Cross-Disciplinary Experimentation

CDE

Lead: Vijay Kumar

Govt. Lead: Jonathan Fink

Cross-Disciplinary Experimentation (CDE)

Cross-disciplinary experimentation serves to explore and discover interdependencies across research areas.

CDE Tasks

Norm-setting with respect to experiments in terms of how we can show research progress that affects real-world problems

Lower barrier for moving from individual task experiments to cross-disciplinary experiments

Support academic-government collaboration and eventual technology transition

Program Goals

- Autonomous robots
- Complex and large scale
- Rapid operational tempo
- Heterogeneous
- Indoor/outdoor
- Human teammates
- Force protection
- Force multiplication

Cross-Disciplinary Experimentation (CDE)

CDE Tasks

CDE1: Plug-and-play interfaces for experimental platforms (Hsieh, Karaman, Roy, Sukhatme)

CDE2: Integration of wireless communication simulators (Ayanian, Hsieh, Taylor, Romberg)

CDE3: Develop common test environments and cases (Christensen, Kumar, Chernova)

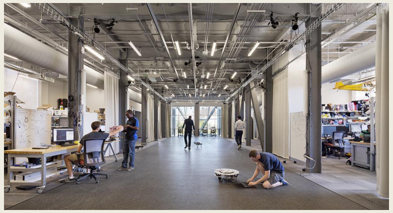
CDE4: Mobile autonomous networks (Loianno, Pappas, Ribeiro, Shah)

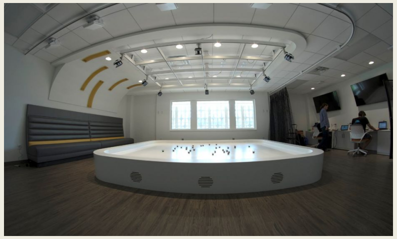
Simulation and testbed-based experiments

Build on open source and shared software development with continuous integration policies

CDE 3

Henrik I Christensen, Sonia Chernova & Vijay Kumar
UC San Diego, Ga Tech and Univ. of Pennsylvania
John Rogers & Jonathan Fink, ARL





CDE 3 - Develop common test environments and cases

Goals

- Define test scenarios for Force Protection and Multiplication
- Define test environments to explore test scenarios
- Define metrics for evaluation

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CDE.1
Plug-and-play interfaces for experimental platforms

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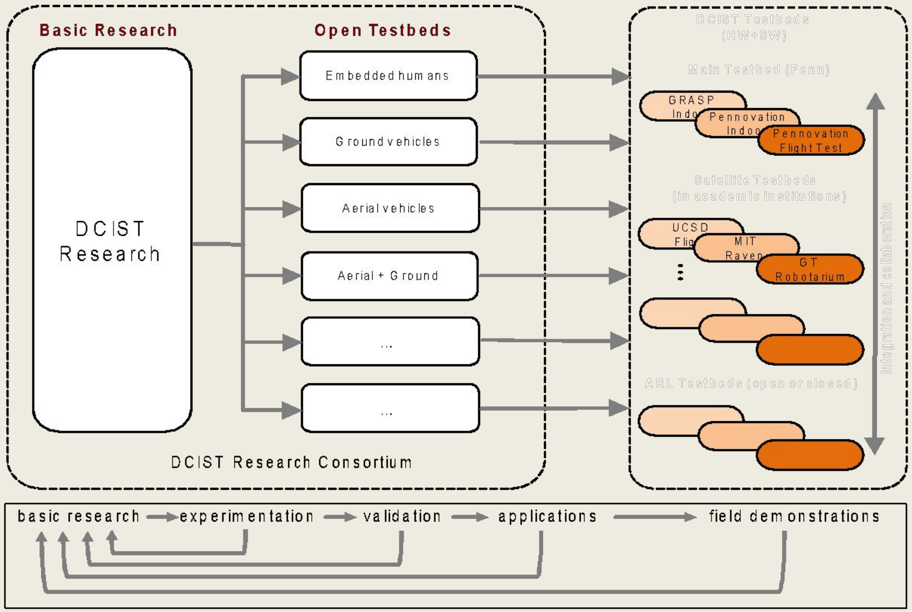
Goals

