CONSERVING NETWORK BANDWIDTH: INVESTIGATING AN ALTERNATE APPROACH TO LASER DESIGNATION IN DIS

Randall K. Standridge, Senior Research Engineer
John D. Micheletti, Research Analyst
Southwest Research Institute
6220 Culebra Road
San Antonio, Texas 78228-0510

ABSTRACT

The current standard for Distributed Interactive Simulation (DIS) applications specifies that simulation entities use the Designator Protocol Data Unit (PDU) to communicate laser designation in support of laser-guided weapons engagement and delivery. The standard also specifies that during lasing activities this PDU be broadcast at a fixed 10 Hz rate. Documented implementations of the Laser (or Designator) PDU have raised questions regarding the use of this fixed transmission rate. While exercises involving relatively small numbers of entities pose little potential for network loading problems, larger exercises may well dictate approaches to conserve network bandwidth. This paper provides the results of a quantitative investigation of an alternate laser designation PDU implementation utilizing laser spot velocity and first-order dead reckoning. The target tracking data used for this investigation was obtained from the Deployable Forward Observer/Modular Universal Laser Equipment (DFO/MULE), a system which provides target acquisition and tracking training for Artillery Forward Observers, Naval Gun Fire spotters, and Forward Air Controllers, as well as laser designation and rangefinding training. PDU transmission rates were calculated from this data based on various dead reckoning thresholds, and the overall performance contrasted to the current fixed-frequency approach. The lessons learned from this investigation are discussed, along with suggestions and recommendations for future study.

ABOUT THE AUTHORS

Randall K. Standridge is a Senior Research Engineer in the Training Systems Development Section at Southwest Research Institute. He has over six years of experience in systems modeling, analog and digital design, and system integration and testing as applied to training system development. He received a B.S. and an M.S. in Electrical Engineering from the University of Texas at Arlington. Address: Southwest Research Institute, 6220 Culebra Road, San Antonio, Texas 78238. Telephone: (210) 522-3992.

John D. Micheletti is a Research Analyst in the Training Systems Development Section at Southwest Research Institute. He has over ten years of experience in the design, coding, testing, and documentation of avionics and simulation software systems. He received a B.A. in Computer Science from the University of Texas at Austin.

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INTRODUCTION

Volatile modern-day battlefield conditions require that targets be quickly and accurately located for conventional munitions as well as the array of laser-guided weapons available to military air and ground forces. Field commanders, who need to know where enemy-held positions and targets are located, rely on forward air controllers and forward observers to provide target coordinates. Laser designation systems have been developed in order to provide these personnel with a means of acquiring and accurately locating targets for attack by supporting artillery, naval gunfire, and close air support elements. In addition, laser-based weapons currently under development may also contribute to the proliferation of lasers on the battlefield.

In recognition of laser designation's role in modern combat, the current standard for Distributed Interactive Simulation (DIS) (DIS 2.0 Draft 4) supports laser designation simulation through the Designator Protocol Data Unit (PDU). This PDU provides information in support of laser-guided munitions engagement and is broadcast at a fixed rate of 10 times per second during any designation. In addition to specifying a laser spot location, this message also identifies the lasing entity, the entity being lased, and designator-specific system information (e.g., laser code, wavelength, and power).

As previously documented (Standridge et al., 1994), this fixed 10 Hz transmission rate utilizes a disproportionate amount of network bandwidth. Larger distributed exercises may dictate alternate approaches to transmitting the Designator PDU in order to conserve bandwidth, such as lower fixed broadcast rates or laser spot dead reckoning. This paper specifically addresses the application of dead reckoning models to the Designator PDU, an approach first recommended by Evans (1993). Although currently supported within the DIS community, issues such as threshold criteria and appropriate dead reckoning models have not been previously addressed.

This paper describes the simulated laser designation system utilized in this investigation. Next, the approach used to obtain representative tracking data is discussed along with the methods implemented for calculating laser spot velocity for dead reckoning. Finally, the quantitative results of the investigation are discussed and conclusions drawn from the analysis are presented.

