Welcome Virtual Teammates – Modeling the Acceptance of AI-based Entities for Training

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Abstract
The goal of a team-centered training approach is to optimize both individual and team performance as a group of individuals band together to pursue complex objectives in complex environments. Teams are a common strategy for both large and small organizations to use in pursuit of their goals. This paper considers technical approaches to model and validate the performance of virtual teammates where their decision-making and behaviors are driven by intelligent agents which are autonomous entities which observe their environment through sensors and act within that environment to achieve assigned goals. In military training, virtual teammate technology has also been referred to as a "stand-in BLUFOR" where BLUFOR denotes friendly or allied forces. As with human teams, human-agent teams seek to cooperate to achieve their common goals and trust plays a critical role in the success of the team. The primary goal of this paper is to describe a validation process to raise the level of technology acceptance of virtual teammates by their human teammates.

Keywords
Human-Agent Teams, Intelligent Agents, Teams, Teamwork, Technology Acceptance, Testbed Methodologies, Virtual Teammates

1. Introduction

Higher technology acceptance by human trainees is theorized to improve both the realism of the training and the cohesiveness of hybrid human-agent teams as the level of the trust and acceptance of virtual teammates develops. Higher team cohesiveness during training is also more likely to influence improved team performance in operational (work) environments [1-3].

Training to support organizational learning goals, collaborative problem solving, and mission execution often takes the form of team training or hierarchical teams of teams planning, practicing, and working together. Indeed, many of the required 21st century digital skills and processes [4] are anticipated to shift from individual to collaborative problem-solving tasks and from individual to collective creativity while simultaneously enhancing the use of information technologies. These digital norms are improving the effectiveness of distributed teams.

The complexity of understanding the behaviors and interactions of teams is well documented in the literature [5-6]. The complexity of modeling team attitudes, behaviors, cognition, and states is what makes team assessment difficult during training. The complexity of the missions that teams train for complicates team training even more.

To offset these complexities, training departments attempt to cycle teams through a variety of challenging scenarios to exercise their critical thinking skills and decision-making processes. This is not always practical since it is not always realistic to be able to gather large teams together for training events. In the past, other human trainees would be used as training aids to support training for smaller groups. There was usually little or no training benefits for the training aids. To enable more frequent

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and efficient training opportunities, trainers have added virtual teammates to fill in for missing human team members.

As noted, team training often involves complex objectives and environments, but measuring and assessing team performance is also complex [7]. Teamwork is a large contributor to successful team performance, and team performance consists of affective, behavioral, and cognitive dimensions. Teamwork is the "coordination, cooperation, and communication among individuals to achieve a shared goal" [5]. Teamwork measurement involves the assessment of individual and team behaviors that may be difficult to capture and understand.

Many live military training systems still use human observers, Observer-Controller/Trainers (OCTs) to assess live training events and identify teamwork behaviors. The goal for emerging and future training systems is to rely more heavily on automated assessment processes and machine-based (e.g., intelligent agents) observations. Automated processes provide several advantages to developing and managing team training including objective assessments and scalability. Autonomous agents in the form of virtual teammates also pose some significant challenges and barriers to optimizing teamwork and trust. The acceptance of virtual teammates is not easily modeled, and these autonomous agents may be easily recognized by the human team members as less capable or adaptable thereby reducing trust within the human-agent team.

2. Challenges

Our goal is to anticipate challenges and design virtual teammates that can be contributing members of a fully functioning team where interdependent factors like teamwork, trust, and cohesiveness are high. This poses a significant challenge on teams composed solely of humans and greater challenges with teams composed of humans and intelligent agents. The challenges in creating high functioning mixed teams of humans and agents are technical, economic, and cultural. To optimize teamwork, trust, and cohesiveness, we focus on challenges related to communication, roles and responsibilities, affect (e.g., emotions), and trust within the human-agent team while also exploring technical, economic, and cultural barriers.