- Common DCIST cross disciplinary research experimentation infrastructure
- Set up a framework for continuous integration (CI) of DCIST software development

Status

- Identifying and assessing baseline DCIST component technologies and capabilities (PIs: Sukhatme (USC), Hsieh (Penn), Roy (MIT), Fink (ARL))
- Identifying and developing a baseline human model using a pre-defined set of human-robot interactions (Pis: Hsieh (Penn), Karaman (MIT))
- Identifying and establishing preliminary set of human interfaces for DICST simulations from the baseline human model (PIs: Hsieh (Penn), Karaman (MIT))



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CDE.2 Integration of wireless communication simulators

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Goals

- Develop suitable approaches to model, simulate, and validate a heterogeneous communication network in a common DCIST cross disciplinary research experimentation infrastructure
- Develop an architecture that can scale to handle hundreds or thousands of interacting nodes.

Status

- Identifying an initial set of network technologies useful for DCIST template mission scenarios (PIs: Hsieh (UPenn), Ayanian (USC), Fink (ARL))
- Performing a survey of existing robotic and network simulation packages and characterizing their capabilities (PI: Taylor (UPenn)

Future Work

- Identify suitable analytical models that approximate signal propagation for the initial set of network technologies
- Develop joint robotic and network simulation architecture that can be effectively scaled to handle tens, hundreds, and thousands of interacting nodes

Candidate Experiments

- Perimeter surveillance task with simulated heterogeneous communication models for the initial set of network technologies

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CDE4 Mobile Autonomous Networks

ARL

Loianno, Pappas, Ribeiro, Shah

Goals

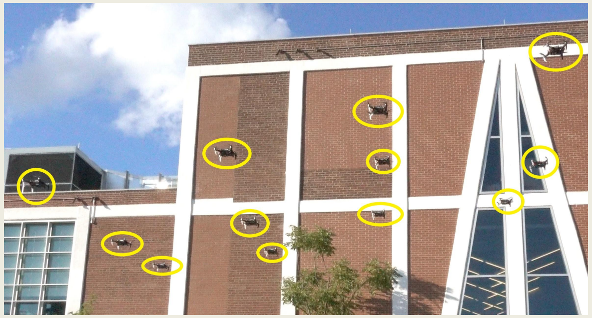
- Co-design Perception-Action-Communication loops
- Heterogeneous multi-robots/multi-humans interaction
- Realize PAC-loop architecture from tasks RA1.C1, RA1.B3, RA1.C1 in experimental infrastructure

Preliminary Work

- Exploring Human/robots localization and exploration using **cameras** and **gaze data** from eye tracking glasses
  - Force **protection**
  - Support humans and robots communication
  - Investigating different interaction paradigms
- Scalable approach up to 20 robots and multiple humans in the loop
  - Tested 12 quadrotors without motion capture systems
  - Force **multiplication**
- Dynamic allocation of **perception** and **action** across platforms (without high bandwidth communication)

Candidate Experiments

- Single robot/human demo by October/November 2018 considering human/drone interaction using VR/Eye tracker device (possibly multiple drones)



Force multiplication can be obtained using our VIO swarm

Force protection

Eye tracking glasses

Cross-Disciplinary Experimentation (CDE)

CDE Tasks

CDE1: Plug-and-play interfaces for experimental platforms (Hsieh, Karaman, Roy, Sukhatme)	CDE2: Integration of wireless communication simulators (Ayanian, Hsieh, Taylor, Romberg)	CDE3: Develop common test environments and cases (Christensen, Kumar, Chernova)	CDE4: Mobile autonomous networks (Loianno, Pappas, Ribeiro, Shah)

Simulation and testbed-based experiments

Build on open source and shared software development with continuous integration policies

CDE 1: Plug-and-play interfaces for experimental platforms

- **Subtask 1(a) Assessment of baseline DCIST capabilities and best-practices**
- **Subtask 1(b) Human modeling**

Consortium PIs: M. Ani Hsieh, UPenn, Sertac Karaman, MIT, Nicholas Roy, MIT, Gaurav Sukhatme, USC

Objective:

- Facilitate collaboration, integration, and cross disciplinary experimentation in common environments and test scenarios
- Create the necessary software infrastructure for research experimentation for common DCIST platforms, environments, and scenarios.
- Build towards a universally available software interface supported by a collection of open-source simulation testbeds and open and possibly closed-source experimental testbeds.

