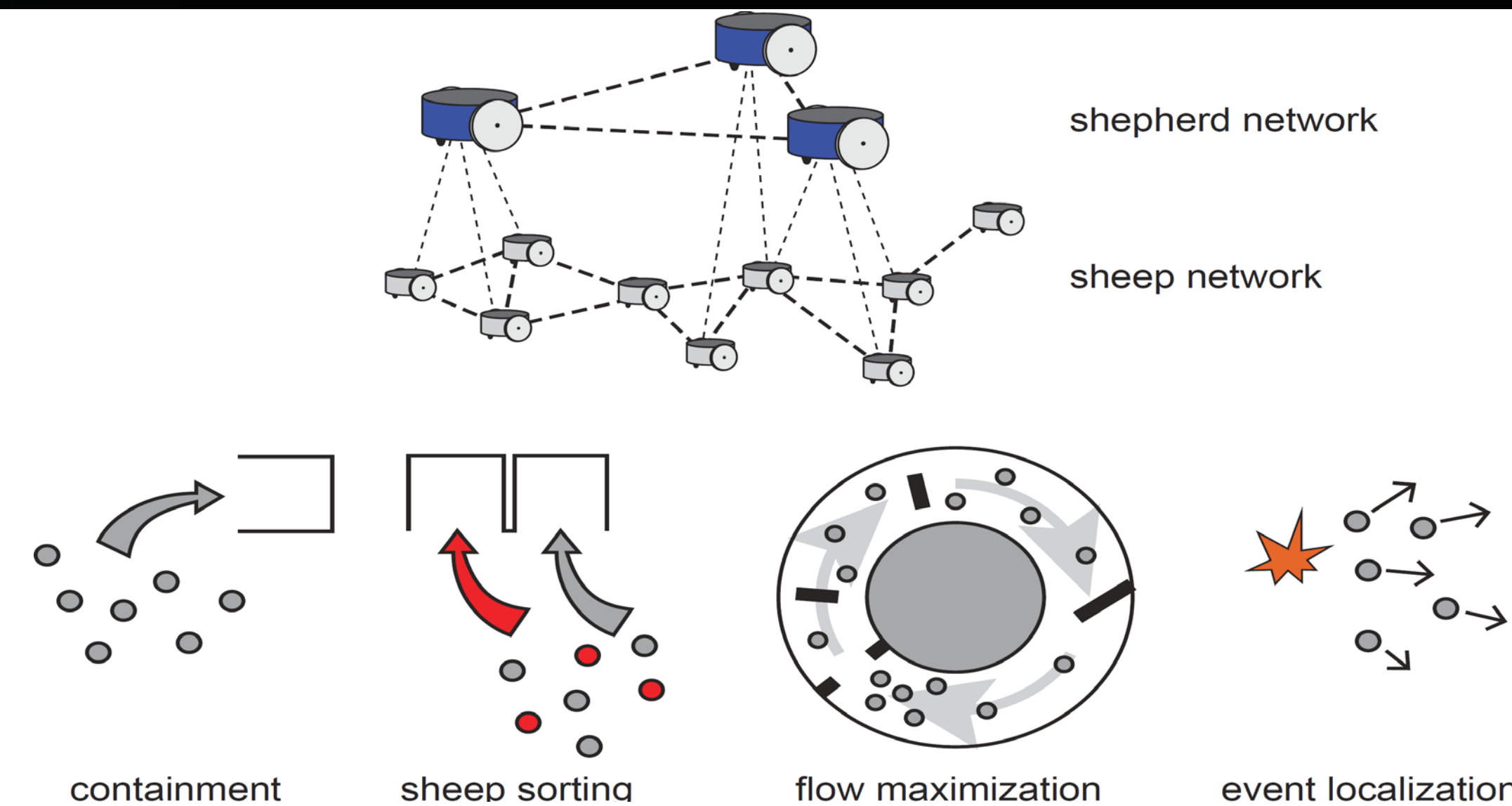# Robotic Shepherding for Flow Control in Uncertain Dynamic Environments

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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

shepherd network

sheep network

containment   sheep sorting   flow maximization   event localization

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

Proposed Solutions

- Flock configuration estimation and control
  - Formulate costs to encode global flock objectives and develop gradient descent and accelerated gradient descent control strategies
  - Model predictive control (MPC) for more sophisticated tasks
  - Investigate flock configuration controllability and observability
  - Swarm formation control

- Coupled stability analysis
  - Design tractable nonconservative coupled stability analysis
  - Develop controller and use integral quadratic constraints framework
  - Provide ranges of parameters with guaranteed stability

- Flexible distributed sensing and learning
  - Propose flexible distributed algorithm framework with flexible tradeoff for communication, computation and locomotion depending on the environment
  - Investigate convergence guarantees
  - Design optimal algorithms for the robotic shepherd applications

- Robot sheep and shepherds
  - CoachbotV2.0: Raspberry Pi, scalable, 10cm in diameter, 12cm high
  - Faithful hardware simulator for fast prototyping
  - Teleoperation capability: human operators may control partial robotic team remotely

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