

CORRELATION FILTERS WITH LIMITED BOUNDARIES

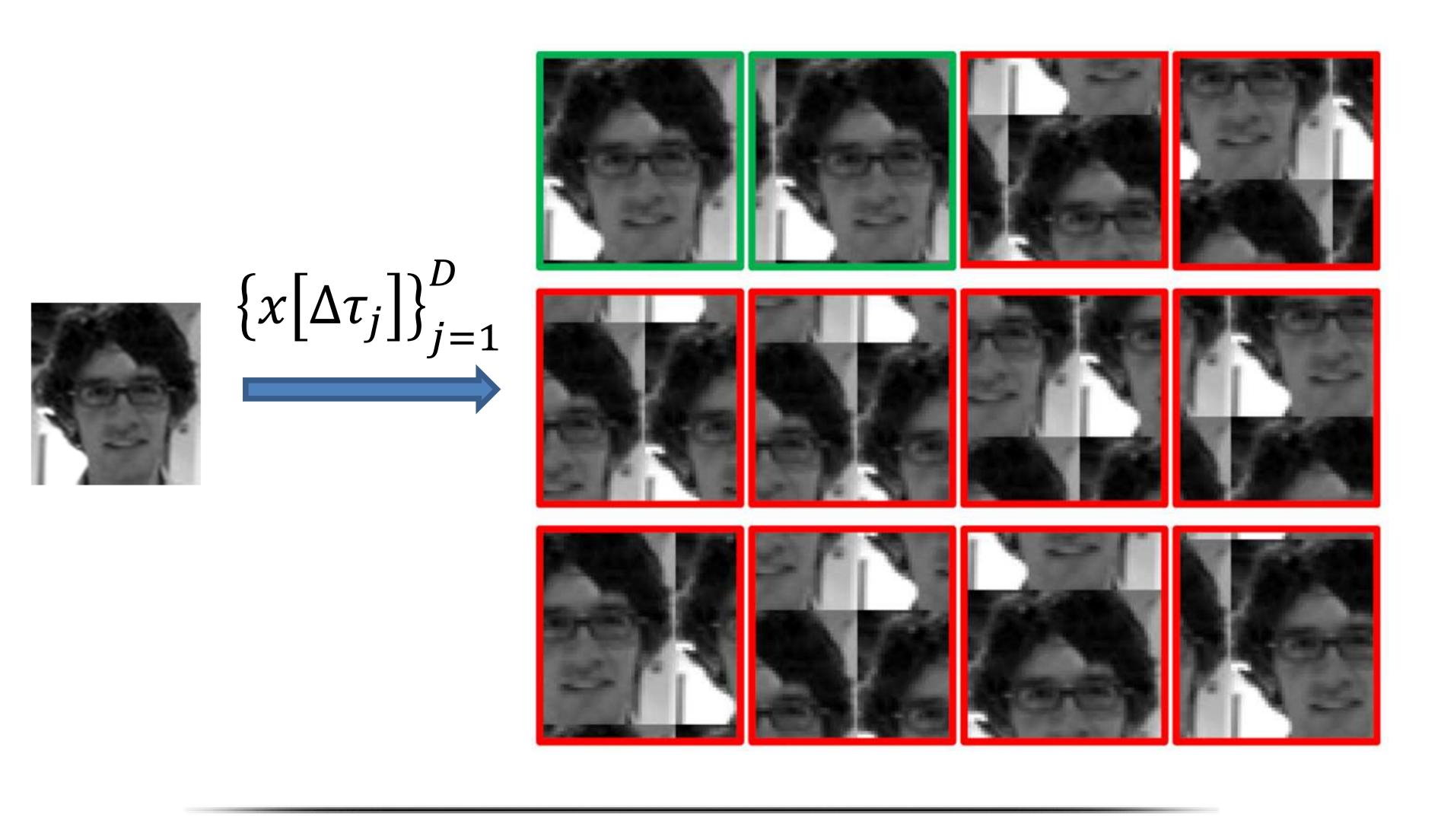
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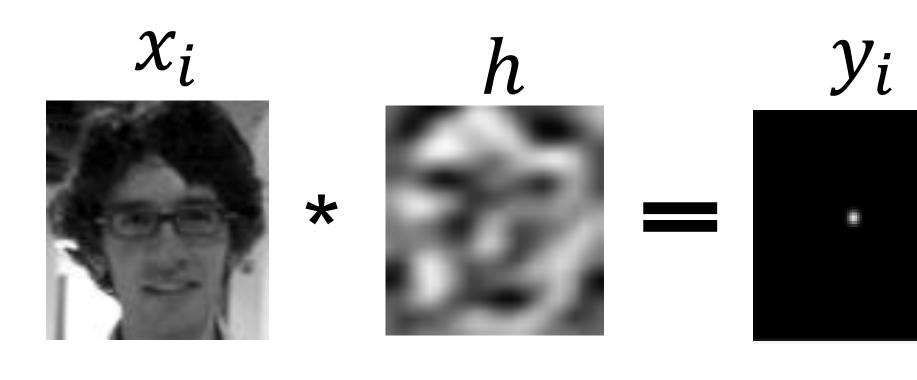
BOSTON