Approach:

- Establish standard best practices for common DCIST test scenarios.
- Define standard plug-and-play interfaces for common environmental, dynamics, and communication models for various single robot, multi-robot, and robot swarm tasks.
- Develop a range of capabilities that will enable the integration of human agents in simulation and hardware experimentation.
- Set up a framework for continuous integration (CI) of DCIST software development

CDE 2: Integration of Wireless Communication Simulators

Principal Investigator Nora Ayanian, USC, M. Ani Hsieh, UPenn, Camillo J. Taylor, UPenn, Justin Romberg, GT

- **Subtask CDE.2 (a) Development of channel models**
- **Subtask CDE.2 (b) Design of wireless and robotic simulation architecture**

Goal:

- Simulating long-range communications – with attributes like latency, error rates, power usage and bandwidth – is challenging and complicated by the mobility and heterogeneity of our robots and the complexity of the operating environment.
- Focuses on overcoming the technological and scientific challenges necessary for high-fidelity simulation of DCIST scenarios with large teams of heterogeneous agents equipped with a heterogeneous communication network.

Approach:

- Survey the available robotic and network simulation packages to characterize their capabilities along a number of dimensions including: fidelity of physical simulation, fidelity of sensor simulation, number of agents supported, fidelity of the communication model and scalability.
- Develop an architecture that will find an appropriate tradeoff between the need for accurate network simulation and the need for effective physical simulation.
- Work on developing an architecture that could be effectively scaled to handle the hundreds or thousands of interacting nodes.
- leverage existing open source infrastructure such as ROS 2.0 to provide researchers with familiar APIs on which to develop and test their distributed coordination algorithms.

CDE 3: Develop common test environments and cases

Principal Investigators: Henrik I Christensen, UC San Diego, Vijay Kumar, UPENN, Sonia Chernova, Georgia Tech, John G. Rogers, ARL

Objective:

- Develop scenarios to ensure that the 6.1 research has a clear value to Army operations.
- Ensure that the research is demonstrated in a context where it is self-evident that it has relevance to present and future concepts of operation.
- Define data-sets and metrics for evaluation of performance in the presence of failures to the swarm and how that impacts the overall team (human and swarm)

Approach:

- Formally define a set of missions that fully expose the research performed by the DCIST consortium, the links to ARL researchers, and the contributions to the objectives.
- Develop a library of common test environments and testing scenarios for experimental verification and validation of DCIST capabilities and establish metrics for evaluation of different components of the system.
- The testing scenarios will include comprehensive models of planned annual demonstrations and joint experiments with a view of facilitating experimental validation, evaluating research progress, verification of project milestones and encouraging collaborations within the Alliance.

CDE 4: Mobile Autonomous Networks

Principal Investigator: Giuseppe Loianno, UPenn, George Pappas, UPenn, Alejandro Ribeiro, UPenn, Julie Shah, MIT

Objective:

- Develop a team of autonomous aerial robots for experimental verification and validation of DCIST capabilities and establish metrics and testing scenarios for PAC loops co-design approaches.
- Test heterogeneous multi-robots/multi-humans systems.

Approach:

- Will design methodologies to let teams self organize ad-hoc mobile wireless networks to support mission accomplishment while not compromising the perception capabilities of the entire team.
- Support techniques developed in tasks RA1.C1, RA1.B3 considering an initial setup of 10 aerial robots.
- Complement tasks RA1.C1 considering safe actions and trajectories that are compatible with respect to the communication constraints.
- Build on the learning view of wireless systems design, which aims to learn optimal resource allocations.
- Complement RA1.B3 and RA2.A2 establishing a way to localize the entities with respect to each other. This allows the ability to locate robots and humans such to receive information in a common coherent reference system.

