# Boundary Flow: A Siamese Network that Predicts Boundary Motion without Training on Motion

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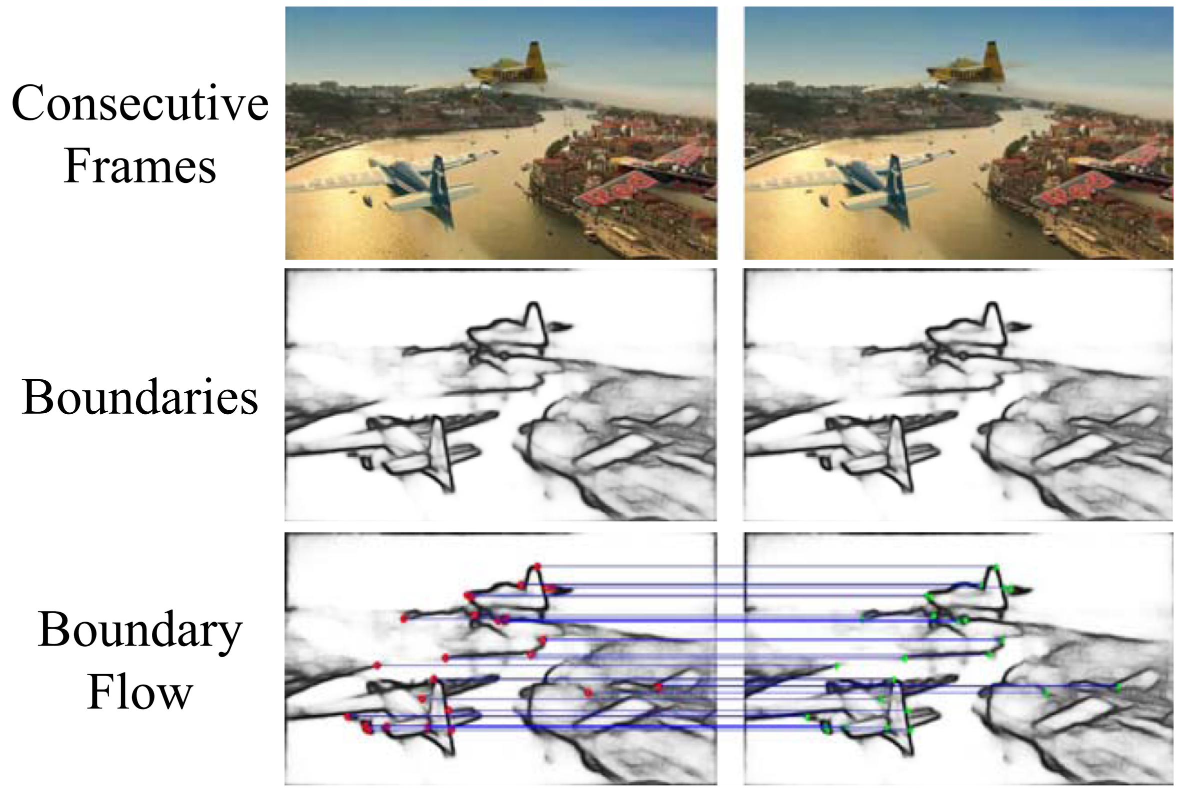
## Problem: Boundary Detection and Boundary Motion Estimation in Videos




## Motivations

- Boundaries (esp. semantic boundaries) are the most informative pixels in an image.
- Optical flow (OF) is often not well-defined and difficult to compute near boundaries.
- Some high-level tasks (e.g. video object segmentation) may not need motion at every pixel.

