Technologies for Human-Robot Interactions (HRI) in Soldier-Robot Teaming
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Terrance M. Tierney
HRI ATO Manager
Intelligent Systems Business Area

Email: terrance.m.tierney@us.army.mil
(586) 574-8678 / DSN 786-8678

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## Technologies for Human-Robot Interactions (HRI) in Soldier-Robot Teaming

**Author:** Terrance Tierney

**Performing Organization:** U.S. Army TARDEC, 6501 East Eleven Mile Rd, Warren, Mi, 48397-5000

**Sponsoring/Monitoring Agency:** U.S. Army TARDEC, 6501 East Eleven Mile Rd, Warren, Mi, 48397-5000

**Abstract:**
Briefing Charts

**Subject Terms:**


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Agenda

SUPERIOR TECHNOLOGY FOR A SUPERIOR ARMY

• Background
  – Why HRI is necessary
  – Previous programs, how they feed

• TARDEC’s HRI Approach
  – Program Methodology
    • Requirements analysis/Task decomposition
    • Ontology/Behaviors development
  – Modeling Environment
    • End-to-end modeling environment
    • Constructive modeling/simulation
    • Component/system/vehicle modeling
    • Virtual and HWITL simulation
  – Technology Exploration
    • Multi-model devices
    • Interfaces
The soldier has an ever increasing task load...  

- **Interact with:**  
  - Other soldiers  
  - Manned systems  
  - Unmanned systems  
    - Ground vehicles  
    - Air vehicles  
    - Ground sensors  
- **Operating with varying**  
  - Mobility  
  - Payloads  
  - Missions  
  - Levels of autonomy  
- **While operating**  
  - Mounted  
  - Dismounted  

...and still must perform his primary mission!
Problem Definition (cont)

- Many different unmanned systems in existence
- Each system has developed unique Interface
  - Integrator specific – unique solution to unique problem
  - Typically engineering solutions – not soldier-centric
- Lack of standardization for WMI’s
- Increased complexity and diversity of systems and interfaces requires:
  - specialized training
  - Retraining/familiarization when moving between systems
- Under time critical life/death situations, this is unacceptable to the soldier
September 2002 ASB Study

Findings

- No existing program is systematically addressing the challenges of humans and complex unmanned systems interactions.
- Lack of human-robot design rigor can lead to catastrophic results.
- Catastrophic problems would result in severe setbacks to the fielding of robotic systems.
- No “user-pull” for semi/autonomous systems to couple user needs with research.
- Robotics communities are fragmented, no advocate or manager for robotics technology.
- Unfocused efforts will restrict development and deployment into force.
Create a new “systems-oriented program for analysis, understanding, development and improvement of human-robot interactions” with ARL as program steward (with other agency cooperation), stimulating spiral development.

- Requirements Community should:
  - establish operational architecture for autonomous robots
  - validate with available field testing
- FCS Increment I should have as a minimum:
  - follower robots w/ significant level of autonomy
  - surveillance and reconnaissance robots operating in limited environment
Background

- Focus is Integration
- VTI Program
  - Crew integration and Automation Testbed (CAT) ATD
  - Robotic Follower ATD
Crew integration & Automation Testbed (CAT) ATD

Technologies
- Crew Driving and Decision Aids
- Advanced Warfighter Interfaces (AWI)
- UGV, small UGV, and UAV Control
- Multi-mission Crew stations
- Autonomous Navigation for MGV
- Embedded Simulation System

Warfighter Payoff
- Enhance performance and minimize workload to support reduced crew size
- Control various unmanned systems from a common crew station interface
- Mission planning and rehearsal while deployed with embedded simulation
- Develop TTPs for unmanned systems through continual field experiments

Demonstrating the crew interfaces, automation, and integration technologies for Current and Future Systems
• COTS Sharp 20.1” TFT-LCD display was selected due to video requirements
  – Resolution: 1600 X 1200
  – Optical Response: 5 ms ON, 20 ms OFF

