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Target Response Adaptation for Correlation Filter Tracking

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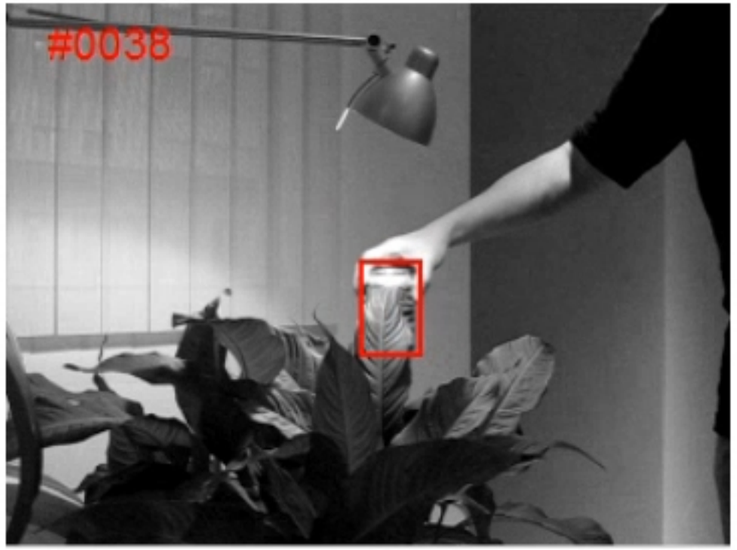
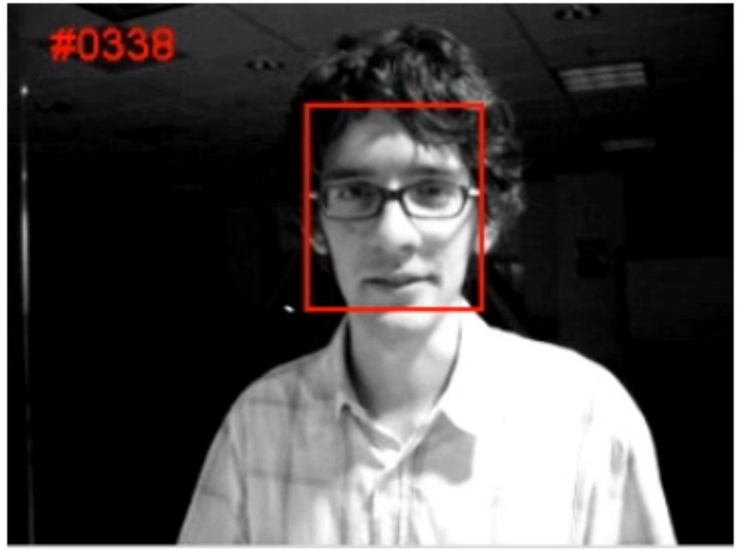
Problem Definition

- Goal of Visual Tracking
  - Estimate the state (position and scale) of the target over time under different conditions

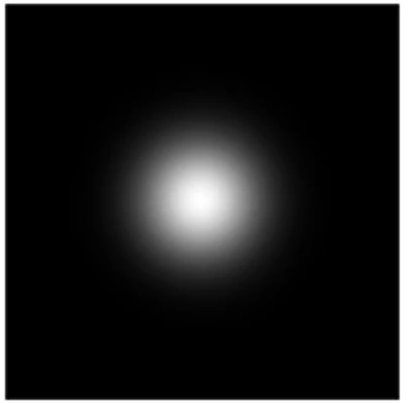




Correlation Filters (Original Formulation)

$$\min_{\mathbf{w}} ||\mathbf{X}\mathbf{w} - \mathbf{y}||_2^2 + \lambda_1 ||\mathbf{w}||_2^2$$

$\mathbf{y}$



Primal Solution:

$$\mathbf{w} = (\mathbf{X}^H\mathbf{X} + \lambda_1\mathbf{I})^{-1}\mathbf{X}^H\mathbf{y}$$

