Adaptive and Resilient Behaviors

RA3

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Adaptive and Resilient Behaviors

Develop theory and methods for heterogeneous teams to carry out tasks under dynamic and varying conditions in the physical world.

Adaptive

- Dynamic environments
- Changing teams
- Unpredictable communications
- Increased operational tempo

Resilient

- Agent failures
- Adversaries
- Uncertainties in localization, mapping, and sensing

Tactical Behaviors

- Coordinated rapid multi-agent maneuver in complex environments
- Swarm release and control for threat identification and engagement
- Response to electronic attack
- Persistent surveillance for extended time periods
- Mobile soldier services, e.g., network healing, threat sensing, and decision making

Army Relevance

The Army challenge: complex unknown environments, little or no infrastructure, and high operational tempo.

Goal:

Systems must quickly **adapt** to new and rapidly changing missions while being **resilient** to adversarial actions and uncertainty.

Megacities and Mixed Civilian/Adversary Population

Jungle

Subterranean

Technical Challenges

Off-line learning is fragile in dynamic environments

- Learning that adapts quickly in non-stationary environments
- Robust and resilient to unexpected or adversarial data

Agents adapting to uncertainty measures across distributed heterogeneous information types

- Semantic, metric, model, environment, mission, communication, topological, knowledge base uncertainty

System-wide resilience for large number of failures or attacks

- Resilience approaches are off-line, centralized, or non-scalable
- Resilience/performance tradeoffs are not quantitative

Technical Innovations

Thrust RA3.A Robust Perception, Action, and Learning

Fast learning adaptation using meta-learning
Estimating probabilistic confidence of learning models
Adversarial learning (including reinforcement learning)
Robust, self-improving inference for long missions

Thrust RA3.B Information and Adaptation for Resilience

Tensor decomposition model for scalable heterogeneous uncertainty
Learning-based MPC for information-theoretic optimal control
Distributed information-theoretic stochastic optimal control

Thrust RA3.C Macro-scale resilience

Quantitative tradeoffs of resilience/performance/computation
Online, distributed resilience mechanisms exploiting discrete convexity

Resilient communications and networking (topological, QoS)

Research Plan

Thrust RA3.A Robust Perception, Action, and Learning

Task RA3.A1 Robust Adaptive Machine Learning
Levine, Pappas, Sukhatme
Task RA3.A2 Robust Self-Improving Inference, Perception, and Action
Carlone, Christensen, Daniilidis

Thrust RA3.B Information and Adaptation for Resilience

Task RA3.B1 Adaptive Swarm Behaviors for Uncertainty Mitigation
Atanasov, Karaman, Tsiotras

Thrust RA3.C Macro-scale resilience

Task RA3.C1 Resilient Situational Awareness
Pappas, Atanasov, Hsieh
Task RA3.C2 Resilience to Failures of Subsets of Networks
Sukhatme, Karaman, Kumar

RA3: Expected Outcomes & Impact

- **Dynamic online learning** that responds to rapid changes in the environment and is resilient to unexpected and adversarial information
- **Adaptive agent-based behaviors** that reason over rich representations of uncertainty to trade off performance and risk
- Techniques to ensure **macro-scale resilience** as a function of mobility, swarm size, heterogeneity, sensing, and communication.

Impact

Distributed systems that are able to **engage in complex, time-varying, and contested environments** to accomplish Army missions by leveraging a mix of online adaptation and system-wide resilience.