Robust, scalable, distributed semantic mapping for co-robots

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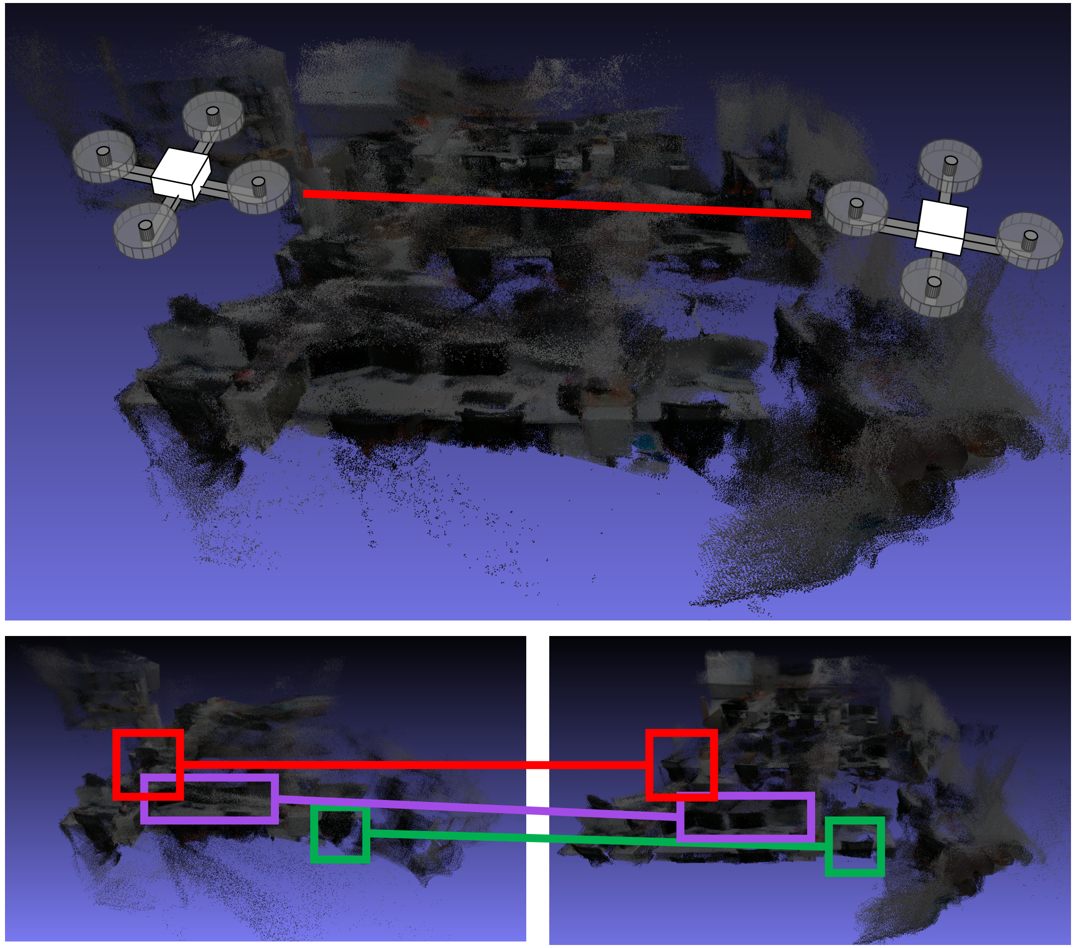
IIS-1734454/IIS-1734362

