JOHNS HOPKINS UNIVERSITY

Center for Imaging Science

Multispectral Sensor Fusion for Target Recognition

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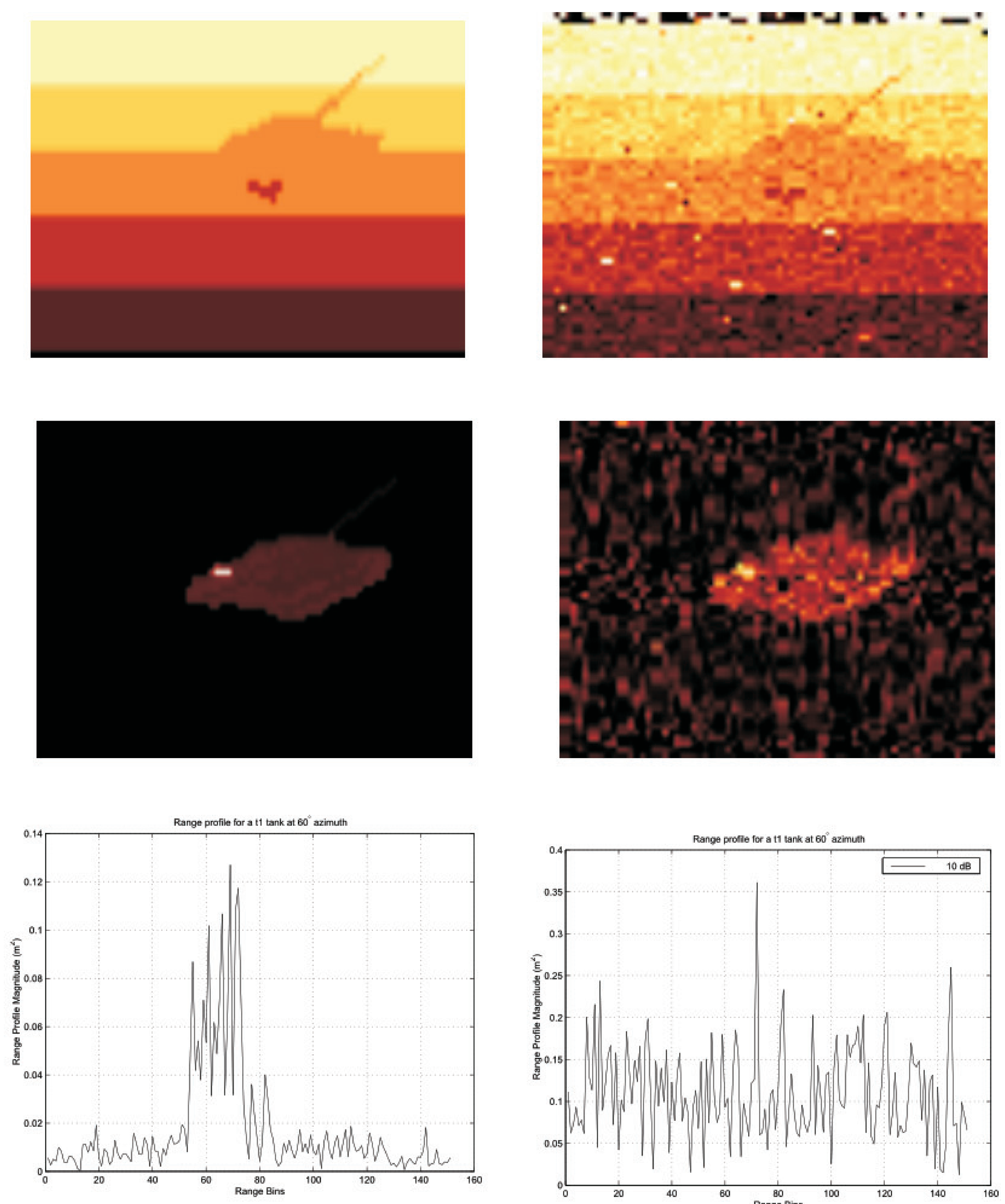
Members of the the Center for Imaging Science have been studying object recognition and identification through multiple sensors. Recognizing 3-D objects invariant to arbitrary pose from imaging sensors has received considerable attention in the past few years. Our work addresses pose estimation for ground-based targets viewed with a combination of active and passive sensors, including laser radar (LADAR), forward-looking infrared (FLIR) and high resolution range radar (HRR) sensors. We study optimum pose estimation using Hilbert-Schmidt estimators (HS) defined as:

$$\hat{O}_{HS}(D) = \text{argmin}_{\hat{O}}\left[E\left(\|O-\hat{O}\|_{HS}^2\right)\right] = \frac{\int_{-\pi}^{\pi} d\theta\, O_\theta \pi(\theta \mid D)}{\sqrt{\det\left(\int_{-\pi}^{\pi} d\theta\, O_\theta \pi(\theta \mid D)\right)}} \quad \text{where } O_\theta = \begin{bmatrix} \cos(\theta) & \sin(\theta) \\ -\sin(\theta) & \cos(\theta) \end{bmatrix} \in SO(2) \quad \text{and} \quad \pi(\theta|D) = \frac{\pi(\theta) L(D|\theta)}{Z(D)}.$$

The objective is to develop Cramer-Rao-type bounds for the mean-squared error which explicitly reveal the roles of sensor and scenario parameters, and permit quantitative assessment of the benefits of sensor fusion. The Hilbert-Schmidt norm is used as the measure of error.