Backup

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(some) ARL Experimental Resources

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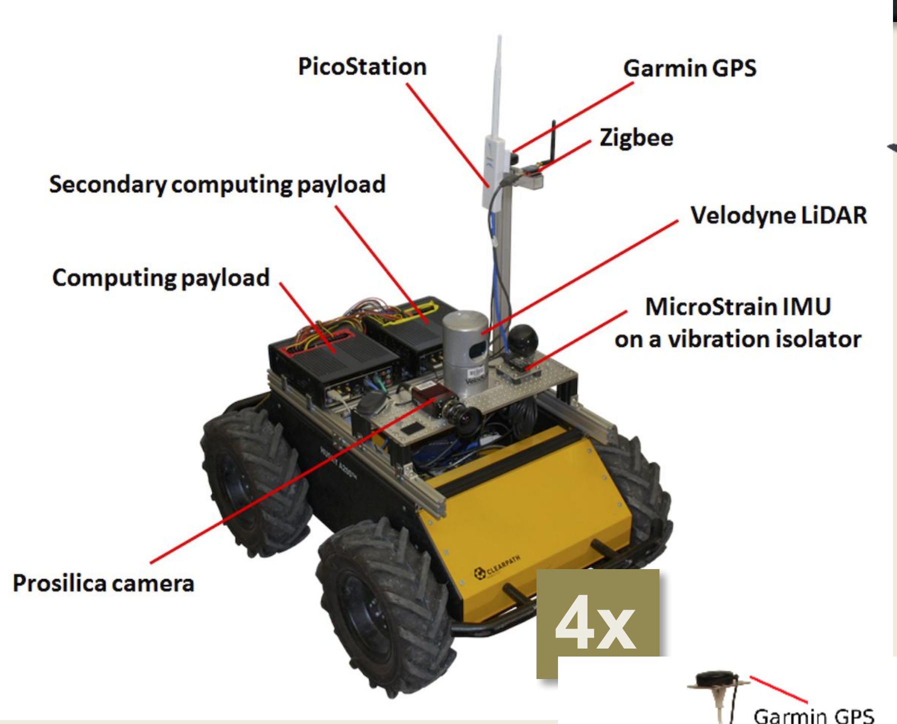

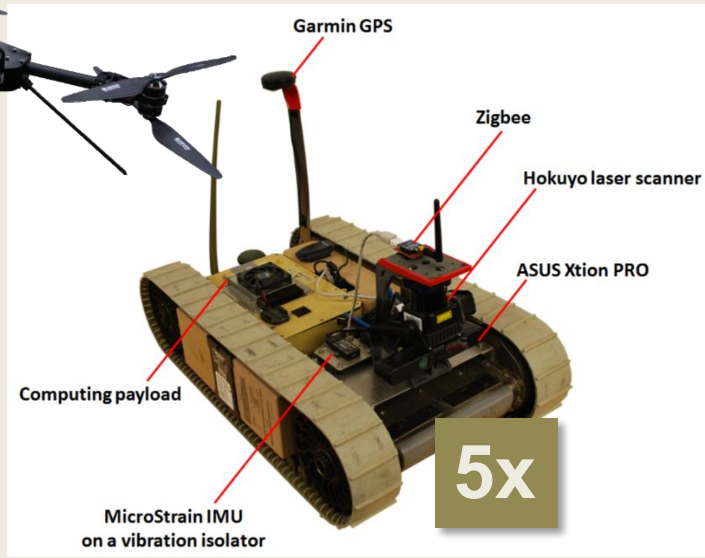

And others….

- Ground Robots
- Quadrotors
- Mesh radios
- Novel radios (e.g., miniature 40MHz)
- High Performance Computing

ARL Experimental Facilities

Adelphi, MD

Ft. Indiantown Gap, PA

Camp Lejeune, NC

Aberdeen, MD

ARL Experimental Facilities

Adelphi, MD

Ft. Indiantown Gap, PA

COMING SOON Graces Quarters