SIMULATED DESIGNATOR SYSTEM OVERVIEW

The simulated laser designation system used in this investigation was the Deployable Forward Observer/Modular Universal Laser Equipment (DFO/MULE), a modular personal computer (PC)-based system designed to provide training for MULE, Naval Gun Fire (NGF), Artillery (ARTY), and Close Air Support (CAS) personnel. Figure 1 illustrates the system configuration consisting of an Instructor Operator Station (IOS), a projector image generator computer, a MULE image generator computer, a high-resolution projector, and a simulated MULE.

The MULE image generator produces a simulated Laser Designator Rangefinder Module (LDRM) daylight scene with a 3.6-degree field of view. The background scenes used on all display devices are digitized high-resolution terrain images producing an extremely rich visual presentation. Terrain scene images are derived from Digital Terrain Elevation Data registered and correlated with elevation data (DTED) so that accurate visibility effects (occulting, pitch, etc.) are rendered for moving targets and munitions effects.

The LDRM images are produced on a 640x480-pixel liquid crystal shutter monitor with separate reticle and focusing optics through which the designator views the terrain and target images. The simulated LDRM images are correlated to a separate wide-field-of-view image by means of a highly accurate set of position-encoding hardware mounted within a Stabilized Tracking Tripod Module (STTM). As

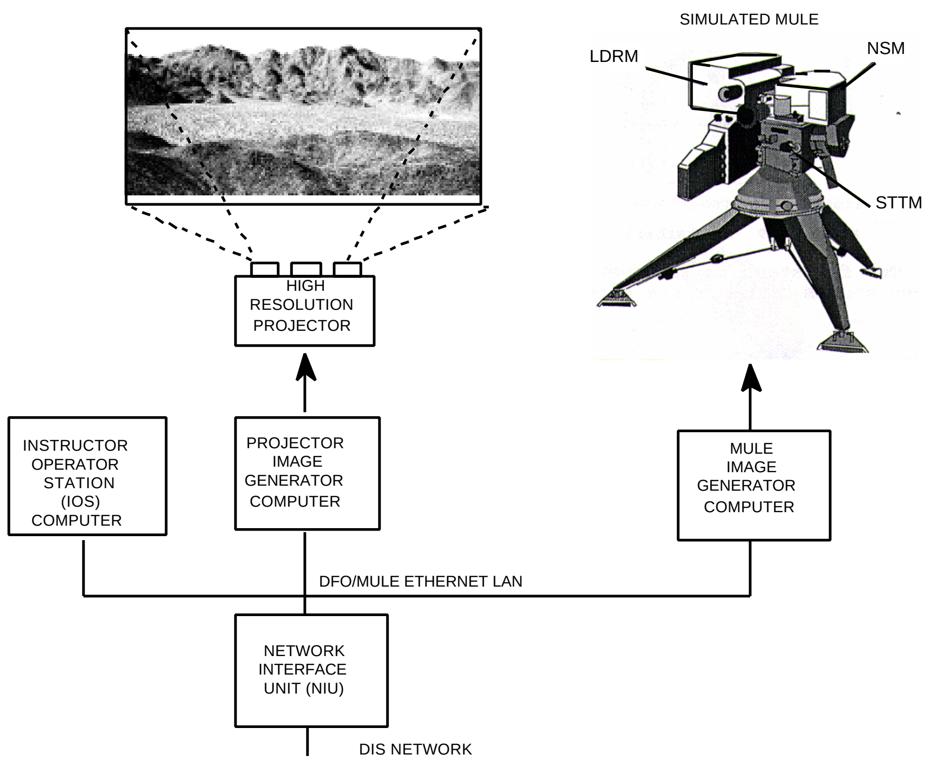

Figure 1 - Deployable Forward Observer/Modular Universal Laser Equipment (DFO/MULE) system used to obtain laser designation tracking data.

the user acquires a target in the projected wide-field-of-view image and points the simulated designator at the target on the screen, the image viewed in the LDRM sight corresponds to that portion of the larger image. In addition to providing azimuth and elevation data to the DFO/MULE simulation, the STTM also duplicates the viscous-damped tracking characteristics of the actual MULE system. This duplication of tracking response is obtained by utilizing the actual STTM, a lightweight tracking system which provides precise, proportional feedback to the operator to minimize tracking jitter.

