April 23-24th 2014

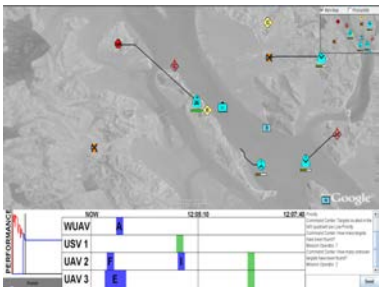
Mission Planning and Predictive Models for Supervisory Control Environments

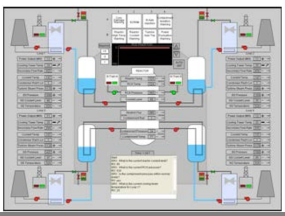
Alexander Stimpson
ajstimps@mit.edu

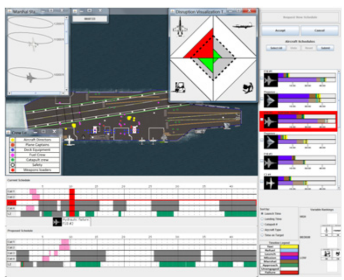
Halab.mit.edu
Youtube.com/halabatmit

HAL Research

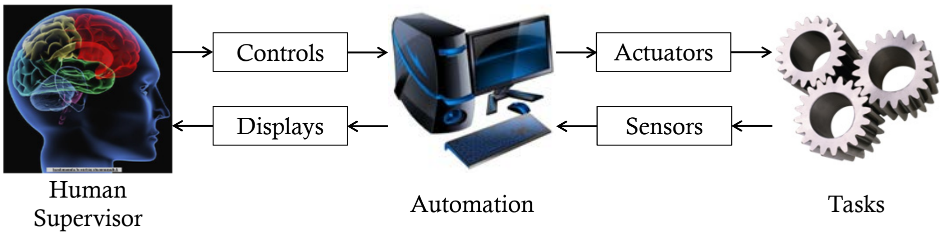
- Focuses on the interactions of human and computer decision-making in complex socio-technical systems, such as:
  - Multi-UAV Missions
  - UxV planning and scheduling
  - Air Traffic Control
  - High speed railway operations
  - Aircraft carrier deck operations
  - Bus and metro systems
  - Emergency and first response systems
  - Nuclear Power Plants



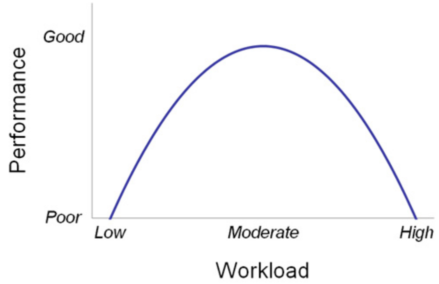




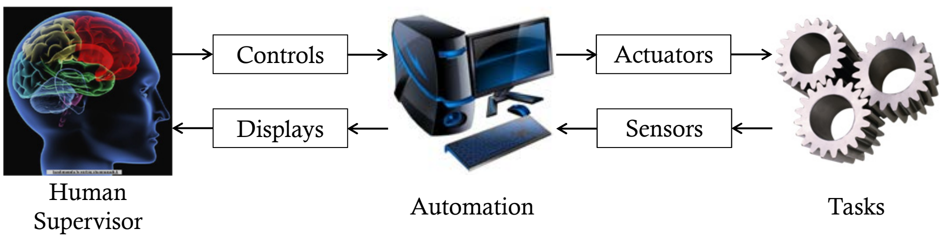
Human Supervisory Control



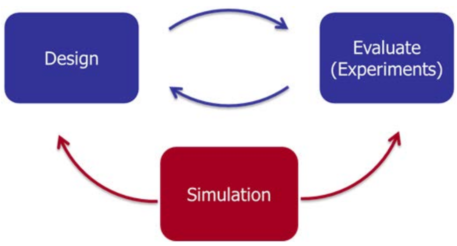
- Complex, time-pressured, high risk domains
- Humans on the loop vs. in the loop
- Supporting knowledge-based versus skill-based tasks
- Individuals and Teams
- Decision-Support Systems



