LARGE-SCALE MONITORING, EXPERT INPUT, AND THE ECOLOGICAL IMPACT OF AUTONOMY IN AGRICULTURE

Coordination at Scale Lab, Virginia Tech

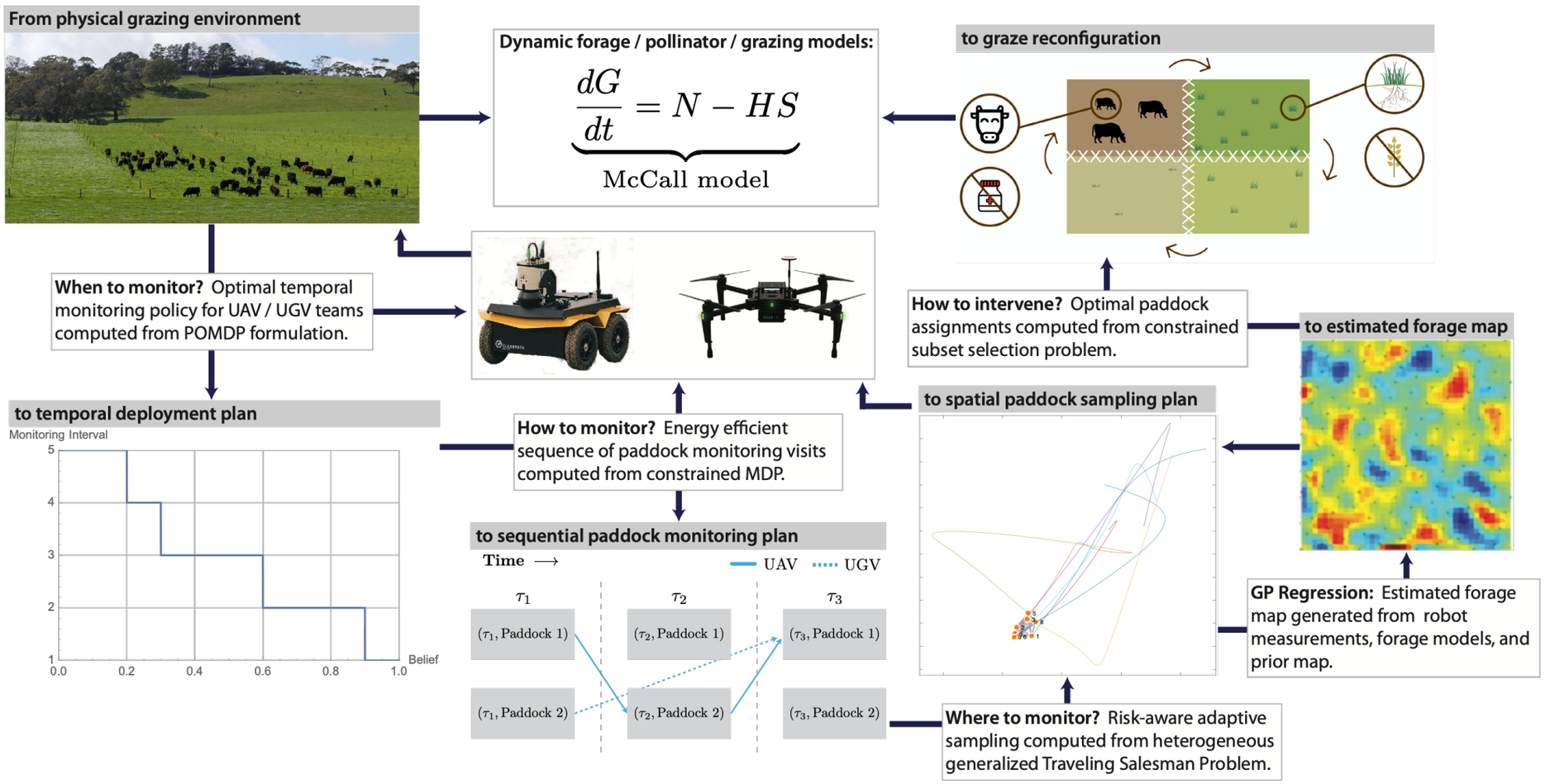
Ryan K. Williams

- CAS Lab started in Fall 2016 at Virginia Tech.
  - https://caslab.ece.vt.edu/
- Autonomy in large-scale systems.
- Study relationships between agent-to-agent interaction and scalable coordination.
- Theory + in-field validation and practical applications.

