Decision Support for Complex Human-Autonomy Team Missions

Julie A. Adams
Department of Electrical Engineering and Computer Science
Vanderbilt University
Nashville, TN USA
julie.a.adams@vanderbilt.edu

Abstract

Humans are very good at making daily, straight forward decisions; however, due to our propensity to be case based reasoners, errors can be introduced while making complex decisions. Technology becomes more complex daily, and as we move towards autonomous vehicles and future integration of smart robotic technology, it will become more difficult for humans to understand the fundamental functioning of this complex technology and to make accurate and beneficial decisions in very complex situations. Future mission deployments will team human personnel with heterogeneous unmanned systems that will vary not only by type (e.g., ground, aerial and underwater), but also in their intelligence and autonomous capabilities. Many complex situations differ significantly from prior events, such as a chemical explosion; thus, there is no existing accurate case to support the human's reasoning. Additionally, technology exists to incorporate factors impacting human team members' performance into the decision making process. The human mission planner can specify a number of criteria to be met by the mission deployment, but the number of factors (e.g., individual human performance differences, unmanned vehicle capabilities) can increase exponentially, overwhelming the human decision maker and leading to errors during the decision processes. Artificial Intelligence provides a number of approaches for supporting the human's decision making process and reducing the potential for error.

Coalition formation allocates a team of agents to solve a particular mission by mapping tasks to the available agents, based on mission constraints and the capabilities of the agents. There is no restriction on the type of agents to which missions can be allocated. Our research focuses on allocating teams composed of humans and unmanned vehicles; however, several limitations to coalition formation exist. The coalition formation problem is NP-Complete; thus, most coalition formation algorithms rely on algorithmic approaches incorporating heuristics to allocate teams. Unfortunately, this approach can cause coalition formation algorithms to be brittle, particularly when faced with dynamic and uncertain domains. The intelligent Coalition Formation for Humans and Robots (i-CiFHaR) system addresses this issue through a number of unique characteristics. First, i-CiFHaR incorporates a library of coalition formation algorithms that address a broad spectrum of problem domains. Second, the system uses conceptual clustering and intelligent reasoning to reduce the problem complexity and select a subset of algorithms to apply to the allocation problem. Third, if the resulting coalition does not meet all the human specified mission criteria, the human mission planner can be presented with an analysis of the suggested teams and decide to select one of the teams or modify mission criteria and request a new allocation of teams. A limitation of coalition formation is that it can only intelligently allocate the team members for the mission. Even though coalition formation ensures that the allocated team members possess the capabilities necessary to complete the mission, coalition formation does not ensure that given an otherwise specified mission plan and the given team members, that the plan steps can be carried out given the distribution of the collective team members' capabilities across the individual team members. Assume that a mission requires lifting a table and mopping underneath it. Logically to a human, a plan for this mission would be to have individuals lift the table while others mopped underneath it, in order words there is a sequence of clear and simple tasks to be completed. Standard coalition formation does not consider this sequence and simply identifies agents possessing the necessary capabilities to complete the mission. A valid solution to the allocation problem is a single robot that can both lift the table and mop underneath it, but not simultaneously. A second valid solution allocates two robots that combined have the capabilities so that the two robots can cooperate to lift the table and one of the robots can mop the floor, but both tasks cannot be executed simultaneously.

A limitation of the table lifting and mopping example is that it is very simple and easy for humans to reason over and develop a viable solution. However, determining how to respond to and allocate resources (e.g., humans and unmanned vehicles) to a complex chemical, biological, radiological, nuclear or explosive device response is not as straightforward and exemplifies the need for developing new intelligent decision support capabilities that incorporate complex mission planning with the team allocation. Such capabilities are necessary to ensure the human decisions makers do not make errors in their attempt to save lives, minimize property damage, and not place response personnel in dangerous. A complete mission planning decision support system must combine the team allocation with mission planning; however, doing so is not straight forward. The prior example demonstrates the limitation of allocation teams prior to planning the mission. An approach that plans the complex mission first, even when the mission is decomposed to simpler tasks, and then allocates the teams also may be unable to derive a solution. For example, a plan may be developed and the coalition formation is unable to allocate a team due to the distribution of the needed capabilities across the available agents. Solutions that partially plan a solution and complete partial coalition formation also suffer a number of limitations. A proper solution requires closely integrating the planning and coalition formation problems. Our team is currently developing such a solution that goes beyond standard robotic task allocation algorithms that focus on coordinated path planning. Details of this approach will be discussed.

The resulting system will provide the human mission planner with a clear idea of the derived plan and the allocated team members' likelihood to successfully complete the designated mission. One question that may lurk for artificial intelligence experts is how can such a system address human error? Three classes of human errors exist. Skill-based errors represent slips or lapses in which the human does something that they was unintended. Rule-based errors occur when humans develop intentions to achieve a goal and their resulting actions do not achieve the goal because they incorrectly apply a rule or have an inadequate plan. Finally, knowledge-based errors occur when the human's actions are unable to achieve the goal due to a lack of knowledge. The decision support capabilities provided by the described complex mission allocation and planning system have the most potential for mitigating rule- and knowledge-based human errors, but can also mitigate skill-based errors that occur during the specification of criteria a mission must achieve. The proposed system can better capture complex operating procedures and rules and couple them with a large set of real-time and historical information to develop a more accurate mission plan, while reducing the likelihood of rule-based errors. Further, the algorithm's ability to integrate and reason over large sets of real-time and historical information, such as individual human performance capabilities, will reduce the risk of human's introducing knowledge-based errors.