Video Segmentation using Spectral Clustering on Superpixels

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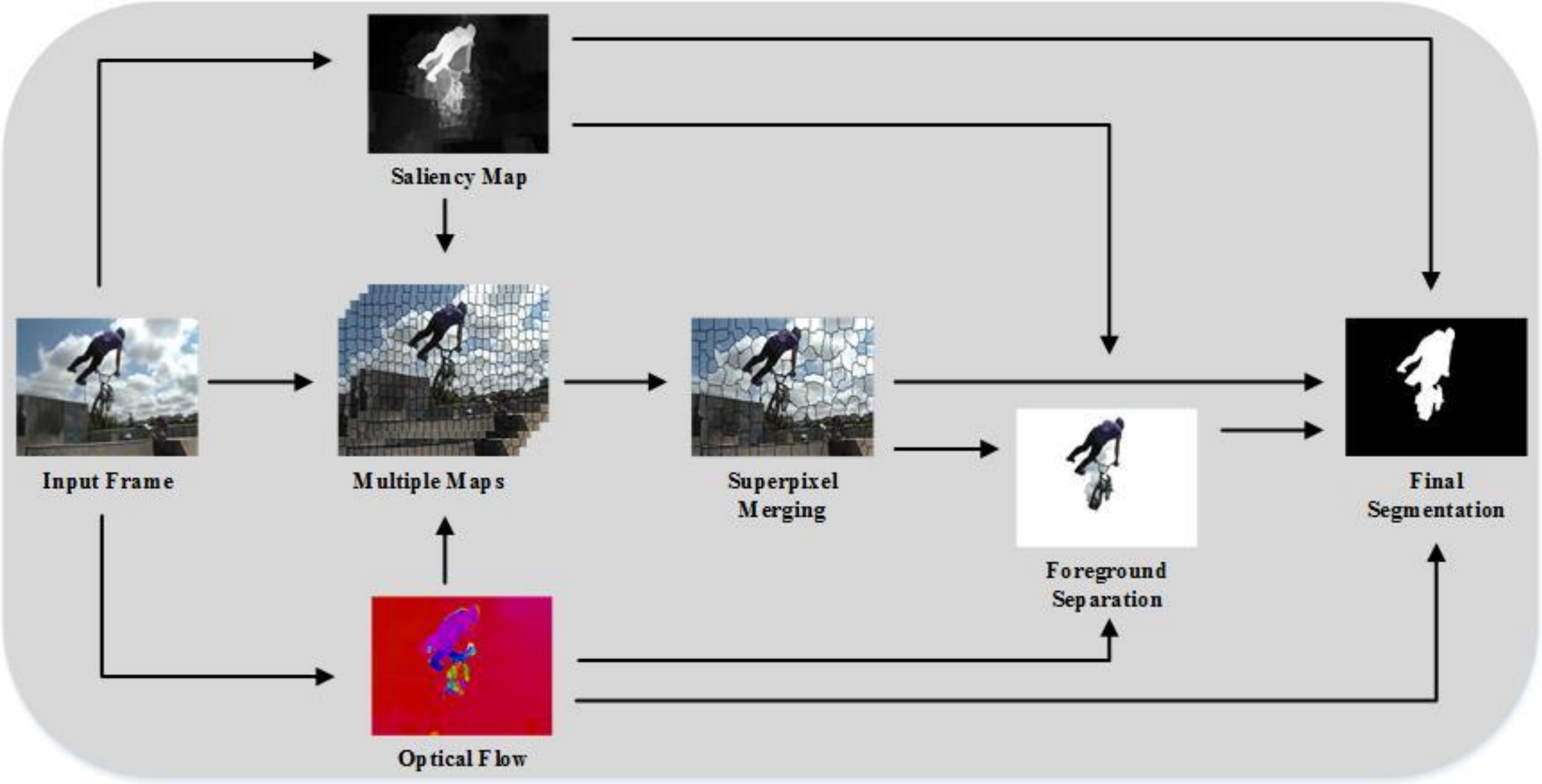
Video Object Segmentation

- Video object segmentation is the extraction of all objects from a given video sequence.

- A binary labelling problem where all the pixels belonging to an object are labelled as (1) while the background pixels are labelled as (0).

- Segmentation allows suppression of unnecessary/irrelevant information.

Proposed Framework



Feature Extraction

- We extracted multiple features for each frame of video sequence.

- Use of existing solutions to obtain:
  - CIELAB color representation.
  - CIELAB color representation of dense optical flow.
  - Spatio-temporal saliency score.

Superpixel Segmentation & Merging

- We extended existing segmentation technique to perform spatio-temporal superpixel segmentation of videos.