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CORRELATION FILTERS

Boundary Effects: Synthetic training patches





$$E(\mathbf{h}) = \frac{1}{2} \sum_{i=1}^{N} ||\mathbf{y}_i - \mathbf{x}_i \star \mathbf{h}||_2^2 + \frac{\lambda}{2} ||\mathbf{h}||_2^2$$

1- Frequency domain: $\mathcal{O}(ND \log D)$

$$E(\hat{\mathbf{h}}) = \frac{1}{2} \sum_{i=1}^{N} ||\hat{\mathbf{y}}_i - \operatorname{diag}(\hat{\mathbf{x}}_i)^{\top} \hat{\mathbf{h}}||_2^2 + \frac{\lambda}{2} ||\hat{\mathbf{h}}||_2^2$$

 $(\hat{\mathbf{y}} denotes the DFT of vector \mathbf{y})$

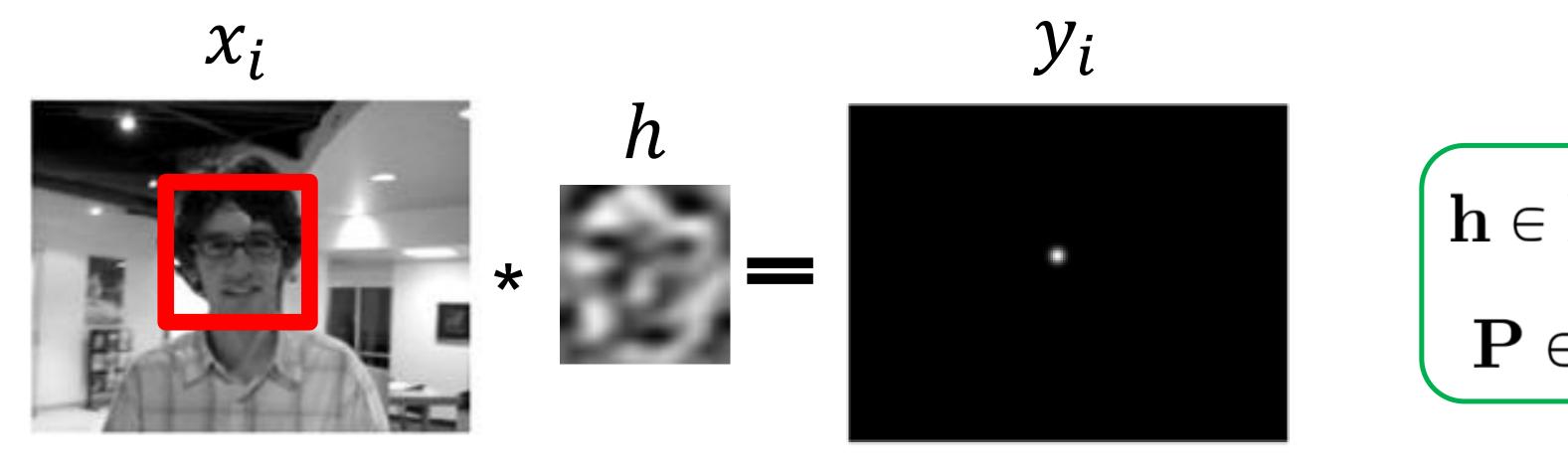
2- Spatial domain: $\mathcal{O}(D^3 + ND^2)$

$$E(\mathbf{h}) = \frac{1}{2} \sum_{i=1}^{N} \sum_{j=1}^{D} ||\mathbf{y}_i(j) - \mathbf{h}^{\top} \underbrace{\mathbf{x}_i[\Delta \boldsymbol{\tau}_j]}_{\text{circular shift}} ||_2^2 + \frac{\lambda}{2} ||\mathbf{h}||_2^2$$

CONTRIBUTIONS

- 1. A new correlation filter objective to drastically reduce the number of synthetic patches.
- 2. Optimizing the new objective using ADMM with very efficient complexity and memory usage.