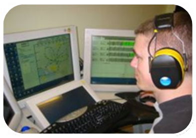
Human Supervisory Control



- Complex, time-pressured, high risk domains
- Humans on the loop vs. in the loop
- Supporting knowledge-based versus skill-based tasks
- Individuals and Teams
- Decision-Support Systems



Overview


Interface Design


HSC and Mission Planning




Predictive Models of Operator, Team, and System Behaviors

INTERFACE DESIGN

Human Control of Small UAVs with an iPhone

- Miniature Aerial Vehicle-Visualization of Unexplored Environments (MAV-VUE
  - Using an iPhone to explore unknown territory with a Micro Aerial Vehicle
  - High level goal – develop a mobile interface for interacting with an autonomous MAV
  - Create collision detection and avoidance displays for navigating crowded environments

Map Display and General Interface of MAV-VUE for high level control

Overview of Nudge Control Interface for low level control

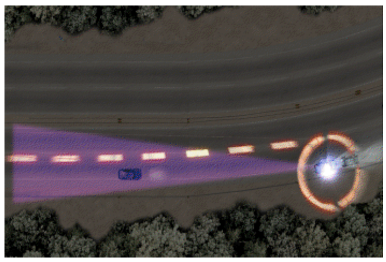
Flying the vehicle using the MAV-VUE interface on the iPhone

NIJ Divert and Alert Project

To prevent vehicle collisions and injury of officers during roadside stops

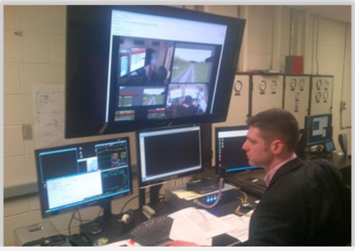
Proposed Effort: three thrusts

- Motorist Diverting Mechanism (MDM)
  - Project laser light onto roadway to guide oncoming vehicles around stop site
- Officer Alerting Mechanism (OAM)
  - Monitor oncoming traffic with machine vision, asses threat level, and generate timely warning alerts
- Human Factors
  - Easy to activate, configure, and use
  - Effective in diverting traffic and alerting officers
  - Appropriate and feasible economically and technically



FRA – MIT High Speed Passenger Rail Project

Cab Technology Integration Laboratory (CTIL)



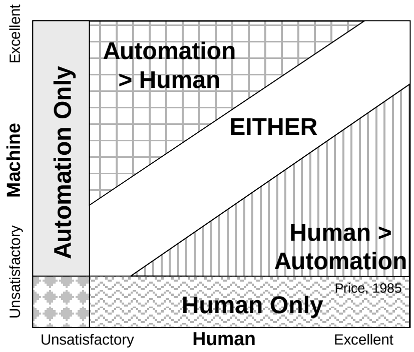
CTIL Control Room/Observation Area

- Project focuses on the use of displays to aid locomotive engineers while operating trains
- FRA sponsored project provides access to the Cab Technology integration Laboratory (CTIL)
  - Located at the Volpe Center in Kendall Square (Cambridge, MA)

HSC AND MISSION PLANNING

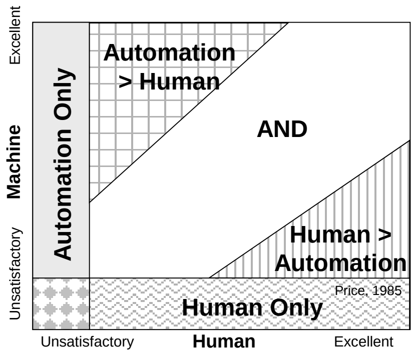
Collaborative Human-Computer Decision-Making

- Both humans and computers bring different strengths and limitation to problems solving in large problems spaces with many variables, some changing dynamically
- Determine how humans and computer optimization algorithms can complement each other
  - Decision Support for Multi-UAVs Mission Replanning
  - Scheduling algorithms for UAV and Carrier Operations