Shown in the left columns are LADAR, FLIR, and HRR data being studied in the Center for Imaging Science. Statistical sensor models have been characterized for LADAR, FLIR, and HRR and form the basis for optimum estimation. The LADAR likelihood is:

$$p(\hat{R} \mid R) = [1-\Pr(A)]\frac{\exp\left(-\frac{(\hat{R}-R)^2}{2\delta R^2}\right)}{\sqrt{2\pi\delta R^2}} + \frac{\Pr(A)}{\Delta R}$$

where R and ΔR represents true and range accuracies, and Pr(A) is anomaly probability. The likelihood model for FLIR in the high count Gaussian limit is:

$$p(\Delta\hat{T} \mid T_b) = \frac{\exp\left(-\frac{(\Delta\hat{T}-\Delta T)^2}{2(NE\Delta T)^2}\right)}{\sqrt{2\pi(NE\Delta T)^2}}$$

where ΔT represents temperature differences, and NEΔT is noise equivalent temperature. The HRR model is:

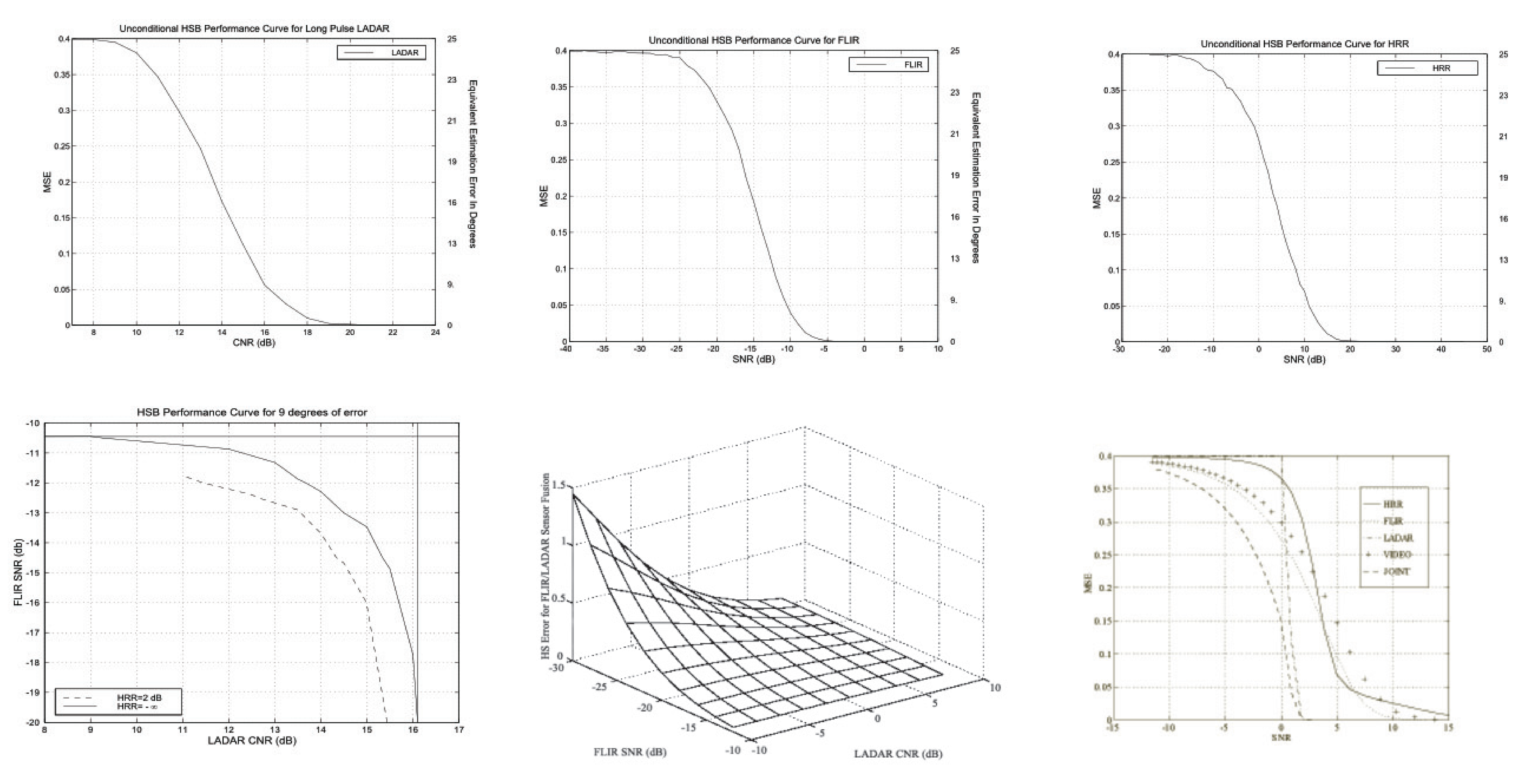
$$p(\hat{\sigma} \mid \sigma_s) = \frac{\exp\left(-\frac{\hat{\sigma}+\sigma_s(1-\beta)}{\sigma_s\beta+\sigma_n}\right)}{\sigma_s\beta+\sigma_n} I_0\left(\frac{2\sqrt{\hat{\sigma}\sigma_s(1-\beta)}}{\sigma_s\beta+\sigma_n}\right) \quad \text{for } \hat{\sigma} \geq 0$$

where σ represents radar cross sections, and β is target fluctuation.

Simulation results

The figures depict Hilbert-Schmidt bounds for the LADAR (top left), FLIR (top center), and HRR images (top right). Simulations are performed to calculate performance gain for sensor fusion.

The lower left graph shows the Hilbert-Schmidt performance gain for the FLIR/LADAR fusion system; the corresponding performance gain for the FLIR/LADAR/HRR system is shown in the middle left graph; the Hilbert-Schmidt performance for the fused system as a function of the signal-to-noise ratio (SNR) is shown in the lower right graph. By fusing information from all four sensors (HRR, FLIR, LADAR, and video), optimal performance is achieved (JOINT).



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