KEY IDEA



 $\mathbf{h} \in \mathbb{R}^D$ $\mathbf{x}, \mathbf{y} \in \mathbb{R}^T$ $\mathbf{P} \in \mathbb{R}^{D \times T}$ $\mathbf{T} \gg \mathbf{D}$

$$E(\mathbf{h}) = \frac{1}{2} \sum_{i=1}^{N} \sum_{j=1}^{T} ||\mathbf{y}_{i}(j) - \mathbf{h}^{\top} \mathbf{P} \mathbf{x}_{i} [\Delta \boldsymbol{\tau}_{j}]||_{2}^{2} + \frac{\lambda}{2} ||\mathbf{h}||_{2}^{2}$$



- 1. # of training patches: T vs. D ($T \gg D$)
- 2. # of patches affected by circular shift (synthetic): $\frac{D-1}{T}$ vs. $\frac{D-1}{D}$
- 3. Complexity: $\mathcal{O}(D^3 + NDT)$

$$E(\mathbf{h}, \hat{\mathbf{g}}) = \frac{1}{2} \sum_{i=1}^{N} ||\hat{\mathbf{y}}_i - \operatorname{diag}(\hat{\mathbf{x}}_i)^{\top} \hat{\mathbf{g}}||_2^2 + \frac{\lambda}{2} ||\mathbf{h}||_2^2$$
s.t. $\hat{\mathbf{g}} = \sqrt{D} \mathbf{F} \mathbf{P}^{\top} \mathbf{h}$ (F: $D \times D$ discrete Fourier transform matrix)

Augmented Lagrangian

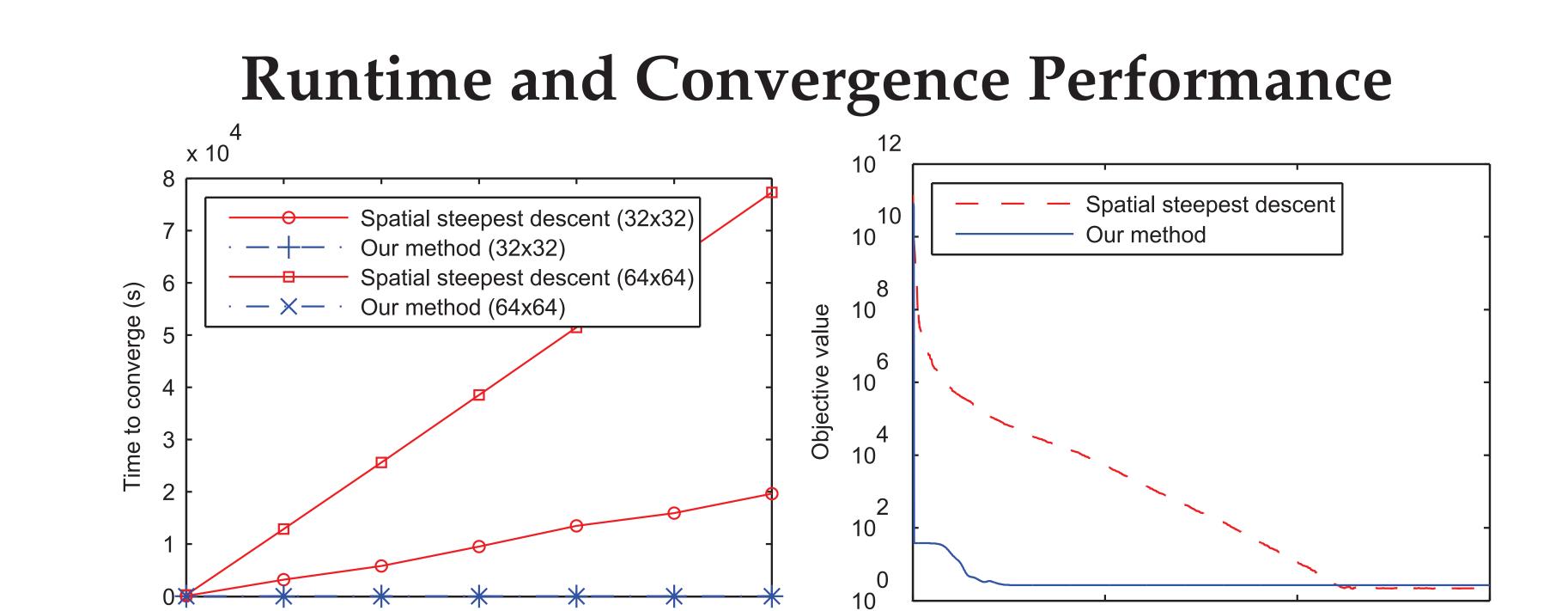
$$\mathcal{L}(\hat{\mathbf{g}}, \mathbf{h}, \hat{\boldsymbol{\zeta}}) = \frac{1}{2} \sum_{i=1}^{N} ||\hat{\mathbf{y}}_i - \operatorname{diag}(\hat{\mathbf{x}}_i)^{\top} \hat{\mathbf{g}}||_2^2 + \frac{\lambda}{2} ||\mathbf{h}||_2^2 + \hat{\boldsymbol{\zeta}}^{\top} (\hat{\mathbf{g}} - \sqrt{D} \mathbf{F} \mathbf{P}^{\top} \mathbf{h}) + \frac{\mu}{2} ||\hat{\mathbf{g}} - \sqrt{D} \mathbf{F} \mathbf{P}^{\top} \mathbf{h}||_2^2$$

