



## MOTIVATION

Objects that Change in Scale

- ▶ Objects approach the camera
- ▶ Camera approaches the object
- ▶ Objects deform naturally

How to track these objects

- ▶ Use Template Tracking to Localize
- ▶ Use Novel Temporally Local Optimal Updates

## TEMPLATE MATCHING

- ▶ Optimally warp a template or “model”  $M(x)$  onto an image  $I(x)$
- ▶ Find the best warp parameters  $p$  (we use translation only)
- ▶ We optimize in terms of sum of squared differences (SSD)

$$p^* = \operatorname{argmin}_p \sum_x [I(W(x; p)) - M(x)]^2,$$

Using only the subset of pixels with high  $\nabla I(x)$  we can increase speed by orders of magnitude with little loss in accuracy.

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Determine dominant subset  $X \subseteq I$   
**repeat**  
 Compute  $I(W(x; p))$   
 Compute residual  $[T(x) - I(W(x; p))]$   
 Compute  $\nabla I \cdot \frac{\partial W}{\partial p}$  and form the Hessian  $H$  as in (??)  
 Solve for  $\Delta p$  as in (??)  
 $p \leftarrow p + \Delta p$   
**until**  $p$  has converged

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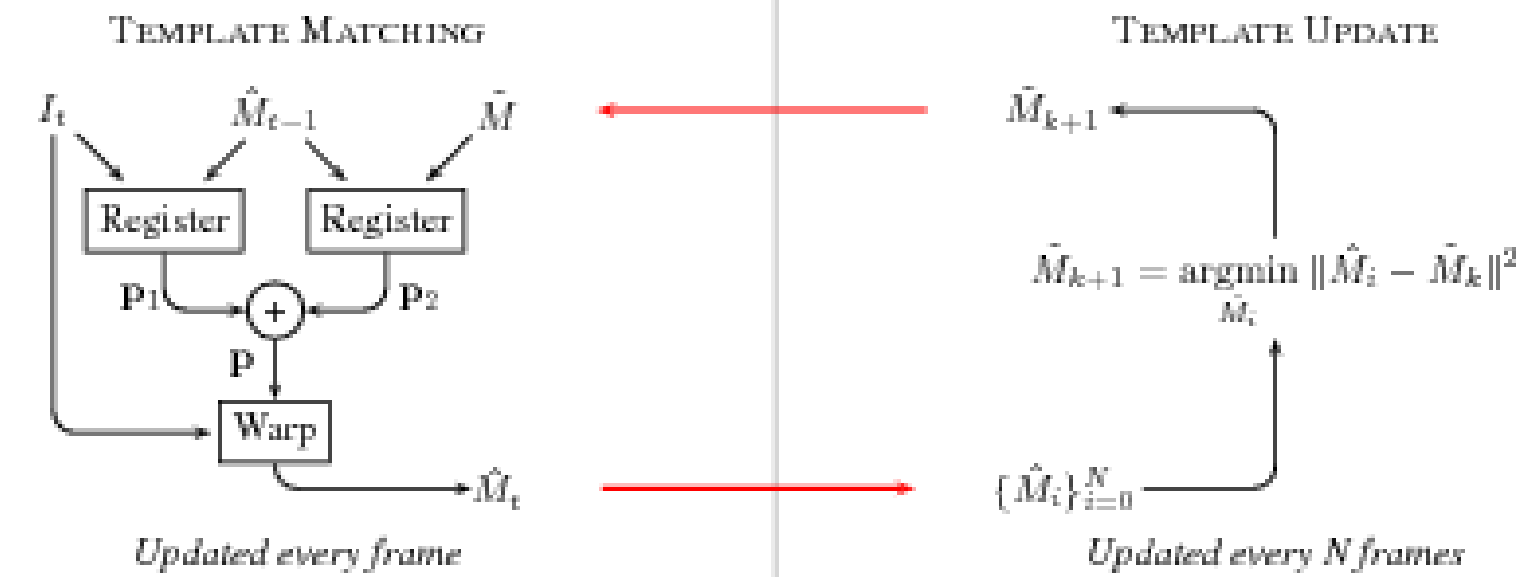
## TWO-PHASE MATCHING

- ▶ Two registrations are used to prevent drift

- 1) Registration with the current image  $I(t)$  and the previous model  $\hat{M}_{t-1}$
- 2) Registration between the previous model  $\hat{M}_{t-1}$ , and the most recent *key model*  $\tilde{M}$

