SoftwarePilot: An Open Source Middleware for Fully Autonomous Aerial Systems

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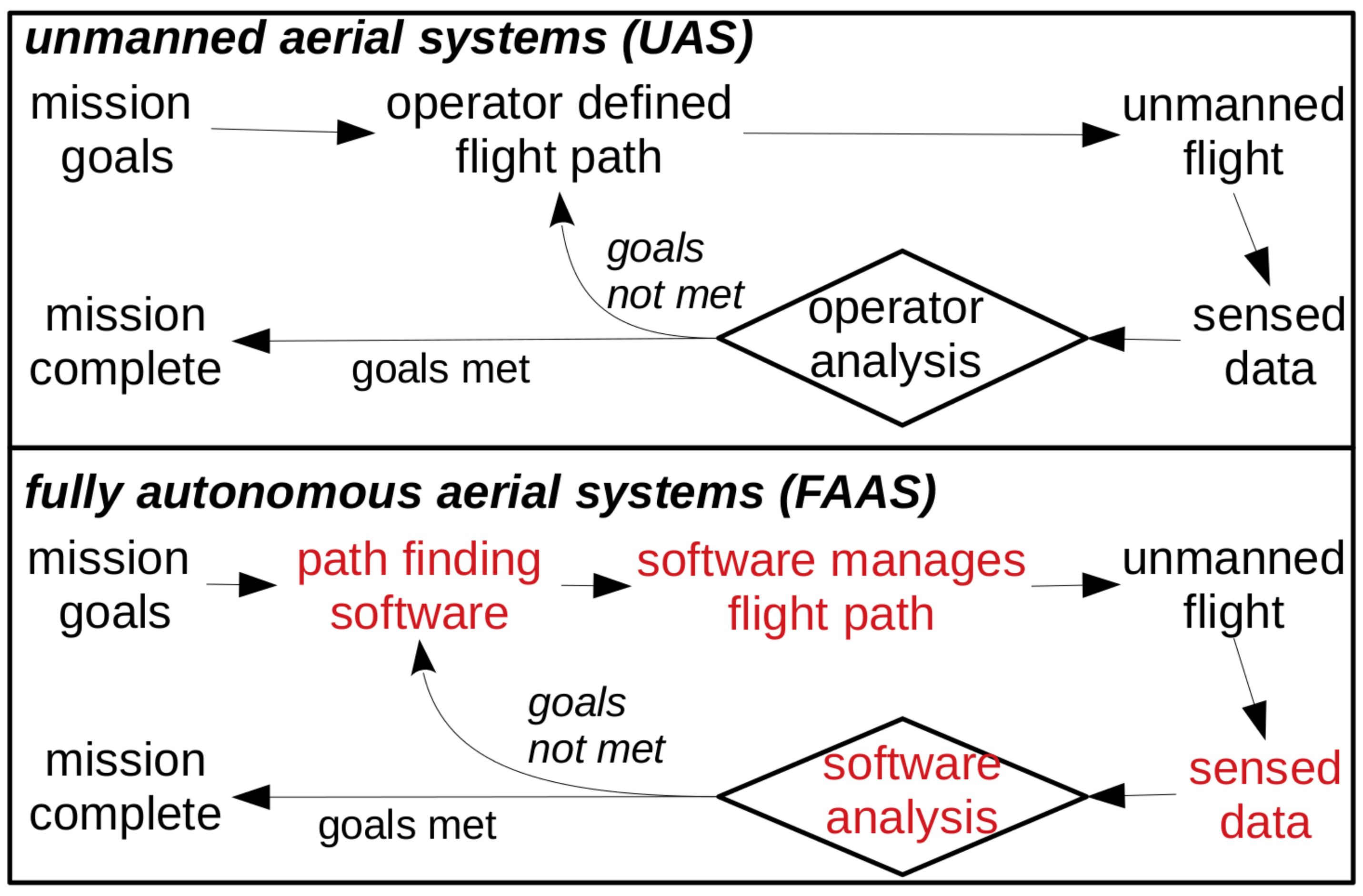
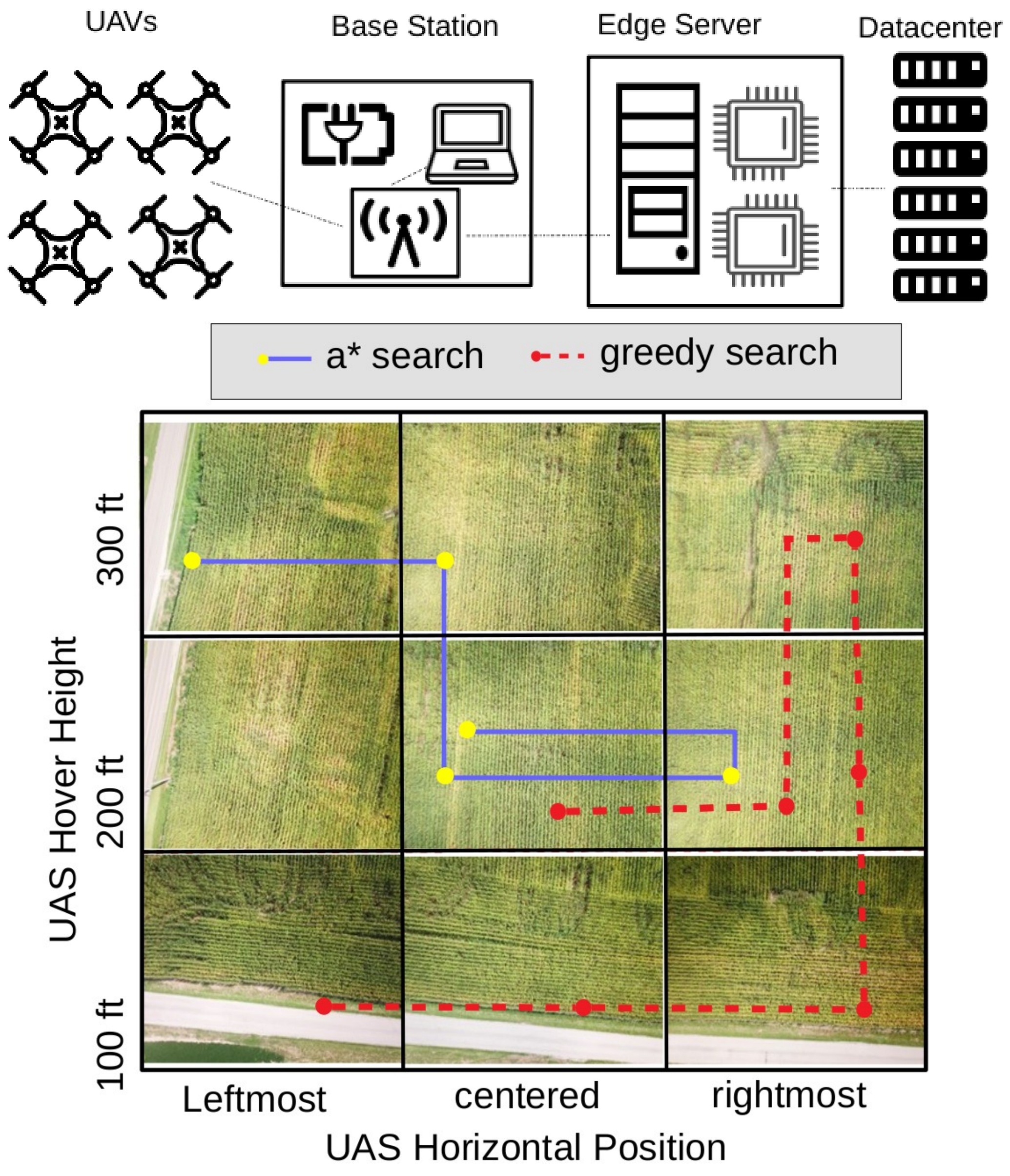
INTRODUCTION