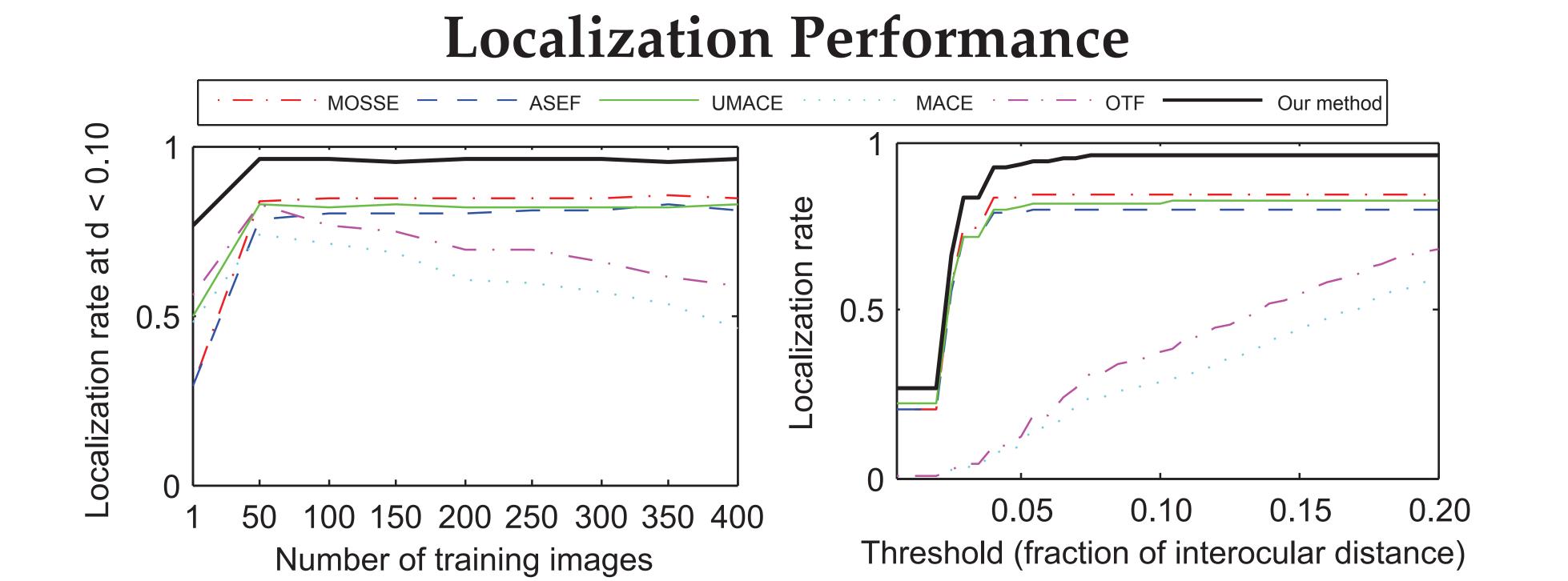
Augmented Lagrangian is solved using Alternating Direction Method of Multipliers (ADMM) with a time complexity of $\mathcal{O}([N+K]T\log T)$ and memory usage of $\mathcal{O}(T)$.