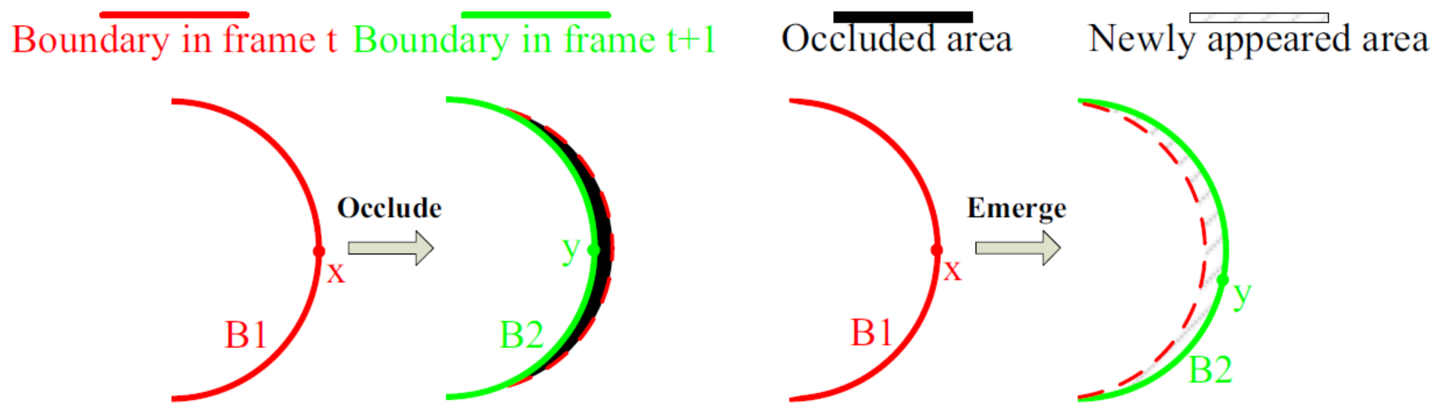
## Definition of Boundary Flow (BF)

BF maps each boundary pixel to its nearest boundary pixel in the next frame:

(a) $BF(x) = OF(\underset{y,\exists OF(y)}{\operatorname{argmin}} \|y - x\|_2)$, if OF(x) does not exist;

(b) $BF(x) = \underset{y \in B_2}{\operatorname{argmin}} \|y - (x + OF(x))\|_2 - x$, if OF(x) exists;

(c) BF is undefined if *argmin* in (a) or (b) does not return a unique solution.