- 8-dimensional spatio-temporal feature vector used for superpixel segmentation:

$$p = (L, \alpha, \beta, x, y, u, v, s)$$

- Mapped to 16-dimensional feature vector:

$$l_1(i,j) = \cos\frac{\pi}{2} . l(i,j)$$
$$l_2(i,j) = \sin\frac{\pi}{2} . l(i,j)$$

- Spectral Clustering performed to get final superpixels.

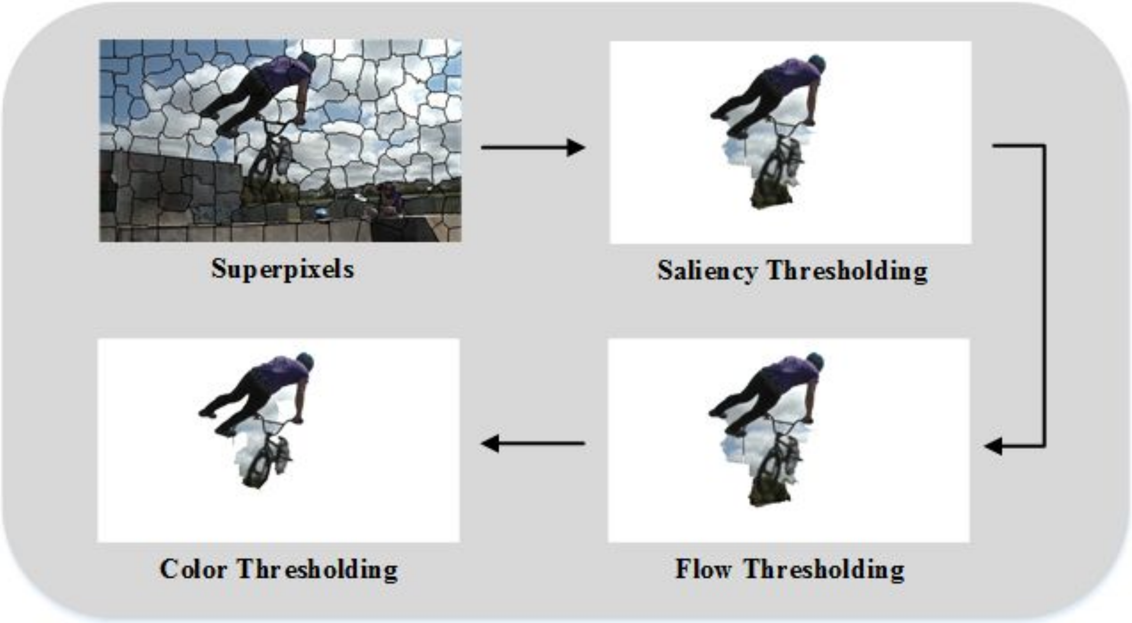
Superpixel Segmentation & Merging

- We obtained 5 different superpixel segmentations using different values for color, saliency and flow constants.

- Multiple segmentation merged into one using existing superpixel merging technique.

Foreground Separation Model

- Multiple thresholding steps performed on merged superpixel segmentation to get initial labelling for each frame.



Interframe Spectral Clustering

- Merged superpixel segmentation of each frame used.
- Distance between each feature (color, spatial, saliency and optical flow color) of every two segments calculated.
- Interframe graph constructed across all frames:

$$dist(i,j) = \sqrt{\lambda_1 C + \lambda_2 F + \lambda_3 P + \lambda_4 S + \lambda_5 L}$$

- Affinity matrix constructed using:

$$affinity(i,j) = \exp\left(\frac{-dist(i,j)}{2\sigma^2}\right)$$

- Spectral Clustering performed for final labelling.

Dataset

- We used SegTrack v2 dataset for experimentation.
- 14 video sequences with varying number of frames.
- Each video had different properties with respect to foreground, background and motion.
- For long videos, first 50 frames used for experimentation.

Experiments

- Evaluation measures:
  - Average per-frame pixel error rate
  - Precision, recall and F-measure.

- Comparison with state-of-the-art solutions:
  - Lee et al., 2011
  - Galasso et al., 2012
  - Zhang et al., 2013