Single Template Solution

$$\hat{\mathbf{w}} = \frac{\hat{\mathbf{x}} \odot \hat{\mathbf{y}}}{\hat{\mathbf{x}} \odot \hat{\mathbf{x}}^* + \lambda}$$

$$\hat{\mathbf{w}} = \frac{\sum_i \hat{\mathbf{x}}_i \odot \hat{\mathbf{y}}}{\sum_i \hat{\mathbf{x}}_i \odot \hat{\mathbf{x}}_i^* + \lambda}$$

Multi-Template Solution

Dual Solution:

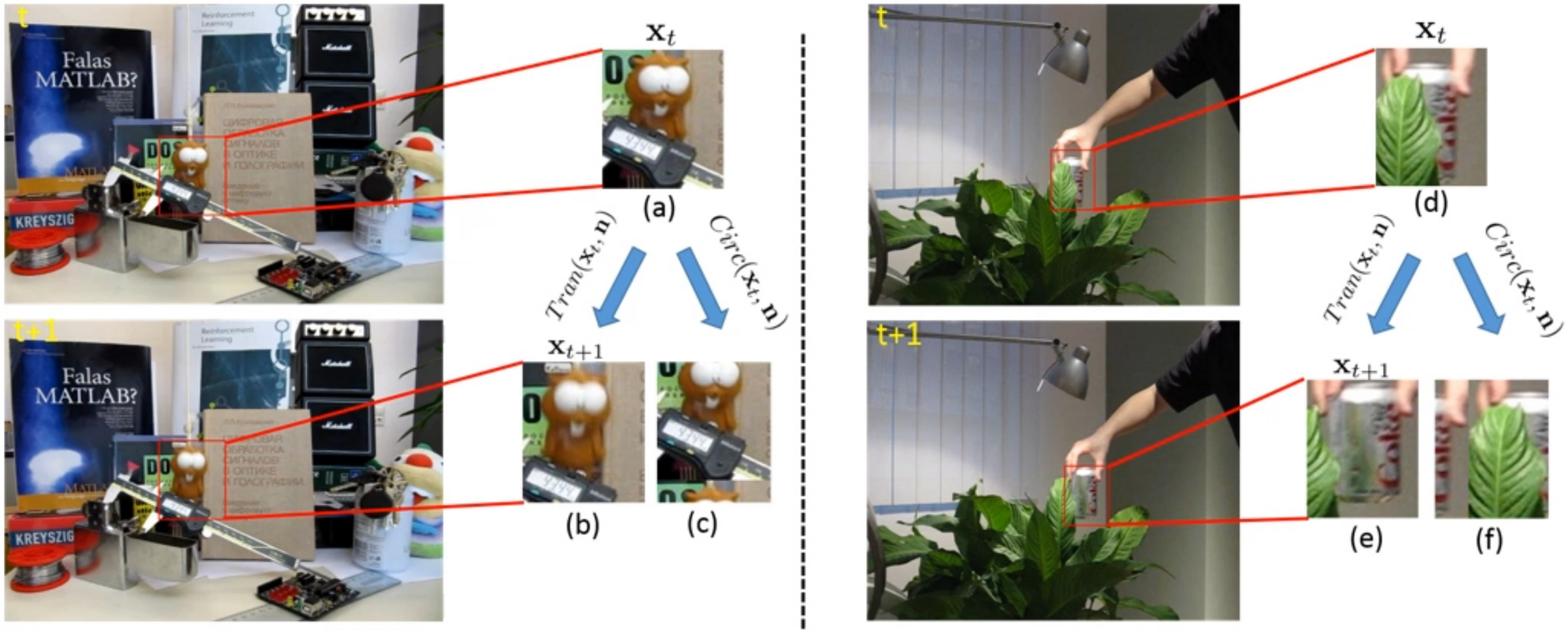
$$\alpha = (\mathbf{X}\mathbf{X}^H + \lambda_1\mathbf{I})^{-1}\mathbf{y}$$