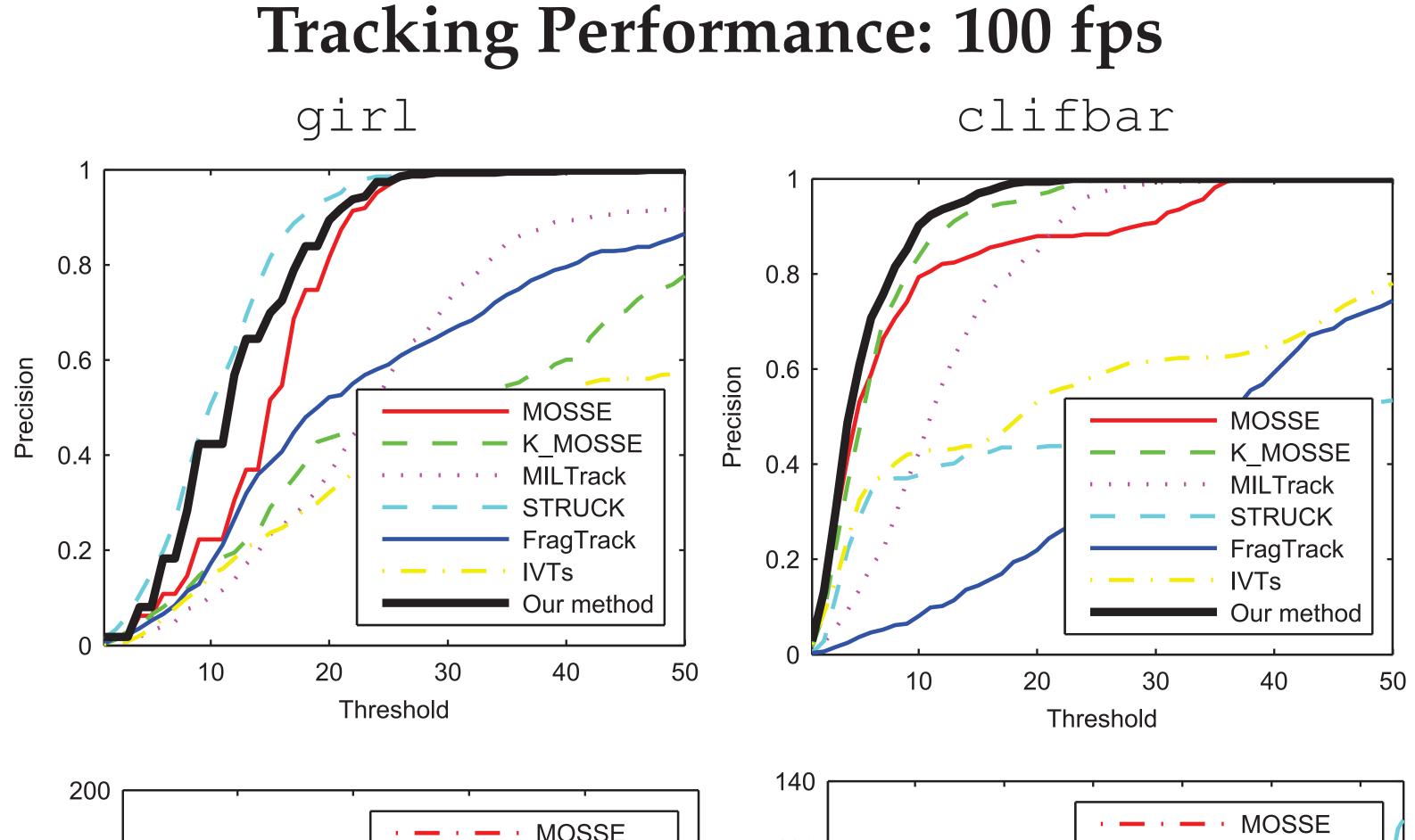
RESULTS (2)

