DELEGATION APPROACHES TO MULTIPLE UNMANNED VEHICLE CONTROL

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Abstract
We argue that as Unmanned Vehicles (UVs—a term we use to refer generically to Unmanned Air, Ground or Sea vehicles) become more intelligent and capable, and as we attempt to control more of them with fewer humans in the loop, we need to move toward a model of *delegation* of control rather than the direct control that characterizes current practice. Delegation is the process of expressing intent, by various means, to an agent who will retain some autonomy for selecting exactly how to achieve that intent—though the degree of autonomy can be highly flexible and under the control of the supervisor. We identify and describe five delegation methods which can serve as building blocks from which to compose complex and sensitive delegation systems: delegation through (1) providing *goals*, (2) providing full or partial *plans*, (3) providing *negative constraints*, (4) providing *positive constraints* or *stipulations*, and (5) providing priorities or value statements in the form of a *policy*. We then describe two implemented delegation architectures that illustrate the use of these delegation methods in different combinations.

The first is a "playbook" interface for UV mission planning and control (so called because it allows tasking UVs, either singly or in collaborative teams, at all of the levels and manners that a sports team's coach can interact with and task his or her players). Our playbook approach has emphasized goal, plan and positive and negative constraint approaches to delegation. We have previously implemented limited playbook prototypes for Unmanned Air Vehicle mission planning and Tactical Mobile Robot mission planning and control. We are currently developing a more capable playbook for heterogeneous UV control by small units in urban terrain.

The second is a "policy" interface for optimizing the use of battlefield communications resources. This approach emphasizes intent declaration by means of less concrete "policies" or value statements which guide, rather than more explicitly instructing, automation in selecting a high value approach to mission success. We believe that policy declaration will be more appropriate at more abstract and/or temporally distant levels of command and control.

For each method, the literature gives us reason to suspect that delegation affords the potential to avoid many of the traditional ills of human interaction with advanced automation including: improved situation awareness, more accurate usage decisions, more balanced mental workload, increased user acceptance, and even improved overall human + machine performance and reduced training time. While we are only beginning the implementation and testing of these approaches, initial results are encouraging. Initial experiments with our policy interface have shown that, in even a mildly resource-constrained communications environment, applying policies to the allocation of communication bandwidth can significantly increase the value of information delivered. Similarly, experiments with a limited playbook interface for controlling multiple robots in a "capture the flag" environment have shown that the flexible nature of playbook interactions proves superior to fixed levels of control, especially when opposing force behaviors are unpredictable.