$$\mathbf{w} = \mathbf{X}^H\alpha$$

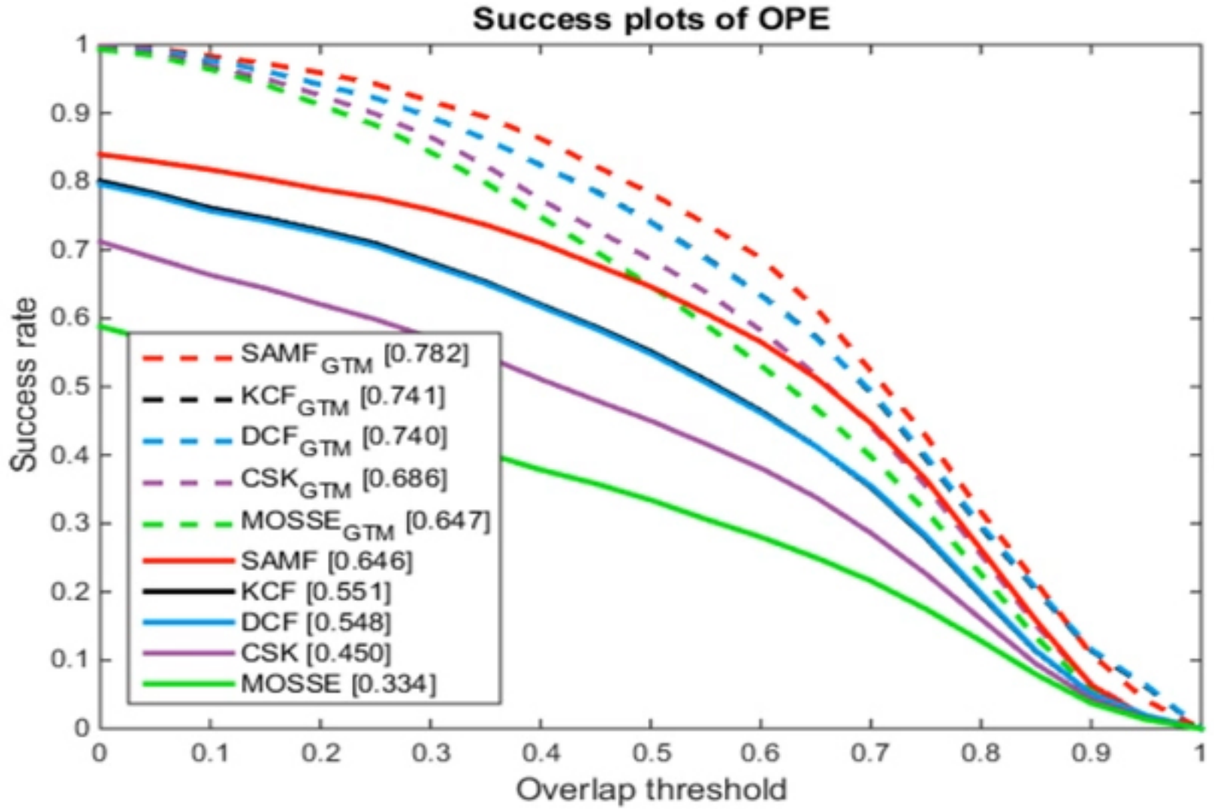
$$\hat{\alpha} = \frac{\hat{\mathbf{y}}}{\hat{\mathbf{x}} \odot \hat{\mathbf{x}}^* + \lambda}$$