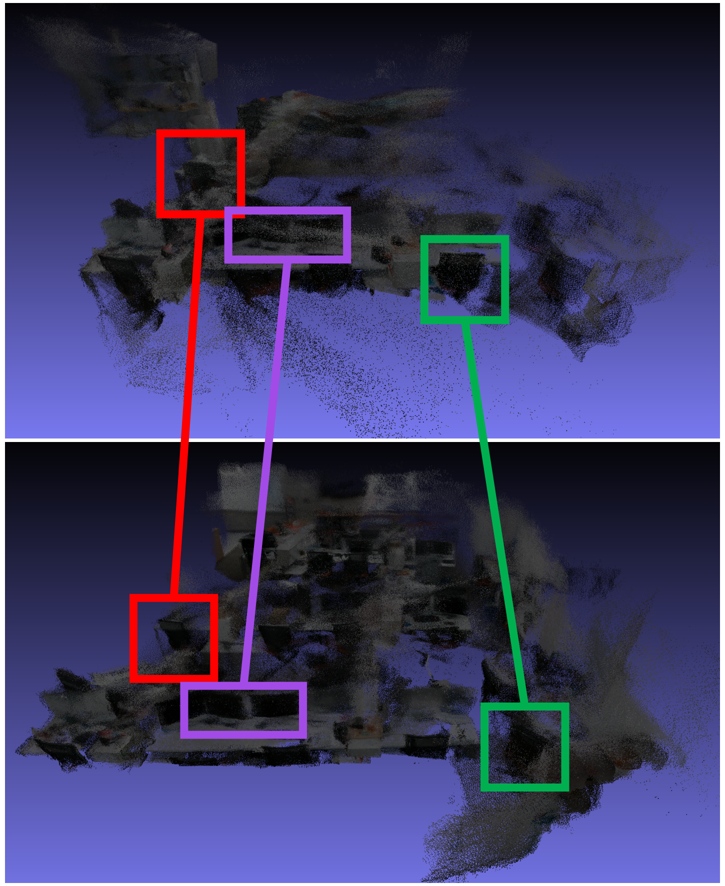
Motivation



Goal: robust and efficient multi-robot mapping and semantic understanding

- Incorporate semantic information (object detections)
- Use redundancy from cycles to detect and correct inconsistencies
- Share computational resources (via offloading, outbursting)
- Make intelligent use of local resources via the approximate-computing paradigm (tradeoff accuracy for speed)

Loop-based statistical outlier identification



Motivation: Finding correspondences between different parts of a map

Challenge: Potential correspondences (e.g., from objects) vs gross errors (outliers)

Opportunity: Geometric loop closure gives evidence for statistical inference

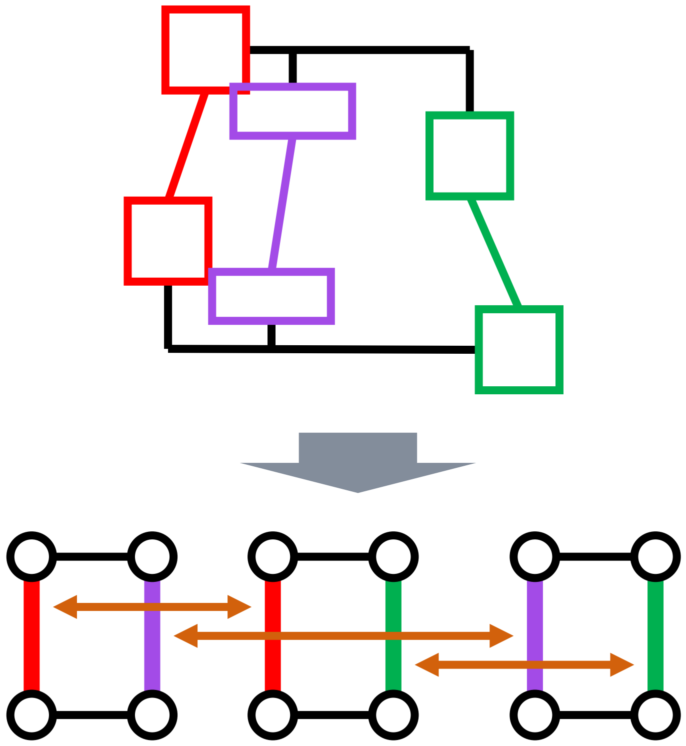
Questions:

How do we estimate which edges are outliers?

What are the fundamental limits?

Estimation of outlier probabilities

Evidence on loop closures, EM inference on edge probabilities, noise variance



Challenge:

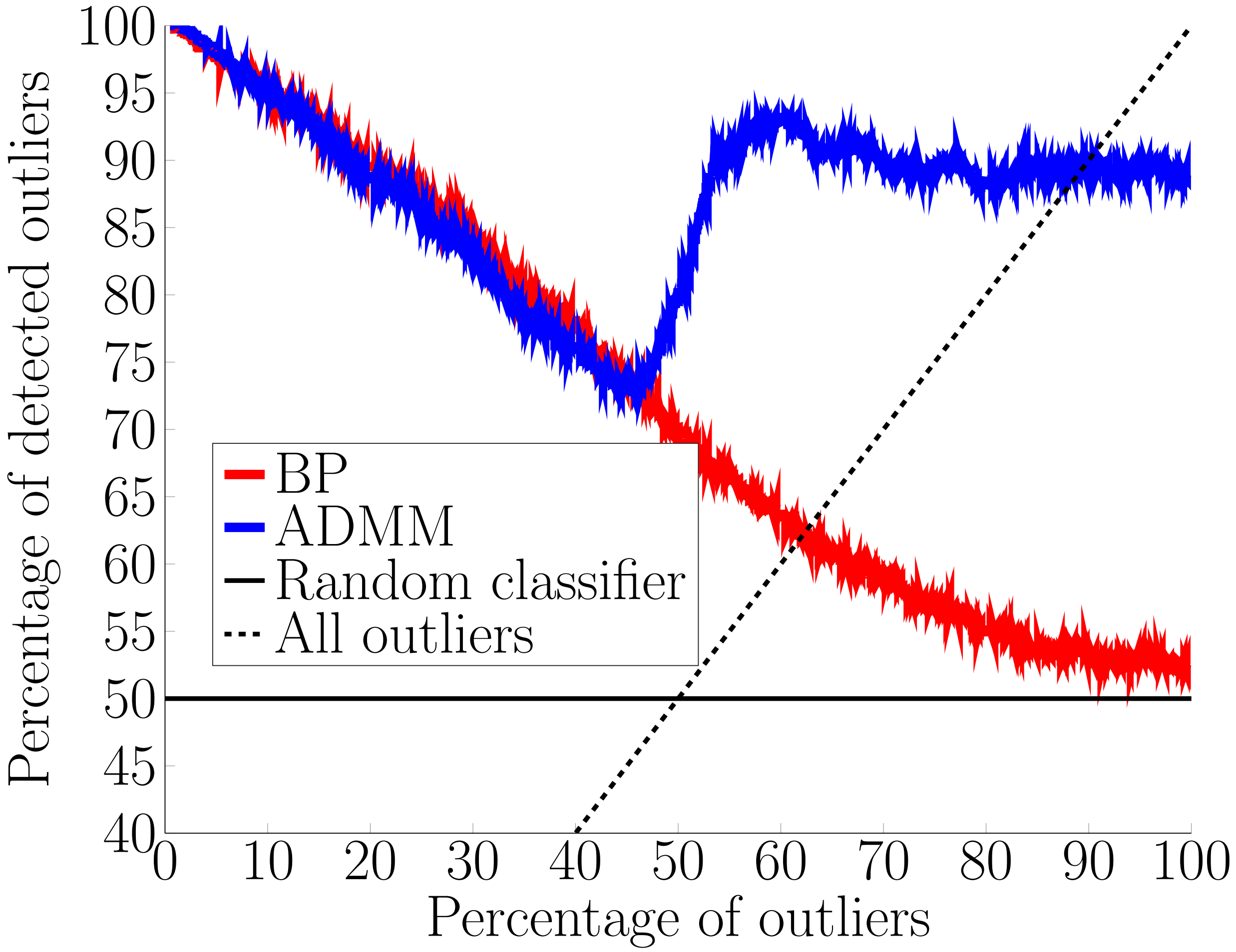
- Loopy inference is practically intractable
- Standard approximation (Loopy Belief Propagation) does not reliably converge

Novel approach:

- Alternating-Direction Method of Multipliers (ADMM)
- Solve (exactly) the inference problem on each cycle, then enforce agreement on shared edges

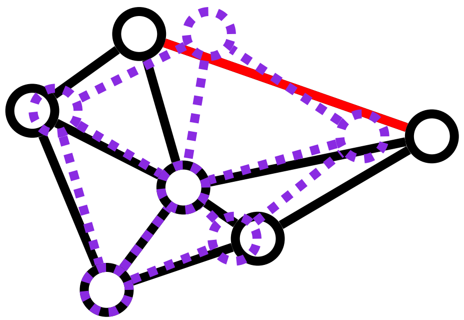
Estimation of outlier probabilities

- Better than Belief Propagation
- Naturally distributed
  (except for cycle basis)
- The hardest case
  is 50% outliers