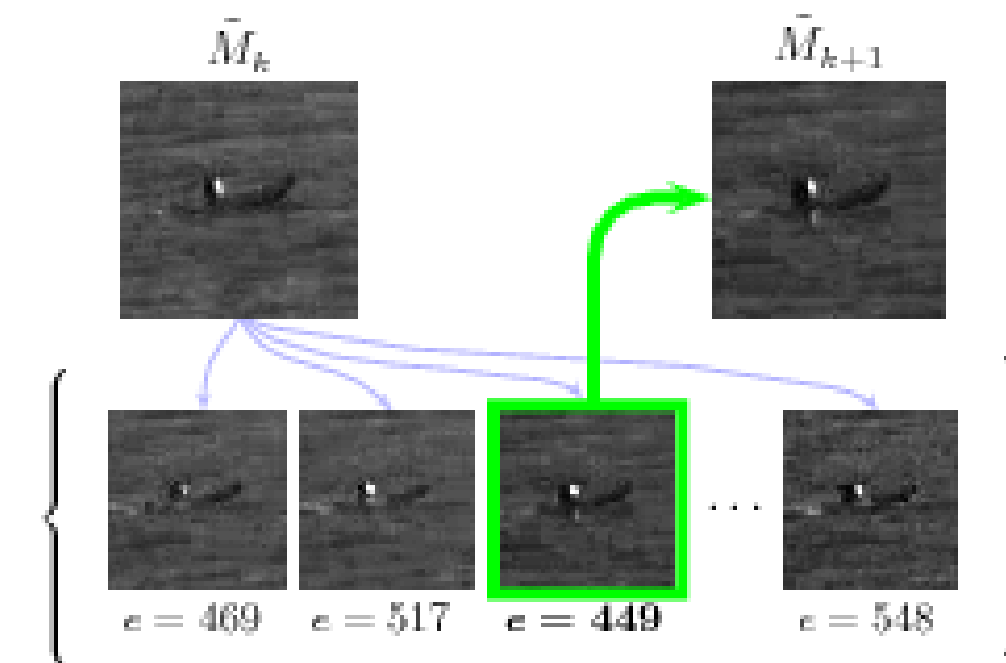
- ▶ Using two registrations reduces drift that may occur from frame-to-frame registrations only

## OVERALL ALGORITHM



## TEMPLATE UPDATE

- ▶ Goal: Allow the template to change over time
- ▶ Problem: Template updates can lead to feature drift
- ▶ Solution: Update with temporally local optimal template



- ▶ Collect previous  $N$  models  $\{\hat{M}_i\}_{i=1}^N$
- ▶ The next key model  $\tilde{M}_{k+1}$  is the best among these
- ▶ Here *best* refers to lowest SSD error,  $e$ :

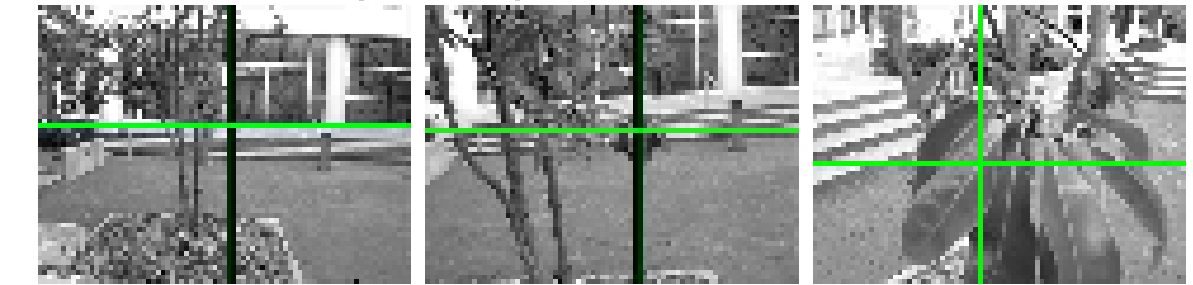
$$e(\hat{M}, \tilde{M}) = \|\hat{M} - \tilde{M}\|^2$$

$$\tilde{M}_{k+1} = \operatorname{argmin}_{\tilde{M}_i} e(\{\hat{M}_i\}_{i=1}^N, \tilde{M}_k)$$