Single Template Solution

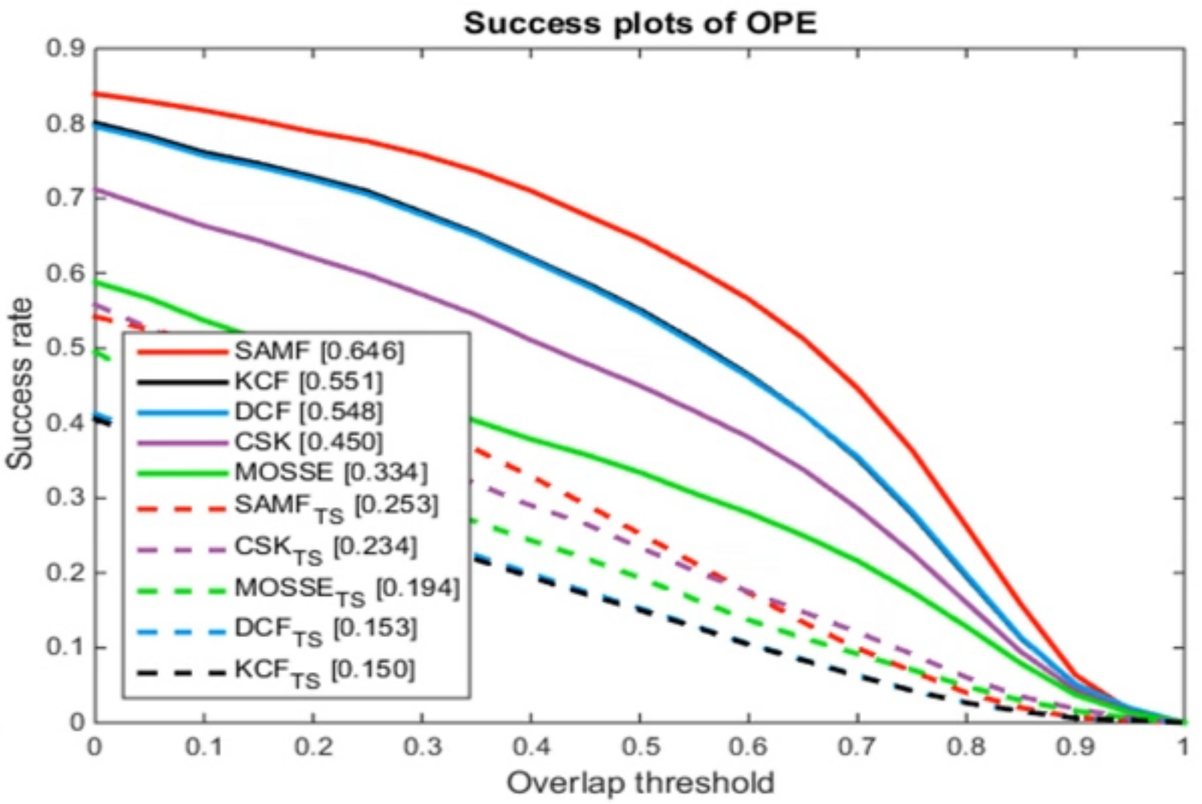
Motivation


t
t+1
Falas MATLAB?
KREYSZIG
$\mathbf{x}_t$
(a)
$Tran(\mathbf{x}_t, \mathbf{n})$
$Circ(\mathbf{x}_t, \mathbf{n})$
$\mathbf{x}_{t+1}$
(b)
(c)
(d)
(e)
(f)