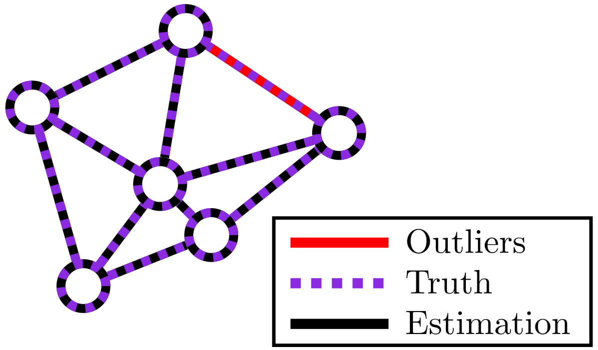


Identifiability theory for outliers

Non-robust cost



Robust cost

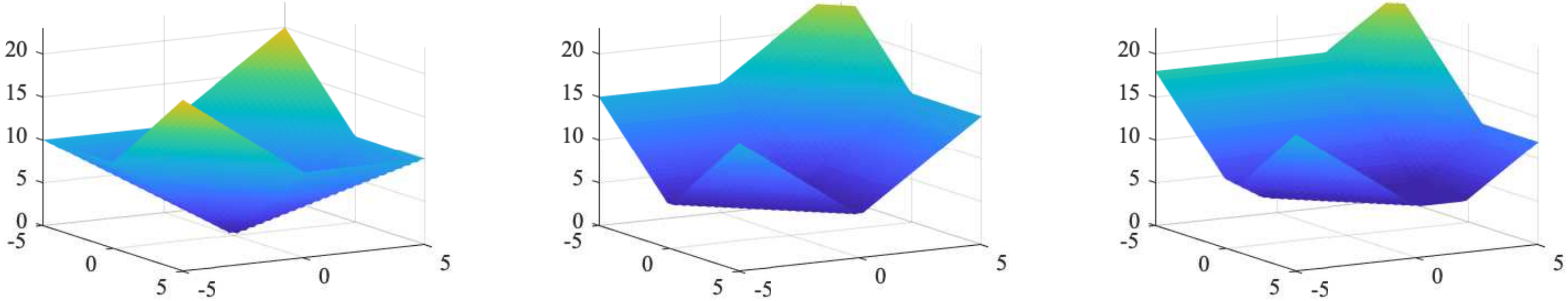


Optimizing a robust cost function can remove outliers

Motivation: Under what conditions is this possible?

Novel approach: Theory for translation-only case

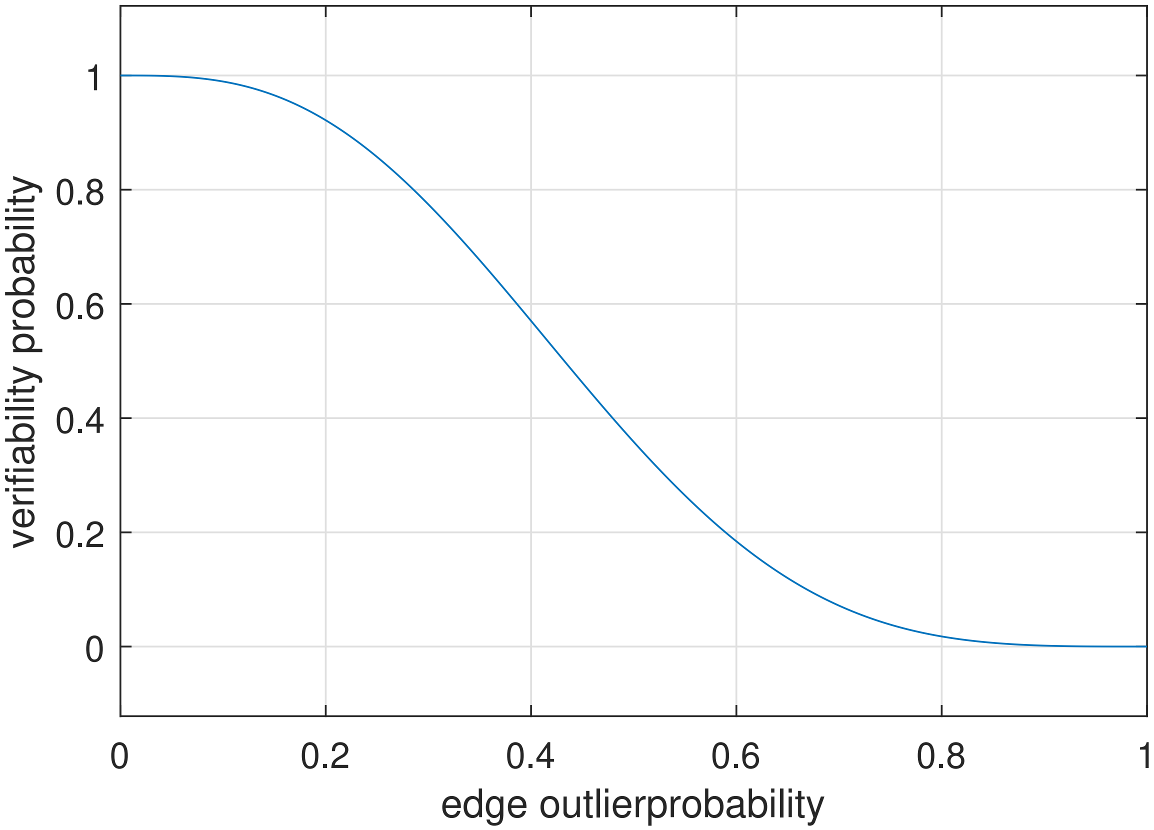
Based on analyzing cost using convex optimization



