Deliberated Domain Bridging for Domain Adaptive Semantic Segmentation

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Introduction

- What is Domain Adaptive Semantic Segmentation (DASS)?

  The Goal:
  - Train segmentation models on a labeled source domain
  - Generalize models for the target domain that has different data distribution.

  The Main Roads for DASS:
  - Directly transfer by adversarial training
  - Gradually transfer by constructing intermediate domains, which is dubbed domain bridging (DB).

  Four Types of Domain Bridging (DB):
  - Input space (style-transfer based)
  - Feature space
  - Output space (self-training based)
  - Joint space (data-mixing based)

Introduction

- Motivation
  - We conduct comprehensive experiments about the existing DB-based methods with the same benchmark and pipeline.

(a) Comparison of style transfer-based DB methods.

Method	mIoU
Source only	26.3±0.9
+ CycleGAN [72] (S→T)	37.8±0.4
+ Color Transfer [47] (S→T)	38.7±1.2
+ FDA [61] (S→T)	41.3±0.6
Pseudo Labeling	30.7±0.4
+ CycleGAN (T→S)	28.9±0.5
+ Color Transfer (T→S)	31.4±0.5
+ FDA (T→S)	**42.6**±0.6

(b) Comparison of global blending-based and region-based DB methods.

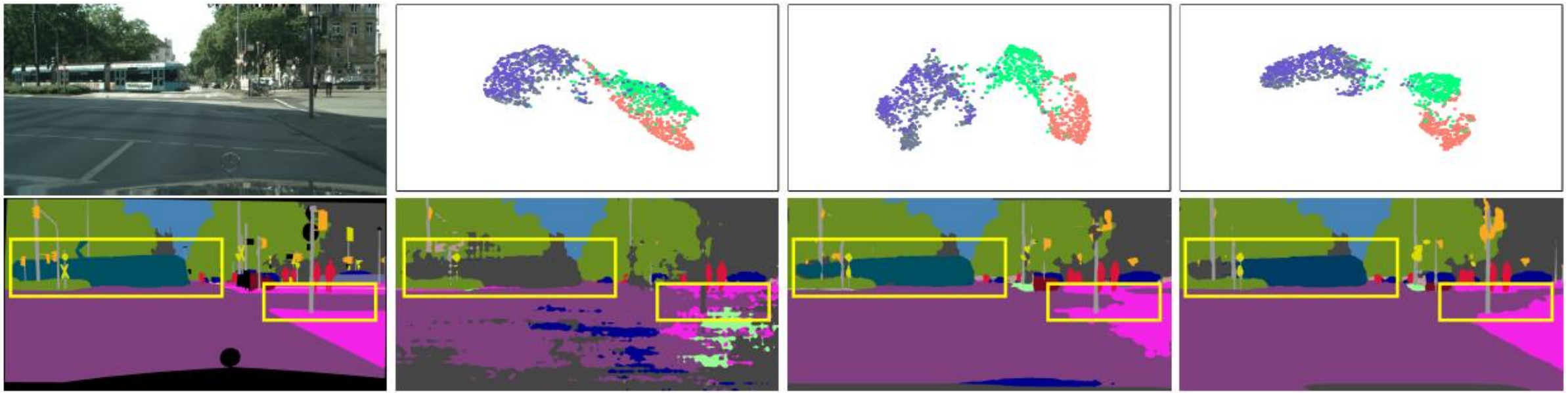
Method	mIoU
Pseudo Labeling	30.7±0.4
+ Mixup [63]	31.6±0.6
+ CowMix [14]	50.7±0.4
+ FMix [18]	50.0±0.2
+ CutMix [62]	**54.9**±0.2
+ ClassMix [43]	54.3±1.4

(c) Comparison of combined DB methods of different groups.