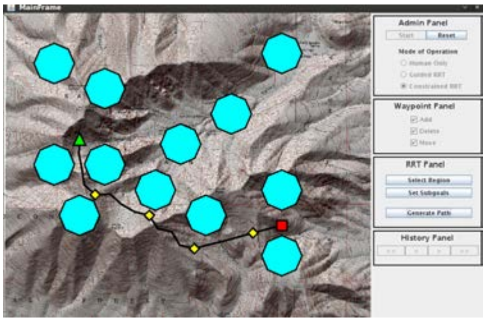
Collaborative Human-Computer Decision-Making

- Both humans and computers bring different strengths and limitation to problems solving in large problems spaces with many variables, some changing dynamically
- Determine how humans and computer optimization algorithms can complement each other
  - Decision Support for Multi-UAVs Mission Replanning
  - Scheduling algorithms for UAV and Carrier Operations



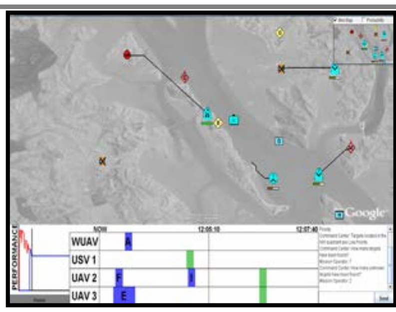
Supervision of Mission Path Planning

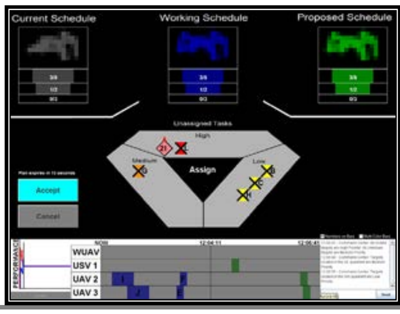
- Rapidly–Exploring Random Trees (RRT) for UAV Mission Path Planning
  - RRTs are a continuous-space path planner that produces random, but feasible, solutions
  - Goal – reduce path planning workload for human supervisors during UAV mission planning
  - Assess the sustainability of the RRT algorithm for human-automation path planning



Supervisory Control of UAVs in a Search and Track Task

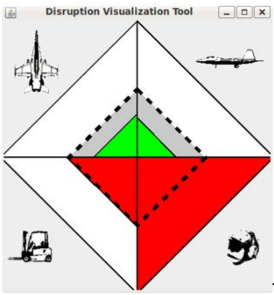
- OPS-USERS
  - Operator can now control multiple heterogeneous UVs
  - Optimization algorithms are notoriously "brittle"
  - Combine computational ability of optimization algorithms combined with the judgment and adaptability of human supervisors
- HAL has developed and tested such systems
  - Simulation-based experiments, indoor flight tests, and outdoor flight tests
  - Human-computer collaborative system can best handle a realistic scenario with unknown variables, possibly inaccurate information, and dynamic environments

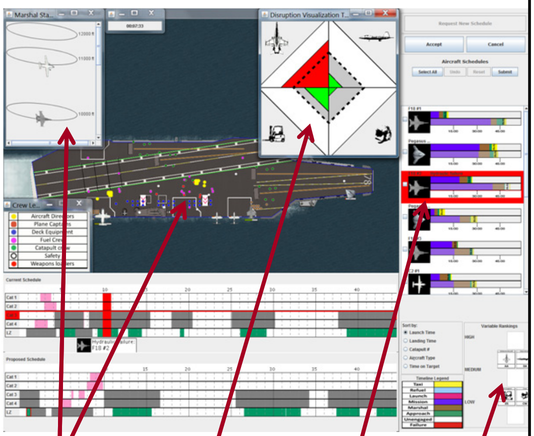




Supervision and Replanning of Complex Operating Schedules

- Deck operations Course of Action Planner (DCAP)
  - Motivation – the integration of UAVs into complex, heterogeneous operating environments
  - Objective – develop a decision support tool that enables real-time planning of aircraft carrier deck operations



