Simple-to-Complex Discriminative Clustering for Hierarchical Image Segmentation

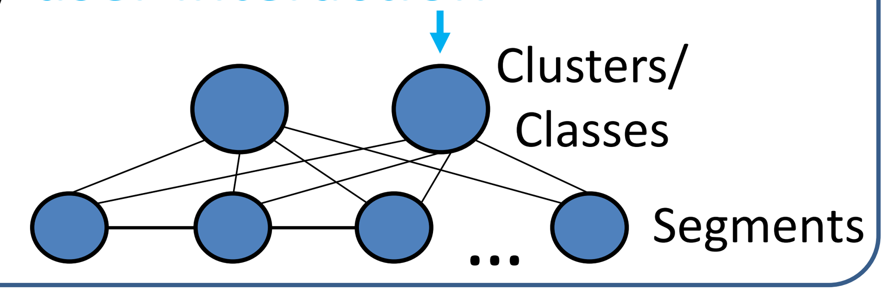
Haw-Shiuan Chang and Yu-Chiang Frank Wang
Research Center for Information Technology Innovation, Academia Sinica, Taipei, Taiwan

Motivation

- Contour-based methods like gPb-OWT-UCM [1] typically outperform region-based ones (e.g., SAS [2]).
- Potential issues of contour-based approaches:
  - Probabilistic interpretation or theoretical supports
  - Heavy memory cost (e.g., large-scale eigen problems)
  - Require training data (and possibly overfitting)

Related Works

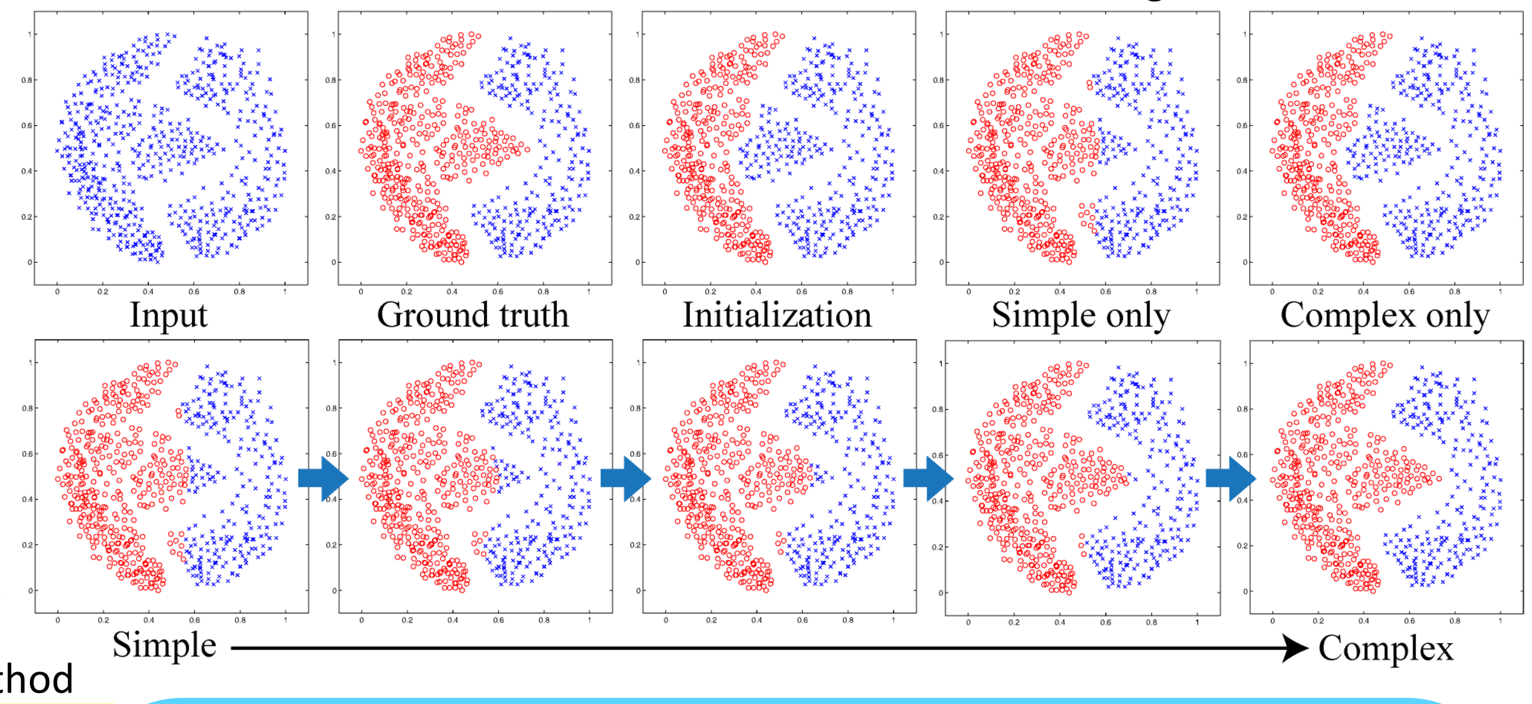
- Discriminative clustering [3]: Classification → Clustering
  - Need to determine the cluster number
- GrabCut [4]: Figure/ground segmentation by MRF
  - Need prior knowledge by user interaction
- GMM clustering:
  - Assume the Gaussian distributions of clusters