Method	mIoU
Pseudo Labeling	30.7±0.4
+ CutMix + CycleGAN (S→T)	47.6±1.1
+ ClassMix + CycleGAN (S→T)	53.9±1.0
+ CutMix + FDA (S→T)	46.8±1.2
+ ClassMix + FDA (S→T)	50.6±1.1
+ CowMix ⊕ CutMix	51.7±0.4
+ FMix ⊕ CutMix	50.6±0.7
+ FMix ⊕ ClassMix	54.5±0.5
+ CutMix ⊕ ClassMix	**55.2**±1.0

Introduction

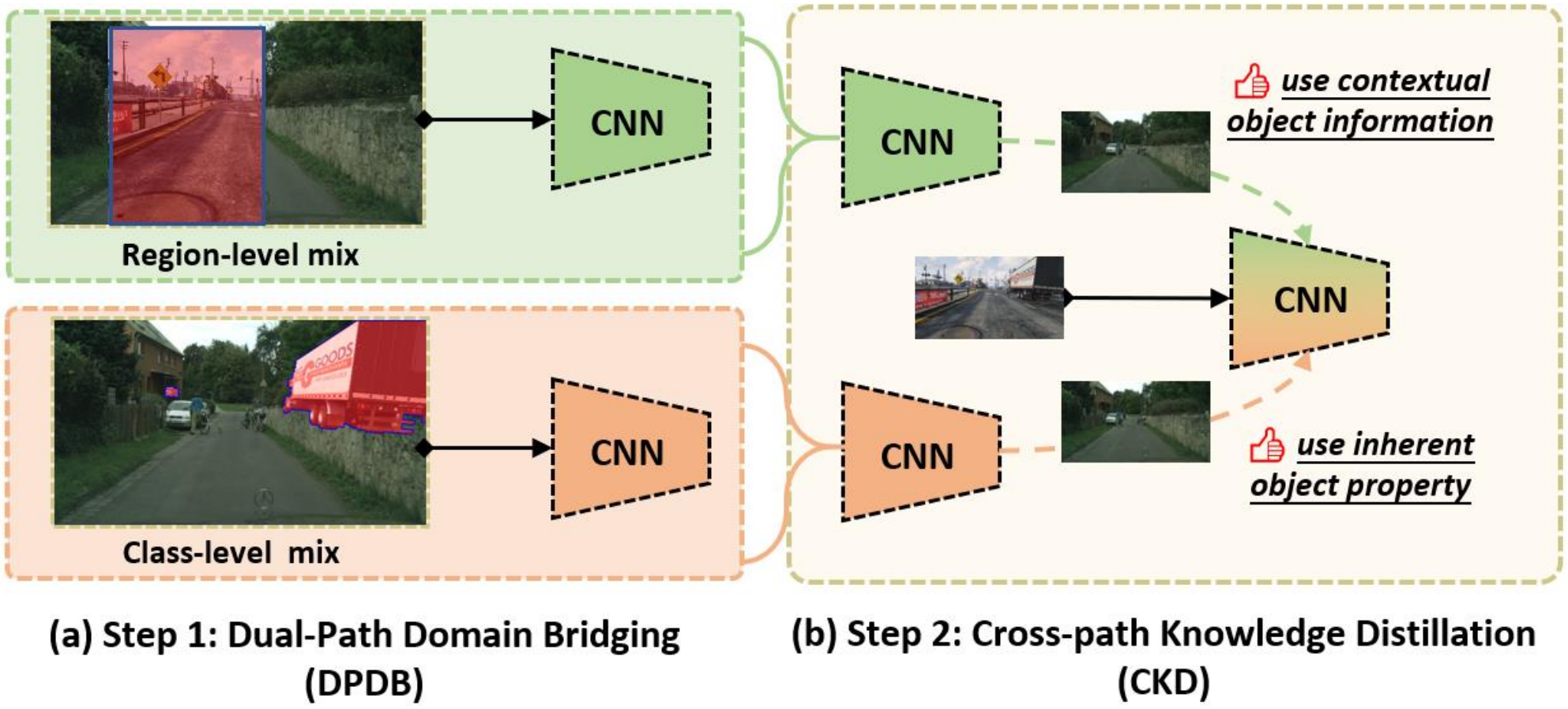
- Motivation
  - We find that the region-level based DB-method and class-level based DB-method are complement with each other.



