Human and Swarm Teaming Part 1

Presentation by Helen Wang and Nyomi Morris

Introduction

For ethical and functional reasons, we need humans and swarms to interact:

- Trickiness for autonomous system accountability
- Hard to fully optimize mission objectives fully human or fully autonomous

Autonomy in Human-Swarm Interaction

3 kinds of autonomy in HSI

- Fixed Autonomy
  - System could be too rigid
  - Human can become over or underloaded
- Human-based Flexible Autonomy
  - Time consuming
  - Potentially dangerous for overloaded task demands
- Agent-based adaptive autonomy
  - Adaptive agent at the interface between human and swarm

Framework

An **adaptive agent** at the interface will coordinate the interaction by managing different states of each component

It performs two tasks:

- monitoring and state assessment step
- adaptation step

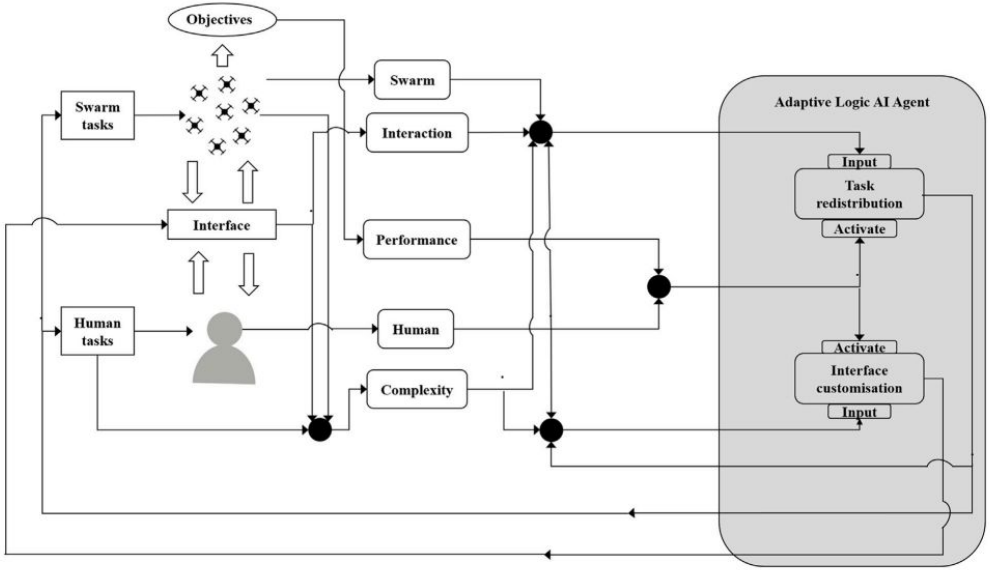


FIGURE 1 | Framework for adaptive autonomy in HSI.

Indicators

Senario: search-and-rescue (SAR)

- mission performance
  - i.e. Rate of victim collection
- swarm automation
  - How well the swarm perform
  - i.e. Number of collisions
- Interaction
  - Effectiveness of the interaction between human and swarm
  - i.e. Whether the increase in human involvement in one task causes an increase in the rate of victim collection.
- human cognitive states
  - The human doesn’t get constantly overloaded or underloaded
- task complexity

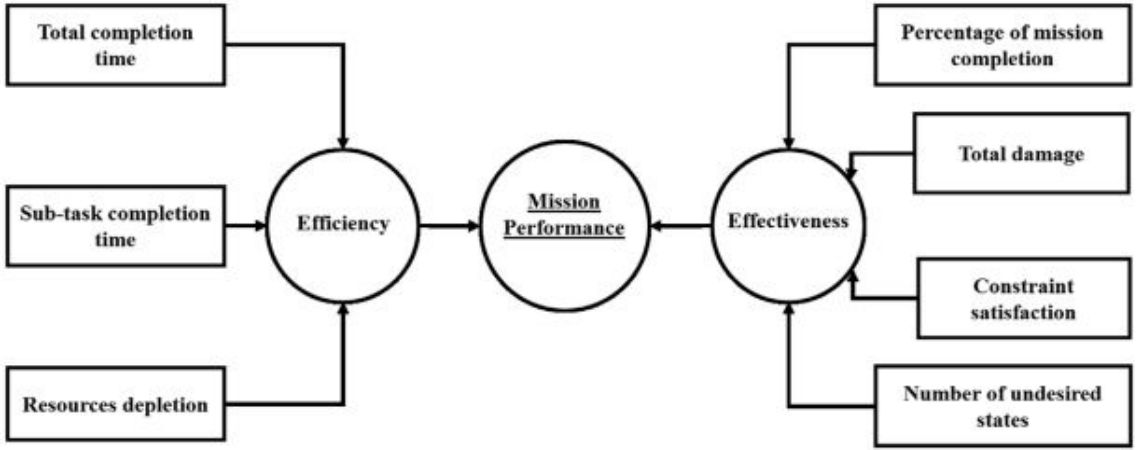
Mission Performance

Automation vs Autonomy

- Automation level - agent's capacity to perform a task
- Autonomy - freedom to make decisions

Effectiveness vs Efficiency

- Effectiveness - achieving mission success
- Efficiency - achieving success with minimal resources/time



More on Mission Effectiveness

Example from Search and Rescue

- Metrics like number of localized victims, found obstacles, packages supplied
- Assign reward points to mission effectiveness

General Mission Effectiveness Metrics

- Percentage of mission completion
- Total damage to human-swarm system (Ex: # robots lost/damaged
- Mission constraints satisfaction
- Number of undesired states (EX: obstacles encountered)

*Defining Metrics such as these are a good way that we might set up our success metric for our project!

More on Mission Efficiency

Mission efficiency tells us how competent the human and swarm are together

General Mission Efficiency Metrics:

- Total Completion time
- Time for completion of Individual Sub-tasks
- Resource Depletion

Example: For robots in SAR, if power is limited/scarce then effectiveness is affected due to limited progress. If power is non-scarce, power-consumption becomes a metric of efficiency.

Swarm Automation Level

Definition: the swarm’s capacity at a certain moment in time to complete its task without a need for human intervention.

Human dependence:

- neglect tolerance: how the performance of the robot decreases while it is being neglected
- interaction efficiency: how the performance of the robot increases when a human starts interacting with it after a period of neglect

Measurement of robot performance

$$P(\pi, C, t) = \begin{cases} P_I(\pi, C, t_{on}, T_N), & \text{if interacting} \\ P_N(\pi, C, t_{off}), & \text{otherwise} \end{cases}$$

π - level of autonomy

C - Task complexity

t - time since the start of interaction(on) and neglect(off)

T_N- time the robot is neglected before the interaction

- Cohesion
  - connectivity
- Diffusion
  - convergence and separation
- Center of Gravity
  - distance from central point to other points
- Directional Accuracy
  - accuracy of the movement comparing to the desired traveling path
- Flock Thickness
  - density
- Resource Depletion
  - the consumption of limited resources
- Swarm Health
  - Number of straggler
  - Subgroup number and size
  - Collision Count