SENSORS FOR DYNAMIC RETARGETING OF EXTENDED RANGE MUNITIONS

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ABSTRACT

The Sensors and Electron Devices Directorate of the Army Research Laboratory (ARL) has developed a simulation that integrates digital map data, sensor models, target models, networking, communication, and battlefield dynamics into a framework for virtual experimentation. We show the use of this simulation to predict targeting capabilities and to evaluate potential of notional sensors and distributed sensor concepts to provide relevant and timely location information for indirect-fire extended range munitions.

1. INTRODUCTION

An important element of Army transformation efforts is the development of significantly improved munitions. A centerpiece of this activity is the Armaments Research, Development, and Engineering Center (ARDEC) led Multi-Role Armament and Ammunition System Advanced Technology Demonstration (MRAAS ATD). Among the aggressive goals for this program is a capability to achieve "one shot… at least one kill…" for non-line-of-sight encounters at extended ranges. This objective places unprecedented requirements on sensor technology. At these extended ranges the latency between the time that the sensors detect the target and the time of seeker acquisition will lead to errors in the estimate of the location of moving locations. This error can easily increase to the extent that, at extended ranges, the required search area of the munitions seeker will be so large as to make it more probable that a false target will be engaged instead of the desired target. We illustrate this in figure 1 for a scenario where (1) a cluster of ground sensors measures the target position and velocity at some time prior to firing, (2) a firing platform predicts the projected target position and fires the projectile, (3) by the time the seeker is activated the target has changed course and is not within the seeker window.

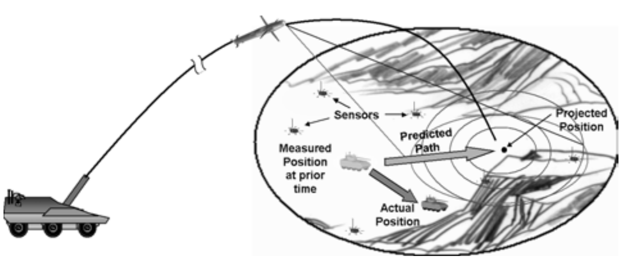

Figure 1. Impact of latency.

A way to overcome this target-location latency is to enable the sensors to provide updated predictions of the target location as the projectile approaches the point of engagement. These sensors might be located on a scout vehicle or a UAV, or they may be a part of a low-cost distributed sensor network. These sensors must be able to detect, locate, and track the targets; to predict their positions; and to periodically uplink that information to the projectile while it is in flight. For extended range encounters, where the target may have moved one or two kilometers since the projectile was fired, these dynamic updates of target location would enable the projectile to be more responsive to target maneuvers. In addition, these dynamic updates would permit a smaller seeker window; thereby, reducing false alarms and making the projectile more lethal.

2. APPROACH

Our approach is to develop a simulation that integrates digital map data, sensor models, target models, networking, communication, and battlefield dynamics in order to predict the targeting capabilities. The visual portion of the simulation is built around digital map data from the National Imagery and Mapping Agency. A graphical user interface (GUI) permits the user to select a region of the map for a detailed view and to create battlefield scenarios through sensor and target configuration submenus. We position sensors onto a digital map; specify their type, complexity, supervisory capability, and the standard deviation of the Global Positioning System (GPS) error associated with the sensor position; and define cueing strategies. We also position targets onto the same digital map, characterize them, and define their movement through waypoints. Target characteristics, such as radar cross-section (RCS) and spectral representation for acoustic sensors, are based on data and modeling. Currently, the user can select from an acoustic sensor, an array of acoustic sensors, and a number of RF sensor types differentiated by range resolution and velocity resolution.

3. IMPLEMENTATION AND OUTCOMES

Since any simulation is only as good as performance models, we are building the physics into the sensor models. The RF sensor model is modular software package that can emulate variety of radars. By modifying input parameters, we can accommodate different waveforms and tailor the sensor to the application. The acoustic sensor is a derivative of a detailed model, developed in the Computational and Information Sciences Directorate of ARL. This model accounts for atmospheric and environmental effects that lead to phenomena such as diffraction. Since this model is very computationally intensive, we use the existing software tools to pre-calculate and pre-store the signal-to-noise ratios (SNR) for different scenarios as look-up tables. The appropriate scenario can then be determined based on the characteristics of the terrain between the target and the sensor, and the appropriate SNR look-up table can be accessed. Once the SNR is known, a probability of detection (Pd) can be selected for a desired probability of false alarm (Pfa) based on pre-stored values that have been calculated based on certain assumptions about the nature of the background noise.

