Robust Object Detection via Kronecker Tensor Decomposition

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Tensor Completion

$$min||P_\Omega(X) - P_\Omega(M)||_F^2$$

s.t. rank(X) = R

Reformulated via auxiliary variable C:

$$min||X - C||_F^2$$

s.t. rank(X)=R, $P_\Omega(C) = P_\Omega(M)$

Random KTD FRAMEWORK

Kronecker Tensor Decomposition (KTD):

$$X = \sum_{r=1}^{R} \sigma_r X_r^{(1)} \otimes X_r^{(2)} \otimes \cdots \otimes X_r^{(M)},$$

Random KTD algorithm:

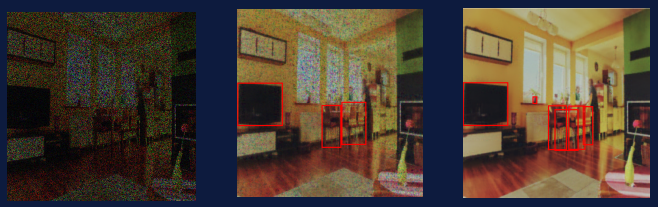
1. **Compression**: Apply random projections to each mode of the tensor, reducing dimensions from I_n to $k_n$where $k_n \ll I_n$
2. **Decomposition**: Perform KTD on the compressed tensor
3. **Reconstruction**: Recover the full decomposition using the random projection matrices

ROBUST DETECTION PIPELINE

$$X^{(n)} \leftarrow \mathscr{L}(C^{(n)})$$ <-- KTD Restore

$$C^{(n+1)} \leftarrow \Omega \odot M + (1 - \Omega) \odot X^{(n)}$$ <-- Estimate the masked pixels

Visualization of restoration



Step 0 Step 15 Step 30

Key Insight: *Masking 70% of pixels disrupts structured adversarial perturbations. KTD completion restores clean image structure — enabling the detector to succeed despite attacks.*

EXPERIMENTAL RESULTS — YOLOv11m on COCO

Attack Type	Image	Precision	Recall	F1	mAP
No Attack	Original	74	61	67	**59**
TOG-Localization	Attacked	29	29	29	**23**
	KTD-Restored	71	42	53	**44**
TOG-Vanishing	Attacked	5	37	9	**22**
	KTD-Restored	73	45	56	**47**
TOG-Mislabeling	Attacked	51	20	29	**15**
	KTD-Restored	76	47	58	**46**
TOG-Fabrication	Attacked	33	13	19	**19**
	KTD-Restored	76	45	56	**47**

+21%
mAP gain vs attacked (Localization: 23→44)

76%
Precision restored (Mislabeling & Fabrication)

30
Optimal iteration count for restoration

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