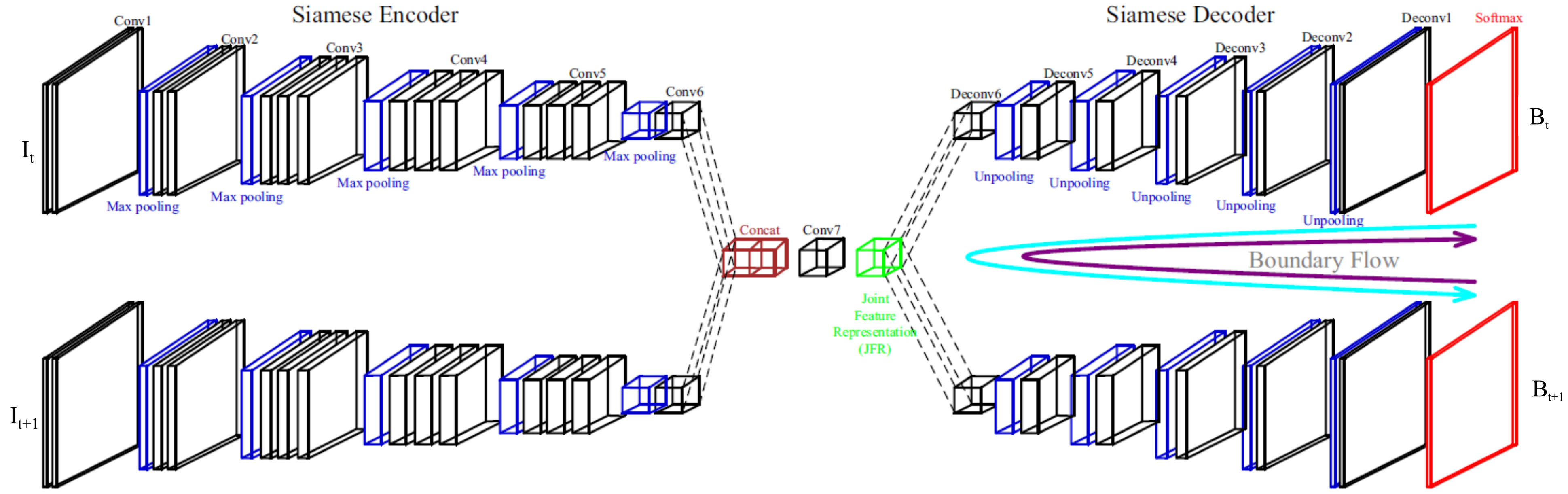

(a) Occlusion (b) Emergence

## Contributions

- A rigorous definition of BF, a new deep architecture and a self-supervised approach to estimate BF with only per-frame boundary annotations.
- State-of-the-art performance on spatiotemporal boundary detection, the first results on BF estimation, and competitive improvement on dense OF.

## Key Ideas: Jointly Detect Object Boundaries using a Siamese Network and Estimate Their Flow by Bridging Two Decoder Branches

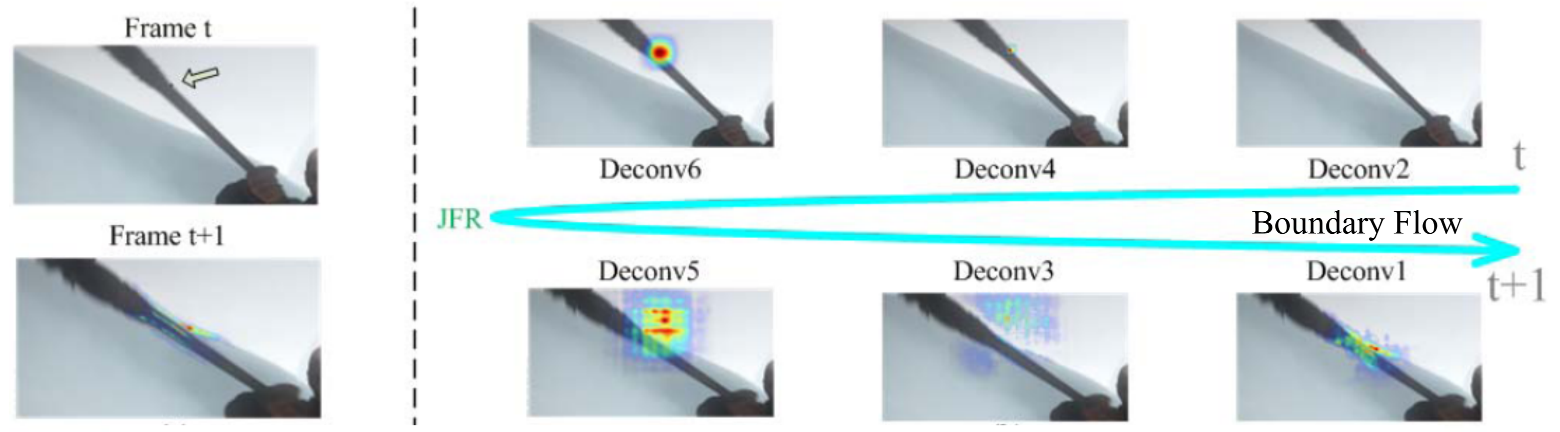
Fully Convolutional Siamese Networks (FCSN) with both frames as input and boundary annotations in (at least) one frame as training signal. Both branches share parameters, only difference is max-pooling indices.




Key intuition: A common edge representation in JFR for each edge enables us to match the corresponding boundaries in the two images.