2.1. Team Communications Challenges

Teams that communicate effectively are generally more efficient and complete their missions more quickly [8]. Communications involve an exchange of information between team members to enhance their shared mental model of their assigned processes and tasks [9]. The shared mental model should provide the team sufficient information to gauge their progress towards assigned goals, support the execution of their individual roles and responsibilities, and enable their decision-making and problem-solving processes. The design process for effective virtual teammates should include concepts for ranking and regulating agent communications in terms of information importance (quality), frequency, and timeliness.

Technical barriers to team communications relate to the intelligence required to determine what information should be shared and when it should be shared. Virtual teammates should be designed with functional natural language understanding so they can maintain a mental model of the assigned processes and tasks with the rest of the team. They should also have a credible understanding of the domain and the ability to recognize the information needed by others to accomplish their roles and responsibilities within the team. For complex training domains, it can be an expensive proposition to develop speech recognition (what was communicated), understanding (what it means) and generation of information (how to respond) for an expansive corpus or collection of texts which represents the knowledge in the domain and establishes shared understanding within the team.

2.2. Team Roles & Responsibilities Challenges

While we note the importance that communications play in being effective in team roles and meeting assigned responsibilities, success involves more than just communication. Success in assigned roles and responsibilities revolve primarily around the virtual teammate's (agent's) knowledge and skills in the domain, their situational awareness, and their understanding of when (and when not to) act as optimized by reward or utility functions. A virtual teammate should understand its assigned goals as part of its roles and responsibilities within the team, but it should also understand larger team goals, the roles and responsibilities of others, and be able to assess the impact of its actions (or lack of actions) on the team's performance.

Domain knowledge should be represented as an ontology [10-11] as a method to define domain concepts, their relationships, and properties. The technical and economic barriers to defining domain knowledge are that more complex domains require more elaborate ontologies, and all ontologies require high-level skills to develop. This translates to higher complexity and development costs.

The last challenge related to roles and responsibilities is cultural. The concept of a virtual teammate is that of an augmentation to the team. The virtual teammate is there to fill in or enhance the capacity or capabilities of the team. Especially in training, the virtual teammate is not necessarily present to fill the role of the most capable team member. In fact, it may be that optimal learning takes place when the virtual teammate requires guidance, support and leadership from a human team member. So, the virtual teammate should not be designed to take over the team workload even when capable during stressful events. If it does, the concept of a team may disappear while giving rise to frustration, boredom, or other negative emotions in human teammates.

2.3. Team Affect Challenges

When we discuss *affect* this encompasses the personalities, mood, and emotions within the team [12]. While virtual teammates may be designed to express emotions, detect team member emotions, and demonstrate empathy, their emotional needs are essentially zero. However, their human counterparts may experience job-related stress based on time constraints or dissatisfaction with suboptimal decisions or problem solutions.

Given the significant influence of affect on teamwork, and teamwork as a contributor to team success, our next step is to understand which dimensions of affect might influence the acceptance of virtual teammates by human team members. According to a meta-analysis of the team performance literature [6], affective state model contributors included trust, collective efficacy, cohesion, and psychological safety. Historically, these team states have been technically difficult to detect, model, and assess. Larger teams increase the difficulty in identifying shared states. Hierarchical models have been used to chunk the model into smaller pieces [13], but reducing the team model to individual interactions can have the opposite effect by driving up computational resources during real-time training events [14].

2.4. Team Trust Challenges

Trust, part of social acceptance, is a critical element of the technology acceptance model (TAM) which suggests that the acceptability of technology (tools or methods) like virtual humans are determined by two primary factors: *perceived usefulness* and *perceived ease of use* [15]. We contend that ease of use is not a factor in the acceptance of autonomous virtual teammates since human teammates interact with, but do not program their capabilities.

Usefulness, however, infers characteristics of credibility where teammates are expected to exhibit trustworthiness and demonstrate a predictable level of expertise (competency) associated with their experience (and perhaps rank). With trust also comes an expectation of performance with measurable milestones and timely progress toward assigned goals.

Experienced individuals and teams expect (and trust) the performance of teammates as this enables them to focus on their own roles and responsibilities. It is noteworthy that trust models [16-17] are bidirectional between humans. Is it important for virtual teammates to trust human teammates, and how might the level of trust influence human-agent team performance?

