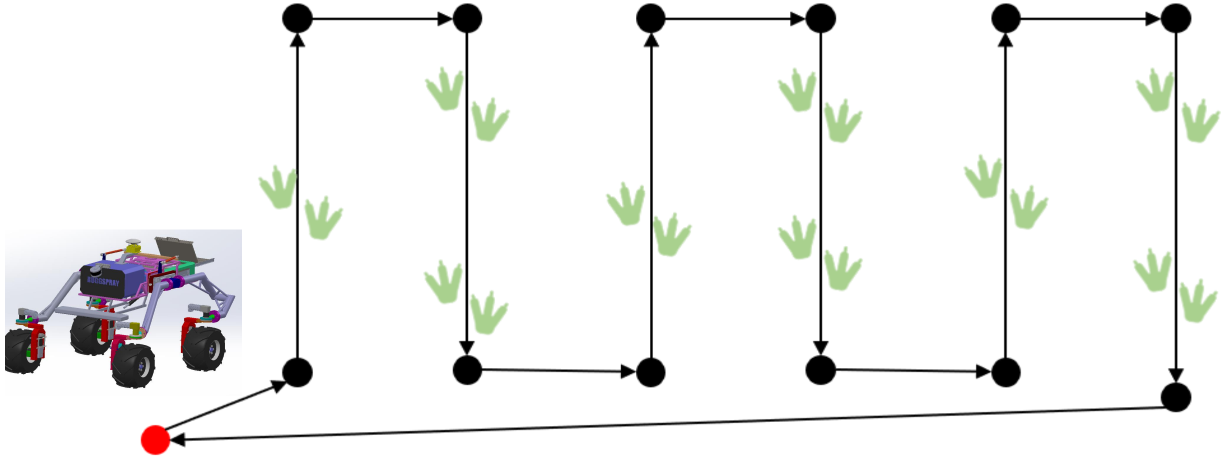




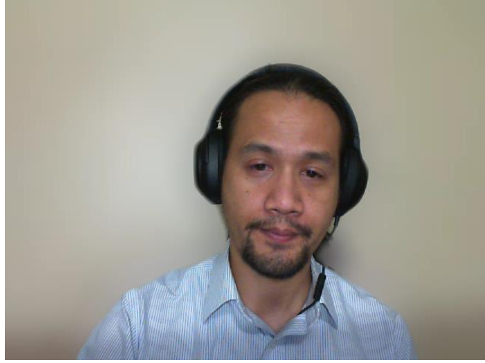
Objective 3: Design and develop a high-level task planning and control (fleet optimizatio



- Preliminary optimization model
  - Multiple types of weeds
  - Multiple vehicles
  - Non-linear
  - Perfect estimation of weed distributions
- Current optimization model
  - Linear
  - Considering the uncertainty of weed distributions



Objective 3: Current optimization model



$$\min_{x} c_{\mathrm{d}} \sum_{(i,j)\in E} d_{ij} \sum_{n\in N} x_{ijn} + c_{\mathrm{t}} t$$

Minimize the total cost

s.t.

$$\sum_{i\in V} x_{ijn} = \sum_{i\in V} x_{jin}, j \in V, n \in N$$

$$\sum_{i\in V\setminus\{j+1\}} x_{ijn} = x_{j,j+1,n}, j = 1, 3, ..., |V| - 2, n \in N$$

$$\sum_{i\in V\setminus\{j-1\}} x_{ijn} = x_{j,j-1,n}, j = 2, 4, ..., |V| - 1, n \in N$$

$$\sum_{i\in V\setminus\{j\}} \sum_{n\in N} z_{ijhn} \geq q_{jh}, \forall q_{jh} \in D_j, i, j \in V\setminus\{0\}, i \neq j, h \in H, n \in N$$

Considering all possible weed distributions

$$D_j = \{(q_{j1}, q_{j2}, ..., q_{j|H|}) | q_j \geq 0, \sum_h q_{jh} \leq Q_j\}$$

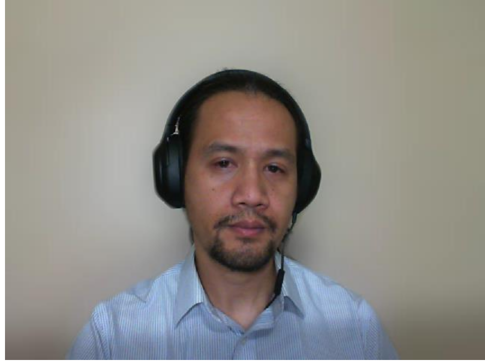
The weed distribution is partially resolved by UAVs, i.e., know the total amount of weeds

