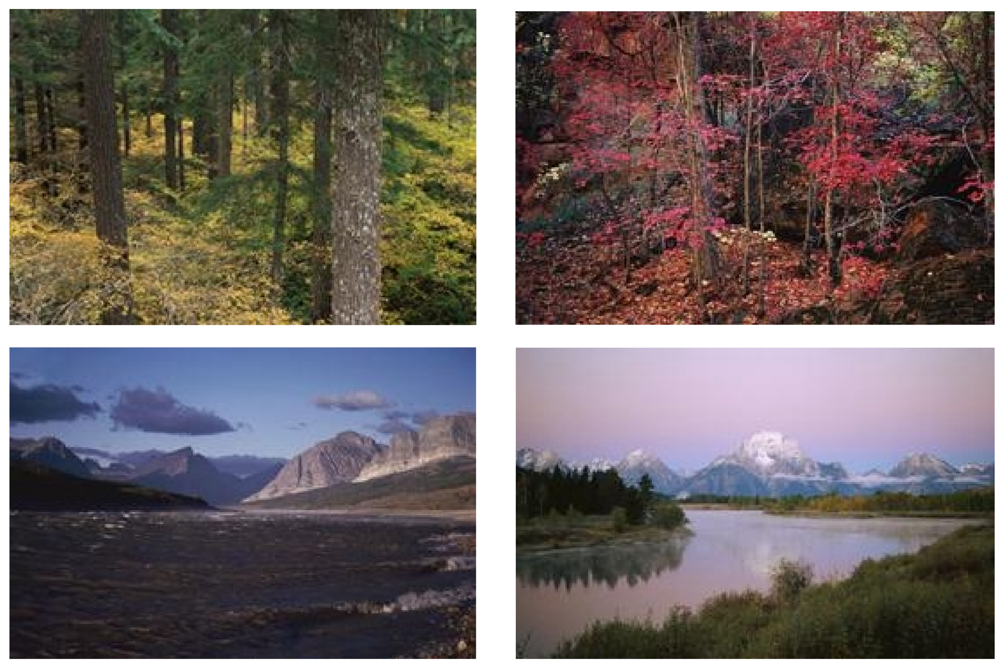
JOHNS HOPKINS
UNIVERSITY
Center for Imaging Science