Given our understanding of teams, teamwork, and technology acceptance, it is now possible to begin discussing the design process for an effective virtual teammate for training. Virtual teammates provide an advantage over human teammates in that their states and processes can be designed to support principles of explainability (transparency) and thereby enhance trust. This makes it easier to acquire measures of assessment, understand agent processes, project future states and behaviors, and to train teamwork processes and habits under a varied set of conditions. Training scenarios might include the introduction of faults to exercise teamwork skills (e.g., communication, coaching or conflict resolution).

Teamwork behaviors as indicators of team states may be used to understand developing levels of trust within a team. Observations of increasing communication behaviors including sharing of information and strong social interaction are a sign of growing team trust [18]. Identifying measures of trust is a first step toward modeling trust between virtual and human teammates. We can begin to explore methodologies to objectively assess trust and weigh its influence on team performance.

3. Discussion

In this section, we are seeking to identify the design parameters and constraints of virtual teammates. There are factors that we have touched on earlier in this paper that either increase or reduce the acceptance of teammates. Whether homogeneous human teams or human-agent teams, *individual competency*, *trust*, and *team cohesion* are factors to consider when designing efficient, cooperative, and credible virtual teammates.

3.1. Virtual Teammate Competence

Revisiting the TAM, usefulness is the perception that a particular system or technology enhances user tasks, missions, or job performance, in this case within a human-agent team. Going a step further, what measures of usefulness and methods of assessment are needed to validate virtual teammate performance and usefulness? Measures of usefulness may involve its expected utility or its quantifiable advantages over alternative methods. When considering the usefulness of a virtual teammate, the context of performance should be specified to support comparable measurement. Various contexts and outcomes may involve multiple measures of assessment with different weights. Efficiency and task proficiency should also be considered in usefulness and measures. The confidence, speed, and accuracy with which a virtual teammate executes their assigned roles and responsibilities can influence the perception of human teammates.

3.2. Modeling Trust in Human-Agent Teams

The rationale for modeling trust in human-agent teams is to determine whether it is at an acceptable level for the team to accomplish its assigned goals. If trust is not sufficient, then some intervention within the team is necessary to modify member behaviors and build trust. Can we model the development and maintenance of trust between virtual and human teammates? Usefulness in the form of actual individual performance is a basis for trust within teams. So, we can model and even manipulate trust within the team by adapting a virtual teammate's domain competency, but why would we want to do this? If the goal of the training session is to exercise leadership, it is necessary to create problems, challenges, or decision points for the team leader to address.

Is trust bidirectional between humans and agents as it is between human teammates? We would assert that virtual teammates assess their level of trust for human teammates so they can evaluate the probability of success for a given task, mission, or job. If the virtual teammate's trust for a human teammate is low, then it is likely that the probability of success is also low. The virtual teammate may elect to take specific actions (e.g., communicate more frequently) to increase the team's probability of success.

3.3. Cohesion in Human-Agent Teams

In homogenous human teams, team cohesion refers to the level of closeness that individual team members feel about their social relationships and emotional attachments, their tasks and goals, and their perceived unity of purpose. Enhancing any one of these factors will enhance team cohesion. For human-agent teams, we can expect virtual teammates can influence team cohesion by their ability to: 1) be socially intelligent and empathetic toward human team members, 2) support a set of common goals and values, and 3) be useful contributing members of the team. To optimize team cohesion, methods must be developed to validate the social intelligence, competency, and performance of virtual teammates. Only through a rigorous set of design principles and practices will virtual teammates be widely accepted as trusted agents in professional occupations.

4. Recommendations for Designing Virtual Teammates

Toward the goal of improving the acceptance of virtual teammates by their human counterparts, the authors provide the following recommended design principles and practices for their specific application in training simulations.

