Combining Narrative-Based Representations and Model-Checking for Robust Supervised Autonomy

The concept of narrative applies to human-machine systems because it (a) enables an explicit representation for interactions between actors, (b) is amenable to formal modeling, and (c) is compatible with summaries that enable human understanding. The explicit representation of narrative in emerging systems produces interactive systems that are engaging to humans and compatible with the ways humans understand and predict complex behaviors. Moreover, a narrative framework is a natural way to consider how the activities of one agent constrain or influence the activities of another, allowing a formalism for analyzing how different roles affect a mission.

Three elements of narrative-based systems enable robust human-machine interaction: First, there exist good techniques for representing narratives, including automata-based representations for encoding operator intent. Second, a narrative can be represented as a trajectory through a state space of possible situations. A mission is a planned trajectory through a state space, with agent choices and environment input alternative trajectories. Third, narrative-based systems support flexible allocations of authority and autonomy, thus allowing distributed humans and machines to robustly perform a mission.

We propose two classes of models. First, we propose to use (deterministic) timed automata to explicitly represent the set of possible behaviors of agents in the system. This builds on our previous work (Modeling UASs for Role Fusion and Human Machine Interface Optimization; Proc of IEEE Conf on Sys, Man, and Cybernetics, 2013). These timed automata are appropriate for human-machine interaction because they implicitly represent the set of afforded behaviors of the team.

Second, we propose to use Markov chains to represent likely outcomes of agent behaviors. Systems that operate in the real environment with real humans must be robust to deviations from a deterministic plan. Probabilistic models allow us to quantify performance bounds as a function of level of uncertainty and to inform a human operator of the level of persistence required to produce a robust outcome (Abstraction and Persistence: Macro-Level Guarantees of Collective Bio-Inspired Teams under Human Supervision; Proc of Infotech@Aerospace, 2012).

Model checking is particularly effective in isolating violations of system-level properties. A user posing "what-if" scenarios is able to assess possible outcomes and quickly isolate trajectories that enter high-risk, high workload, or failure situations. The proposed verification approaches will (a) use symbolic execution and SMT technology to manage state explosion and (b) leverage advances in probabilistic analysis to express bounds on high-risk trajectories. This yields the ability to detect and predict problems, with guidance on how to mediate these problems.

Narrative-based representations provide a comprehensible and flexible way to explore agent behaviors and interactions with their environment over time and from different perspectives of inquiry. We propose to use narrative-based performance summaries, building on work by the proposers for remote supervision of NASA planetary robots (NASA Phase II STTR. Anytime Summarization for Remote Robot Operations). These summaries orient personnel quickly about the performance of remote agents performing complex tasks with variable levels of autonomy. Summary measures identify what progress the agents have made and, when progress is impeded, indicate what went wrong. Trending measures determine how well agent assets are being utilized, identify opportunities to improve agent productivity, and detect impacts to productivity resulting from degraded agent capabilities. Key to our approach is the ability to summarize important differences between actual performance and performance expectations.

Keywords: ???ADD KEYWORDS???