Robotic Shepherding for Flow Control in Uncertain Dynamic Environments

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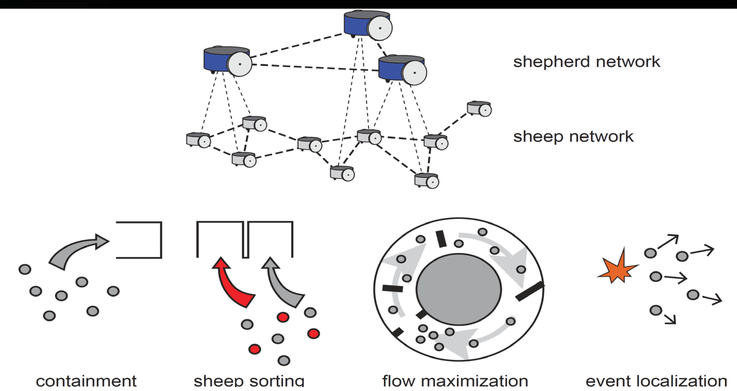
Technical Challenges

- Networked shepherds and sheep
- Coupled stability analysis for flock configuration estimation and control
- Distributed sensing and learning
- Robotic shepherds and sheep



Scientific impact

- Multi-agent coordination and control
- Coupled estimation and control with optimal sensing
- Adaptive distributed algorithms, tunable depending on hardware specifications
- Economic scalable robotic hardware

Key innovations

- Robust distributed optimization
  - Developed robust distributed gradient algorithm for unconstrainted convex optimization: has exact convergence, communication-efficient, hot-pluggable allowing entrance and leave, robust to packet loss
  - Proposed new classes of proximal algorithms for constrained and nonsmooth distributed optimization: SVM can be solved iteratively with simple closed-form expressions
- Shepherding
  - Control laws in both continuous and discrete time for single sheep and dog shepherding, preliminary works on multiple sheep systems
  - Scalable adaptive shape formation: robust against removal of agents
- Flexible distributed sensing and learning
  - Proposed flexible distributed algorithm framework with flexible tradeoff for communication and computation depending on the environment and provable performance guarantees
  - Developed hybrid distributed method that can work with heterogenous hardware components, especially for a mixture of first and second order computation
- Robot sheep and shepherds hardware
  - CoachbotV2.0: Raspberry Pi, scalable, 10cm in diameter, 12cm high
  - Faithful hardware simulator for fast prototyping
  - Upgraded hardware with autonomous charging capabilities

Applications

- Disaster evacuation
- Crowd control
- Military scenarios in collaboration with Army Research Laboratory (ARL)

Education and Outreach

- Curriculum development: K-12, college, graduate
- Online education: YouTube channel
- Underrepresented groups: SWE, Northwestern Summer Research Opportunity Program (SROP)
- Public outreach: Museum of Science and Industry in Chicago

Potential Impact

- Utilize autonomous robots in unknown and potentially hazardous environments
- Reduction in cost and time in delivery of necessities and evacuation after natural disasters
- Enable human and robot collaboration via teleoperation

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