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Current Army Aviation combat operations utilize an employment strategy that teams a rotary wing aircraft with an unmanned aircraft system (UAS), thereby leveraging strategic advantages of each aircraft's unique capabilities, endurance, and payloads. Clear and effective communications between the airborne helicopter pilot and the ground-based UAS operator are critical for successful Manned-Unmanned Teaming (MUM-T) missions. Previous studies have recommended additional training in tactical communications for the UAS payload operator in order to support precision and timeliness in teaming engagements. In accordance with Army Learning Model 2015, an engaging, skills-adaptive, computer game was developed to train critical MUM-T skills for the UAS payload operator. The training game emphasizes the UAS operator's concise tactical communications exercised in doctrinally correct MUM-T mission scenarios with immediate Soldier feedback. Game players are initially exposed to scripted MUM-T training mission scenarios that culminate in a freeplay mission campaign. Performance measures focus on both accomplishment of mission objectives and accurate tactical communications protocol. Game players are given individual scorecards that display skill advancement and potential remediation for knowledge and skill deficiencies. An initial user assessment is scheduled for game and feature refinement. Future implementation of aggregated soldier data will be explored with UAS course instructors. Results from the user assessments and recommendations on tactical communications training will be disseminated when available.

Over the past decade, the primary role for U.S. Army unmanned aircraft systems (UAS) has evolved from simply surveillance and intelligence gathering to participating in tactical scout-reconnaissance missions. The complexity of the evolving UAS role requires the UAS operators not only to develop tactical skills (Stewart, Bink, Barker, Tremlett, & Price, 2011), but also to develop the ability to directly interact with ground units and other aviation assets (e.g., AH-64 attack helicopter). The development of these tactical and communication skills represents a training challenge for UAS operators (Stewart, et al.), especially as manned-unmanned aviation teaming (MUM-T) is formalized into operational requirements. This paper describes recent research and development conducted by the U.S. Army Research Institute (ARI) to train MUM-T skills for UAS operators.

MUM-T is a special case of aviation scout-reconnaissance operations involving a UAS and armed scout or attack helicopter as a tactical team. Each type of air platform has its own complementary asset and sensor advantages, and MUM-T exploits both. The UAS typically operates above 8,000 feet (above ground level) while the helicopter, in order to evade detection and hide from the enemy, seldom exceeds 1,000 feet on the typical scout-reconnaissance mission. Whereas the helicopter has limited endurance and must return to base after 45 minutes to one hour, the UAS can remain aloft for 6 hours or more depending on airframe. For these reasons, the UAS becomes a persistent combat aviation capability with a very different vantage point. For UAS missions, prolonged time over target yields greater likelihood to detect, identify, and report a threat than shorter rotary wing missions. As part of the Army's Aviation Restructuring Initiative (US Army Aviation Center of Excellence, 2008), MUM-T operations are being formalized in Attack Reconnaissance Battalions. Organic manned-unmanned units are being constructed, whereby the UAS platform assumes the role of scout helicopter.

In previous ARI research, communication skills were identified as the most critical among the set of skills required for UAS operators to effectively conduct MUM-T operations (Sticha, Howse, Stewart, Conzelman, & Thibodeaux, 2012). At present, UAS operators lack the formal training and common terminology that allows them to communicate in a tactical mission with manned aviators. Communication skills such as target handover and battle damage assessment require tactical knowledge as well as knowledge of proper reporting formats. There are additional communication dynamics that contribute to effective tactical communications such as timing and brevity (Stewart, Bink, Dean, & Zeidman, 2015). To address this important training gap, a training game, was developed that incorporated empirically-based training approaches for critical MUM-T skills. The game was developed in collaboration with Night Vision and Electronic Sensors Directorate as part of the Night Vision Tactical Training (NVTT) suite. The game is called NVTT-Shadow.

NVTT-Shadow Overview

NVTT-Shadow is intended to train Soldiers enrolled in Advanced Individual Training for U.S. Army 15W UAS Operators at Ft. Huachuca, AZ. Introduction to the game may occur after initial Phase 1 Common Core Aviation ground school and prior to Phase 2 aircraft-specific instruction. NVTT-Shadow is designed to augment current curriculum instruction of MUM-T-related tasks with specific focus on accurate and timely tactical communications. Gameplay is intended reinforce instruction given. For example, NVTT-Shadow can be used when there is downtime or delays in flight line training.