CAS•LAB
Coordination At Scale

[UAV Coordination, CAS Lab]

- CPS: Medium: Multi-Scale Planning in Robot Teams for Persistent Monitoring and Intervention in Precision Grazing
- Pasturelands are integral to agricultural production in the United States.
  - Cover approximately 48 million ha providing forage that supports over 54 million head of livestock.

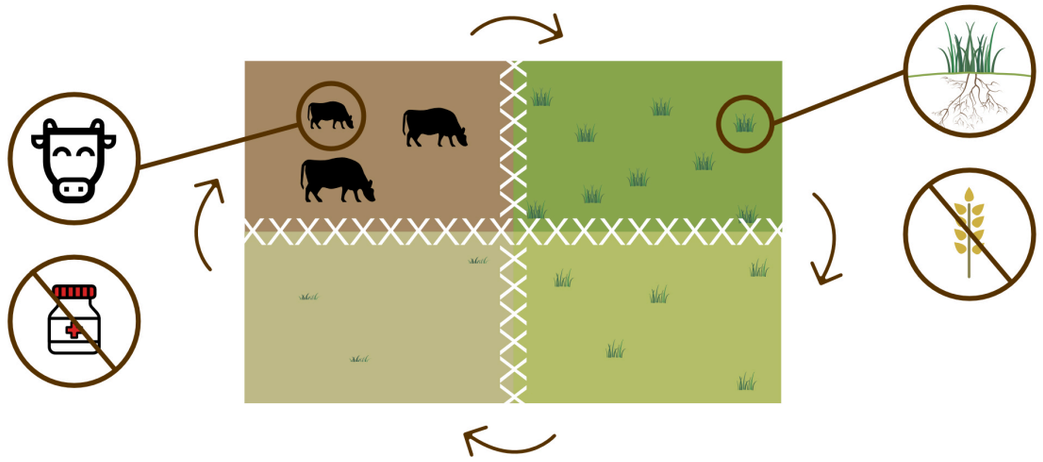


[Autonomy in Precision Grazing]

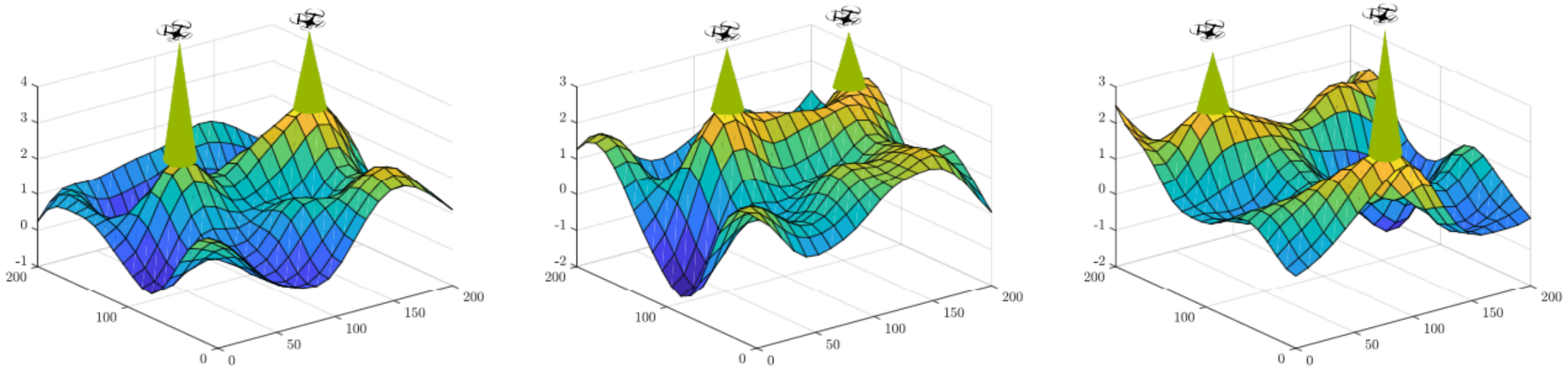
What are our current problems and results?

