Adaptive Human-Swarm Teaming: Sections 6-10

Paper by Aya Hussein, Leo Ghignone, Tung Nguyen, Nima Salimi, Hung Nguyen, Min Wang and Hussein A. Abbass

Presentation by Sal Altobellis and Ryan Bowering

Interaction Indicators

- Interaction Efficiency
  - Decreases when size and complexity of the swarm increases
  - More difficult for human operators to understand and keep track of whole system
  - Can be mitigated by higher level control schemes

  IEm = f(N(t)) x interaction time

- Equation for interaction efficiency for multiple units
  - N(t) :Number of units interacted with at time t
  - f(N(t)) : relationship between agents and time needed to manage system

Interaction Indicators

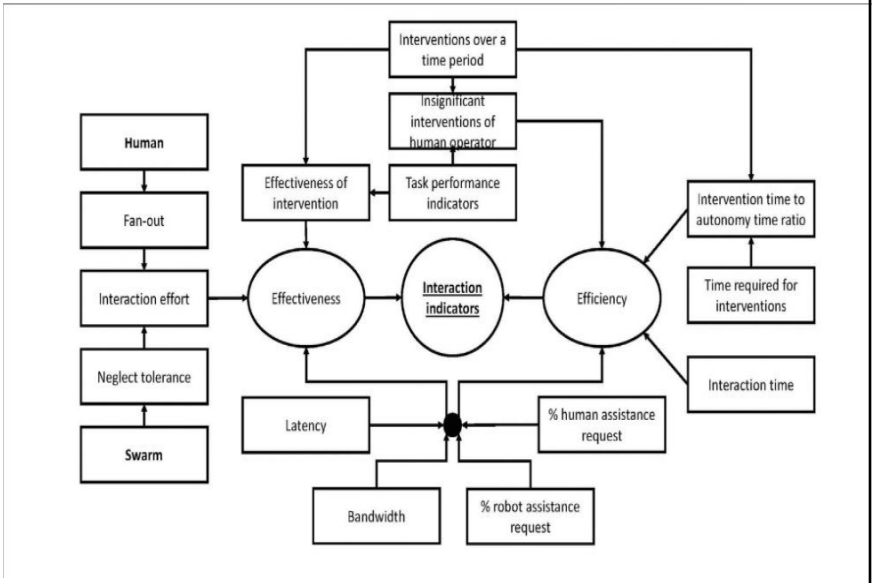
- Neglect Efficiency
  - Efficiency of units without human oversight
  - Measured as time a unit can be neglected until error threshold is exceeded
- Attention Allocation Efficiency
  - Efficiency in which human operator allocates attention between units of a swarm
  - Considers switching time between units, and the time it takes to decide which unit to help
  - In typical systems, some units must be neglected to prioritize others that are completing an important sub-objective

Interaction Indicators

- Intervention Metrics
  - Interventions are unplanned interactions
  - Estimate cognitive and mental efforts of human operator
  - Consists of
    - Average number of interventions over a time period
    - Time per intervention
    - Effectiveness of interventions
    - Ratio of intervention time to autonomy time

Human Cognitive States

- Consideration of human cognitive states can benefit the system
  - Tracking operator fatigue allows the system to adjust to reduce their load
  - Also allows for future work to be done to adapt the system better

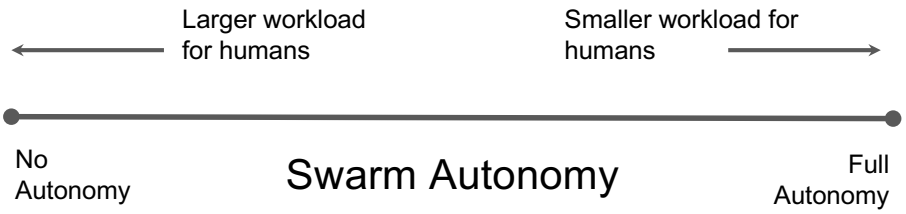


Human Cognitive States

- In order to better design the system, a range of operator data is taken
  - Questionnaires used to gather subjective data
  - Performance data is gained from monitoring error rates, reaction speed, and completion times
  - Physiological Data is also collected, using body responses to get an accurate state of the human body.
    - EEG, ERP, HR, EMG,
      - EEG, ERP - brainwave activity
      - EMG - muscle response
    - Using these to gauge user fatigue allows the system to adjust in real time
    - Allows for dynamic user profiles to be created as they use the system

