Optically-Based Small Arms Targeting (OBSAT) for Air Defense Applications

Abstract — Cole Engineering Services, Inc., has developed technology to train operators of shoulder-fired anti-aircraft missiles during force-on-force events without the need for laser engagement systems or expensive virtual reality dome-based training environments. This technology involves the innovative use of computer vision and image processing to assess whether the operator has successfully demonstrated proper firing procedures to get credit for a hit or miss. We present the basic motivation for the task, our design, and initial results.

1 Introduction

Cole Engineering Services, Inc., has developed patented technology to replace laser engagement systems for live, force-on-force, small-arms training. We have demonstrated the ability to engage stationary, moving, and partially occluded targets at ranges in excess of 375 meters. We also compensate for the known negative training associated with laser engagement systems. We do this by using the sight picture when the trigger is pulled and state-of-the-art computer vision technology to compensate for inaccuracy of position and orientation sensors to accurately assess hits and misses.

Our recent work has applied the OBSAT technology to enabling Stinger, shoulder-fired missile gunners to participate in force-on-force field training without the need for appended equipment on the aircraft or the Stinger gunner. Previously, no full-task trainer existed to enable Stinger gunners to participate in force-on-force exercises. This paper describes the original OBSAT small arms training technology and how that led to the OBSAT ADA system. Previous training systems required an expensive dome-based training environment or the firing of real missiles. Our solution enables Stinger gunners to fully participate in field training during force-on-force exercises.

2 Previous Work in Small Arms

Laser engagement systems for small arms training have a number of known limitations that lead to negative training. Stuster and Coffman showed that there is a significant reduction in unit casualties after a unit's first five firefights [1]. A major contributing factor to the higher casualty rates was shown to be improper use of cover and concealment. Obstacles that provide only concealment in the real world also appear to provide cover in training using laser engagement systems, which perhaps contributes to these higher, early casualties. Laser engagement systems contribute to negative training by subliminally blurring the line between cover and concealment. Laser engagement systems also reinforce bad basic rifle marksmanship habits, such as failing to lead moving targets and not adjusting barrel elevation based on target range. For example, the M-203 grenade launcher is a major weapon system in the infantry squad, but the grenadier cannot practice employment of this key squad weapon during force on-force training, and squad and platoon leaders cannot train on the tactical employment of these systems.

Conventional wisdom says that to replace laser engagement systems with mathematics or "electronic bullets" a system must know the position of all participants to 4cm of accuracy and the weapon orientation to 100 micro radians. That is two orders of magnitude more strict than current, feasible sensor accuracies in a field environment without significant sensing infrastructure. We compensate for lack of sensor accuracy by using a piece of information that was heretofore unavailable: the sight picture when the trigger is pulled. With this sight picture, the inaccurate position and location information, and sophisticated computer vision technology, CESI has developed patented technology that has been demonstrated for shooters to engage targets at 375 meters or longer, whether stationary, moving, or partially occluded [2]. This technology requires little appended equipment beyond a soldier's go-to-war kit. We are currently maturing this technology with an eye toward possible replacement of laser engagement systems in the foreseeable future.

3 Air Defense Application

Having successfully demonstrated this capability for small arms, we were asked to apply the technology to Stinger missile training. The intuition behind this approach was that the current orientation and location technologies used for OBSAT are sufficient to identify which aircraft is the intended target for identification of friend or foe (IFF) and target engagement. The original requirement for the OBSAT Air Defense Artillery (ADA) project did not include IFF, but we found that the technology easily supported implementing that feature. The overall architecture of OBSAT ADA is shown in Figure 1 and Figure 2.

The OBSAT ADA application includes a player unit, which is an Android-based smart phone, as a surrogate for the US Army Net Warrior device or the US Marine Corps (USMC) Marine Air Ground Task Force (MAGTF) common handheld. The surrogate Stinger missile system includes an embedded thermal scope to simulate the thermal seeker of the actual missile.

The player unit collects the location and orientation information and passes that to a common training instrumentation architecture (CTIA) gateway as shown in Figure 2. The OBSAT gateway subscribes to the position location information (PLI) of any aircraft in the training area. We use the orientation and location of the Stinger missile compared to the PLI of aircraft to determine which aircraft the gunner is targeting.