4.1. Knowledgeable, Skillful & Sociable Virtual Teammates

While we have invested significant time and space within this paper to the concept of usefulness (both perceived and measurable) as part of the TAM, it is evident that rapport based on sociability also plays a role in acceptance. It is not just possible, but probable that a virtual human could in some contexts be more engaging than a human, "suggesting that such technology can serve, both as a methodological tool for better understanding human-computer interaction, and as a means to establish rapport and its associated a range of socially desirable consequences" [19]. The virtual teammate design process should consider not just the knowledge and skill of the virtual teammate, but also their ability to recognize the needs of human teammates, offer help, and be perceived as useful as a supportive member of the team.

4.2. Virtual Teammates as Multi-Agent Systems

As we noted in section 3.1, the need to apply virtual teammates in a variety of contexts and outcomes involves multiple measures of assessment with different weights. A multi-agent system is a good design choice for virtual teammates since we are concerned with measures of knowledge, skill, task performance, and sociability as indirect assessments of acceptance. Multi-agent systems enhance "overall system performance, specifically along the dimensions of computational efficiency, reliability, extensibility, robustness, maintainability, responsiveness, flexibility, and reuse" [20]. Since they are modular, multi-agent systems provide easy extensibility and scalability as the system functions become more complex.

4.3. A Validation Methodology for Virtual Teammates

Now that we have determined desirable outcomes (e.g., knowledgeable, skillful, sociable) and capabilities (e.g., recognition of need) for virtual teammates, our next recommendation centers on the development of a validation methodology to measure their effectiveness/impact on team outcomes (e.g., mission performance). A testbed methodology [21] offers the opportunity to objectively evaluate virtual teammate performance in context and with rigorous measurement processes. In other words, a testbed approach offers a structured process where a virtual teammate (intelligent agent) can be assessed while performing relevant tasks under relevant conditions to an expected standard or measure of performance.

Part of the goal of such a testbed is to examine the various applications of modeling technologies to determine the one which is the best fit to the desired task or training scenario. The relevant tasks, conditions, and measures are identified as a scenario consisting of several events that exercise the skills required by the assigned training objectives. Testbed architectures have existed in many forms over the last 30 years, but have been largely driven by human observers. The US Army's Learning & Readiness Intelligent Agent Testbed (LARIAT) is designed to be largely automated.

While it is not necessary to have an automated testbed to evaluate the performance of an intelligent agent, it is the goal of the LARIAT research & development project to:

reduce the time, cost and skills required to evaluate a variety of Artificial Intelligence (AI) capabilities used in training systems

apply a testbed methodology and a set of intuitive dashboards to guide the conduct of effectiveness evaluations of virtual teammates and other agent-based technologies

provide a simulation sandbox in which to visualize and evaluate agent-based capabilities

The LARIAT architecture is currently under development and its initial prototype baseline includes an operator station called the evaluation and experimentation station (EES) which is composed of several dashboards or user interfaces for simulation scenario editing, agent editing, assessment editing, an evaluation initialization and control dashboard, and a report dashboard to visualize results as shown in the concept of operations (Figure 1).

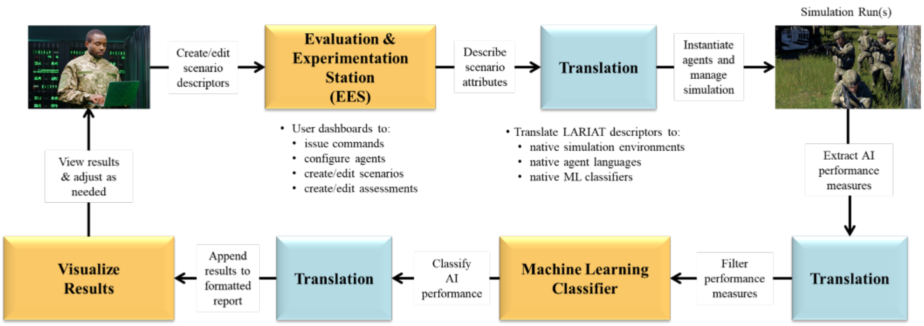

Figure 1: Concept of Operations

The EES is integrated with a runtime architecture that includes a simulation server for visualization, an agent server to control agents in the simulation, a machine learning server for agent assessment, and associated application program interfaces (APIs).

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