

# What Has Been Tampered?

## From A Sparse Manipulation Perspective

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### Malicious image tampering is usually unnoticeable!

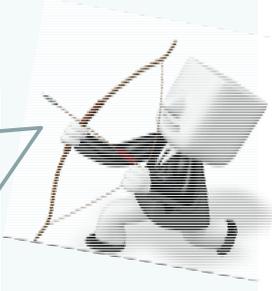


Devil in the details!



**Sparse Manipulation**

- **Achilles' heel**  
...observed in general tampering scenarios
- **How to exploit the priors?**
- **Locating image tampering!**



**Our Ideas**  
 ...inspired by RPCA [WGRM09]

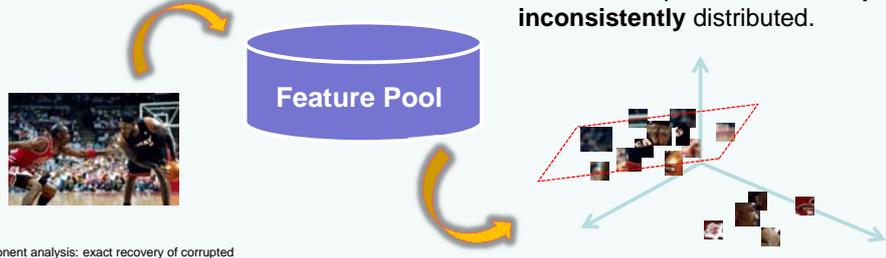


**Assumption 1**

- A reliable forensic feature space exist!

**Assumption 2**

- Authentic areas share similar feature behaviors.
- Those of tampered areas are **sparse** and **inconsistently** distributed.



[WGRM09] J. Wright, A. Ganesh, S. Rao, and Y. Ma, "Robust principal component analysis: exact recovery of corrupted low-rank matrices via convex optimization," In *Proc. NIPS*, 2009.



### Probabilistic Rank-Sparsity Decomposition

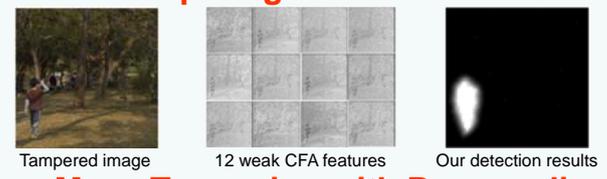
Given  $\mathbf{X} = [\mathbf{x}_1, \dots, \mathbf{x}_N] \in \mathbb{R}^{k \times N}$  ( $N$  image units),  
 Define  $p_i = P(\text{tampered}|\mathbf{x}_i)$  and  $1 - p_i = P(\text{authentic}|\mathbf{x}_i)$ .

Solve  $\hat{\mathbf{R}}, \hat{\mathbf{p}} = \text{argmin} \alpha \|\mathbf{R}\|_* + \beta \sum_i p_i + \gamma \sum_{i,j} (p_i - p_j)^2 w_{i,j} + \sum_i (1 - p_i) \|\mathbf{x}_i - \mathbf{r}_i\|^2$   
 s. t.  $0 \leq p_i \leq 1$ .

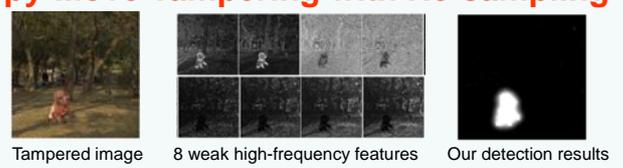
- Low-rank priors on authentic areas
- Sparsity priors on tampered areas
- Priors of spatial coherency
- Priors of Gaussian noise in feature space
- Priors of probability

■ Iteratively solved by low-rank matrix approximation and quadratic programming (QP)

### Copy-Move Tampering from Different Cameras



### Copy-Move Tampering with Re-sampling



### Locating Tampered Blocks in Recompression