(a) Target Image/GT (b) Source Only (c) Region-level based (d) Class-level based

Methodology

- Deliberated Domain Bridging for DASS



(a) Step 1: Dual-Path Domain Bridging (DPDB)

(b) Step 2: Cross-path Knowledge Distillation (CKD)

Experiments

- State-of-the-art performance on GTA → Cityscapes

Method	road	sidewalk	building	wall	fence	pole	light	sign	vege.	terrain	sky	person	rider	car	truck	bus	train	motor	bike	mIoU
Source only	75.8	16.8	77.2	12.5	21.0	25.5	30.1	20.1	81.3	24.6	70.3	53.8	26.4	49.9	17.2	25.9	6.5	25.3	36.0	36.6
CyCADA [22]	86.7	35.6	80.1	19.8	17.5	38.0	39.9	41.5	82.7	27.9	73.6	64.9	19.0	65.0	12.0	28.6	4.5	31.1	42.0	42.7
ADVENT [52]	89.4	33.1	81.0	26.6	26.8	27.2	33.5	24.7	83.9	36.7	78.8	58.7	30.5	84.8	38.5	44.5	1.7	31.6	32.4	45.5
BDL [31]	91.0	44.7	84.2	34.6	27.6	30.2	36.0	36.0	85.0	43.6	83.0	58.6	31.6	83.3	35.3	49.7	3.3	28.8	35.6	48.5
FADA [53]	91.0	50.6	86.0	43.4	29.8	36.8	43.4	25.0	86.8	38.3	87.4	64.0	38.0	85.2	31.6	46.1	6.5	25.4	37.1	50.1
CAG [65]	90.4	51.6	83.8	34.2	27.8	38.4	25.3	48.4	85.4	38.2	78.1	58.6	34.6	84.7	21.9	42.7	41.1	29.3	37.2	50.2
IAST [40]	93.8	57.8	85.1	39.5	26.7	26.2	43.1	34.7	84.9	32.9	88.0	62.6	29.0	87.3	39.2	49.6	23.2	34.7	39.6	51.5
DACS [50]	89.9	39.7	87.9	30.7	39.5	38.5	46.4	52.8	88.0	44.0	88.8	67.2	35.8	84.5	45.7	50.2	0.0	27.3	34.0	52.1
SAC [1]	90.4	53.9	86.6	42.4	27.3	45.1	48.5	42.7	87.4	40.1	86.1	67.5	29.7	88.5	49.1	54.6	9.8	26.6	45.3	53.8
CTF [38]	92.5	58.3	86.5	27.4	28.8	38.1	46.7	42.5	85.4	38.4	**91.8**	66.4	37.0	87.8	40.7	52.4	**44.6**	41.7	59.0	56.1
ProDA [64]	91.5	52.4	82.9	42.0	35.7	40.0	44.4	43.8	87.0	43.8	79.5	66.5	31.4	86.7	41.1	52.5	0.0	45.4	53.8	53.7
ProDA+*distill*	87.8	56.0	79.7	**46.3**	44.8	45.6	53.5	53.5	88.6	45.2	82.1	70.7	39.2	88.8	45.5	59.4	1.0	48.9	56.4	57.5
UndoDA [32]	89.1	34.3	83.6	38.3	27.5	28.9	34.7	17.6	84.2	41.0	85.1	57.8	33.7	85.1	38.5	41.3	30.7	31.1	48.0	49.0
UndoDA+ProDA	92.9	52.7	87.2	39.4	41.3	43.9	55.0	52.9	**89.3**	**48.2**	91.2	71.4	36.0	90.2	**67.9**	59.8	0.0	48.5	59.3	59.3
CPSL [28]	91.7	52.9	83.6	43.0	32.3	43.7	51.3	42.8	85.4	37.6	81.1	69.5	30.0	88.1	44.1	59.9	24.9	47.2	48.4	55.7
CPSL+*distill*	92.3	59.9	84.9	45.7	29.7	**52.8**	**61.5**	**59.5**	87.9	41.5	85.0	**73.0**	35.5	90.4	48.7	**73.9**	26.3	**53.8**	53.9	60.8
Source only	60.4	15.1	58.3	8.7	21.3	20.9	33.2	22.4	77.7	8.6	71.3	55.8	13.2	77.0	22.8	22.1	0.4	14.1	6.1	32.1
DDB(Ours)	**95.3**	**67.4**	**89.3**	44.4	**45.7**	38.7	54.7	55.7	88.1	40.7	90.7	70.7	**43.1**	**92.2**	60.8	67.6	34.2	48.7	**63.7**	**62.7**