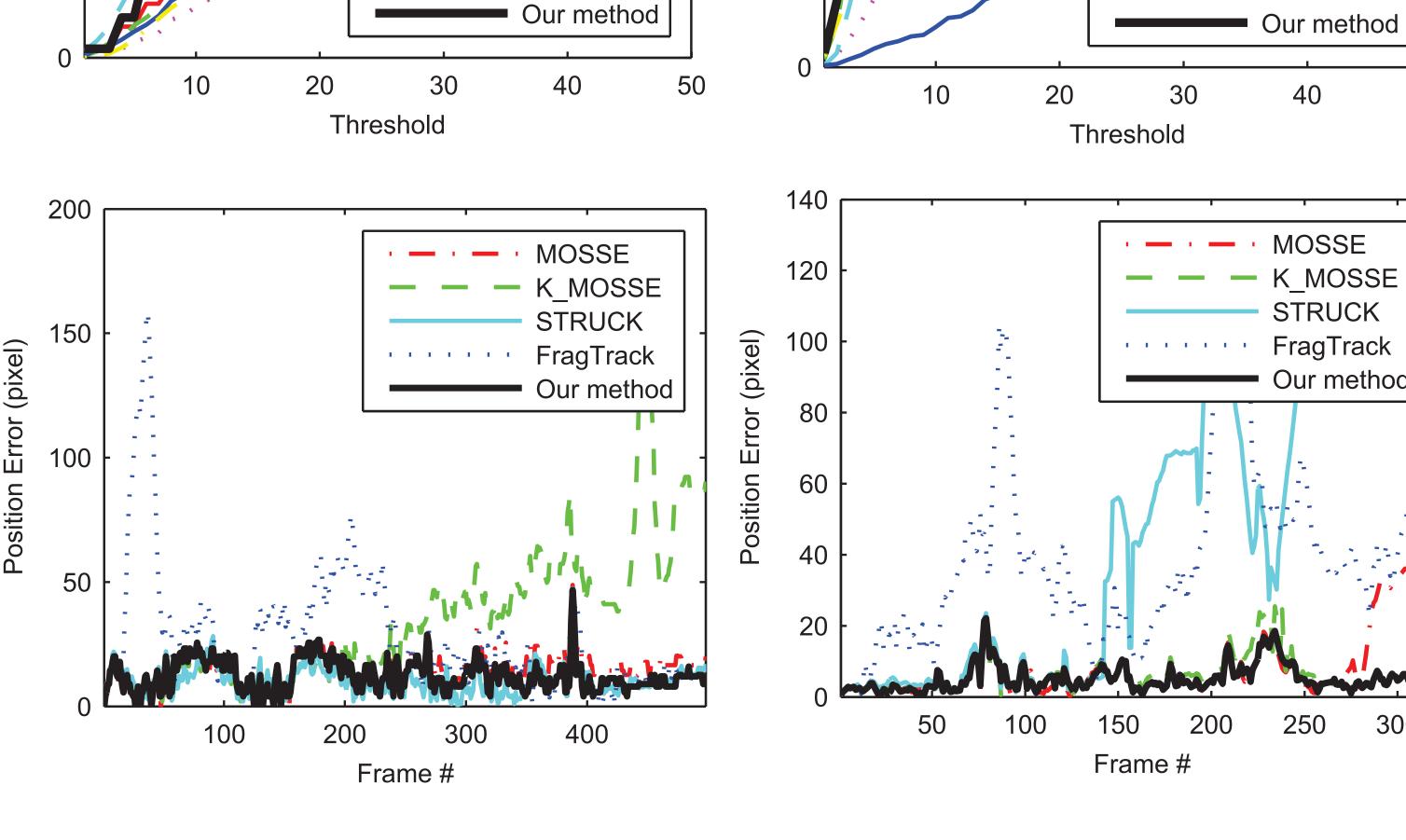


RESULTS (1)









REFERENCES

- [1] D. Bolme, J. Beveridge, B. Draper, and Y. Lui. Visual Object Tracking using Adaptive Correlation Filters *CVPR'10*
- [2] Code and Demo: http://www.hamedkiani.com/cfwlb.html