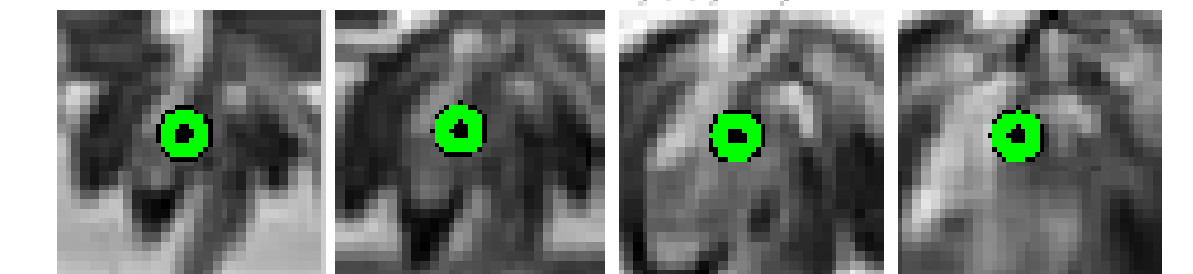
- ▶ Maintaining key models in this way helps prevent drift
- ▶ Allowing the template to change over time allows tracking though scale

## LEAVES EXPERIMENT

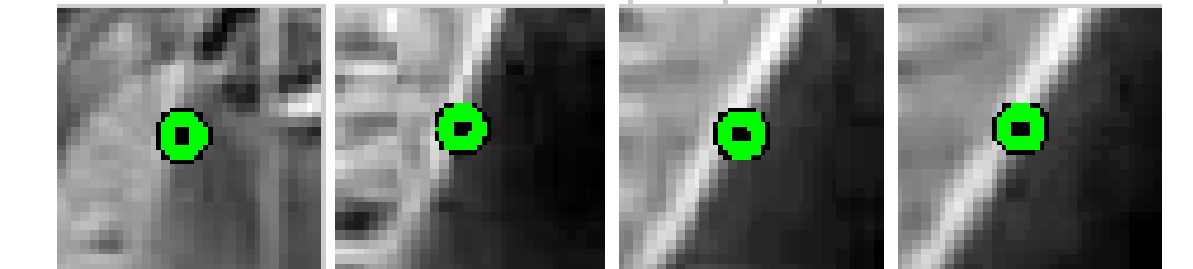
First, middle, and last tracked frame



Model at frames 28, 55, 81, and 108

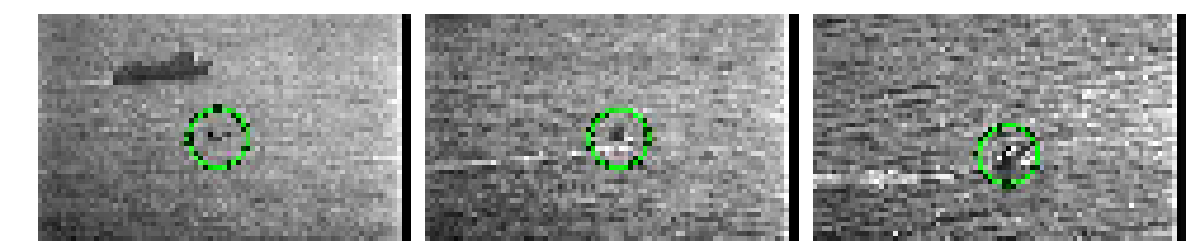


Model at frames 134, 161, 187, and 214

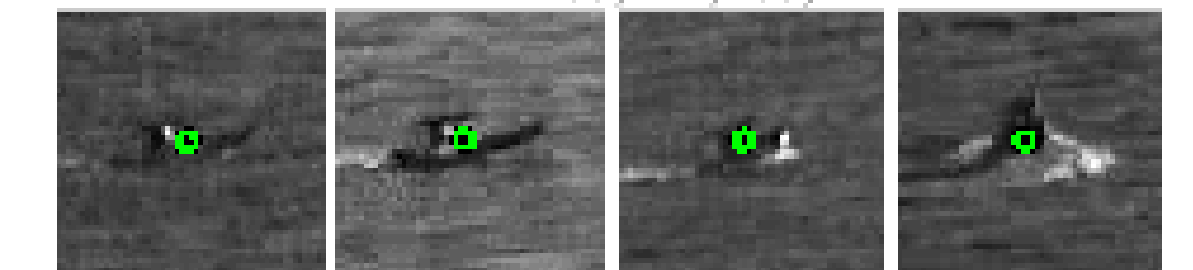


## BOAT EXPERIMENT

First, middle, and last tracked frame



Model at frames 53, 104, 155, and 206



Model at frames 257, 308, 359, and 410

