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Reference: Government Contract No. N00014-09-C-0050, "Enhancing Simulation-based Training Adversary Tactics via Evolution (ESTATE)"
Charles River Analytics Contract No. C08098

Subject: Contractor's Status Report: Quarterly Status Report #2
Reporting Dates: 3/15/2009 – 06/15/2009

Dear Dr. Hawkins,

The following is the Contractor's Quarterly Status Report for the subject contract for the indicated period. During this reporting period work has concentrated on Task 1: Identify Training Goals, Task 4: Develop Trainee Model Processing, and Task 6: Perform Simulation-based Training System Integration

1. Summary of Progress

1.1 D&I Program Review

A program review was held 2-3 JUN 2009 bringing together several researchers funded under Dr. Hawkins in the areas of affordable human behavior modeling (AHBM), neuroplasticity, and human, social, cultural, behavioral (HSCB) modeling. The goals of this program review were to bring ONR management up to date on programmatic developments, to explore new opportunities, to provide a setting to encourage possible future collaborations among researchers, and gather ammunition technical accomplishments and transitions to showcase the program. The ESTATE effort was briefed as a way to improve training through simulation-based training technology that provides tailored training experiences. The high-level overview presented was a way to introduce this new effort, which is at the early stages compared to much of the other research presented. While there was no immediate overlap in this research with the other work presented, this meeting allowed us the opportunity to collaborate with other research institutions in the near future.

1.2 Review of Training Manuals and Guiding Documents

During the indicated period, we were able to obtain training manual and other guiding documentation from PM TRASYS to aid in establishing training requirements and gaps. The first document reviewed was the *Irregular Warfare (IW) Joint Operating Concept*

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(JOC)[1] a strategic document for future joint force commanders (JFCs) in conducting protracted irregular warfare on a global or regional scale against hostile states and armed groups. The IW JOC defines irregular warfare as "A violent struggle among state and non-state actors for legitimacy and influence over the relevant populations. IW favors indirect and asymmetric approaches, though it may employ the full range of military and other capabilities, in order to erode an adversary's power, influence, and will." As a result, the focus becomes the legitimacy of a political authority to control or influence a relevant population, a focus that differs from conventional warfare of defeating an enemy militarily. When referring to the tactical level of war, the IW JOC identifies that "the focus is probably on asymmetric applications of tactics, techniques, and procedures (TTP) that may be applied differently in an IW operation than it would under a conventional operation."

The IW JOC refers to the 2006 Quadrennial Defense Review (QDR 2006) that helps define the concept of employing "general purpose forces (GPF) continuously to interact with aliens, build partner capability, conduct long-duration COIN operations, and deter aggressors through forward presence." In regards to this, the IW JOC identifies that one of the major risks is "operating in an ambiguous IW environment will create new mental and physiological demands on personnel conducting long-term assignments in foreign austere settings." The IW JOC recommends a mitigation procedure in regards to this risk.

> "Create IW models and simulations using **live, virtual, and constructive environments** that provide joint force leaders and members the opportunity to **practice engagement with foreign forces and populations in daily routine activities as well as IW operations. Exercise communicating, persuading, and negotiating skills** using the members' language proficiency (or lack thereof), cultural knowledge, and crosscultural communications skills."

Using this guiding direction, we can steer the ESTATE work towards addressing these goals, focusing on interactions instead of traditional combat operations. The question now becomes whether the original proposed research under ESTATE is applicable to this setting.

In addition to the IW JOC, we also obtained the *NAVMC 3500.44 Infantry Training and Readiness (T&R) Manual* [2], the established Core Capability Mission Essential Tasks (MET) for training the Marine Corps infantry battalion. Of interest within the T&R Manual is the use of simulation codes, which indicate whether (A) simulation can replace live training, (B) simulation supplements training before field/live fire training, (C) distance learning / web-based training capability exists, or (D) no simulation is available.

