# Associative Hierarchical CRFs 

$$
\begin{aligned}
& \text { for Object Class Image } \\
& \text { Segmentation }
\end{aligned}
$$

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## Microsoft'

## Research

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## Pairwise CRF over Pixels



## sky

tree

$E(\mathbf{x})=\sum_{i \in \mathcal{V}} \psi_{i}\left(x_{i}\right)+\sum_{i \in \mathcal{V}, j \in \mathcal{N}_{\mathbf{i}}} \psi_{i j}\left(x_{i}, x_{j}\right)$.
TextonBoost (Shotton ECCV06)

## Pairwise CRF over Pixels

- No quantization errors
- Lacks long range interactions
- Results oversmoothed


## Pairwise CRF over Segments



Shi, Malik PAMI2000, Comaniciu, Meer PAMI2002, Felzenschwalb, Huttenlocher, IJCV2004 Yang et al. CVPR07, Batra et al. CVPR08,

## Pairwise CRF over Segments

- Allows long range interactions
- Better performance for VOC dataset
- Can not recover from incorrect segmentation
- Impossible to obtain perfect unsupervised segmentation


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Person Road
Car
Tree
Building $\square$
Sky
Sign

## Robust $\mathrm{P}^{\mathrm{N}}$ approach



## Robust $\mathrm{P}^{\mathrm{N}}$ approach

- Robust to misleading segmentations
- Segment consistency as a weak constraint
- Allows multiple segmentations
- Unary and pairwise potentials only at the pixel level


## Robust $\mathrm{P}^{\mathrm{N}}$ reformulation



## Associative Hierarchical CRF



Super Clique Variables

Clique Variables


Clique (Segments)


Super Clique


Pixel Context


Segment Context

- Allows unary potentials for region variables
- Allows pairwise potentials for region variables
- Allows multiple layers and multi hierarchies


## Analysis of the new model

Let's have one segmentation and potentials only over segment level

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Interlayer connection is symmetric and semimetric

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Let's have one segmentation and potentials only over segment level
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- Minimum will be segment-consistent
- The cost of every segment consistent labelling is the same as the cost of the pairwise CRF labelling over segments
- Equivalent to pairwise CRF over segments


## Associative Hierarchical CRF

- Merges information over multiple scales
- Allows multiple hierarchies
- Allows long range interactions
- Easy to train weights
- Interlayer connection limited(?) to associative relationship


## Inference over Hierarchical CRF

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- $\alpha \beta$-swap (potentials must be semi-metric)
- Ishikawa construction over ( $\alpha-\mathrm{F}-\beta$ transition)
- $\alpha$-expansion (potentials must be metric)
- Reparametrization of interlayer connection to metric potential
- Ishikawa construction over ( $\alpha$-F-old transition)
- For more details read our technical report


## Associative Hierarchical CRF

- Pixel layer
- TextonBoost-like unary potential with multiple features (texton, SIFT, Opponent SIFT)
- Intensity dependent pairwise potential
- Superpixel layer
- Consistency potential
- EMD-distance of colour histograms pairwise potential
- Segment layer
- Unary potential based on histograms of features (texton, SIFT, Opponent SIFT, Location)
- And one other layer..


## Results



## Take home message

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- Inference code available soon!


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- Use your favourite potentials


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- Use your friend's favourite potentials


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- Vision solved (..almost)


## Thank you

- Questions?