• Portrait Orientation
  – Allows up to 2 “SMI displays” per display

• 3 displays per crewstation
  – Combined 135° HFOV (45° each)

• Two side displays were angled for equal viewing distance to each panel

• Goal: Seamless gap between displays for indirect vision imagery
  – Display and touchscreen hardware resulted in 2” gap between displays (1” around each display)
Crew Station Features - Screen Functionality

- RSTA Viewer & Browser
- ARV Drive Tactical Map
- Target Acq Sensor & Unmanned Asset Control
Crew Station Features - Multi-modal Inputs

Multi-modal Interface

Redundant Inputs

- Hard (bezel) buttons
- Touch buttons
  - Button type indicators can be used to anticipate button behavior.
- Yoke
- Voice commands
- Keyboard/Trackball
Embedded Simulation System

**MISSION APPLICATIONS**
- Embedded Training
- Mission Rehearsal
- Mission Planning

**SIMULATION CAPABILITIES**
- Simulated Turret
- Virtual Lethality
- Virtual Sensors
- Simulated ATR
- Simulated ATT
- Simulated C2

**VEHICLE SIMULATIONS**
- Mobility
- Survivability
- Virtual OPFOR
- Virtual Friendlies

**OPERATIONAL APPLICATIONS**
- Battlefield Visualization
- Terrain Registration
- Virtual Sensor Coverage
- Virtual Lethality Coverage
HRI Program Methodology

Program Methodology

- Requirements analysis/Task decomposition
- Ontology/Behaviors development
- Modeling Environment
  - End-to-end modeling environment
  - Constructive modeling and simulation
  - WMI decomposition
  - Component/system/vehicle modeling
  - Virtual and HWITL simulation
- Technology Exploration
  - Multi-model devices
  - Scalable interfaces
Technology for Human-Robot Interaction (HRI) in Soldier-Robot Teaming

**Goal:** Provide intelligent, scalable mounted and dismounted control for unmanned ground and air systems and optimize human-robot teams

**Pacing Technologies:**
- Human-robot teams
- Intelligent scalable interface
- Intelligent agents and adaptive automation
- Recursive end to end modeling environment
What HRI provides for the Warfighter

- Reduces training/retraining burden between mounted and dismounted controlling missions
- Reduces task timelines
- Eases cognitive burden on soldier
- Provides human-centered design
- Standardizes air and ground unmanned systems interfaces
- Provides scalability for varying screen sizes
- Sheds tasks when soldier is overloaded, adds tasks to keep soldier alert
- Consolidates Army interface programs
- Optimizes soldier-robot teaming
HRI ATO and ART ATO Focus

**Soldier Focused**
- Reduce Controlling Workload
- Optimize Teaming w/ vehicle
- Scale SMI for Mounted & Dismounted Ops
- Provide like control for UGV's & UAV's

**Vehicle Focused**
- Increase current perception capabilities
- Make vehicle more survivable
- Address anti-tampering issues
- Provide tactical behaviors

**Components**
- Scalable Interface
- Intelligent Agents
- Adaptive Automation
- Increased Perception
- Survivability & Anti-tampering
- Tactical Behaviors
Intelligent Systems Behavior Simulator

HRI Knowledgebase
- Tasks, behaviors
- Models
  - Component
  - System
  - Vehicle
- Repository
  - Data
  - Software
  - Documentation

Ontology

HRI ATO-D

OWL-S Translator
Behaviors

Human Agents
Agent Workflow

Machine Agents
Agent Workflow

Workflow Execution Engine*

Resource Data Collection
and Reporting

Environment Interface

SA Knowledge Repository

Virtual Simulation
- ESS
- IWARS

Candidate Workflow Execution Engines*
- Microsaint (IMPRINT)
- Cougar
- JESS
- FCS TIN Services
- VTI DSS

Timelines Workload

Superior Technology for a Superior Army

U.S. Army Tank-Automotive Research Development and Engineering Center
Objective: Desire easy to use (intuitive) device with highest level of control.
Scalable Interface Configuration Approach