- UAS application domains are many
  - Agriculture, Surveillance, Photography, etc
  - Each domain requires different configurations
- Fully Autonomous Aerial Systems (FAAS):
  - UAV, Edge systems, cloud systems
  - Fly dynamic missions with little operator interference
- Many software suites exist for UAV, but none that support FAAS
  - Autonomous decision-making does not exist in UAS siutes
- SoftwarePilot:
  - A programmable middleware that supports FAAS
  - Dispatches microservices for FAAS tasks like:
    - Pathfinding, computer vision, flight control, autonomy policies



DESIGN

- 4 layers to control different components across the stack
  - Hardware: UAVs, Edge systems, etc needed for FAAS
  - Runtime Management: Containers and VMs for software support
  - API: Custom interface between FAAS Hardware and SP apps
  - Application: Java apps that use SP API to implement FAAS
- Software Support:
  - reinforcement-learning based pathfinding methods for autonomous navigation of unknown environments
  - Docker Container and VM for platform independence
  - Implementations of key FAAS kernels
  - Heterogeneous computing support



IMPLEMENTATION and RESULTS

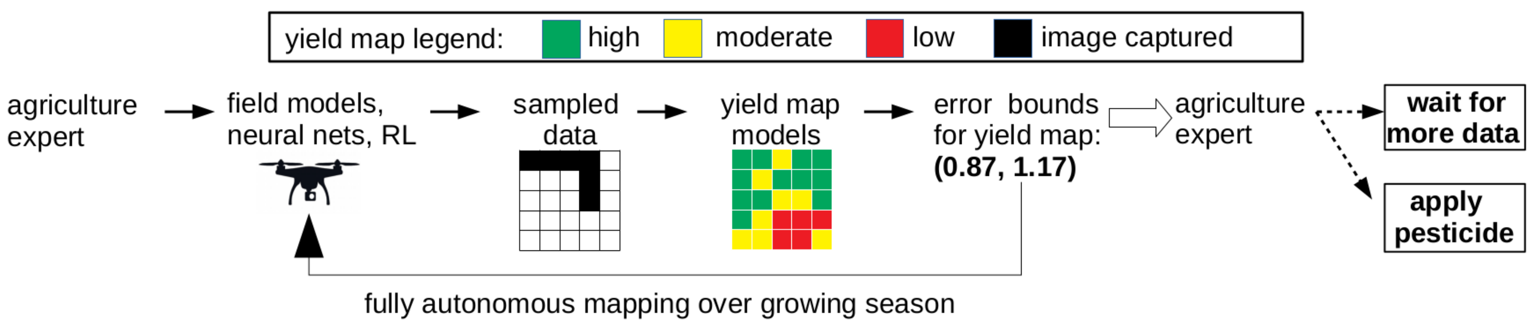
SoftwarePilot Implementations in Different Domains:

Autonomous Photography

- Key kernel to autonomous photography: Target recognition and optimization (TRO)
  - Find a target in an open environment
  - Capture a quality picture of that target for future analysis
- We used SoftwarePilot to implement a TRO FAAS [1]
- Our TRO FAAS includes reinforcement learning based A* pathfinding to decrease search waypoints
  - Optimal autonomy settings speed up TRO by 4.1X
- System management techniques also speed up execution:
  - Adaptive GPU duty cycling: 1.3X
  - Appropriate hardware selection: 2.25X
- By combining all of these techniques, we were able to increase TRO throughput by 10x and reduce costs by 87% over naive approaches

Fully Autonomous Precision Agriculture

- SoftwarePilot is being used to construct yield maps for crop fields [2]
- Yield Map: Crop growth predictions for individual zones within a crop field; Inform farmers of under-performing areas



- Autonomous pathfinding allows us to sample the field intelligently and key regions useful for predicting field outcomes
- SofrwarePilot FAPA can produce accurate yield maps by sampling only 40% of a crop field, saving energy and compute resources

Citations:
[1] J. Boubin, N. T.R. Babu, C. Stewart, J. Chumley, and S. Zhang,“Managing edge resources for fully autonomous aerial systems,”in2019 IEEE/ACM Symposium on Edge Computing (SEC), IEEE,2019
[2] Jayson Boubin, John Chumley, Christopher Stewart, and Sami Khanal.Autonomic computing challenges in fully autonomous precision agri-culture. In2019 IEEE International Conference on Autonomic Computing(ICAC). IEEE, 2019.

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