Tendency-driven Mutual Exclusivity for Weakly Supervised Incremental Semantic Segmentation

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Introduction

Task: Weakly incremental learning for semantic segmentation (WILSS), the initial training of a segmentation model takes place on a set of classes with pixel-level annotations. In the following incremental phases, WILSS shifts its focus exclusively to the utilization of image-level labels for new classes, without access to the old data.

Contradiction:

- A pixel's label is predicted as belonging to an old class by the previous segmentation model but is simultaneously predicted as a new class by the seed area in the incremental phases.
- With only image-level labels available for the new classes, a formidable conundrum arises in determining whether this pixel's true label corresponds to the new classes or not.

Motivation:

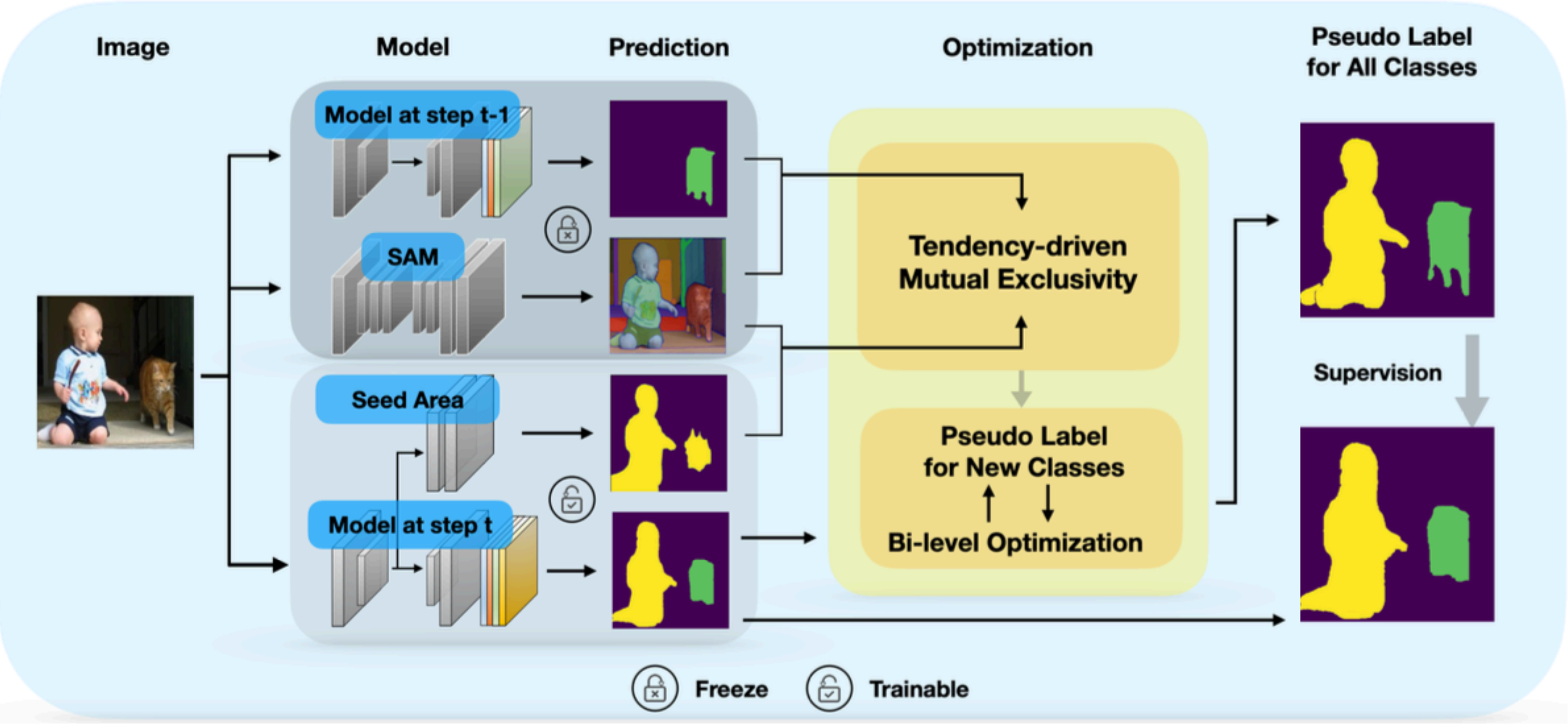
- How might we generate high-quality pseudo pixel-level labels for the new classes to address this conflict issue?

Contributions:

- We propose a novel tendency-driven relationship of mutual exclusivity in WILSS, which effectively mitigates the conflict of the predictions generated by the pre-trained model and the seed areas.
- We propose a TME constrained bi-level optimization problem, through which we can simultaneously generate pixel-level pseudo labels for all classes and update the model parameters.
- sExtensive experiments show that Teddy significantly outperforms state-of- the-art approaches in existing scenarios and data sets, establishing new benchmarks.