NVTT-Shadow is aimed at developing the tactical communication skills of the payload operator through accomplishing outlined mission objectives in routine UAS missions (e.g., Route reconnaissance, Convoy Security). Coordination with external agencies and manned aircraft scout/attack teams are emphasized. The tasks presented in the game were derived from U.S Army doctrine (e.g., Department of the Army 2009, 2014) as well as critical MUM-T skills identified in research (Sticha, et al., 2011) and other Army publications (United States Army Aviation Center of Excellence, 2014). Examples of critical MUM-T tasks include the following:

- Utilize standardized radio communication and signal operating procedures
- Provide accurate description of target to support target selection
- Perform battle damage assessment
- Conduct call for direct fires

- Utilize standard execution commands to initiate Deliberate Attack
- Call for and Adjust Indirect Fire
- Perform Target Hand Over to an Attack Helicopter
- Trasmit a Tactical Report
- Request and Adjust Indirect Fire
- Request Close Combat Attack (AH-64 cannon and rockets)

NVTT-Shadow System Description

The NVTT-Shadow software runs on two rack-mounted software servers and is displayed on a 22-in HD 1920x1080dpi monitor. Necessary controls for gameplay are a joystick, keyboard, and monitor. The laptop can be used by a game procter/instructor as a duplicate of the soldier's game display. The ability to monitor correct transcription of speech-to-text is also accessible via voice menu software residing on the laptop. The integration of client and server-side components are synchronized by a web server, which resides in a data center providing links between the User Interface and simulation services. Game software is comprised of the following three integrated simulation services that function across a Distributed Interactive Simulation (DIS) to generate the mission training environment: 1) One Semi-Automated Forces (OneSAF), 2) AVSim Flight Model, and 3) Night Vision Image Generator (NVIG). Where applicable, government-owned or commercial-off-the-shelf simulation tools were leveraged to advance scenario bulding capabilities.

The game uses intelligent, speech-enabled entities as a means to automate training and create an interactive system without requiring human role-players. Underlying technologies include the following: DIS radio simulation, intelligent behavior modeling, and a customized natural language processing (NLP) pipeline. This combination of technologies enables simulation entities to rapidly transcribe, interpret, and respond to trainee radio transmissions. A prescribed set of tactical communications protocol are supported. The NLP pipeline uses a combination of rule-based and machine learning techniques to perform information extraction, named entity recognition, and text normalization. As a result, the system is able to correctly interpret the semi-structured speech from a trainee. System robustness accommodates difficulties such as disfluencies and extraneous words that are often present in radio transmissions from trainees. The output of the NLP module is JSON-formatted data that is readily used by other game functions. All speech transcriptions and natural language interpretations are shared on the DIS network, enabling modular development and integration with performance assessment and after-action-review systems.

NVTT-Shadow utilizes a geographically diverse terrain database depicting the fictional countries of Atropia and Ariana. Terrain features include steep mountains, rivers, valleys, and coastal regions. Correlated satellite imagery overlays the wireframe terrain world, such that cultural features (e.g., bridges, roads) are represented. The presence of simulated ground vehicles and dismounted soldiers is defined within OneSAF and subsequently overlayed onto the terrain database. A single terrain database is utilized for all game missions.

NVTT Shadow Gameplay

NVTT-Shadow serves to reinforce classroom instruction with the Soldier's ability to practice tactical communication skills in an engaging and interactive gaming environment. The game is divided into Training missions and Campaign missions. Each mission begins with a briefing that outlines the high level mission objective (e.g., Area Reconnaissance) and critical actions required for success (e.g., "locate hostile threats and conduct target handover to Apache 11 using laser target marker"). The ten Training missions exercise progressively more difficult skills in increasingly complex situations. Training missions serve as a tutorial for understanding command and control of the aircraft and sensor, as well as providing training on all tactical communications executed as part of the Campaign missions. Training missions require 5-15 minutes of gameplay depending on player's skill level. The 14 Campaign missions incorporate multiple skills and follow typical Combat Aviation Brigade operations. Mission success is predicated on accomplishing mission objectives in a timely and accurate manner with the appropriate tactical communications. Campaign missions are approximately 20 minutes in duration depending on player skill level.

As players progress through the Campaign missions, they receive scores and formative performance feedback. The feedback not only provides corrective information but also guides players to remediation resources. Players are measured and scored on the transmission and content of tactical communications across five primary dimensions:

1. **Accuracy**: Did the trainee accurately describe and report the event in the scenario? Trainee utterances must match one of a set of predefined possible lexical formulations for the event. Moreover, specificity counts: for example, "red truck" is always preferred to simply "truck". Distinctions such as these are reflected in the accuracy score.
2. **Completeness**: Did the trainee report all required information for the event? Utterances are parsed into slots of required information with respect to communication type. For example, for a SPOT report, slots include number, description, activity, location, time, and "what I'm doing". Completeness is computed as the percentage of slots filled by the trainee.
3. **Order**: Did the order in which a trainee reported the event match protocol? Most communication types must follow a structured format where the order of slots of information is prescribed. Order is computed as the distance in terms of "edits" (re-arrangement of a pair of slots) from the prescribed order.
4. **Brevity**: Did the trainee report the event as concisely as possible? Brevity can be operationalized in at least three ways in the context of communications measurement for military training. First, brevity can refer to the trainee's use of "brevity codes" at the appropriate times. Second, the speed or rate of transmission of the trainee's communication can be measured (e.g., in terms of time of utterance from start to completion). Third, the "density" of information conveyed could capture an intuitive notion of conciseness. Currently, we simply measure the use of brevity codes and length of transmission.
5. **Timeliness**: Did the trainee report the event in a timely manner according to protocol? Timeliness is defined as the speed that a communication is formulated and transmitted relative to event observation in the scenario.