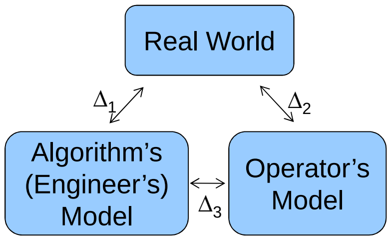


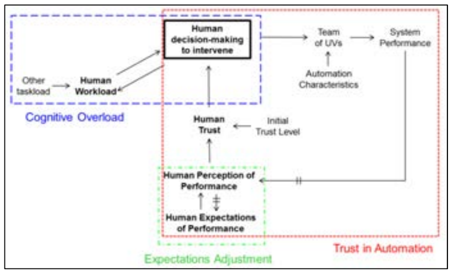
Situational Awareness components	Schedule fitness representation	Local Constraint modifier	Global priorities modifier

PREDICTIVE MODELS OF OPERATOR, TEAM, AND SYSTEM BEHAVIORS

Modeling Human-Automation Collaborative Scheduling of Multiple UVs

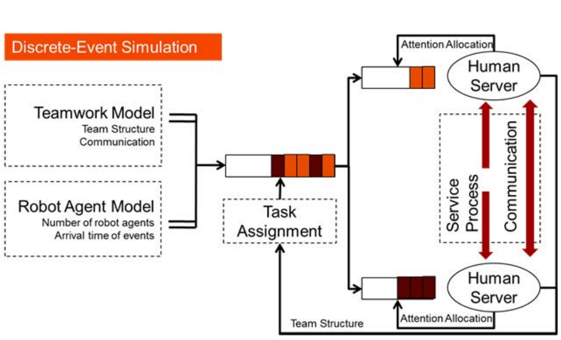
- Major challenges of collaborative multi-UV scheduling include:
  - Undertrust or overtrust in the automation
  - High cognitive workload
  - Poor goal alignment of the human and automation
- Goal: Develop a predictive simulation model of real-time human-automation collaborative scheduling of multiple UVs
  - Test the impact of changes in system design and operator training on human and system performance without costly and time-consuming human-in-the-loop testing and design iteration
- Utilizing System Dynamics modeling techniques
  - Capture non-linear human behavior and performance patterns
  - Model the impact of latencies and feedback interactions on the system
  - Utilize qualitative variables such as human trust

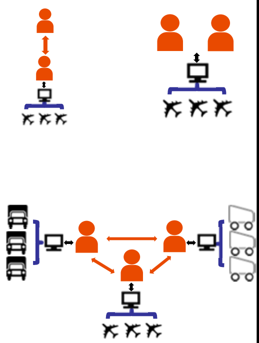




Team Models

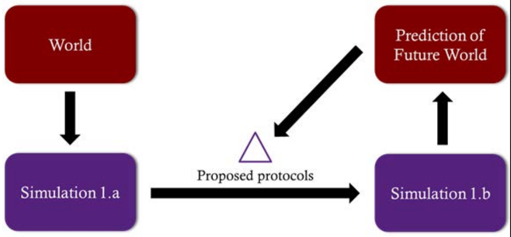
- Modeling Teamwork of Human-Agent Teams
  - Future systems of increase size and complexity, even with enhanced automation, will still require several operators
  - Communication and teamwork in this group is paramount in achieving safe and productive system operations
  - Develop discrete event models of human performance in these domains to capture effectiveness of different strategies





Simulation of Unmanned Systems for Safety and Productivity

- Multi-Agent Safety and Control Simulation (MASCS)
  - Develop agent-based simulation of Human-Unmanned Systems environments to evaluate effects of control architectures and safety protocols on performance.
  - Control architecture defines the capabilities of unmanned vehicles; safety protocols constrain their behavior to promote safety. These exists a tension between the two that leads to potentially problematic interactions. Often, testing is only done through field trials – not possible for larger-scale systems (e.g., National Airspace System)
  - Use simulation as testbed to examine the tradeoffs between the two.



