CPS: Small: Collaborative Research: RUI: Towards Efficient and Secure Agricultural Information Collection Using a Multi-Robot System

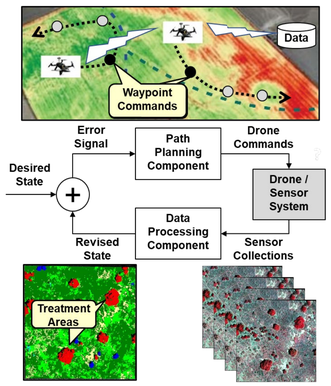
Ayan Dutta, Swapnoneel Roy and Patrick Kreidl (University of North Florida); Ladislau Bölöni (University of Central Florida)

http://ayandutta.domains.unf.edu/unf-prec-ag/

Context: Farmlands throughout the world are experiencing diminishing room for expansion (~15M km^2) yet world population is growing at a faster rate. Farms must, in turn, focus on improving crop yield through *precision agriculture*, or the use of emerging technologies in sensing, automation, communication and computation to increase efficiency of farmland operations.

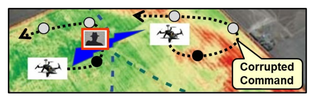
Technical Challenge:

- Coordinate multiple robots to collect maximum information
- Employ blockchain solutions to maintain wireless data integrity
- Minimize energy subject to
  - Maximizing information
  - Maintaining integrity

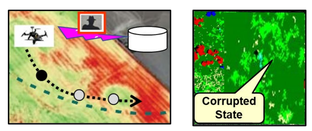


(a) Information Collection in Precision Agriculture

(b) Threat of Data Integrity Attacks in Wireless Links



(c) Influence of Integrity Attacks in Coordination Plane



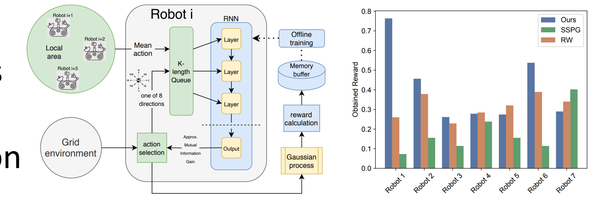
(d) Influence of Integrity Attacks in Processing Plane

Scientific Impact: Efficient and secure info collection raises complicated tradeoffs for cyber-physical systems, in general

- Optimal multi-robot informative path planning is NP hard → <u>efficiency requires custom approximations</u> that are tractable yet remain effective
- Blockchains rely on intensive cryptographic computations → <u>security requires relaxed guarantees</u> that remain achievable under resource limits
- Multi-robot path planning combined with blockchain-based data integrity incentivizes quest for <u>configurable efficiency/security tradeoffs</u>

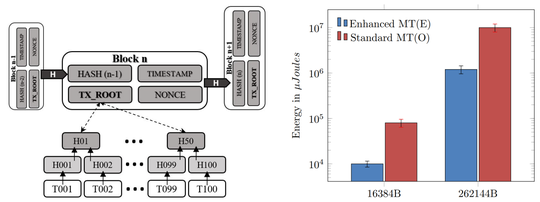
Technical Approach: Two key research thrusts, investigated in tandem, followed by laboratory (and eventual field) experiments

1. Distributed & secure multi-robot path planning with connectivity constraints
2. Combining informative path planning and Gaussian process based estimation for optimal model.



(1.A) Multi-Robot Information Sampling Using Deep Mean Field Reinforcement Learning

2. Energy optimization of blockchain algorithms and core computations
   A. Memory access of Merkle trees
   B. Hashes of Proof-of-Work
   C. Committees of Proof-of-Stake



(2.A) Energy Efficient Merkle Trees for Blockchains

Societal Impact: Help farmers gather info from fields with less time and costs

- Foster among involved students an increased understanding of the agricultural community
- Enhance appreciation by students for what it takes to keep grocery stores well-stocked
- Solutions expected to transfer to other cyber-physical applications (e.g., search and rescue)

Educational Impact: Variety of activities across both universities (UNF and UCF)

- Course development: PI Dutta introduced CIS6930 "Planning in Robotics" in Spring 2020
- Student training: Four grad and one ugrad have worked/are working on this project
- Established Memo-of-Understanding (MoU) for UNF students to receive UCF PhD degrees

RUI Impact: UNF is predominantly ugrad institution with small masters programs

- <u>Metrics:</u> UNF ugrads to enter grad programs; UNF grads to exercise MoU for UCF PhDs
- UNF PIs are steering ugrad student clubs (IEEE, Robotics, Security) into automated gardening

2020 - 2024

Award ID#: 1932300, 1931767