SOLDIER PREFERENCES
- Role/security (MCS commander, access levels, comms config, etc.)
- Physical characteristics (i.e. left handed, health, glasses, etc.)
- Mental (thresholds, baseline)

Environment
- Temperature
- Time of day
- Terrain
- Constraints (ex MOPP gloves)

ICV
- mission
- and tasks

RSV
- mission
- and tasks

MCS
- mission
- and tasks

Intelligent Scalable Interface Builder

WMI Intelligent Agent

WMI repository
- Intelligent Agents
- Widgets
  - behaviors
  - representations

Interrogate HW

HW Results
- Display surface size, devices, etc

Configure WMI

Hardware Systems
- Crewstation, Workstation
- Tablet, PDA, Wearable
- HMD’s
- Joysticks, yokes

ICV
- mission
- and tasks

RSV
- mission
- and tasks

MCS
- mission
- and tasks
Warfighter Machine Interface Goals

- Reduce training between systems
- Standardize interface
  - Inputs are consistent (i.e.: CTRL-C is copy)
  - Behavior is consistent ((ex: button highlights when touched)
  - Intuitive to user – in his/her mission language
  - Steps to do task match TTP’s
- Present information consistently
  - Look and feel (same font, color scheme, etc)
  - Menu system layering
  - Acronyms are identical
- Establish common unmanned system tasks (ground and air)
  - Mobility, navigation
  - RSTA
  - Fire Control
  - Communication link
  - Other
- Target processes to automate
  - Reduce/eliminate controlling aspect of mission to allow soldier to focus on primary mission
HRI Program Methodology

Systems Engineering Approach

- Technology exploration
  - Multi-model devices
  - Interfaces

- Modeling environment
  - Task decomposition
  - Behaviors
  - Constructive, virtual HWITL simulation
  - Logical integration points

- Laboratory facility
  - Recursive simulation
  - Hardware trades
Agent Development

- CAT & FFW
  - Architecture development
  - Workload analysis
  - Intelligent agent development
Alternate Approach

SOAR Tech Contract
- Adjustable Autonomy
- Extensive modeling
- Intelligent Agent development

Adjustable Autonomy Module

- Human Input
- Bayesian Task Recognizer
- Active Task Set
- Mixed-Initiative Interaction Reesoner
- Task Control Matrix
- Task Models
- Current Situation
- Human Performance Architecture
- Device Model
- World Events
Intelligent Agents/Adaptive Automation

Physiological Monitoring Methods
- Heart rate
- Skin changes
- Brain patterns
- Eye tracking

Other Monitoring Methods
- Task execution times
- Error identification
- Observation

Decision aids
Task automation
SMI design enhancements
Vehicle tactical behaviors
Sensor advancements

Monitor/Assimilate/Understand
Stress
Environment
Fatigue

Interactions
Crew members
Outside communications
Soldier

Automate/Adjust
Unmanned assets
WMI/System

Control Methods and automation levels
Other soldiers
Other battlefield entities
End to End Collaborative Modeling Environment
/ Constructive / Virtual / Live / Distributed

Payload Modeling
Unmanned Systems Modeling
Teaming & Adaptive Automation
Human Performance Modeling

Inputs:
- Requirements
- AUTL's, TTP's, FOC's
- Task analysis
- Framework
- Architecture
- Cognitive
- CAT & RF
- FCS/FFW
- Other joint programs

Optimize:
- Task, platform, payload automation mix
- Soldier workload
- Rapid WMI prototyping
- Architecture, components, processing, modularity
- Technology readiness levels
Optimal Multi-modal input combinations

- **Mission (hardware) dependent**
  - Mounted (large display area)
  - Dismounted (limited display area)

- **Potential technologies**
  - Speech recognition
  - Haptic, vibro-tactile
  - HMD’s, ocular, display size scalability
  - 3-D audio, head tracker (comms, alerts, etc.)
  - Biometrics (i.e card reader, user preferences)
  - Soldier monitoring systems (workload, stress)
  - Joystick, yoke, force feedback
  - Face recognition
  - Eye tracking
  - Gesturing