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[1] Department of Defense, *Irregular Warfare (IW) Joint Operating Concept (JOC)* Version 1.0, 11 September, 2007

[2] Department of the Navy, *NAVMC 3500.44 Infantry Training and Readiness Manual*

The Virtual Battlefield System (VBS) is indicated as one of the simulations that can be used for the training event. We are currently reviewing this document to see which METs are (1) appropriate for IW training and (b) can be supplemented through simulation. We have currently identified the following:

- INF-MOBL-3150: React to an unexploded Improvised Explosive Device (IED) (A)
- INF-MOBL-3152: Defend against mines and booby traps during motorized movement (B)
- INF-MOUT-3801: Execute upper-level building entry (B)
- 0300-DEF-1002: Defend a position (A)
- 0300-MOUT-1001: Perform individual movement in an urban environment (A)
- 0300-MOUT-1002: Perform individual actions while clearing a room (A)
- 0300-PAT-1005: Perform individual movement techniques (A)
- 0300-PAT-1008: Perform individual actions in a patrol (A)
- 0300-PAT-1009: Perform immediate actions upon contact with the enemy (A)
- 0300-3568 PAT-1010: Perform individual actions from a vehicle (A)
- 0300-PAT-1014: Perform unaided day/night observation techniques (A)
- 0311-OFF-1001: Perform individual actions in a fire team (A)

Unfortunately, the T&R Manuals are non-specific in regards to how the training should be performed and lack key indicators of measures of performance. Furthermore, they have not been updated to accurately reflect the needs of irregular warfare. We plan to review with PM TRASYS and PM TECOM to establish how these guiding documents can best be used.

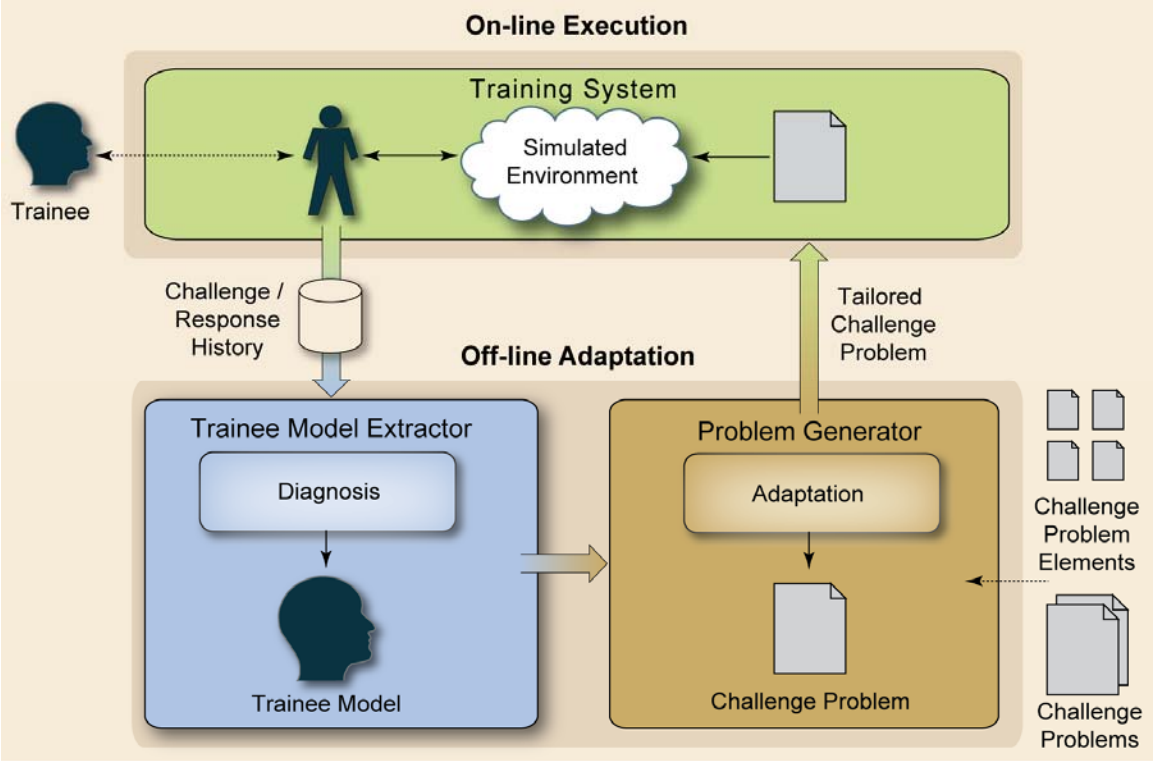
1.3 Virtual Battlespace 2 (VBS2) and OneSAF v3.0 Obtained

During the indicated period, we were also able to secure several of the simulation environments identified during the prior reporting period in-house. Specifically, Virtual Battlespace 2 (VBS2) was received on 6 MAY 2009 as part of the Deployable Virtual Training Environment (DVTE). We have since installed VBS2 on a dedicated machine. Unfortunately, however, the distribution of VBS2 is without any existing training scenarios, which would be of great benefit. Additionally, the existing models seem sparse and the editor functionality has not been fully researched. We are currently looking into the scripting capability within the simulation environment for providing reactive behavior.