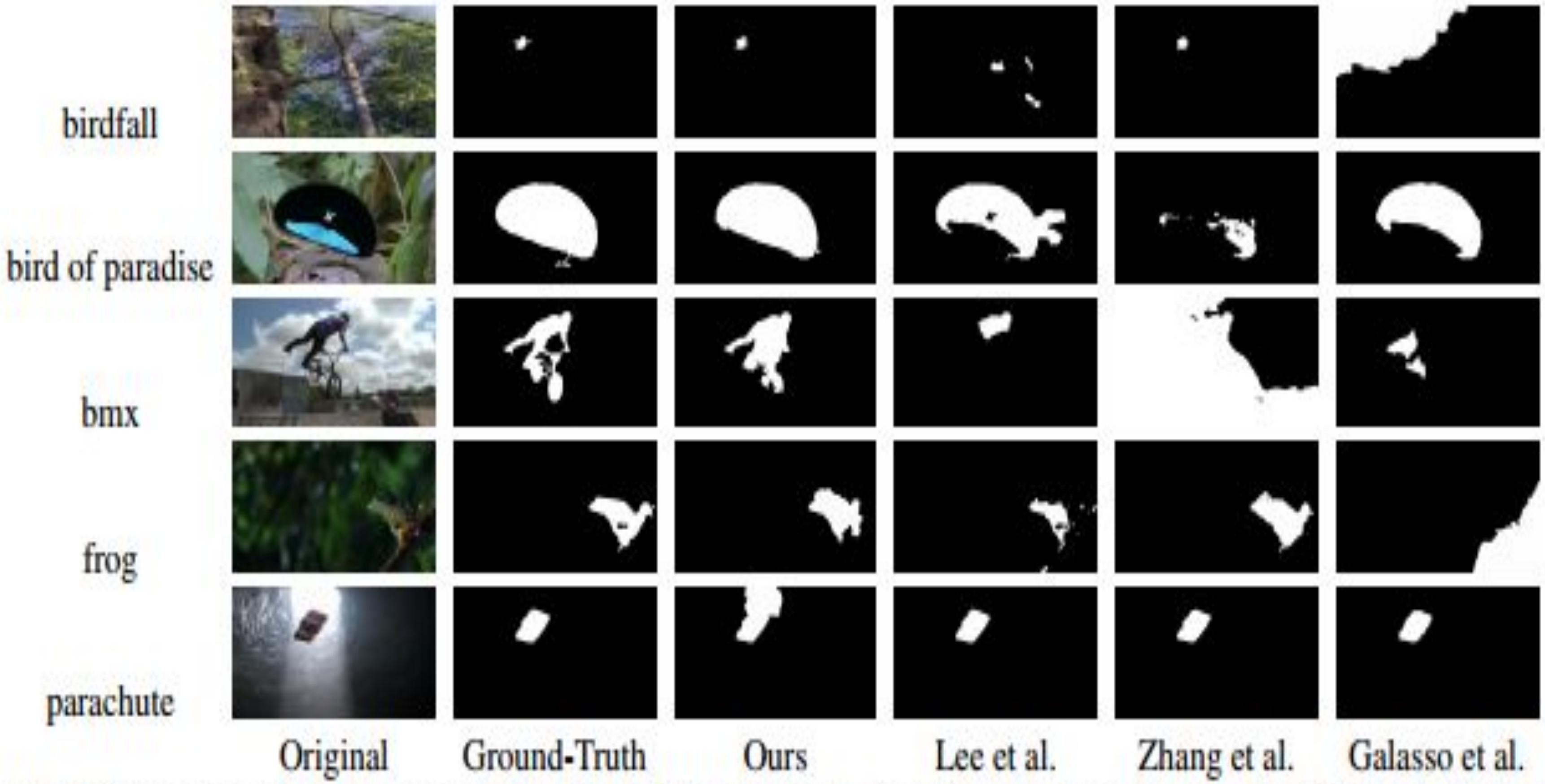
Results (Error Rate)

Sequence	Ours	(Lee et al.)	(Zhang et al.)	(Galasso et al.)
bird of paradise	**4845**	13041	35429	11832
birdfall	980	1091	**150**	18533
bmx	**10339**	12071	152527	17133
cheetah	2626	22977	**1914**	4532
drift	19614	**15503**	147480	42130
frog	2854	3387	**1767**	15216
girl	4802	2054	**1495**	4079
hummingbird	18237	18288	**13601**	21404
monkey	7230	**3205**	3430	18697
monkeydog	8065	9337	**2241**	3671
parachute	1104	**202**	219	382
penguin	36786	**24751**	30205	37022
soldier	6660	57586	24764	**5592**
worm	2839	**1470**	4147	17745
Mean	**9070**	13212	29963	15569

Results

	Ours	(Lee et al.)	(Zhang et al.)	(Galasso et al.)
Precision	0.612	**0.626**	0.617	0.430
Recall	0.597	0.571	**0.661**	0.306
F1-measure	**0.568**	0.521	0.535	0.284

Results


birdfall
bird of paradise
bmx
frog
parachute
Original
Ground-Truth
Ours
Lee et al.
Zhang et al.
Galasso et al.

Experiments

- We have proposed a Spectral Clustering based solution for video object segmentation.

- We extended existing segmentation technique to perform spatiotemporal superpixel segmentation of videos and introduced a foreground separation model to provide initial foreground labelling.

- Results show that our algorithm is comparable to other state-of-the-art solutions.