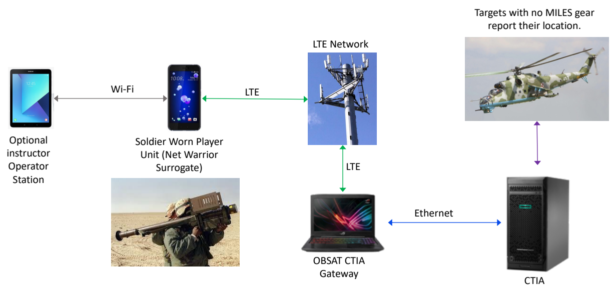

Figure 1: Overall block diagram of OBSAT ADA

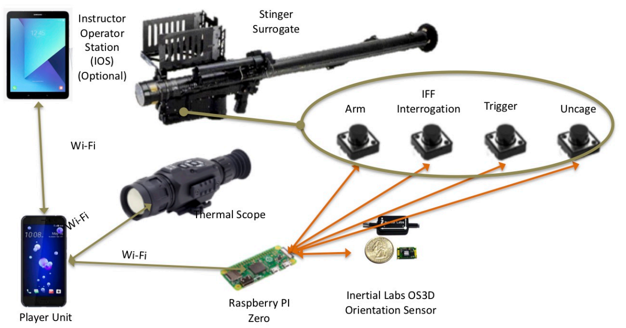

Figure 2: Overall block diagram of the OBSAT ADA player unit.

Given proper identification of the target, OBSAT ADA stimulated the IFF system. When the IFF interrogator trigger is pulled, OBSAT ADA passes that information to a common training instrumentation architecture (CTIA) gateway. If it is a friendly aircraft, the player unit passes this information from the gateway to the surrogate Stinger which plays the "friendly" tone. Otherwise, the "enemy" tone is played.

When the trigger is pulled to fire the missile, OBSAT ADA captures the previous five seconds of video from the thermal scope. Using image processing technology, we determine whether the gunner properly tracked the target and whether the gunner properly super-elevated the Stinger before firing. This image processing is performed on the Android player unit. A fire message is sent from the player unit to the gateway along with the results of image processing. The gateway then adjudicates the shot and determines a hit or miss. By performing the hit adjudication in the gateway, OBSAT ADA collects information from CTIA about whether the target aircraft deployed any countermeasures to adjust the probability of hit. If the missile is judged to have hit the target, we send a "kill" message to CTIA, which forwards that to the affected aircraft. We also provide feedback on the player unit to let the shooter know whether he properly engaged the target and whether the shot was a hit or miss.

OBSAT ADA also has a stand-alone mode. The previous description, using CTIA, explains how OBSAT ADA enables Stinger gunners to participate fully in force-on-force exercises. OBSAT ADA has an additional mode in which an instructor can evaluate the performance of the Stinger gunner through a tablet computer. This instructor tablet can be used with or without CTIA.

4 Future Work

The OBSAT ADA Stinger device was specifically designed with the back portion of the missile available for pyrotechnic devices that would provide an appropriate heat and light signature that would enable aircraft to react properly to being engaged. The current implementation enables OBSAT ADA to notify aircraft that they have been engaged and killed, but additional messages and aircraft instrumentation must be developed to notify the aircraft that they have been interrogated by an IFF system so that they can begin to employ countermeasures. Similarly, CTIA does not currently collect information from the aircraft about any countermeasures that have been deploys, so those countermeasures have no effect on the probability of hit of the Stinger missile. We overengineered the thermal scope to ensure success of the initial effort. We plan to conduct experiments on reducing the cost, range, and resolution of the embedded scope to determine the minimum sufficient capability. Finally, additional hardening and testing for compliance with environmental resistance standards must be conducted.

5 References

[1] J. Struster and Z. Coffman (2010). Capturing Insights from Firefights to Improve Training. Defense Advanced Research Projects Agency. Santa Barbara: Anacapa Sciences, Inc.

[2] J.R. Surdu, J. Crow, R. Noriega, C. Ferrer, P. Garrity, "Optiically Based Small Arms Targeting." *Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC) 2016*, 28 November - 2 December, 2016.

Author/Speaker Biographies

Dr. John R. "Buck" Surdu is a Senior Scientist at Cole Engineering Services, Inc. Dr. Surdu is a retired US Army colonel with a Ph.D. in Computer Science. His research interests are diverse and include improving the fidelity of live training, integration of simulation and mission command, and artificial intelligence.