During the indicated period we also received OneSAF v3.0 in-house for evaluation purposes. Since VBS2 is of higher priority as a target for integration, we have postponed evaluation of OneSAF until VBS2 is further evaluated.

1.4 Formal Framework for Challenge / Response Games

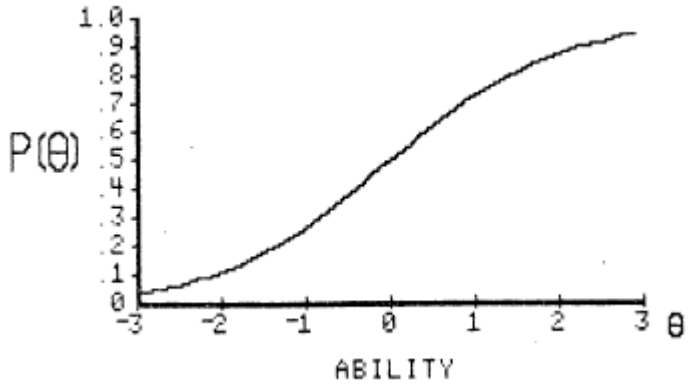
During this reporting period, we extended our work in the conceptual reformulation of ESTATE for Challenge / Response games. Previously, we established that within the challenge / response framework, a challenge problem is presented to the trainee, who then attempts to response to the challenge in the appropriate manner, doing so either correctly or incorrectly (a graded scale of performance also being possible). Based on this response, a new challenge can be generated and presented next that promotes learning. The figure below represents this process within ESTATE.



We took this conceptual framework and then began to apply aspects of Item Response Theory (IRT)[3] to help provide a computational foundation. In IRT, *ability* is used to represent and measure latent traits in individuals performing a function. We represent this term by θ. While θ can range from positive infinity to negative infinity, it is typically given a -3 to 3 range. For each item (or challenge), an individual has a probability of getting the item correct or incorrect. This probability is represented by P(θ). Since P(θ) is a function of θ, we can construct an *item characteristic curve* (ICC) that represents the probability of getting an item correct as a function of an individual's ability level. These ICCs are normally S-curves. The shape of these S-curves can be defined by several mathematical models. The *difficulty* of an item is a location index that describes where the item functions along the ability scale. For our purposes, this can be

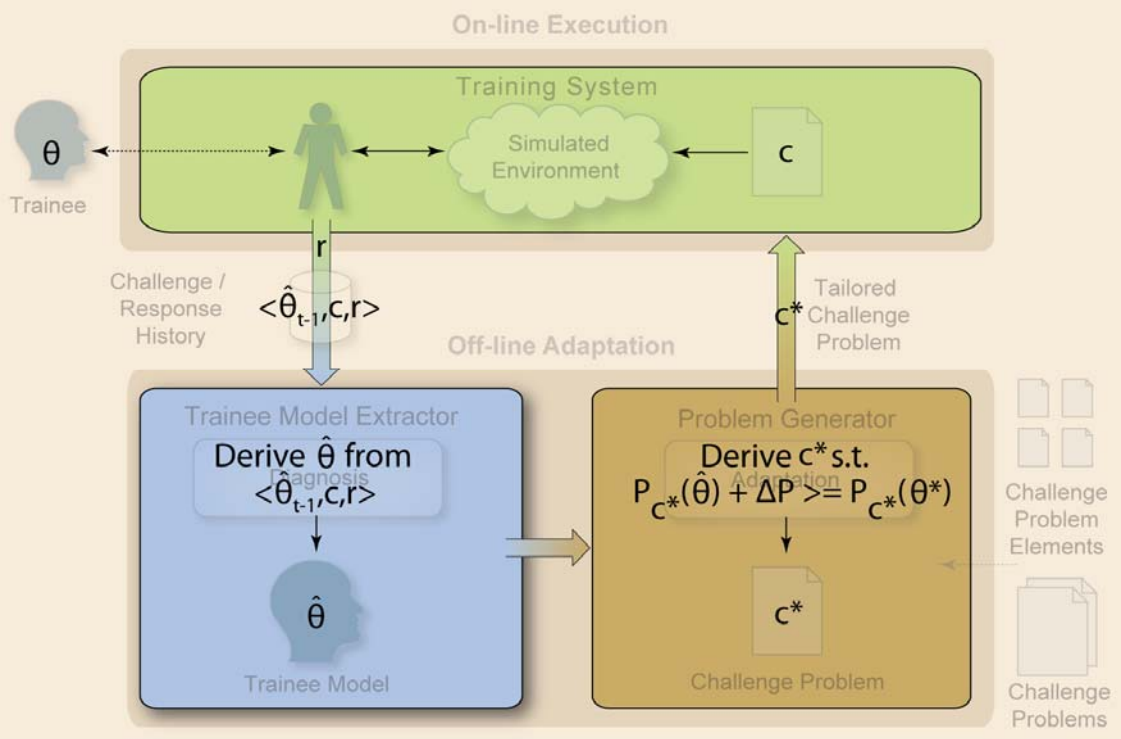
[3] Baker, F.B., (2001), *Basics of Item Response Theory*, ERIC Clearinghouse on Assessment and Evaluation, College Park, MD.