Large-scale monitoring with forage perception.

- How do we choose when to deploy a multi-robot team?
  - Necessitated by large-scale, slowly-evolving process of interest (forage).
- What is the influence of our grassland management decisions on future monitoring?
- We have proposed a coupled combinatorial optimization approach.



[Grassland management]



(a) At time $t = 0$, $a_0 = 1$.

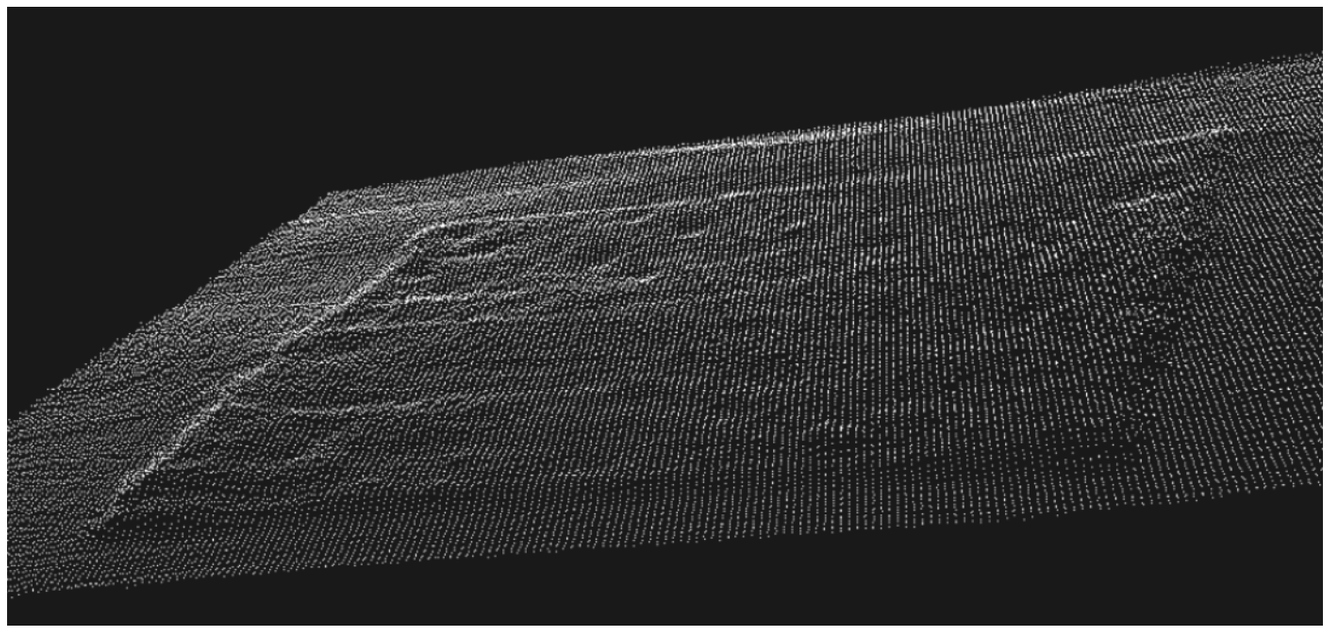
(b) At time $t = 1$, $a_1 = 4$.

(c) At time $t = 5$.

[Intermittent deployment problem]

How to observe processes on large scales?

- Deploy robotic teams to measure forage quality (Co-PI Pratap Tokekar).



[Forage perception]

	Growth from Week 1 - 2	Growth from Week 2 - 3	Growth from Week 3 - 4
50th Percentile (%)	100.04	119.76	-65.11
75th Percentile (%)	70.12	84.80	-28.37
90th Percentile (%)	40.72	38.35	-19.72
95th Percentile (%)	20.32	37.95	-32.62
97.5th Percentile (%)	7.04	29.79	-20.13
99th Percentile (%)	**3.10**	**12.99**	**-7.65**
99.5th Percentile (%)	11.10	16.18	-3.97