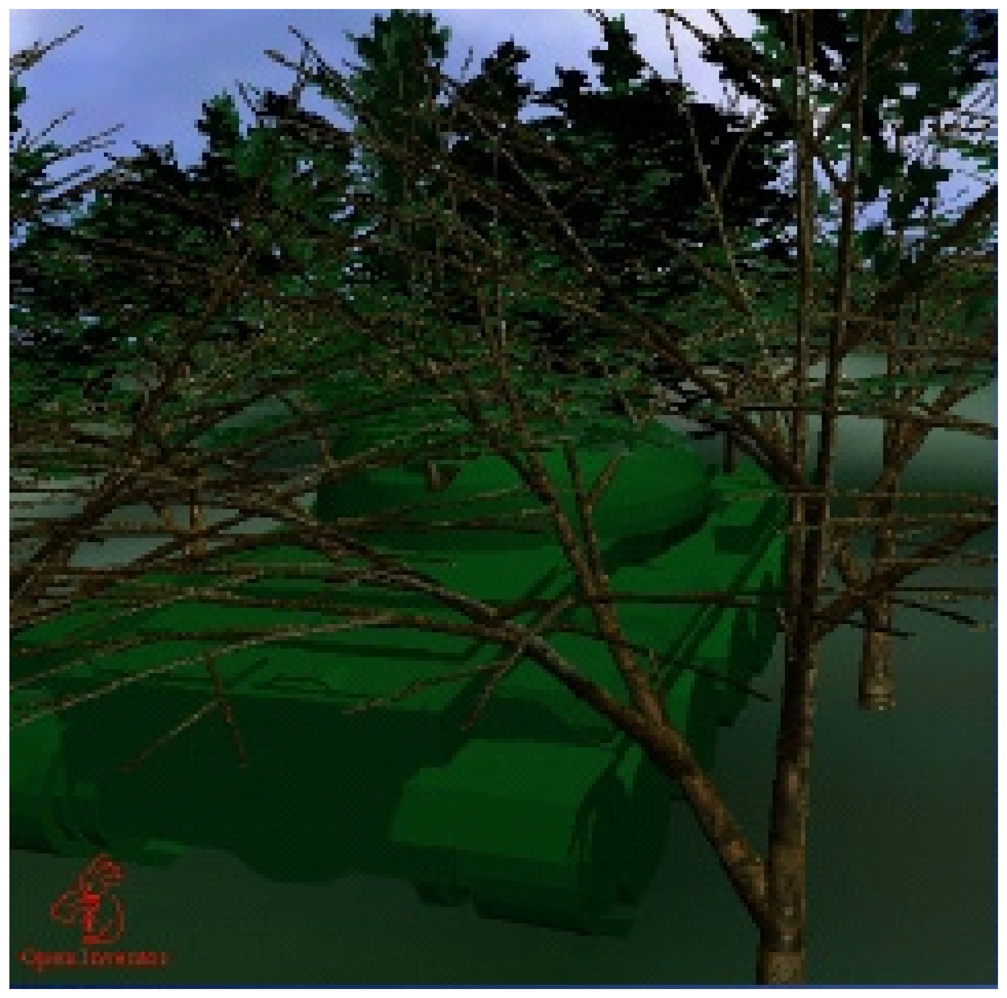
Image Understanding Through Clutter

U. Grenander*, M. I. Miller, P. Tyagi****

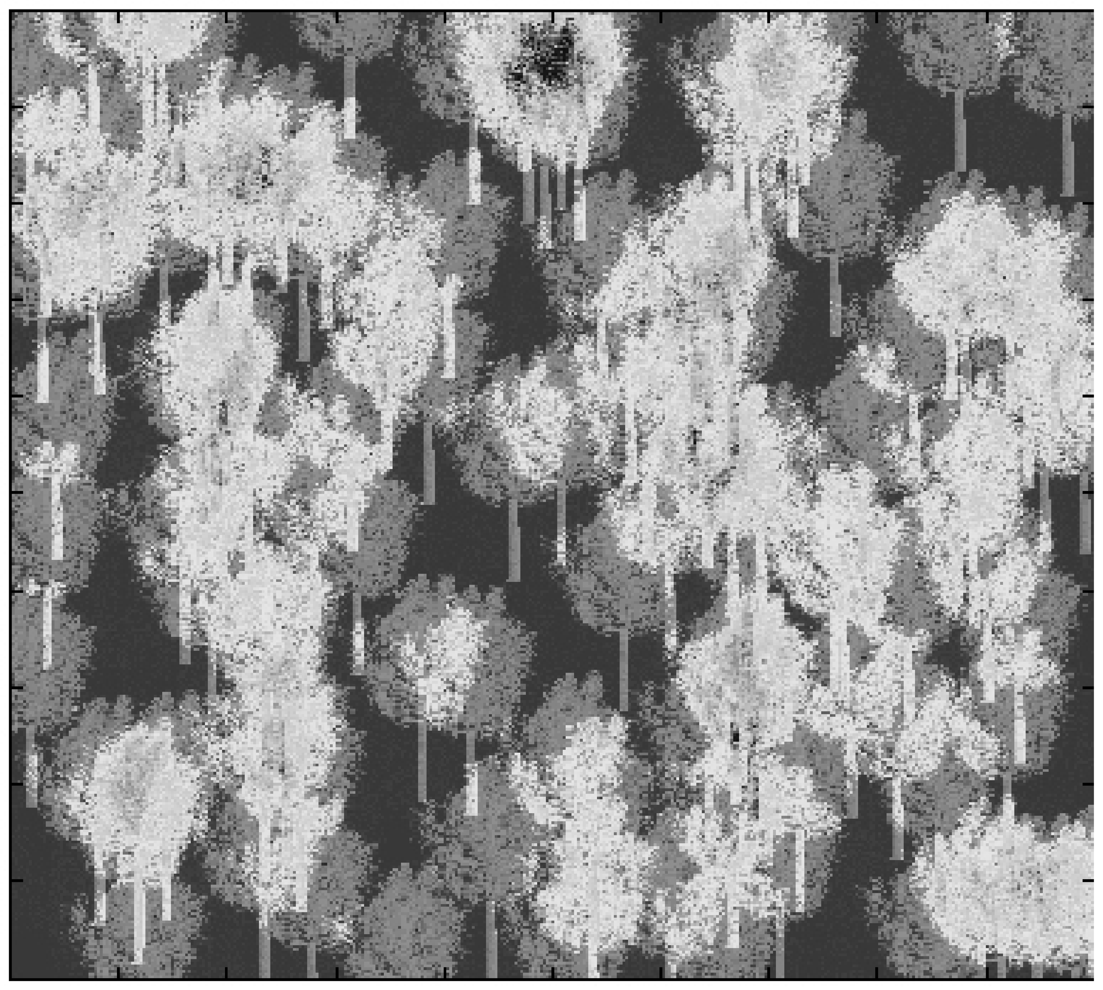
Automatic Target Recognition (ATR) is made complex by natural objects in the scene, such as trees and rocks, which can block, obscure, or be mistaken for the target. These effects are normally referred to in the literature as clutter. Clutter has been identified as one of the key problems in understanding and predicting ATR performance.