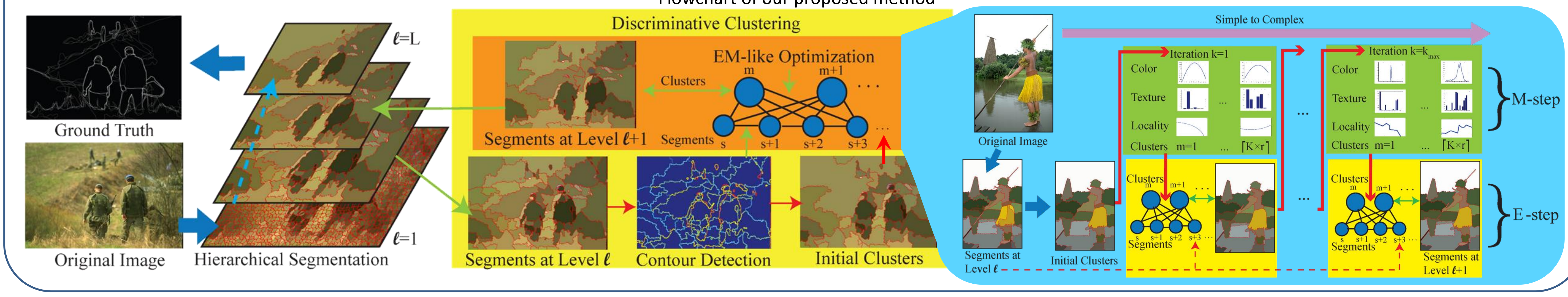
Our Proposed Framework

- Bottom-up hierarchical segmentation: clusters at ℓ → segments at $\ell+1$
- At each level, we perform EM-based discriminative clustering:
  - E-step: Classify segments into clusters by MRF
    M-step: Train classifiers by the clustering result
- Features & classifiers considered:
  - Color → KDE, texture → BoW, spatial info → Gaussian
  - Simple-to-complex discriminative clustering (avoid overfitting):
    - Iteratively increase the complexity of the associated classifiers

Illustration of our discriminative clustering



Flowchart of our proposed method



Experiments

- Our method achieves state-of-the-art performances on multiple datasets in terms of optimal image scale (OIS).
- No training data is required.
- Only 12% of memory costs compared with [1,5].
- Source code is available [6].

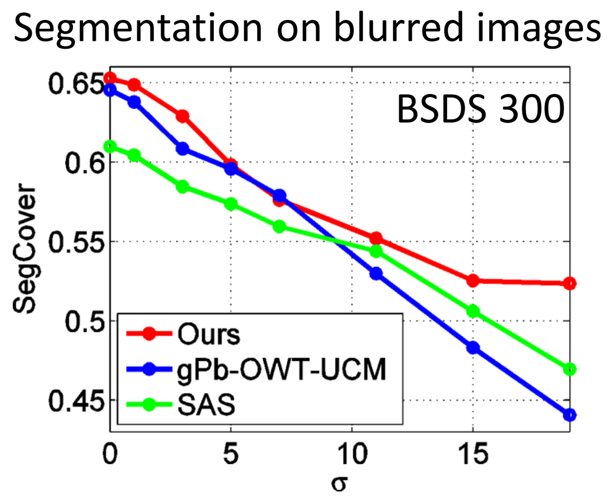
Comparisons of Unsupervised Segmentation (* indicates using the different ground truth)