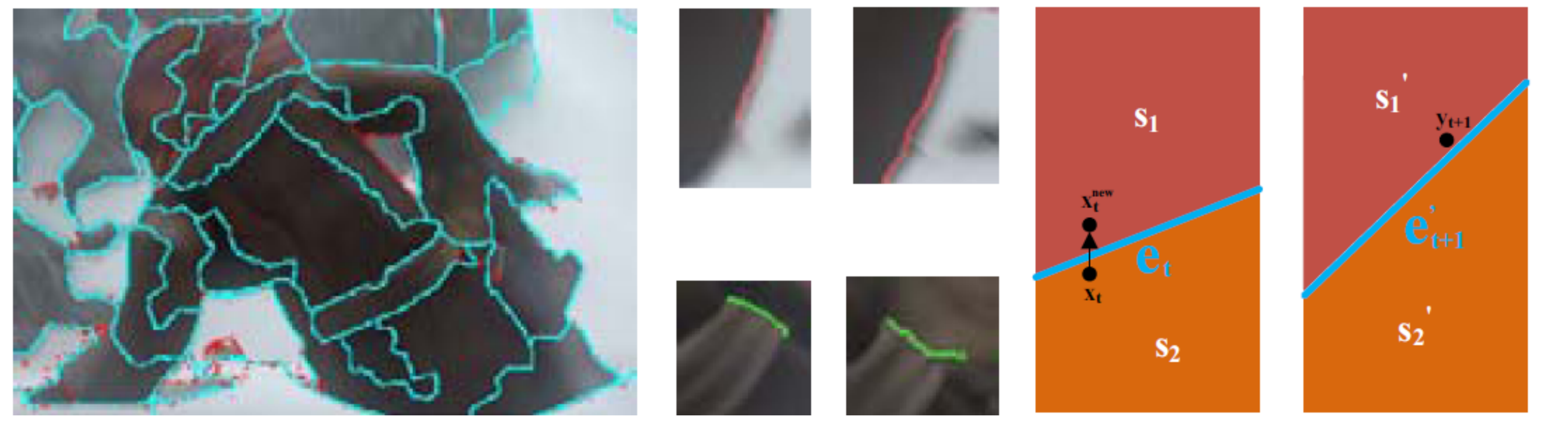
## Attention Score

For each pixel/edgelet, the attentions are sequentially sampled on the path from t to t + 1 via the JFR, based on a conditional winning probability:




## Edgelet-based Matching

Difference between BF and OF: Appearance is only consistent on one side of the boundary.



## Results

Table.1 Boundary detection results on VSB100.

| Method | ODS | OIS | AP |
|---|---|---|---|
| CEDN [Yang CVPR16] | 0.563 | 0.614 | 0.547 |
| FCSN | **0.597** | **0.632** | **0.566** |

Figure.1 Example boundary detection results on VSB100.