At each time step we play out battlefield dynamics, update sensor status, and provide estimates of target location to the command platform. When the sensors have completed a coherent processing interval (CPI), a fusion routine is called to collate detection information in order to locate moving targets in this distributed sensor environment. In figure 2a we show detection of a target by 3 low range resolution (LRR) RF sensors, for which the range gates are 20m wide. The sensors report the range and Doppler velocity of the detected target within the resolution limits. We collate the detects from a number of individual sensors in such a way to yield the estimate of position and velocity (fusion site). Since there is some width to the LRR gates, we can only calculate an estimate of the target location. For the case of multiple sensors and multiple targets, the number of fusion sites becomes quite large. In order to deal with this multiplicity of detect combinations originated by multiple sensors and multiple targets (fig. 2b), we first collate the detects to form fusion sites and then we centroid the fusion sites to form the estimates of position and velocity.

These centroided positions and their respective Doppler velocities are passed to the moving target indication (MTI) tracker. The MTI tracking model associates the centroids of the fused detections with existing tracks (if any), selects the best fits amongst these multiple associations, forms track-measurement bindings, updates existing tracks based on these bindings, initiates new tracks when measurements do not have track bindings, and kills expired tracks. In figure 3 we show the MTI tracker response to three targets moving through a field of 14 ground RF sensors. As the targets move through the field (shown by the three lines), (1) the fusion routine collates the sensor detects and provides the fusion points (the black dots), (2) the centroiding routine then uses a voting scheme to determine centroids of fusion sites (the light gray boxes), and the tracker establishes and updates the tracks (shown with the symbols □, ∗, Δ, □, and ×).

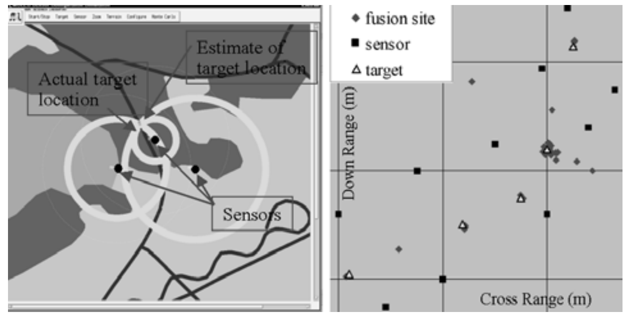

Figure 2. Detection of (a) single target and (b)multiple targets.

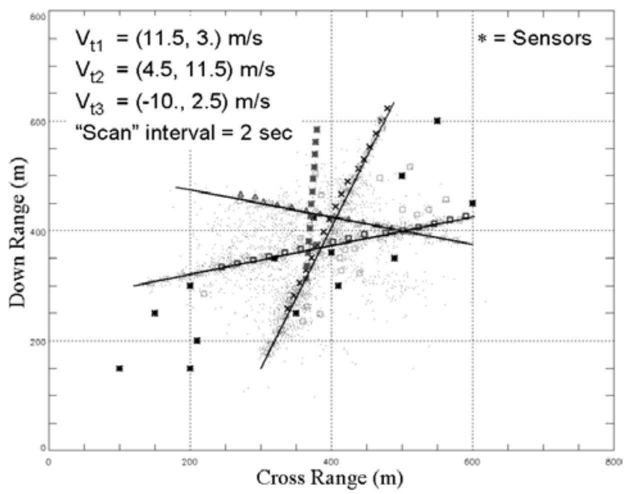

Figure 3. Tracking three moving targets.

4. CONCLUSIONS

We are developing a simulation with which we will be able to assess tradeoffs between individual sensor complexity (and cost) versus the military significance of the information gathered, to evaluate potential of notional sensors and distributed sensor concepts to provide relevant and timely location information for indirect-fire extended range munitions, to describe sensor error budgets for endgame lethality models, and to assess methods to improve seeker capability based upon having access to dynamic information.