Current and Former Projects

- Former projects:
  - Tracking operators' cognitive strategies in mission (re)planning (TRACS)
  - Assisting interruption recovery in collaborative time-sensitive targeting
  - Remote collaboration for urban search and rescue
  - Decision support for lunar and planetary exploration
  - Multimodal Interface Toolkit for UAV Systems (MITUS)
  - Design of an error resolution checklist for shared manned-unmanned environments (GUIDER)
  - Human-Automation Collaborative Taxonomy (HACT)
  - Configural Decision Support for Schedule Management of UAV Operations (StarVis)
  - Decision Support for Systems Acquisition (FanVis)
  - Investigating the effects of low workload in supervisory control of unmanned vehicles
  - Replan understanding for heterogeneous Unmanned Vehicle Teams
- Current Projects
  - Mobile Advanced Command and Control Station (MACCS)
  - Deck operations Course of Action Planner (DCAP)
  - Effects of vigilance on nuclear control operator performance
  - Examination of real versus perceived complexity in the nuclear control room environment
  - Minimum Information Interface for Locomotive Operation (MIILO)
  - Scheduling air for human operator surveillance tasks (HOSS)
  - Human-Automation Collaborative RRT for UAV Mission Path Planning
  - Micro Aerial Vehicle Visualization of Unexplored Environments (MAV-VUE)
  - Effects of workload transition on brain activity in ballistic missile defense operators

All publications are available at halab.mit.edu/publications

Videos at youtube.com/halabatmit

April 23-24th 2014

A Machine Learning Approach To Training Evaluation

Alexander Stimpson
ajstimps@mit.edu

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Why Train?

- Yield knowledge and skills that are useful, durable, and flexible, with the intention of improving the performance of the trainee (Bjork and Bjork 2006)

Goals of Training

Organizational
- Safety
- Productivity
- Efficiency
- Minimize time/cost

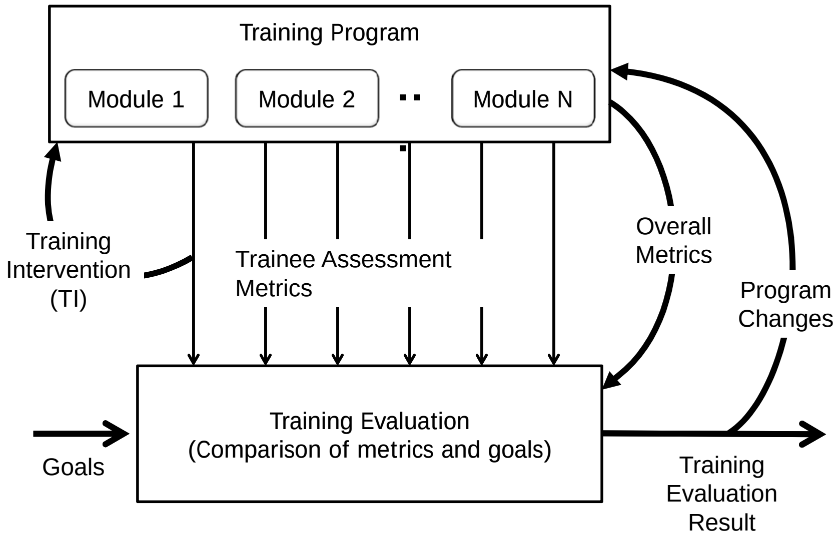
Individual
- Learning
- Job Security
- Safety

- Need to assess whether goals are met (Kraiger et al. 1993, Bjork and Bjork 2006, Eseryel 2002, Alvarez et al. 2004, Blanchard et al. 2000, Ghodisan et al. 1997, ...)

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

22

How do we know training works?