$$-Zx_{ijn} \leq z_{ijhn} \leq Zx_{ijn}, i, j \in V, h \in H, n \in N$$

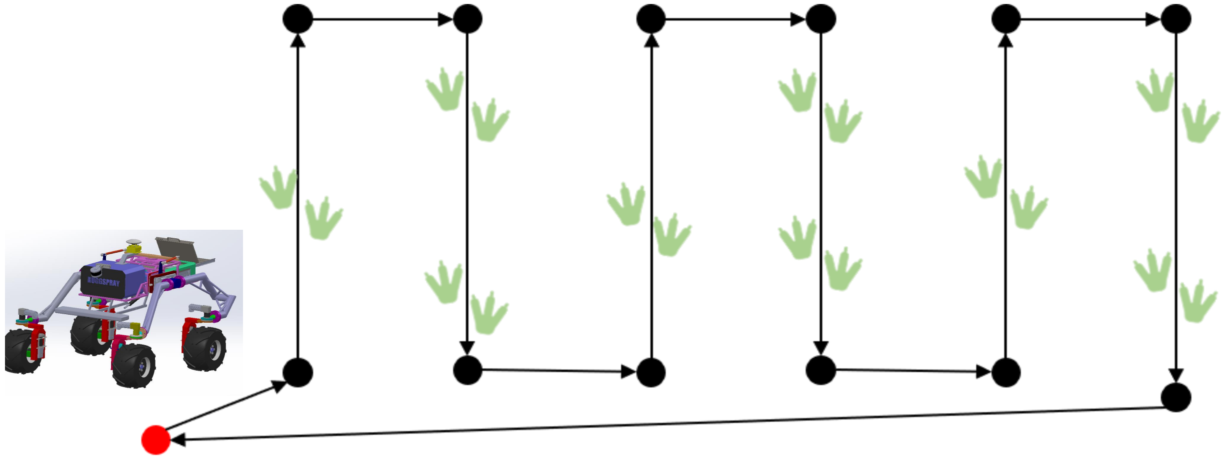
$$(u'_{jhn} - u'_{ihn}) - Z(1 - x_{ijn}) \leq z_{ijhn} \leq (u'_{jhn} - u'_{ihn}) + Z(1 - x_{ijn}), i, j \in V, h \in H, n \in N$$

$$\frac{\sum_{(i,j)\in E} d_{ij} x_{ijn}}{v_n} + t_{\mathrm{r}} \sum_{i\in V} x_{i0n} \leq t, n \in N$$

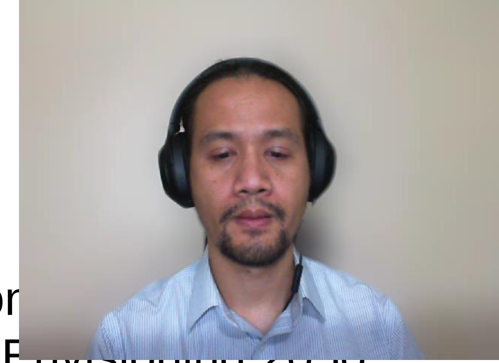
Objective 3: Next



- Explore efficient approaches to solve the model
- Utilize more technologies to resolve the weed distribution uncertainty
- Online optimization, where decisions are updated continuously based on most recent information



Publications



1. Vijayakumar V., Ampatzidis Y., Silwal A., Kantor G., 2022. Machine vision and AI precision management using an integrated autonomous robotic smart sprayer for specialty crops. Envisioning 2050 in the Southeast: AI-driven innovations in agriculture. Auburn, AL, March 9-11 (poster).

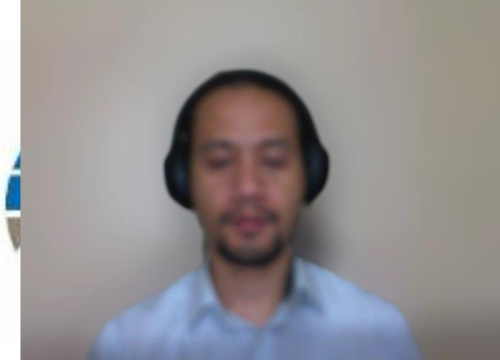
2. Vijayakumar V., Partel V., Ampatzidis Y., Silwal A., Kantor G., 2021. Autonomous smart sprayer for precision weed management using machine vision and AI. 2021 Virtual ASABE Annual International Meeting, July 11-14, 2021.

3. Adosoglou G., Park S., Ampatzidis Y., Pardalos P., 2021. A high-level task planning of autonomous robots with multi-dimensional loading constraints for precision weed management under field variability. 2021 Virtual ASABE Annual International Meeting, July 11-14, 2021, ASABE Paper No. 2100426, doi: 10.13031/aim.202100426.

4. Partel V., Kim J., Costa L., Pardalos P. and Ampatzidis Y., 2020. Smart Sprayer for Precision Weed Control Using Artificial Intelligence: Comparison of Deep Learning Frameworks. Proceeding at the International Symposium on Artificial Intelligence and Mathematics (ISAIM). Fort Lauderdale, FL. January 6–8, 2020.

USDA

NSF



Thank you very much

Question?

See you in the Q&A session

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Carnegie Mellon University
The Robotics Institute