APPROACH

Designator Dead Reckoning

As described in the DIS standard, dead reckoning is a method of position and orientation estimation which has the primary intent of limiting the rate at which entities report their status to other entities on the network. In addition to a high-fidelity model, each simulation is responsible for maintaining a simpler model of the entity it represents. This simpler model is an extrapolation of position and orientation state based on a specified dead reckoning algorithm, and represents the state of the local entity from the perspective of all other entities on the network. The local entity regularly compares the estimated state, as calculated by the simpler model, to the state contained in the high-fidelity model. If the difference between the two states exceeds a specified threshold, the simulation updates the simpler model with state data from the high-fidelity model, and also broadcasts updated entity state data to all other simulated entities so that they may also update their dead-reckoned models of the local entity.

The DIS standard supports a variety of dead reckoning models which may be implemented, depending upon the required order of the approximation and the type of motion of the entity to be modeled (e.g., with or without rotational orientation). For the implementation of a designator dead reckoning model, the spot was assumed to be non-rotating and fixed in rate of position such that an extrapolated position, P, is calculated from the simple equation:

$$P = P_0 + V_0 * \Delta t$$

where P_0 and V_0 are the previous position and velocity states respectively, and Δ t is the simulation frame rate time interval.

In order to obtain designator spot position estimates from dead reckoning models, the velocity of the spot was required. Since velocity is the derivative of position, a simple linear model was chosen to predict spot velocity in each dimension:

$$v_x = (x_2 - x_1)/(t_2 - t_1)$$

$$v_y = (y_2 - y_1)/(t_2 - t_1)$$

The slope from two initial spot positions was used to estimate the velocity along each dimension. This estimated velocity was then applied to the dead reckoning model to predict the *x* and *y* components of the spot's future position:

$$\hat{x} = x_0 + v_x * \Delta t$$

$$\hat{y} = y_0 + v_y * \Delta t$$

Overall position error was calculated from errors in the *x* and *y* dimensions. When the magnitude of these errors exceeded the specified threshold, a state update was issued and the dead reckoning model was updated with new velocity estimates. Designator spot update estimates were obtained using threshold criteria from 1 to 6 meters in magnitude.

Data Collection

The approach taken for data collection was to obtain tracking data from two individuals with a relatively wide range of tracking experience. This variation illustrates the possible tracking performance deviation between operators under various tracking conditions. One subject had significant previous experience with the MULE simulator and was provided with additional tracking practice of the specific target tracks used in the study. The second subject was familiar with the MULE simulator operation but was not experienced in tracking moving targets, nor did he have knowledge of the specific target motions used in this investigation.

The laser designator operators were presented with a series of single target tracks which they were asked to track to the best of their ability +using the simulated MULE. Data was gathered from each operator in six test cases which represented basic types of target motion. Figure 2 illustrates the six motion types used for tracking: constant velocity, accelerating, 180 degree turn, 90 degree turn, decelerating, and static (non-moving). These target tracks were selected as elemental target motions, which could potentially be combined to approximate more complex target movement.

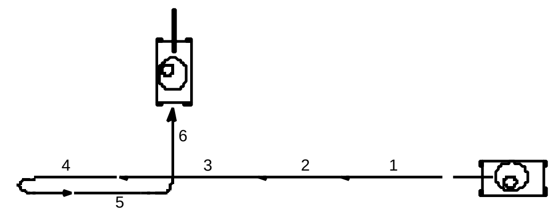

Figure 2 - Illustration of target motion used for laser designation tracking: 1) accelerating, 2) constant velocity, 3) decelerating, 4) 180 degree turn, 5) 90 degree turn, and 6) static.