Methods	MSRC SegCover	MSRC PRI	MSRC Vol (↓)	SBD SegCover	SBD PRI	SBD Vol (↓)
SAS (FH+MS) [2]	0.712	0.823	1.052	0.649	0.856	1.474
gPb-OWT-UCM [1]	0.745	0.850	0.989	0.642	0.858	1.527
ISCRA [5]	0.75	0.85	1.02	0.68*	0.90*	1.50*
Ours (Full)	0.772	0.862	0.920	0.681	0.870	1.425

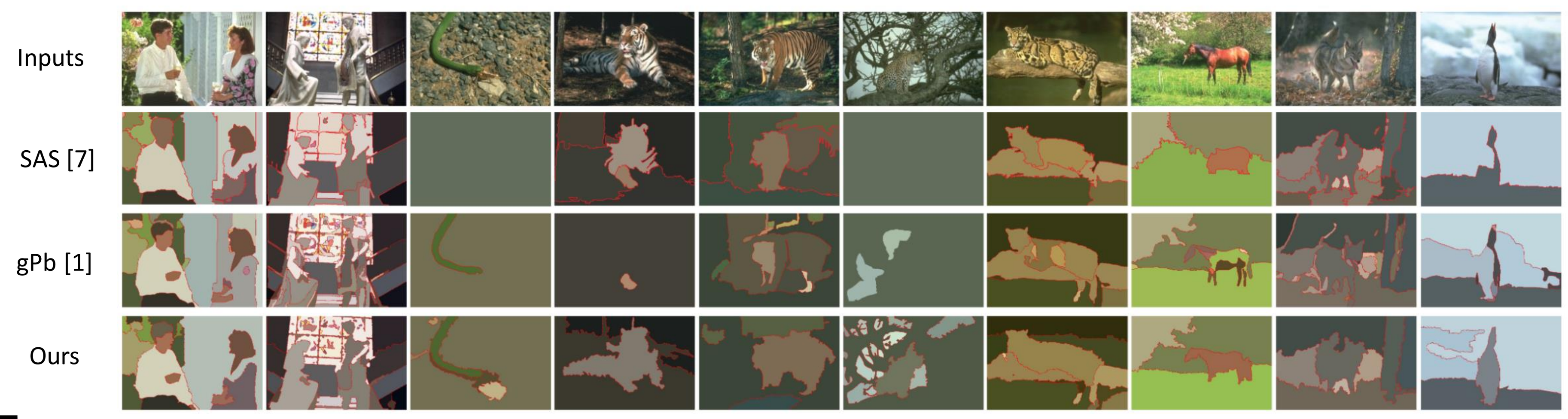
Semantic Segmentation Accuracy

Method	MSRC NB	MSRC SVM	SBD NB	SBD SVM
SAS (FH+MS) [2]	0.272	0.330	0.399	0.423
gPb-OWT-UCM [1]	0.285	0.352	0.406	0.426
Ours (Full)	0.294	0.362	0.414	0.454
Ground Truth	0.366	0.474	0.502	0.570

Segmentation on blurred images



Qualitative and Quantitative Comparisons of Unsupervised Segmentation on BSDS



Methods		BSDS 300 SegCover	BSDS 300 PRI	BSDS 300 Vol (↓)	BSDS 500 SegCover	BSDS 500 PRI	BSDS 500 Vol (↓)
MNCut [7]		0.53	0.79	1.84	0.53	0.80	1.89
SWA [8]		0.55	0.80	1.75	-	-	-
SAS (FH+MS) [2]		0.61	0.834	1.534	0.610	0.840	1.552
gPb-OWT-UCM [1]		0.646	0.852	1.466	0.647	0.856	1.475
ISCRA [5]		0.66	0.86	1.40	0.66	0.85	1.42
Ours (Full)		0.660	0.854	1.443	0.655	0.859	1.454
Ours	Init (w/o DC)	0.583	0.814	1.734	0.578	0.825	1.784
	Complex only	0.627	0.840	1.569	0.618	0.845	1.613
	w/o MRF	0.633	0.843	1.536	0.634	0.849	1.548
	Color	0.595	0.810	1.695	0.598	0.823	1.724
	w/o Texture	0.605	0.824	1.653	0.605	0.832	1.699

Conclusion and Future Work

- Our proposed general framework can be viewed as:
  - An unsupervised version of GrabCut [4]
  - A generalization of GMM clustering
  - A Maximize Likelihood Estimation (see our paper)
- Additional features and classifiers can be easily added.
- Future directions: video, semantic & interactive seg.

Reference

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