- *Does not matter:* Outliers magnitude, node locations
- *Matters:* Topology, support and sign of outliers

Estimation of outlier probabilities

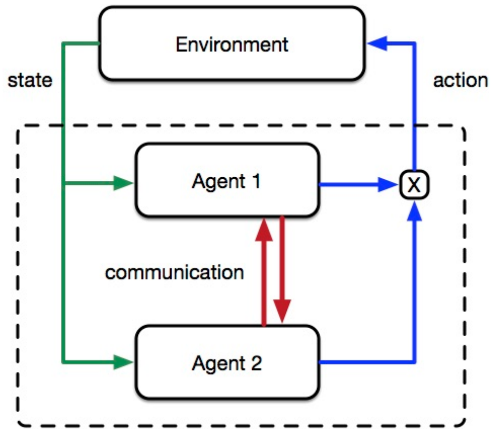
For the first time,
we can compute the a-priori probability of obtaining the true solution given edge probabilities



Multi-agent application: distributed decision making

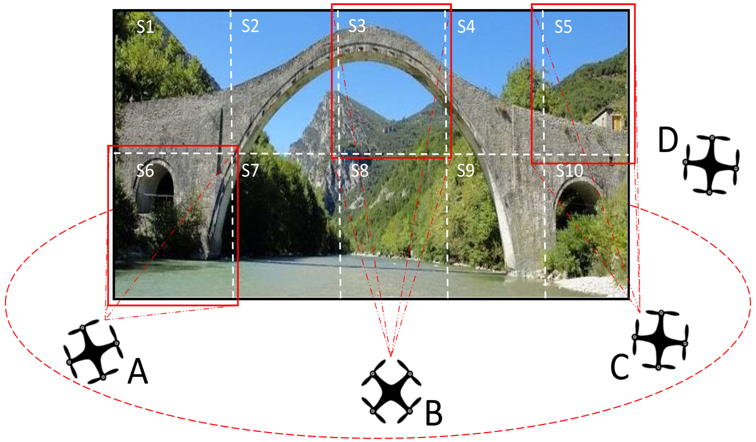
- **Intelligent Physical Systems (IPS)** such as drones
  - Sense and act on the environment
  - Sensing: Create "actionable knowledge" using on-board/externally-mounted devices
  - Planning: Decision-making using actionable knowledge

- **Goal**: Real-time smart and *autonomic* decision making
  - **Technique 1**: Multi-agent Deep Reinforcement Learning (MADRL)
  - **Technique 2**: Approximation in computing
  - **Agents**: Group of IPSs such as drones
  - **Application**: Automatic data collection/multi-object tracking
  - **Environment**: Highly dynamic environment difficult to model