In all six cases, the target was located at approximately 2000 meters with a simulated speed ranging from 0 to 30 mph depending on the type of motion. Each target track had a duration of 20 to 30 seconds with target paths fixed in the x dimension except in the case of turning targets. The laser spot position was obtained in two dimensions, x and y, as the altitude variations were found to be negligible over the small threshold criteria. The position estimation for dead reckoning was limited to two dimensions for this investigation; however, this implementation could easily be applied to a third dimension.

IMPLEMENTATION RESULTS

Tracking Performance Variations

Figure 3 illustrates the results obtained from the two operators under the various target tracks using a 1-meter dead reckoning threshold to calculate update

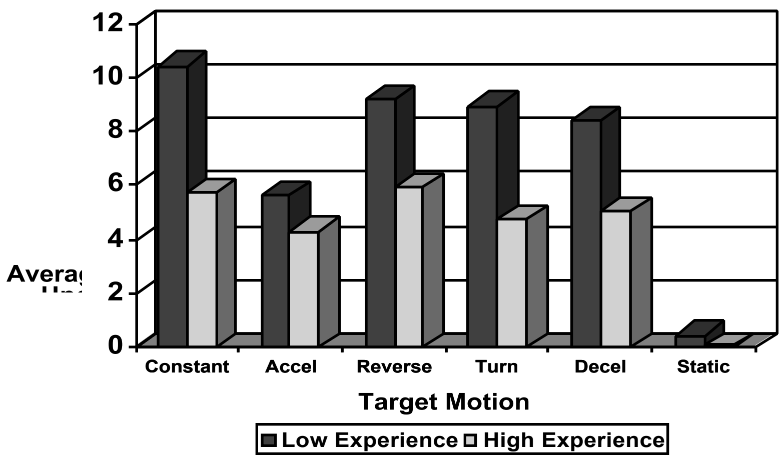

Figure 3 - Average laser spot position update rate (updates per second) required for various tracking motions using a 1 meter threshold criterion

rate. The update rates shown were calculated as an average update value across a 20-second tracking trial. Results from the experienced operator showed dramatic decreases in the position updates required, even at the 1-meter -threshold level. Bandwidth savings over a fixed 10 Hz approach ranged from 40% to 98%, depending on the type of target track.

Although the potential bandwidth savings for the less experienced operator were not as dramatic, they were significant. For the constant velocity case, the calculated update rate from dead reckoning was actually higher than the fixed 10 Hz case. The test condition required that the operator begin tracking a target that was already moving and, consequently, the tracking data exhibited a significant initial error as the operator settled onto the target. This constant velocity target track was the first one presented to the operator. Subsequent trials produced less erratic tracking data as evidenced by the decrease in average update rate, with an overall savings in bandwidth of 7.5% to 95.5%.

As might be expected for both operators, there were substantial differences in the required update rates between moving and static targets. In fact, the static case required less than 10% of the update rate of moving target tracking.

Although this result may initially seem trivial, the designator spot is a unique DIS "entity." Unlike other entities such as aircraft, ground vehicle, and individual combatants, the laser spot has no mass and moves at the speed of light. As illustrated in Figure 4, even with a static target, a small inadvertent movement of the designator system, as from instability or operator error, can produce dramatic targeting errors. Although these overshoot errors also exist in real-world systems, they do not lend themselves well to dead reckoning models, and in turn directly affect update rate requirements. Therefore, the low update rate results for the static target using a 1-meter dead reckoning threshold criteria were not a foregone conclusion.

Transmission Rate Versus Threshold Criteria

Figure 5 shows the average update rate for different dead reckoning threshold values. The update rate was calculated by averaging data across all six target tracks, approximating the results from a complex 120-second target track. Results from the experienced operator provided reductions of 56% to 89%, while those from the less experienced operator provided reductions of 28% to 69%. This reduction in average update rate was not a linear function

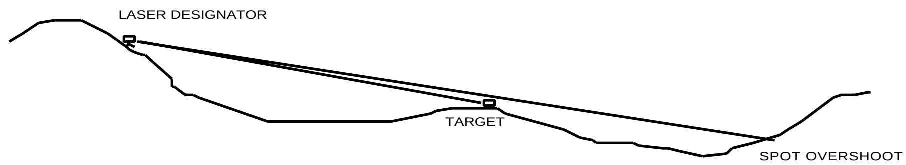

Figure 4 - Illustration of laser spot overshoot. Even with a non-moving target, small movements in azimuth or elevation can produce dramatic target errors.