Motivation

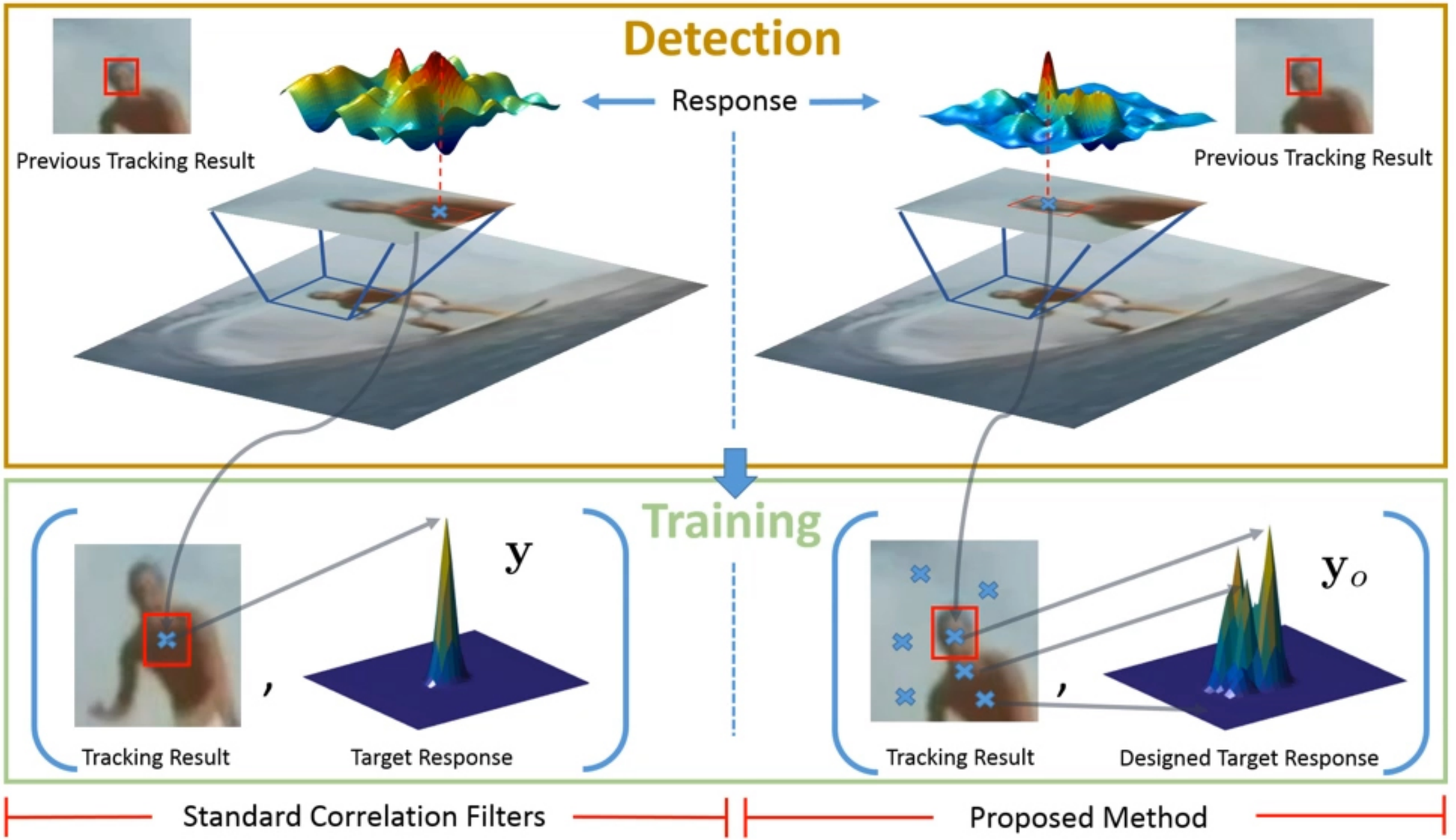


Ground Truth Motion Model



At most 2 Pixels perturbation in the target $\mathbf{y}$

Proposed Pipeline



Proposed Method

$$\underset{\mathbf{w},\mathbf{y}}{\text{minimize}} \quad ||\tilde{\mathbf{X}}\mathbf{w} - \mathbf{y}||_2^2 + \lambda_1||\mathbf{w}||_2^2 + \lambda_2||\mathbf{y} - \mathbf{y}_o||_2^2$$

$$\mathbf{D}\tilde{\mathbf{K}}^{-1}\left(\lambda_2\mathbf{D}^T\mathbf{D} + \lambda_1\mathbf{E}^T\mathbf{E} + \tilde{\mathbf{G}}^T\tilde{\mathbf{G}}\right)\tilde{\mathbf{K}}^{-1}\mathbf{D}^T\alpha = \lambda_2\mathbf{D}\tilde{\mathbf{K}}^{-1}\mathbf{D}^T\mathbf{y}_o$$

$$\tilde{\mathbf{K}} = \left(\lambda_1\mathbf{E}^T\mathbf{E} + \tilde{\mathbf{G}}^T\tilde{\mathbf{G}}\right) \qquad \tilde{\mathbf{G}} = \begin{bmatrix}\tilde{\mathbf{X}} & -\tilde{\mathbf{I}}\end{bmatrix} \in \mathbb{R}^{kn\times 2n}$$

$$\tilde{\mathbf{I}}^\top = [\mathbf{I} \ \cdots \ \mathbf{I}] \in \mathbb{R}^{n\times kn} \qquad \mathbf{E} = \begin{bmatrix}\mathbf{I} & \mathbf{0}\end{bmatrix} \in \mathbb{R}^{n\times 2n}$$

$$\mathbf{D} = \begin{bmatrix}\mathbf{0} & \mathbf{I}\end{bmatrix} \in \mathbb{R}^{n\times 2n}$$