where is P(θ) = 50%. The *discrimination* of an item describes how well the item can differentiate between examinees having abilities below the item location and those having abilities above the item location (essentially the steepness of the ICC in the middle, or the slope of the line where P(θ) = 50%).



Using these concepts, we can think of the ESTATE conceptual formulation in another way. A trainee has an ability level at any given time, represented by θ_t. Since we can never know the true ability of the trainee, we can only estimate it. This estimation is assigned θ_hat_t. Via simulation, we can bring the trainee ability against a challenge c and come out with a result r. We build up a repository of these interactions as a history of tuples <c, θ_hat_{t-1}, r>. During diagnosis, we assess the current estimated skill level of the trainee based on the history of traces and determine θ_hat_t. During adaptation, we attempt to find the optimal challenge c^* that will promote learning to serve the next round. c^* can be derived from finding the challenge such that the probability of getting that challenge correct given the currently estimated ability level of the trainee is greater than or equal to the probability of getting the probability of getting that challenge correct at the optimal ability level minus some delta. Formally, $P_{c*}(\theta\_hat_t) + \Delta P >= P_{c*}(\theta^*)$. We can assume that $P_{c*}(\theta^*) = 0.5$, since at the target skill level, with the optimal challenge, the trainee has a 50% chance of responding to the challenge correctly. Furthermore, we can start with ΔP at 5% or 10% as an assumption of the zone of proximal development. We can then adapt ΔP based on the current trend in answers being correct or incorrect in recent history. Based on this, $60\% >= P_{c*}(\theta\_hat_t) >= 40\%$ with a $\Delta P = 10\%$.

Using our new formulation, we can adapt the above diagram to represent this case. This diagram is shown below.



1.5 Extracting Knowledge from MoneyBee

During the indicated period, we have begun to examine MoneyBee, a money exchange game that teaches algebra, logic, and estimation previously developed under Brandeis University's BeeWeb program (http://www.beeweb.org). First, we began by enumerating all the possible MoneyBee problems. Next, we ran our original difficulty heuristic for each of these problems. We are currently evaluating these results to see if there is any insight to be gained about problem characteristics that determine difficulty. In concert with those efforts, we have also begun to collect MoneyBee data from previously played games to an effort to see if we can come up with item characteristic curves for each problem. Since MoneyBee isn't a pass/fail game, we have cutoff answers at a designated period of time to see if the answer is correct or incorrect. The results are inherently biased, but useful. Next, we have begun to setup a simulated user who will use the ICCs to determine whether a question is answered correctly or incorrectly to answer a question of a given difficulty. We hope to analyze these results in the next reporting period.

2. Scheduled Items

During the next reporting period, we plan to focus on the following tasks:

- Revisit training goals with PM TRASYS and USMC TECOM
- Reengage with VBS2 Program Office to obtain training scenarios
- Examine MoneyBee data to determine item characteristic curves and perform preliminary experiments with simulated user data

- Discuss with Program Manager change of focus from adversary behavior adaptation to challenge adaptation

Sincerely,

Brad Rosenberg
Principal Investigator