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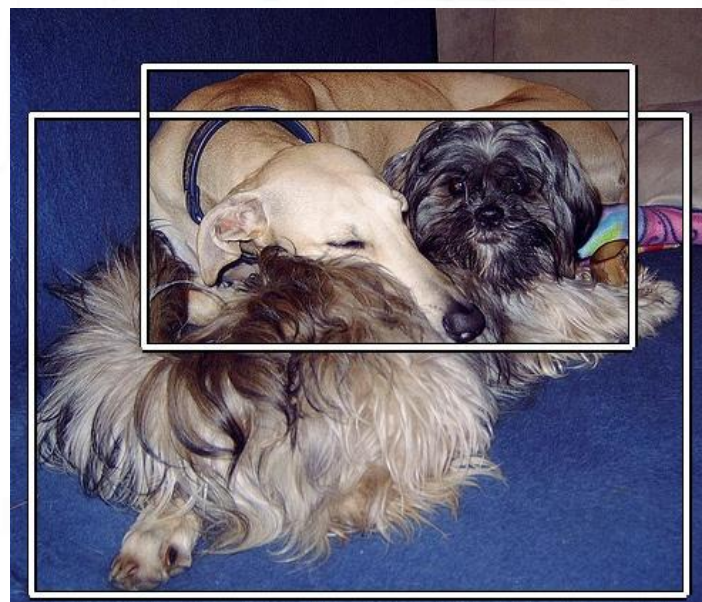
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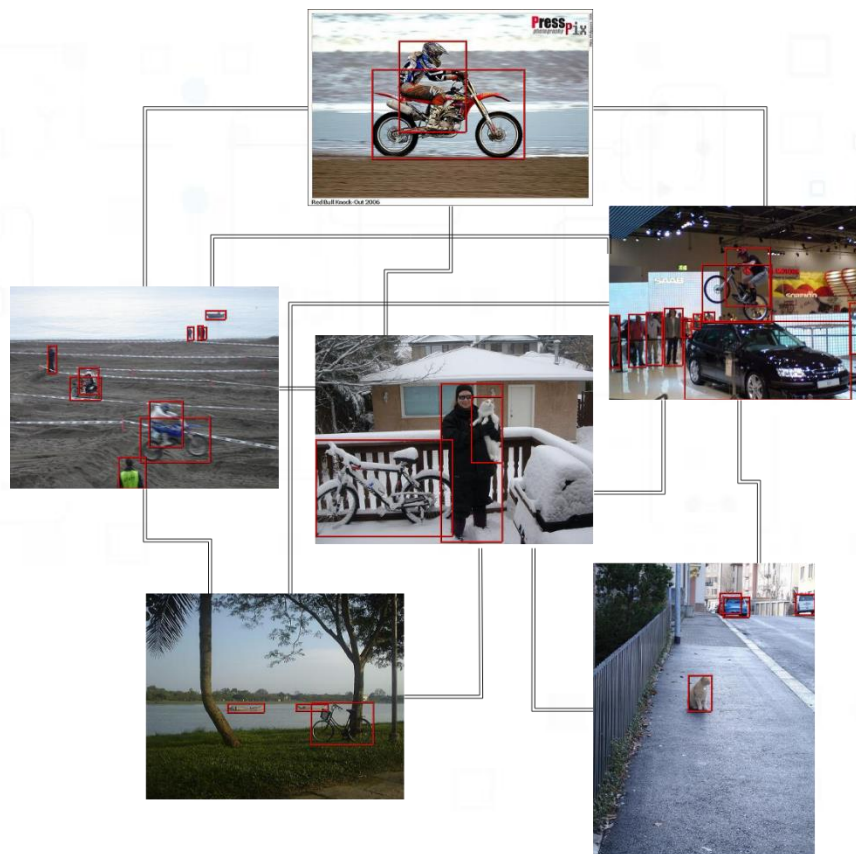
Toward unsupervised, multi-object discovery in large-scale image collections

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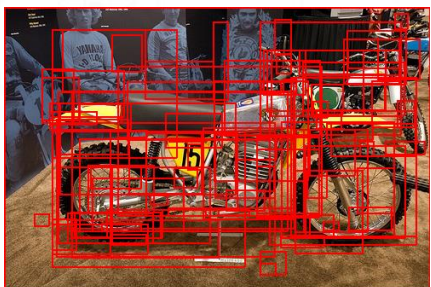
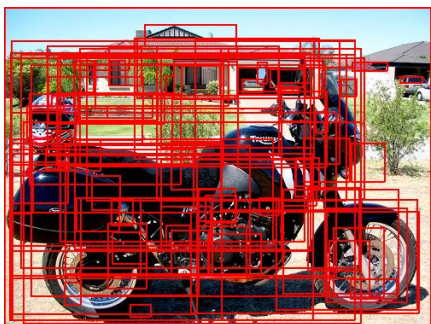
Graph of images

(Cho et al., CVPR'15, Vo et al., CVPR'19)



Object and structure discovery (OSD)