Proposed Method

$$\hat{\alpha}^* = \lambda_2 diag^{-1}(\Upsilon)\left(\frac{\frac{1}{k}\left(\sum_i^k \hat{\mathbf{x}}_{1i}^*\right) \odot \left(\sum_i^k \hat{\mathbf{x}}_{1i}\right) \odot \hat{\mathbf{y}}_0^*}{\sum_i^k (\hat{\mathbf{x}}_{1i}^* \odot \hat{\mathbf{x}}_{1i}) + \lambda_1 - \frac{1}{k}\left(\sum_i^k \hat{\mathbf{x}}_{1i}^*\right) \odot \left(\sum_i^k \hat{\mathbf{x}}_{1i}\right)} + \frac{\hat{\mathbf{y}}_o^*}{k}\right),$$

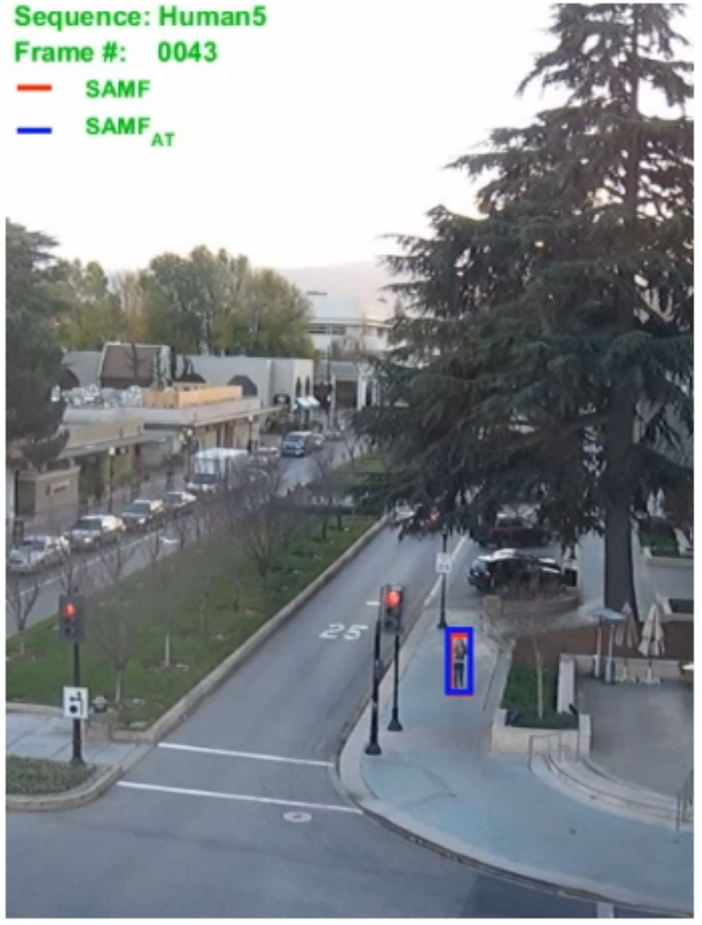
where

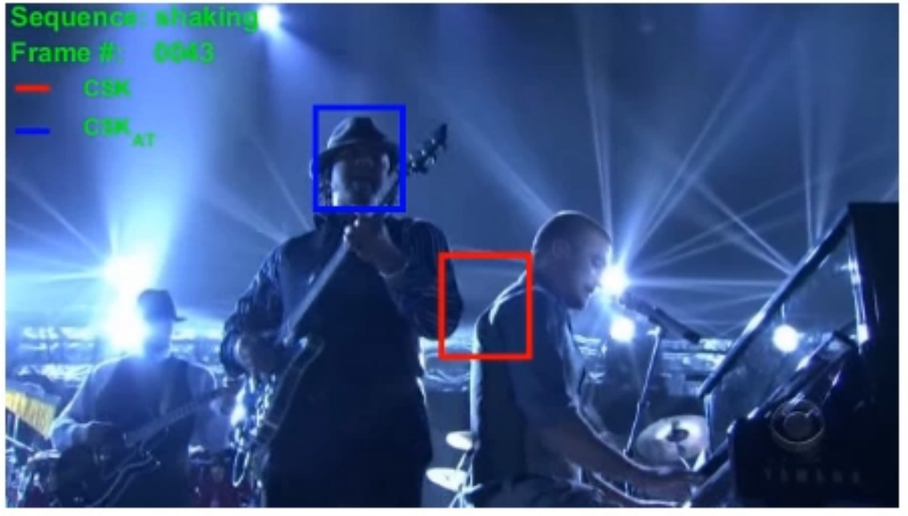
$$\Upsilon = \left(\frac{\frac{-1}{k}\sum_i^k (\hat{\mathbf{x}}_{1i}^* \odot \hat{\mathbf{x}}_{1i}) + \frac{k+\lambda_2}{k}\left(\sum_i^k \hat{\mathbf{x}}_{1i}^*\right) \odot \left(\sum_i^k \hat{\mathbf{x}}_{1i}\right) + \frac{\lambda_1(k+\lambda_2)}{k}}{\sum_i^k (\hat{\mathbf{x}}_{1i}^* \odot \hat{\mathbf{x}}_{1i}) + \lambda_1 - \frac{1}{k}\left(\sum_i^k \hat{\mathbf{x}}_{1i}^*\right) \odot \left(\sum_i^k \hat{\mathbf{x}}_{1i}\right)}\right) \odot$$

