Inter- and Intra-team Coordination from High-Level Specifications

1 Operator gives list of tasks and requirements to system

2 System assigns roles to agents, and divides agents into teams

3 Agents autonomously execute mission

4 System replans if agent failure or re-tasking by operator
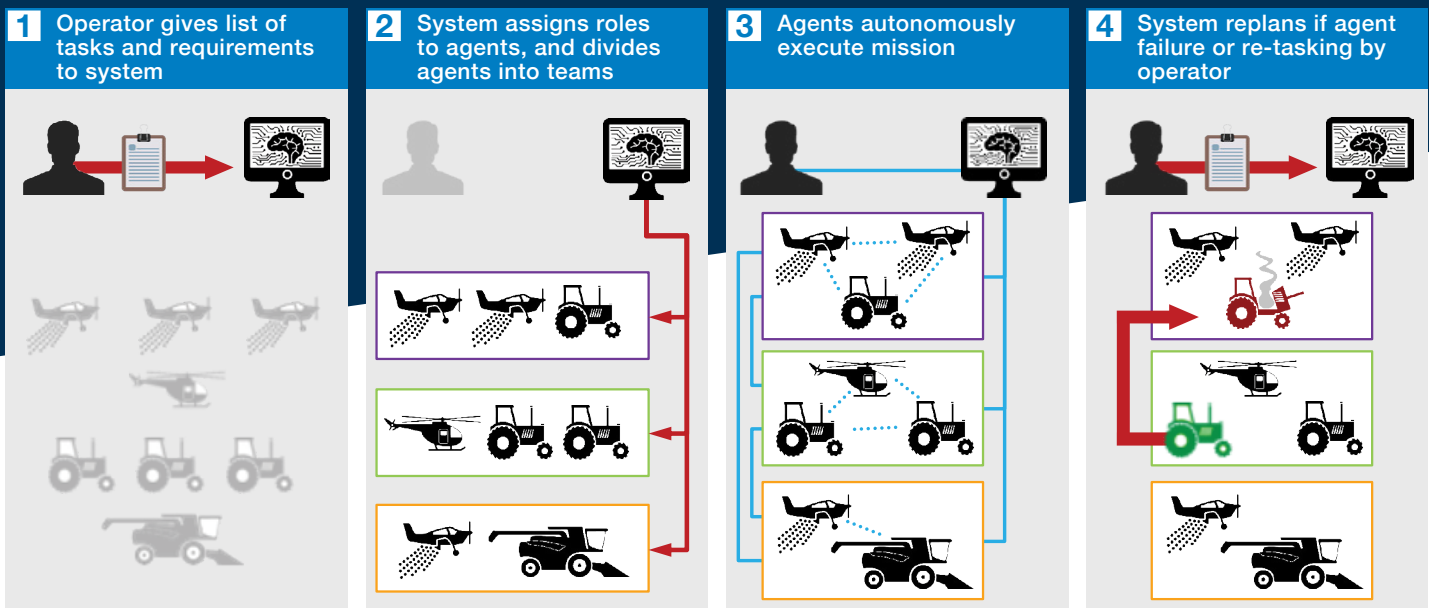
The coordination software works by taking in a list of tasks and requirements from a human operator (1). The system automatically divides the systems into sub-teams according to their capabilities and the input from the human (2). During autonomous execution of the task (3), the system detects changing mission conditions, including loss of a system, and replans accordingly (4).

Effectively managing teams of autonomous systems can overwhelm operators faced with evolving variables in their decision making. Researchers from Lincoln Laboratory and Boston University have addressed this problem with software that enables the safe, accurate control of a heterogeneous team of autonomous systems. With the push of a button, a person reliably directs the team to complete a complex task while also accommodating evolving circumstances. This software could improve the management of autonomous teams used in disaster responses, military missions, and industrial operations.

