Assessing Cognitive Load for Quantifying Swarming Wave Glider System Usability

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Agenda/Outline

• Intro: China's drone display
• Need for distributed swarming systems
• Real-time-strategy game StarCraft II
• Problem statement and research question
• Literature review
• Methodology
• Proposed experiment, simulation, equipment
• Wave glider operations and why this matters
• Conclusion
• Questions
China World Record Display of 1374 Drones
The Need for Distributed Systems

• Distributed unmanned systems have the potential to:
  - Reduce cost related to human operators
    ▪ Safety systems
    ▪ Life support systems
  - Increase flexibility, functionality, and reliability
  - Reduce threats to remote operators
  - Assist mankind in exploration beyond our limits

• Swarming intelligence is a promising approach for unmanned systems that can support various missions such as:
  - Intelligence, surveillance, and reconnaissance (ISR)
  - Space exploration
  - Search and rescue operations
  - Port security
The Need for Distributed Systems

- Larger vehicles
- More extreme environments
- Ghost fleets
- Numerous heterogeneous agents
Where does the human fit and why?

• Most swarms utilized by the military will not require a human operator on board to reduce risk and improve safety

• Legal implications restrict autonomous unmanned systems from running fully autonomous

• Humans likely to participate in a remote supervisory capacity enabling them to take responsibility for critical decisions

• What might this look like?
StarCraft II: Real Time Strategy Game

• RTS games are already widely exercised today
• Players exhibit supervisory command and control to numerous units within an environment
• Requires complex strategy and situational awareness skills across multiple domains
StarCraft II Real Time Strategy Game

• Game enables ability to utilize heterogeneous or homogenous swarms to defeat enemies

• Players must balance task allocation efforts to win
StarCraft II Real Time Strategy Game

- Tasks include:
  - Managing economic resources
  - Building
    - Basic units
    - Advance units
    - Tech upgrades
  - Collecting intelligence
  - Surveys

- Multiple players at once
- Three factions to choose from
- Various strategies for implementation
- AI players trained to beat humans: AlphaStar DeepMind
While we have seen decades of research into swarming algorithm development, the community has lacked a thorough investigation of man-unmanned teaming system design performance.

Research questions:
- Which cognitive load metric is most accurate and meaningful?
- How do we design a system such that its user maximizes performance?
- How do we quantify task difficulty and understand how to compensate with automation?
- How does cognitive load limits compare when experiencing different:
  - Swarm sizes
  - Task complexities
  - System disturbances
    - Cyber
    - Faults and failures
    - Environment
- What is the right level of automation within teaming?
Literature Review on Cognitive Load

• Studies on measuring cognitive load have been done in the past to help us understand interactions between systems and tasking using various means:
  - Khawaja 2013 – Conducted a study to use non-invasive means (linguistics) to help measure cognitive load
    ▪ Fire management studies using table top exercises
    ▪ Team environment based on completing tasks
    ▪ Audio recordings and surveys used to assess cognitive load
  - Evans 2016 – Conducted a study to use eye tracking metrics to assess cognitive load
    ▪ Used real time strategy game for assessing players: Arcanium
    ▪ Varied levels of autonomy in player’s units to elicit varying performance
    ▪ Measured eye fixation rate, run-time, and surveys to assess cognitive load
  - Zhang 2018 – Conducted a study to use pulse rate variability metrics to assess cognitive load
    ▪ Used computer game to assess players performance: Plants vs. Zombies
    ▪ Varied level of difficulty to understand cognitive load response
    ▪ Used Photoplethysmogram (PPG) to measure and quantify cognitive load
### Methodology

- **sVRI (Stressed Induced Vascular Response Index):**
  - Measures the average amplitude for A1 and A2, then computes ratio

- **Algorithm Framework (Bottom Up):**
  - **Statistical Index moderating:**
    - Assesses the normality of the data
  - **Dynamic Sliding Window**
    - Enlarges the data range for smoothing out calculated index
  - **Featured Pattern Extraction**
    - Appropriately identifies features for algorithm processing
Methodology

• Choose simulation or exercise for participants to use for assessing cognitive load using swarms:
  - Agent based simulation of Wave Glider system
  - StarCraft II environment
  - Other simplified RTS game

• Assess Cognitive load using non invasive measures:
  - PPG with appropriate indexes (primary indicator)
  - Eye tracking
  - Surveys NASA task loading index

• Data analysis
  - ANOVA

• Determine which parts of the system design and interaction result in near the “red line” of cognitive limits
Experiment Proposal

- Test subjects
  - Age range
  - Experience level
  - Normalize rest state

- Behavior Executions within Missions
  - Localization
  - Payload execution
  - Navigation through environment
  - Fault injection
  - Objective change in missions

- Test environment
  - Constant conditions
  - Similar timeframe
  - Minimal disturbances
Experiment Goal

- Understand what supervisory control and decision making require the most cognitive load
- Understand what tasks and durations cause human complacency in a supervisory control man-unmanned teaming situation
- Determine which displays impact cognitive load during supervisory control
- Use results to help design autonomy to be adjustable based on cognitive load levels
- Identify overload points in supervisory control
- Understand how usable this system is
Wave Glider System

- Unmanned Surface Vehicles used to remotely monitor maritime environments
- Piloted by operators around the world using Iridium
Conclusions

• Experimentation and results can be used to influence design of swarming unmanned system interfaces
• There is a growing need for this type of integration as the demand for larger swarming systems evolve with increasing capability and size
• Metrics can be defined to help with this process, then used to develop a full model for understanding the feedback loop for adjusting system level autonomy for teaming
• Measuring cognitive load in real time can also give feedback to designers that users cannot always do verbally
References:


- 2018 International Panel on the Regulation of Autonomous Weapons (iPRAW) concluding report.
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Questions