Experiments

- State-of-the-art performance on GTA + Synscapes → Cityscapes

Method	road	sidewalk	building	wall	fence	pole	light	sign	vege.	terrain	sky	person	rider	car	truck	bus	train	motor	bike	mIoU
Source only	85.1	36.9	84.1	39.0	33.3	38.7	43.1	40.2	84.8	37.1	82.4	65.2	37.8	69.4	43.4	38.8	34.6	33.2	53.1	51.6
AdaptSeg [51]	89.3	47.3	83.6	40.3	27.8	39.0	44.2	42.5	86.7	45.5	84.5	63.1	38.0	79.4	34.9	48.3	42.1	30.7	52.3	53.7
ADVENT [52]	91.8	49.0	84.6	39.4	31.5	39.9	42.9	43.5	86.3	45.1	84.6	65.3	41.0	87.1	37.9	49.2	31.0	30.3	48.8	54.2
MDAN [67]	92.4	56.1	86.8	42.7	32.9	39.3	48.0	40.3	87.2	47.2	90.5	64.1	35.9	87.8	33.8	48.6	39.0	27.6	49.2	55.2
MADAN [68]	94.1	61.0	86.4	43.3	32.1	40.6	49.0	44.4	87.3	47.7	89.4	61.7	36.3	87.5	35.5	45.8	31.0	33.5	52.1	55.7
MSCL [19]	93.6	59.6	87.1	44.9	36.7	42.1	49.9	42.5	87.7	47.6	89.9	63.5	40.3	88.2	41.0	58.3	53.1	37.9	57.7	59.0
Source only	82.5	42.4	79.0	27.2	31.7	40.8	53.0	45.6	85.3	30.9	80.6	68.7	35.7	78.3	39.0	42.7	9.6	37.3	55.9	50.9
DDB(Ours)	**96.9**	**75.6**	**90.0**	**54.4**	**48.6**	**47.6**	**61.1**	**66.3**	**89.7**	**48.4**	**93.4**	**74.4**	**52.7**	**92.3**	**60.8**	**74.7**	**58.9**	**53.9**	**71.4**	**69.0**

- State-of-the-art performance on GTA → Cityscapes + Mapillary

Method	Target	road	sidewalk	building	wall	fence	pole	light	sign	vege.	terrain	sky	person	rider	car	truck	bus	train	motor	bike	mIoU	Avg.
Source only	C	53.3	15.2	56.6	8.2	26.2	21.2	30.7	22.2	76.3	9.3	53.3	55.3	15.5	72.9	21.5	4.9	0.9	20.2	7.4	30.1	32.8
	M	55.7	27.1	55.3	9.9	20.6	22.7	33.3	31.6	68.4	21.1	70.6	53.5	30.9	72.7	32.3	11.6	5.6	36.3	14.9	35.5	
CCL [25]	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	45.1	46.8
	M	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	48.8	
ADAS [26]	C	88.3	32.2	82.2	23.8	24.2	30.5	35.0	33.3	83.3	37.9	85.1	56.7	21.9	**84.6**	38.6	46.2	0.5	33.5	33.3	45.8	47.5
	M	84.2	33.9	78.5	25.5	24.5	**35.6**	39.8	**52.4**	**71.2**	40.2	**92.4**	58.7	38.7	82.7	44.4	46.4	15.2	37.8	32.2	49.2	
DDB(Ours)	C	**93.5**	**67.8**	**88.3**	**38.4**	**45.6**	**32.3**	**54.2**	**57.9**	**89.2**	**48.6**	**91.6**	**69.1**	**43.2**	**84.6**	**63.6**	**61.8**	**15.1**	**44.1**	**58.6**	**60.4**	**58.6**
	M	**89.3**	**60.8**	**81.4**	**35.9**	**38.4**	32.9	**48.5**	50.5	69.9	**37.9**	90.1	**62.6**	**49.6**	**86.0**	**62.7**	**62.9**	**26.1**	**52.0**	**42.8**	**56.9**	

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