The figures on the right demonstrate the clutter environments in which we establish estimator bounds for ATR. The four small images show natural scenes taken from the CIS database at www.cis.jhu.edu. The large image shows a simulation of tanks in natural clutter. Using graphical synthesizers, the tank CAD model has been embedded in the CAD model trees. Notice the realism.





A sample image generated with N_0=100



To examine performance, we model clutter as a marked filtered-poisson counting process. The equations for these processes are shown below to illustrate the computational methodology. The clutter is generated using CAD models for trees, as shown in the left panel for N_D=100 trees. The CIS database currently holds twenty tree models.

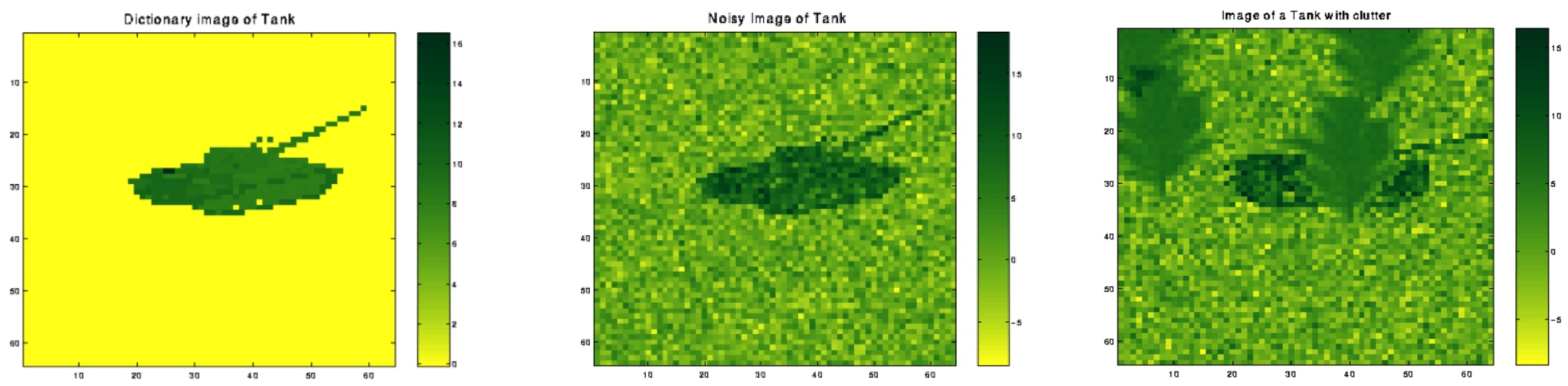
Clutter Process $\{I(x); x \in D \subset \mathbf{R}^2\}$