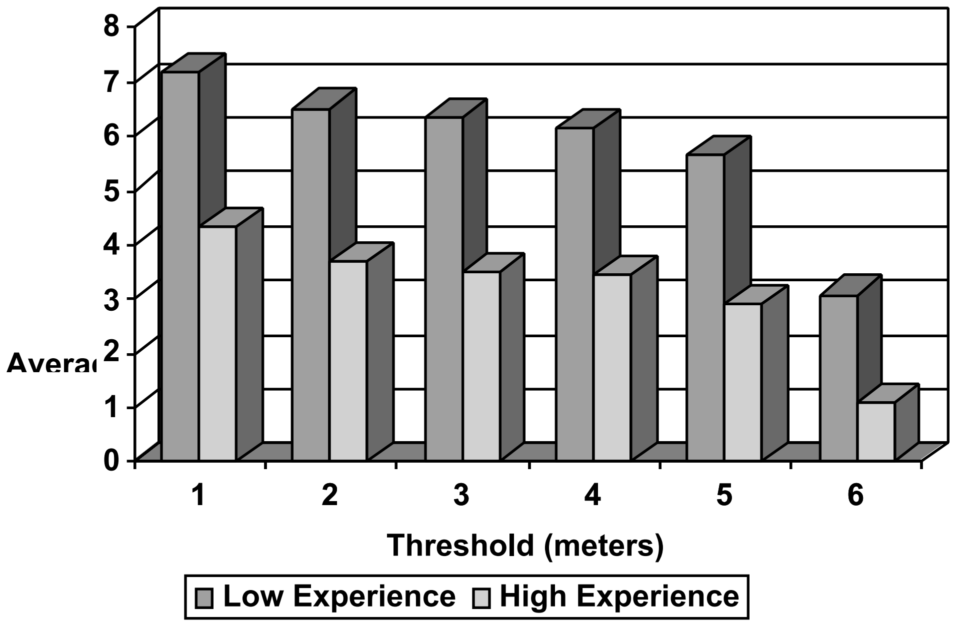

Figure 5 - Average laser spot position update rate (updates per second) versus dead reckoning threshold criteria.

of threshold, nor is it a generalizable result. These results are closely tied to the tracking stability of the system, the experience level of the operator, and the database implementation within the simulation. The specific database implementation of the DFO/MULE system produced a significant decrease in average update rate for the 6-meter threshold criteria.

Systems with different tracking characteristics or stabilities might require more or fewer updates than the DFO/MULE system. A minimally stabilized designation system (e.g., handheld) may necessitate updates significantly higher than those calculated in these studies for equivalent threshold criteria, even for non-moving targets. This result is a function of the azimuth and elevation stability of the system. For example, at a range of 1000 meters, a 1-meter deviation in aim point can be produced from a rotational movement of less than 0.06 degrees. Therefore, a system with minimal stabilization would produce a high update rate unless a larger threshold criteria was used, or additional filtering approaches were employed to minimize the tracking deviations of the system.

CONCLUSIONS

Based on the results of this investigation, it is apparent that a conservation of network bandwidth can be realized from a dead reckoning approach to the designator PDU, even when implemented with a relatively simple velocity estimation algorithm. The magnitude of network bandwidth savings observed depends strongly on the tracking characteristics of the designation system, the ability of the designator operator, the database implementation within the simulated system, and whether the designator target is moving or stationary. Individual laser-based systems must consider these characteristics in order to specify appropriate threshold criteria which will meet simulation fidelity requirements as well as efficiently utilize the overall network bandwidth.

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