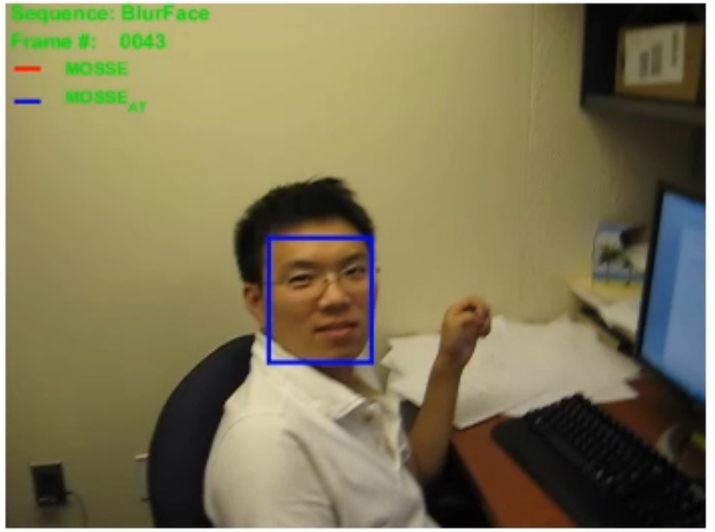
$$\left(\frac{\frac{1}{k^2}\sum_i^k \hat{\mathbf{x}}_{1i}^* \odot \sum_i^k \hat{\mathbf{x}}_{1i}}{\sum_i^k (\hat{\mathbf{x}}_{1i}^* \odot \hat{\mathbf{x}}_{1i}) + \lambda_1 - \frac{1}{k}\left(\sum_i^k \hat{\mathbf{x}}_{1i}^*\right) \odot \left(\sum_i^k \hat{\mathbf{x}}_{1i}\right)} + \frac{1}{k}\right)$$

All operations are elementwise!!

Qualitative Results







Quantitative Results

Trackers	Precision	Accuracy (IOU)
SAMF_AT	0.790	0.680
SRDCF	0.788	0.728
MEEM	0.787	0.632
MUSTER	0.773	0.681
DCF_AT	0.728	0.590
KCF_AT	0.723	0.582
DSST	0.693	0.534
CSK_AT	0.586	0.501
MOSSE_AT	0.546	0.463

Trackers	MOSSE	MOSSE_AT	CSK	CSK_AT	DCF	DCF_AT	SAMF	SAMF_AT
Precision	0.414	0.546	0.543	0.586	0.690	0.728	0.752	0.790
Accuracy (IOU)	0.334	0.463	0.450	0.501	0.548	0.590	0.646	0.680

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[Poster:S-4A-05]