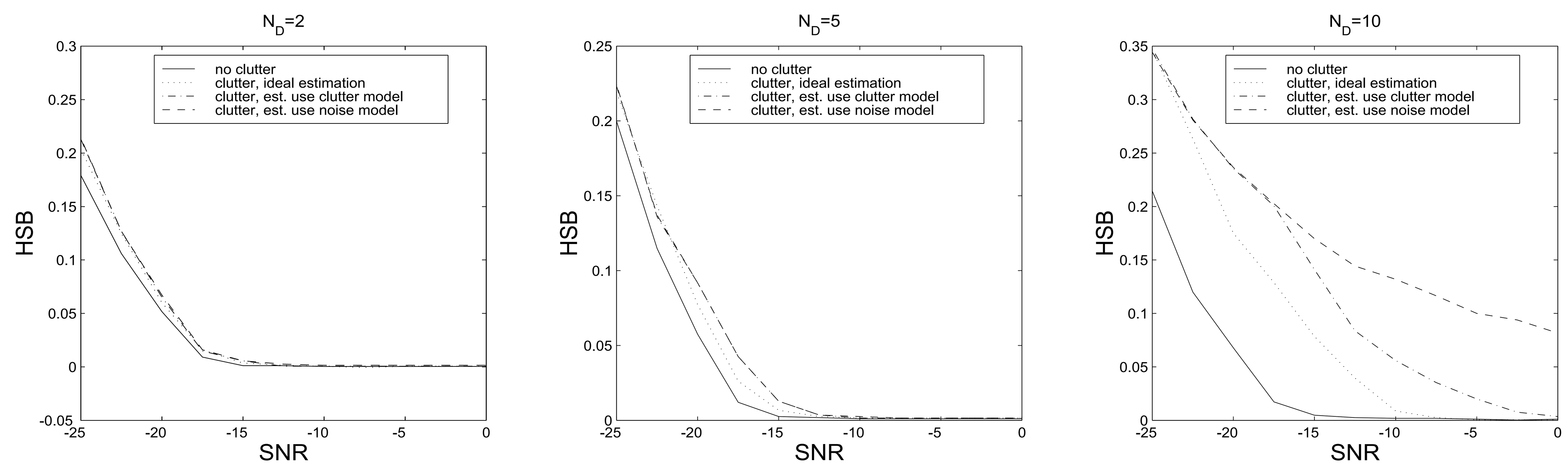
$$I(x) = \begin{cases} 0 & N_D = 0 \\ \sum_{n=1}^{N_D} h(x, X_n; U_n) & N_D \geq 1 \end{cases}$$

where
U_x = Independent mark process
X_n = Position of occurrence of each mark
N_D = Total number of marks or events in $I(x)$
$h(\,)$ = Filtering function, i.e. Image of a single tree

Optimal pose estimation performance has been examined with and without the clutter model. The estimation equations manipulate clutter through its fourth moment, the kurtosis, the equation of which is given below:

$$k(I(x)) = \frac{E[I(x) - EI(x)]^4}{(E[I(x) - EI(x)]^2)^2}$$
$$= 3 + \frac{\ ^{4}}{\ _{2}}$$
$$= 3 + \frac{\int_D \lambda(y) E[h^4(x,y;U)]dy}{(\int_D \lambda(y) E[h^2(x,y;U)]dy)^2}$$





The right panels show simulation results for the tank in clutter. The bottom row shows varying degrees of obscurity, generated by increasing the clutter density from 2, 5, 10. The rightmost panel shows the significance of modeling clutter. Notice the divergence of dashed lines at low SNR with/without clutter modeling.

*Division of Applied Mathematics, Brown University, Providence, Rhode Island
**Center for Imaging Science, The Johns Hopkins University, Baltimore, Maryland

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