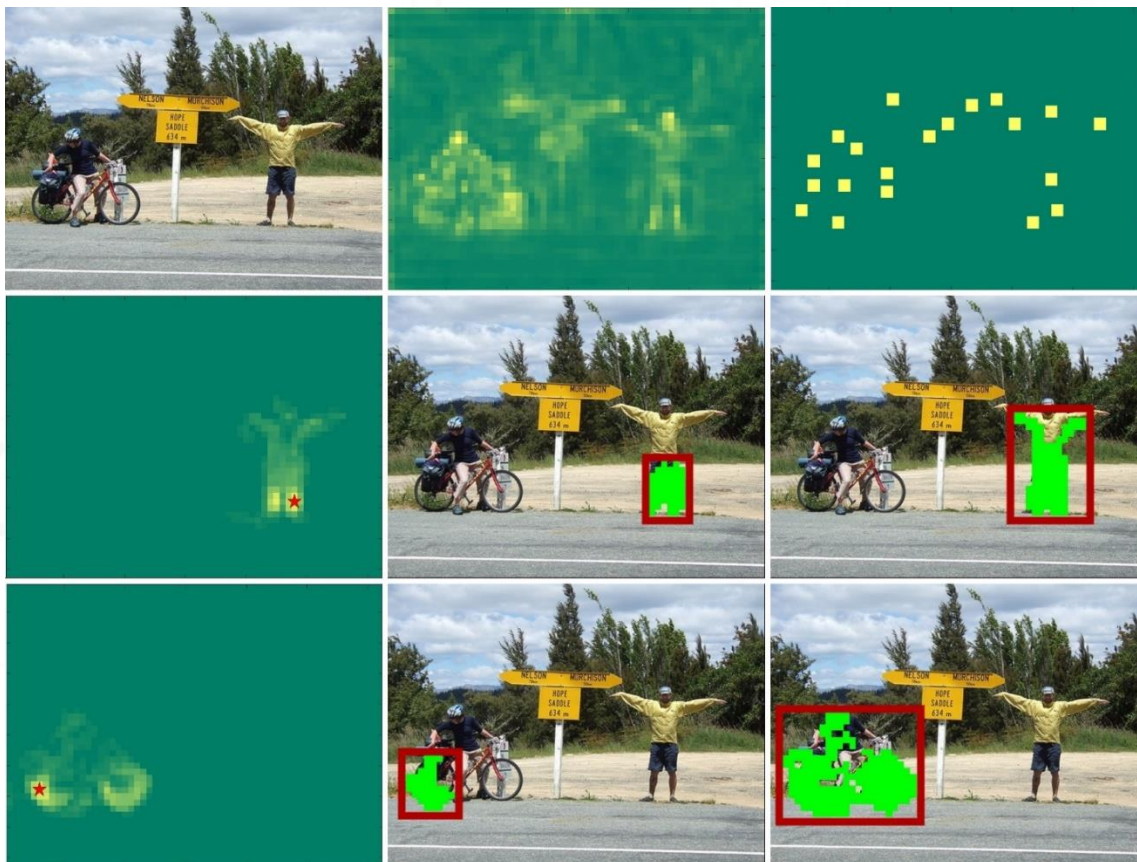
(Vo et al., CVPR'19)



$$\max_{x, e} S(x, e) = \sum_{i=1}^n \sum_{j \in N(i)} e_{ij} x_i^T S_{ij} x_j$$

$$\text{s.t.} \sum_{k=1}^p x_i^k \leq \nu \text{ and } \sum_{j \neq i} e_{ij} \leq \tau \quad \forall i$$