Method

Framework:



Pipeline:

A novel tendency-driven relationship of mutual exclusivity is proposed to regulate the interactions between the predictions produced by the seed areas and the previous model. Moreover, by solving a TME constrained bi-level optimization problem, we can generate pixel-level pseudo labels for all classes and update model parameters simultaneously.

Loss:

$$\min_{\theta^t,\mathbf{U},\mathbf{V}} \quad \mathcal{L}(\theta^t|\theta^{t-1};(\mathbf{x}^t,\mathbf{y}^t)) = \mathcal{L}_{cls} + \mathcal{L}_{loc} + \mathcal{L}_{seg}$$

$$\text{s.t.} \quad \|R(f_{\theta^{t-1}}(\mathbf{x}^t),\alpha)_i\| + \|\delta(S(\mathbf{x}^t,\mathbf{y}^t))_i\| \leq 1, \quad \forall i = (h,w) \in \mathcal{I}.$$

Experiment

Main Performance:

Method	Sup	Single-step: 15-5 VOC 1-15	15-5 VOC 16-20	15-5 VOC All	10-10 VOC 1-10	10-10 VOC 11-20	10-10 VOC All	COCO-to-VOC 1-60	COCO-to-VOC 61-80	COCO-to-VOC All	Multi-step: 10-2 VOC 1-10	10-2 VOC 11-20	10-2 VOC All	10-5 VOC 1-10	10-5 VOC 11-20	10-5 VOC All
FT	P	12.5	36.9	18.3	7.8	58.9	32.1	1.9	41.7	12.7	-	-	-	-	-	-
LWF [34]	P	67.0	41.8	61.0	70.7	63.4	67.2	36.7	49.0	40.3	-	-	-	-	-	-
LWF-MC [47]	P	59.8	22.6	51.0	53.9	43.0	48.7	-	-	-	-	-	-	-	-	-
ILT [41]	P	69.0	46.4	63.6	70.3	61.9	66.3	37.0	43.9	39.3	-	-	-	-	-	-
CIL [30]	P	14.9	37.3	20.2	38.4	60.0	48.7	-	-	-	-	-	-	-	-	-
MiB [8]	P	75.5	49.4	69.0	70.4	63.7	67.2	34.9	47.8	38.7	-	-	-	-	-	-
PLOP [16]	P	75.7	51.7	70.1	69.6	62.2	67.1	35.1	39.4	36.8	-	-	-	-	-	-
SDR [42]	P	75.4	52.6	69.9	70.5	63.9	67.4	-	-	-	-	-	-	-	-	-
RECALL [39]	P	67.7	54.3	65.6	66.0	58.8	63.7	-	-	-	-	-	-	-	-	-
CAM [62]	I	69.9	25.6	59.7	70.8	44.2	58.5	30.7	20.3	28.1	-	-	-	-	-	-
SEAM [56]	I	68.3	31.8	60.4	67.5	55.4	62.7	31.2	28.2	30.5	-	-	-	-	-	-
SS [3]	I	72.2	27.5	62.1	69.6	32.8	52.5	35.1	36.9	35.5	-	-	-	-	-	-
EPS [32]	I	69.4	34.5	62.1	69.0	57.0	64.3	34.9	38.4	35.8	-	-	-	-	-	-
WILSON [7]	I	74.2	41.7	67.2	70.4	57.1	65.0	39.8	41.0	40.6	38.7	22.4	32.5	66.8	46.5	58.1
Teddy	I	**77.6**	**51.4**	**72.0**	**71.2**	**59.4**	**66.5**	**40.6**	**41.8**	**41.5**	**50.3**	**32.0**	**43.1**	**68.9**	**51.7**	**61.7**
Joint	P	75.5	73.5	75.4	76.6	74.0	75.4	-	-	-	-	-	-	-	-	-

Ablation Study:

Row	TME: OB	TME: w/o OB	PF	15-5 VOC 1-15	15-5 VOC 16-20	15-5 VOC All	10-10 VOC 1-10	10-10 VOC 11-20	10-10 VOC All	10-2 VOC 1-10	10-2 VOC 11-20	10-2 VOC All
1				74.1	41.5	67.0	70.4	57.0	65.0	38.8	22.3	32.5
2			✓	75.2	45.6	68.9	70.7	57.5	65.3	47.7	20.1	34.6
3		✓		76.8	46.0	70.1	71.0	58.6	66.0	50.2	23.7	38.5
4	✓			77.0	47.7	70.7	71.2	58.6	66.2	50.0	27.5	40.8
5		✓	✓	76.5	48.1	70.4	71.1	58.5	66.1	51.4	25.2	39.9
6	✓		✓	77.6	51.4	72.0	71.2	59.4	66.5	50.3	32.0	43.1

Qualitative Results:

From left to right: image, WILSON, Teddy, GT