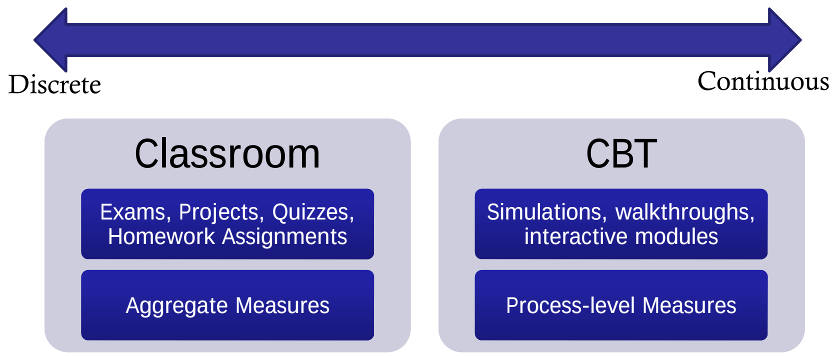


Issues in Training Evaluation

- Attempt to use in-training measures that are predictive of post-training performance (Ghodsian 1997)
- Current lack of correlations between in-training measures and post-training performance (Bjork & Bjork 2006, Christina 1991, Simon 2001, many more)
- Modern changes in trainee assessment may hold the answer
  - Computer-based training (CBT)
  - Advanced simulations
  - "Data-rich" training environments
- Can utilize machine learning approaches

Modern Training Data

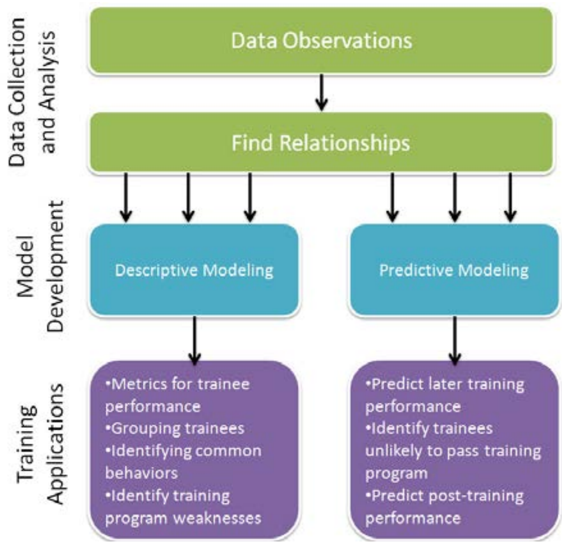
- Changes in Data Specificity



- Issues compared to traditional ML domains
- Number of data points
- Number of features
- Noise

General Approach

- Develop descriptive and predictive models of trainee performance
- Utilize machine learning algorithms as the basis for these models
  - Unsupervised (descriptive)
  - Supervised (predictive)



Case Study – Knowledge-based Environment

- Data collected from MIT undergrad/grad course (N=35)
- 19 Quizzes
- 3 Projects
- 2 Problem Sets
- 2 Exams

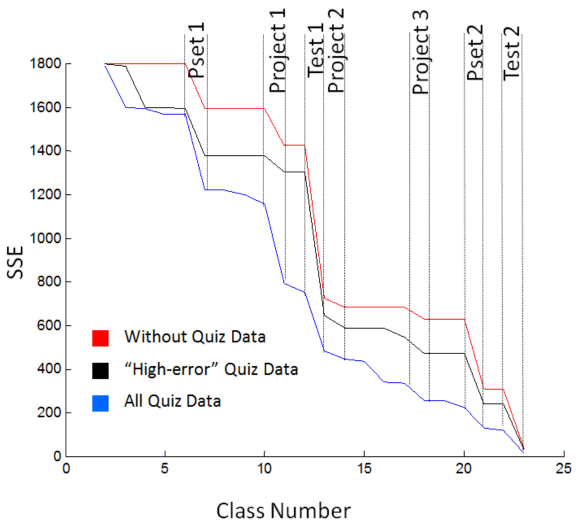
Features

- Final Grade ← **Target**

- Topics included
  - Controls
  - Displays
  - Experimental Design
  - Memory

Temporal Regression Analysis

- Training intervention relies upon early predictions of performance



Conclusions from Knowledge-based Environment

- Process-level information does not contribute to post-hoc prediction accuracy
- Process-level information made major contribution to the timing of accurate predictions – implications for trainee intervention
- Simple ML techniques provide similar prediction accuracy to more complex models
- Need subject matter experts or additional information to clarify machine learning results
- ML can act as a tool
  - Provide objective metrics for trainee assessment
  - Does not replace instructor/supervisor

Questions?

All publications are available at halab.mit.edu/publications
Videos at youtube.com/halabatmit