Mission Complexity

- Overall level of effort needed by both the swarm an the human
- Increased mental workload for the human negatively hinders mission success
- Swarm autonomy and task difficulty affect mission complexity



Factors of Complexity

- Both objective and subjective factors impact complexity
- Subjective factors:
  - Human experience
  - Skillset
  - Self-confidence
- Objective factors:
  - Task structure
  - Interface
  - Environment

Swarm Characteristics Affect Complexity

- Level of autonomy
  - Manual control has the highest human workload
  - Increased autonomy still requires the human to maintain situational awareness
- Size of the swarm
  - Swarm level algorithms can scale fairly well with size
  - The larger the swarm, the more things can go wrong

Interface Design and Task Structure

- Swarm control method can affect complexity
- Need to provide the right amount of information
- Concurrent tasks significantly increase information load
- Problem space factors also affect mission complexity
  - i.e obstacle density for a navigation task

Human Components of Complexity

- Number of actions a human needs to perform affects complexity
  - Size of the swarm can increase required actions
  - Increasing autonomy decreases number of actions
- The scalability of a control method affects how frequently it will be used
- Higher information load requires more energy to retain memory
- More parallel tasks means more task switching for the operator
  - If tasks are similar, it will be harder to recover situational awareness

Mission Complexity Diagram

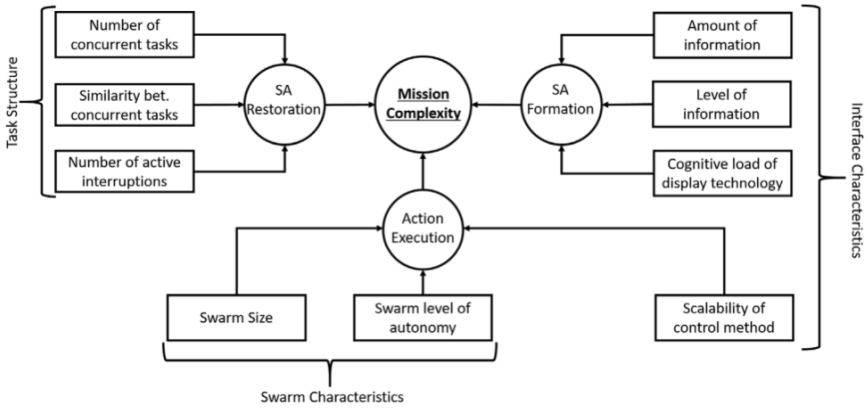


FIGURE 5 | Components of mission complexity.

Indicators needed in adaptive HSI Systems

- Mission performance
  - Specifically selected effectiveness and efficiency measures
- Interaction
  - Quantification of the interaction between the human and swarm
- Mission Complexity
  - Diagnostic information on workload factors
- Autonation Level
  - How much human intervention is needed
- Human cognitive state
  - How overloaded or underloaded the human is

MICAH Diagram

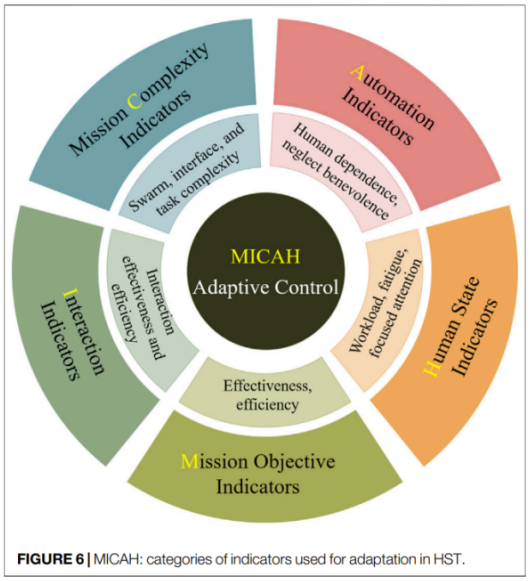


FIGURE 6 | MICAH: categories of indicators used for adaptation in HST.

Limitations of This Work

- Focused on monitoring and assessment, not adaptation
- Human experiments will be expensive
- Obtaining data for the 5 indicators isn't always trivial

Questions?