KEY FEATURES

- Automatically generates new plans from new input specifications without retraining the system on new data

- Scales to at least 50 systems, and handles teams of systems with disparate capabilities, such as different sensors or controllers

- Flexibly recovers from disturbances or individual systems' failures; unexpected changes do not prevent the success of the planned task

- Operates at near real time

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Challenge

Previous approaches for multi-system planning and coordination have fallen short for two reasons: (1) most focus on homogeneous teams in which each member is identical to all others; this focus simplifies the planning process but overlooks the reality that in many teams not all systems are identical; and (2) tools that plan complex tasks by using machine learning techniques require training the tools on specific data; each new task or change requires the tool to undergo a new round of training.

Innovative Approach

A plan for a heterogeneous team of autonomous systems to accomplish a multifaceted task must accommodate several parameters: task requirements, number of systems, and the environment in which the systems will operate. Our software automatically divides task requirements and large teams into smaller, more computationally tractable units, or sub-teams. The core algorithm is an efficient encoding of the planning problem for these smaller units into a mixed integer linear program (MILP) that allows the software to quickly find solutions to planning problems. The solutions to the MILP are then passed to a motion planner, which generates a feedback control policy that each system uses to execute its individual plan. This feedback controller is augmented by a robust safety controller that uses control barrier functions to ensure that systems, such as cars, robots, or drones, do not collide with each other or obstacles in the environment.

The hierarchical framework for inter/intra-team coordination takes in high-level operator input (top) and divides it into input for sub-teams to effectively execute (bottom). The autonomous systems communicate frequently with other members of their sub-teams, and less frequently with other sub-teams and the human operator.
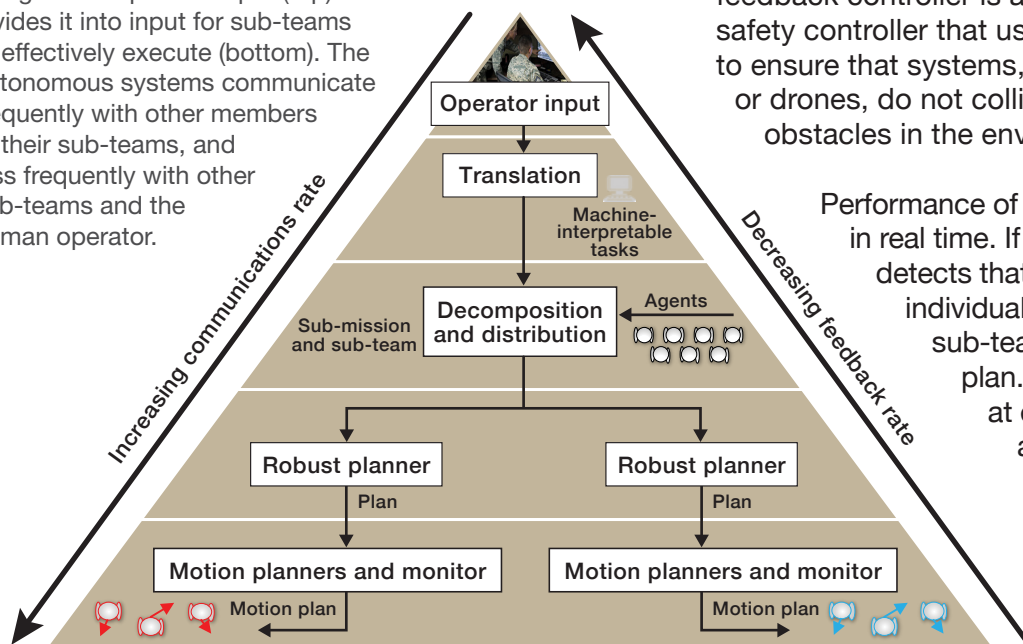
Performance of all systems is monitored in real time. If a system or its teammate detects that it will not achieve its individual objective, then their sub-team attempts to repair the plan. Similar mechanisms exist at each level, attempting to autonomously repair the plan before escalating planning back to the human operator.

More Information

A.M. Jones et al., "ScRATCHS: Scalable and Robust Algorithms for Task-Based Coordination from High-Level Specifications," *Proceedings of the International Symposium on Robotics Research (ISRR)*, 9 Oct. 2019.