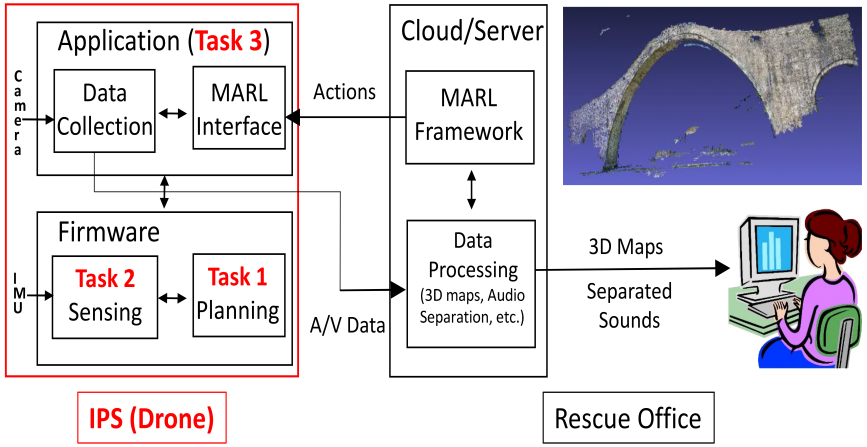


Multi-Agent Reinforcement Learning (MARL)

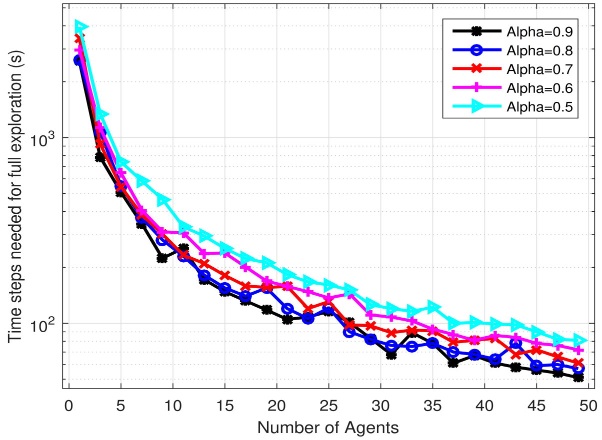
MARL framework for incident data collection to create 3D maps



Modeling of incident zone (bridge inspection) with MDP



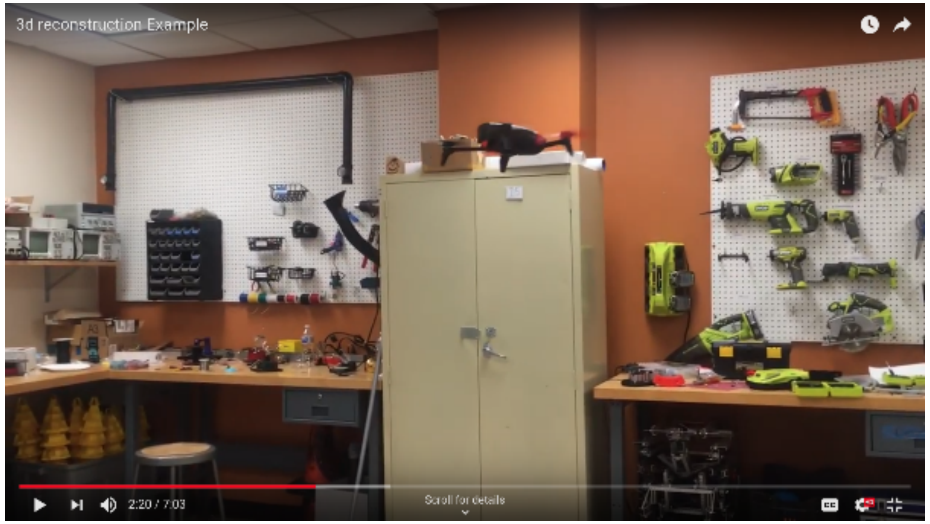
High-level architecture with components



Time for full coverage vs number of agents

Experimental multi-drone platform

Results using drones as the experimental platform



Real-time 3D reconstruction using single drone and ORB SLAM

Multi-Agent Reinforcement Learning (MARL)-based 3D reconstruction

Broader impact

New class, ME416 Introduction to Robotics

- Basics of ROS, kinematics, Machine Learning (ML), controls

New workshop for the BU Upward Bound Science and Math Program

- One-day workshop using Python to control small drones
- High-school students from underprivileged areas

Rutgers ECE Undergraduate Capstone Projects

- Semester-long senior capstone project on building 3D maps via ML techniques
- 3rd and 5th Prize (out of ~68 groups) plus Social Impact Award; Awarded 1st Prize in the Harris Corporation project competition in April'18 for the project SKY-WATCH

Rutgers Day (a free day-long event open to the Rutgers broader community)

- Hands-on learning activities, entertaining stage performances, and exhibitions/demonstrations hosted by Rutgers professors, staff, and students