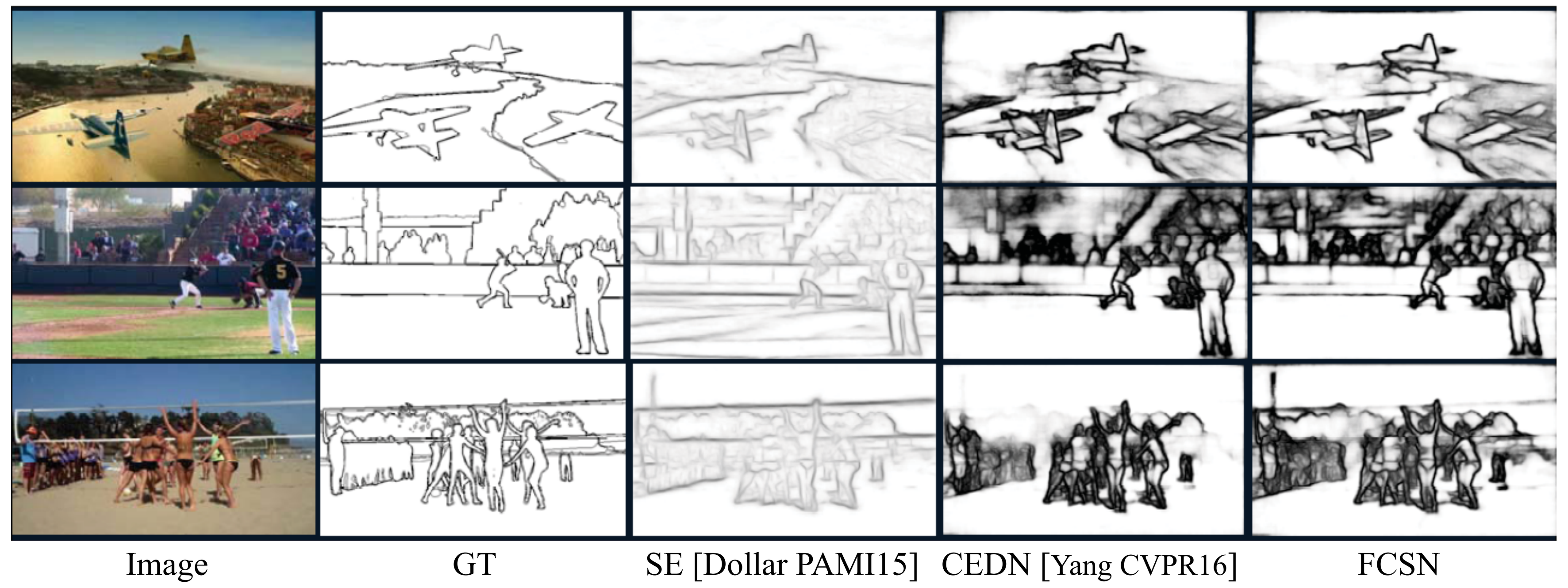


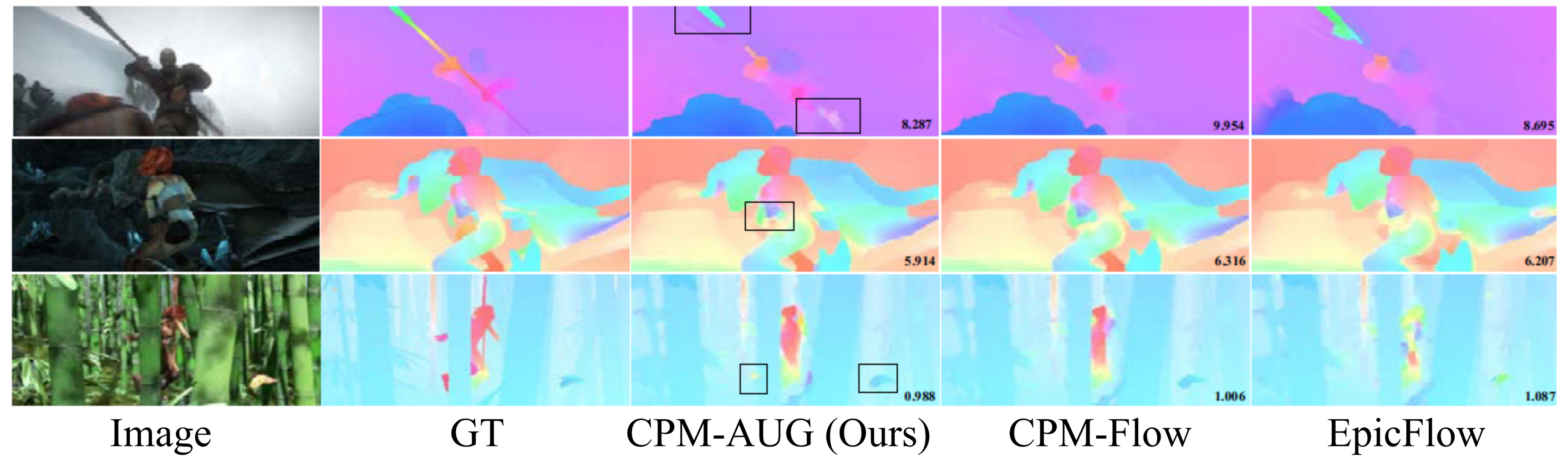

Table.2 Boundary flow results on Sintel training dataset in EPE metric.

| Method | FLANN | RANSAC | Greedy | Ours |
|---|---|---|---|---|
| **EPE** | 23.158 | 20.874 | 25.476 | **9.856** |

Table.3 Optical flow results on Sintel final test set in EPE metric.

| Method | EpicFlow [Revaud CVPR15] | DiscreteFlow [Revaud GCPR15] | CPM-Flow [Hu CVPR16] | Full Flow [Chen CVPR16] | FlowFields [Bailer CVPR15] | CPM-AUG (Ours) |
|---|---|---|---|---|---|---|
| **EPE** | 6.285 | 6.077 | 5.960 | 5.895 | 5.810 | **5.645** |

Figure.2 Example optical flow results on MPI-Sintel test dataset.

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