Region proposal generation process

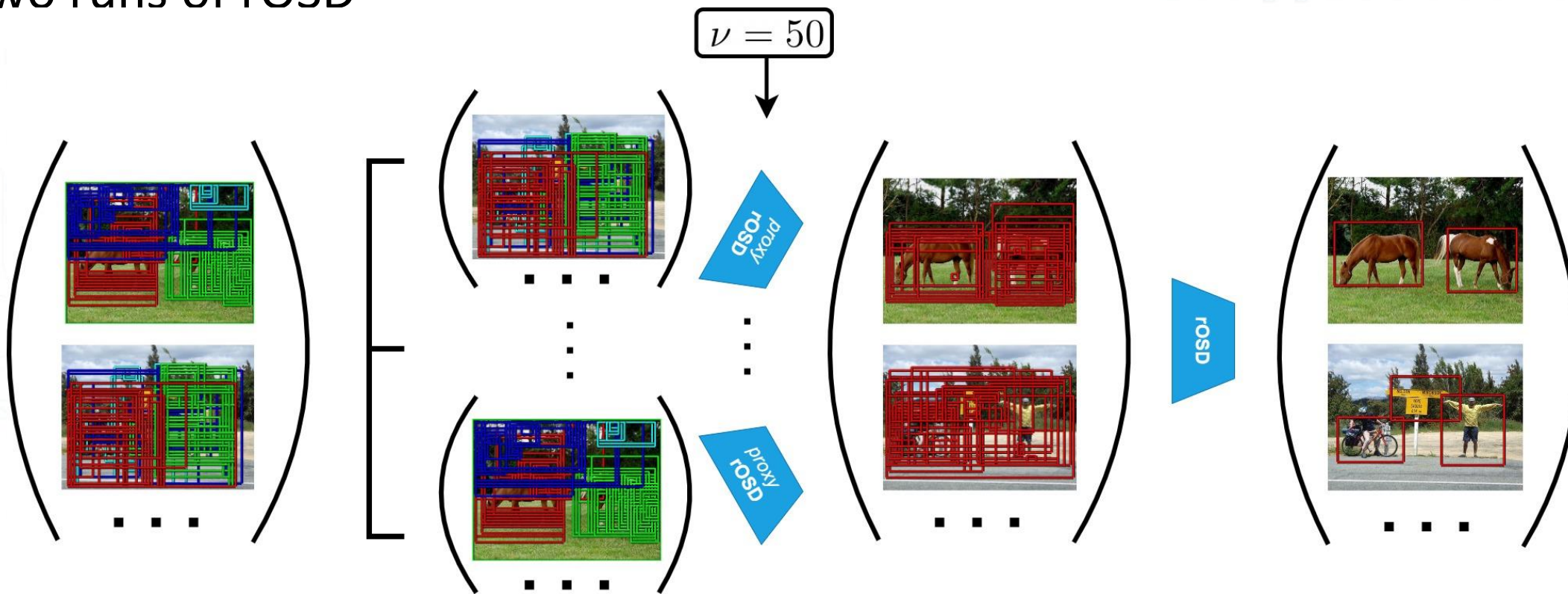


Regularized OSD (rOSD)

$$\max_{x, e} S(x, e) = \sum_{i=1}^n \sum_{j \in N(i)} e_{ij} x_i^T S_{ij} x_j, \text{ s.t. } \forall i \left\{ \begin{array}{l} \sum_{k=1}^p x_i^k \leq \nu, \\ \sum_{k \in G_{ig}} x_i^k \leq 1, \text{ for all groups } g \\ \sum_{j \neq i} e_{ij} \leq \tau. \end{array} \right.$$

Large-scale object discovery

Two runs of rOSD





Experiments

- Data sets: OD, VOC_6x2, VOC_all, VOC12, COCO_20k
- Metrics: CorLoc (correct localization), detection rate
- Features: VGG19
- Multi-object discovery with NMS

Results

Single-object co-localization

Method	Features	OD	VOC _{6x2}	VOC _{all}	VOC ₁₂
Cho <i>et al.</i> (CVPR'15)	WHO	84.2	67.6	37.6	-
Vo <i>et al.</i> (CVPR'19)	WHO	87.1 ± 0.5	71.2 ± 0.6	39.5 ± 0.1	-
Li <i>et al.</i> (ECCV'16)	VGG19	-	-	41.9	45.6
Wei <i>et al.</i> (PR'19)	VGG19	87.9	67.7	48.7	51.1
Ours (OSD)	VGG19	90.3	75.3	45.6	47.8
Ours (rOSD)	VGG19	90.2	76.1	46.7	49.2

Single-object discovery

Method	Features	OD	VOC _{6x2}	VOC _{all}	VOC ₁₂
Cho <i>et al.</i> (CVPR'15)	WHO	82.2	55.9	37.6	-
Vo <i>et al.</i> (CVPR'19)	WHO	82.3	62.5	40.7	-
Wei <i>et al.</i> (PR'19)	VGG19	75.0	54.0	43.4	46.3
Ours (OSD)	VGG19	89.1	71.9	47.9	49.2
Ours (rOSD)	VGG19	89.2	72.5	49.3	51.2

Results

Multi-object

Method	Features	Colocalization		Discovery	
		VOC_all	VOC12	VOC_all	VOC12
Vo <i>et al.</i> (CVPR'19)	WHO	40.7	-	30.7	-
Wei <i>et al.</i> (PR'19)	VGG19	43.3	45.5	28.1	30.3
Ours (OSD)	VGG19	46.8	47.9	34.8	36.8
Ours (rOSD)	VGG19	49.4	51.5	37.6	40.4

Large-scale object discovery

Method	Single-object			Multi-object		
	VOC_all	VOC12	COCO_20k	VOC_all	VOC12	COCO_20k
Baseline 1 (OSD)	41.1	40.5	43.6	31.4	32.4	10.5
Baseline 1 (rOSD)	42.8	42.6	44.5	35.4	37.2	11.6
Baseline 2 (OSD)	47.9	49.2	-	34.8	36.8	-
Baseline 2 (rOSD)	49.3	51.2	-	37.6	40.4	-
Large-scale OSD	45.5	46.3	46.9	34.6	36.9	11.1
Large-scale rOSD	49.4	51.9	48.5	38.3	41.2	12.0



Results





Future work

- Self-supervised features for object discovery
- Very large-scale object discovery

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