Measurement of these dimensions takes into account the content and form of trainee utterances, as well as contextual information from the simulation environment. For example, accuracy of a description in a SPOT report is relative to a known entity or event in the scenario captured from the DIS data stream, and timeliness is measured with respect to the event onset in simulation runtime.

Upon completion of a Campaign mission, a game scorecard is displayed containing performance scores on overall mission objectives as well as the critical MUM-T skills (see Figure 1). Mission scores are totaled utilizing a percent goal accomplished from the stated objectives of the mission. The player has transparency on how effectively he engaged the target in relation to the mission objective. Communications scoring consists of how effectively the soldier completed the appropriate communications report for a prescribed scenario event. A sample audio report of desired communications protocol is accessible via icon within the scorecard for immediate remediation training. Soldier trainees may access their play history through a tabbed window. All missions played-to-date are shown with “Date Played” and “Mission Score.” Individual advancement through the game is denoted by rank attainment displayed at the top of the scorecard. Successful mission completions are summed toward rank credit and advancement. Planned game features include the instructor’s ability to summarize class advancement against critical tasks as well as drill down capability to display individual soldier ranking data. Capabilities for querying specific critical tasks against individual data are in development plans.

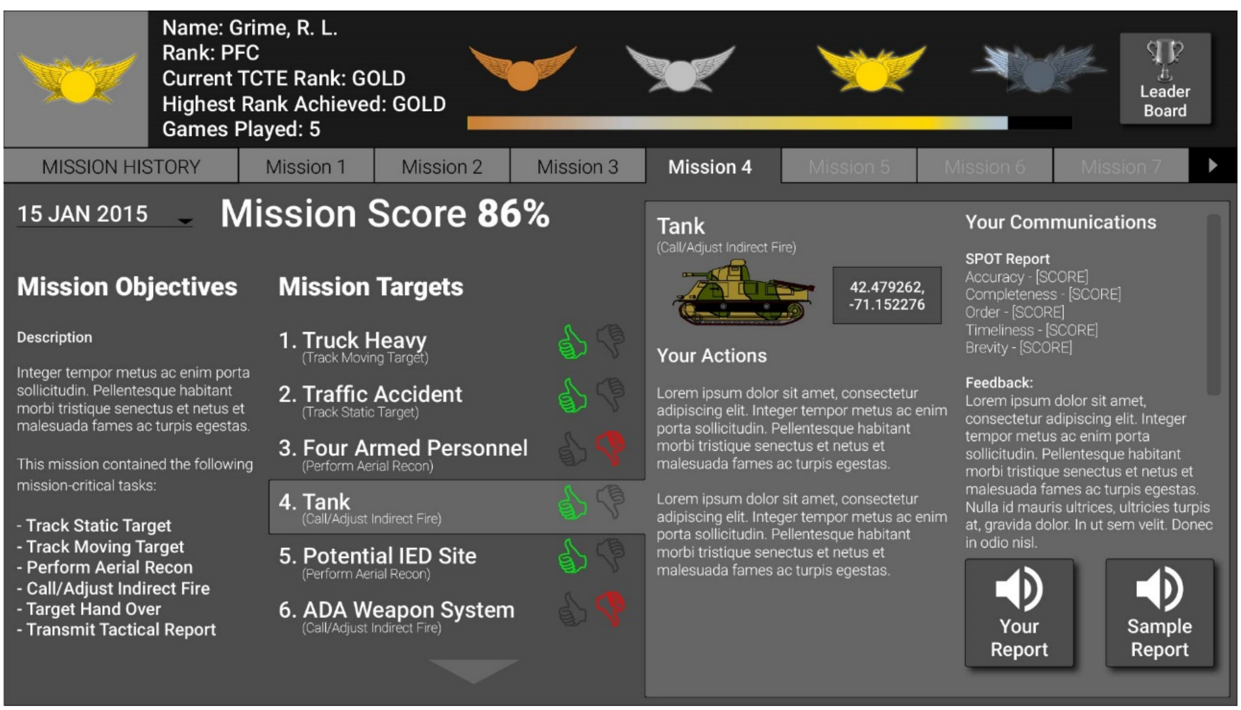

Figure 1. Example mission scorecard and formative feedback.

Utilization

Game Assessment Plans

Initial user feedback will be collected from a sample of U.S. Army 15W AIT soldiers and identified UAS SMEs. Feedback will serve to refine NLP data, scoring measures, and scorecard design. Future implementation of aggregated soldier data will be explored with UAS course instructors. Once design changes are implemented, a game assessment is planned to measure training effectiveness and tactical communications skill advancement for 15W soldier trainees. Data collection is scheduled to commence later this year. Results and critical design considerations will be made available to the training research community in later publication.

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