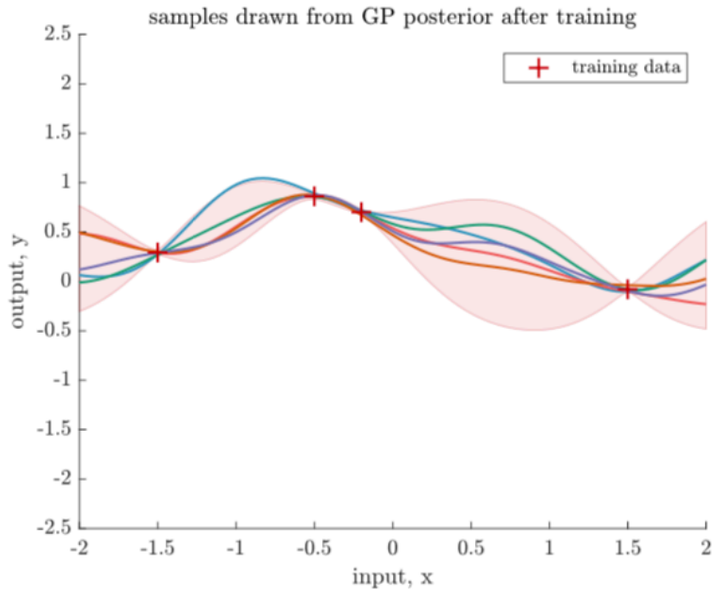
[Forage estimation]

What are future directions?

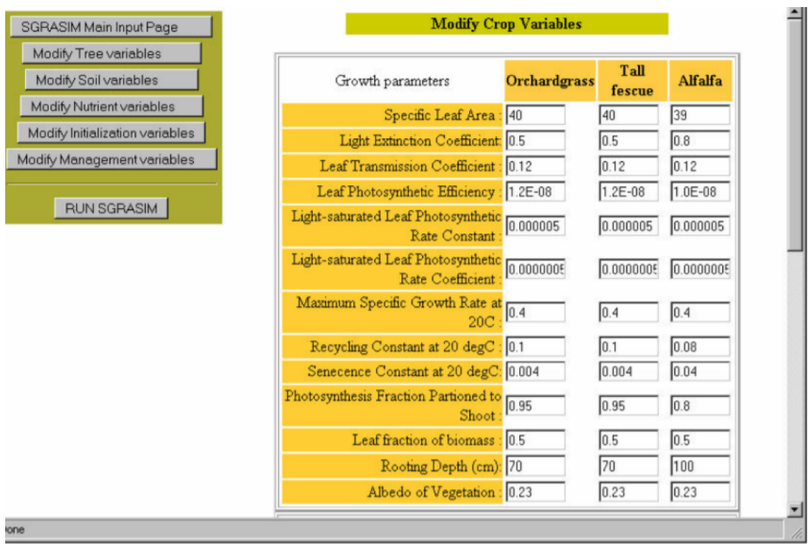
Input from ‘expert’ models and evaluating the ecological impact of our autonomy.

How to reconcile expert models with autonomy?

- Robotic perception is high resolution on large spatial scale.
- Models for forage systems predict temporal behavior with complex inputs:
  - GRASIM
  - SPUR
  - DAFOSYM
  - ALMANAC
  - PHYGROW
- How to exploit the ‘big data’ generated by robots while complementing expert models?
  - For our problem, we believe the solution is a spatial and temporal decoupling.



[Gaussian process]



[GRASIM]

Think more broadly about what we optimize.

- Ecological intensification of agricultural systems is one of the great challenges of the 21st century.
- With a population projected to exceed 9 billion by the middle of this century, business as usual in food production will continue to be a leading cause of biodiversity loss and global pollution.
- These needs are well-known, but the influence of autonomy is unclear.
- For our project, we propose to develop models and algorithms to support ecologically intensified grazing systems that optimize cattle productivity and pollinator conservation.
  - Led by Co-PIs Megan O'Rourke and Ben Tracy.

CAS•LAB
Coordination At Scale

VIRGINIA TECH™

THANK YOU FOR YOUR TIME.

QUESTIONS?

Coordination at Scale Lab, Virginia Tech
Ryan K. Williams

https://caslab.ece.vt.edu/