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CE-OST: Contour Emphasis for One-Stage Transformer-based Camouflage Instance Segmentation

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Content

1. Introduction to Camouflage Instance Segmentation
2. Related work
3. Our proposed CE-OST framework
   - Contour Emphasis Block
   - One-stage Transformer-based CIS
4. Experiments
5. Conclusion

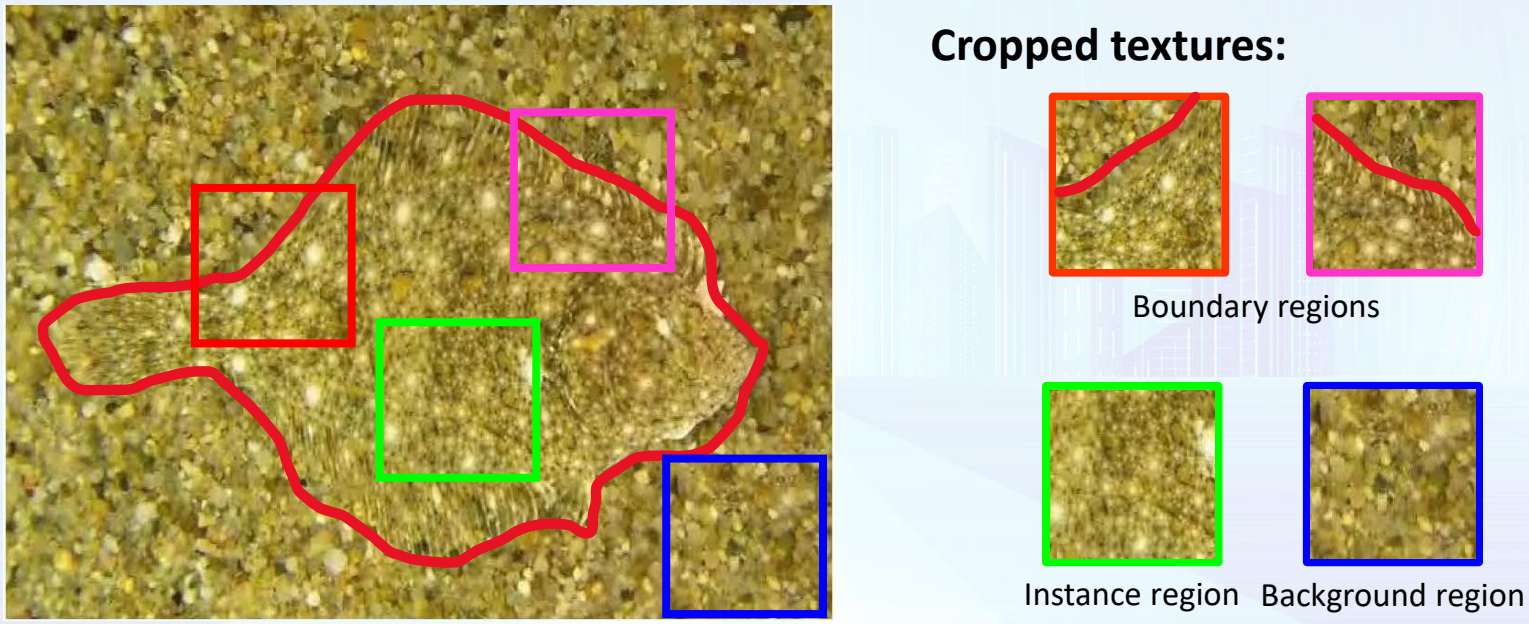
1. Introduction

- **"Camouflage"** is **a defense mechanism** that animals use to **conceal their appearance** by blending in with their environment
- **Applications:** search-and-rescue work, wild species discovery and preservation, medical diagnostic, etc.

Exemplary camouflaged samples extracted from CAMO++ dataset

1. Introduction

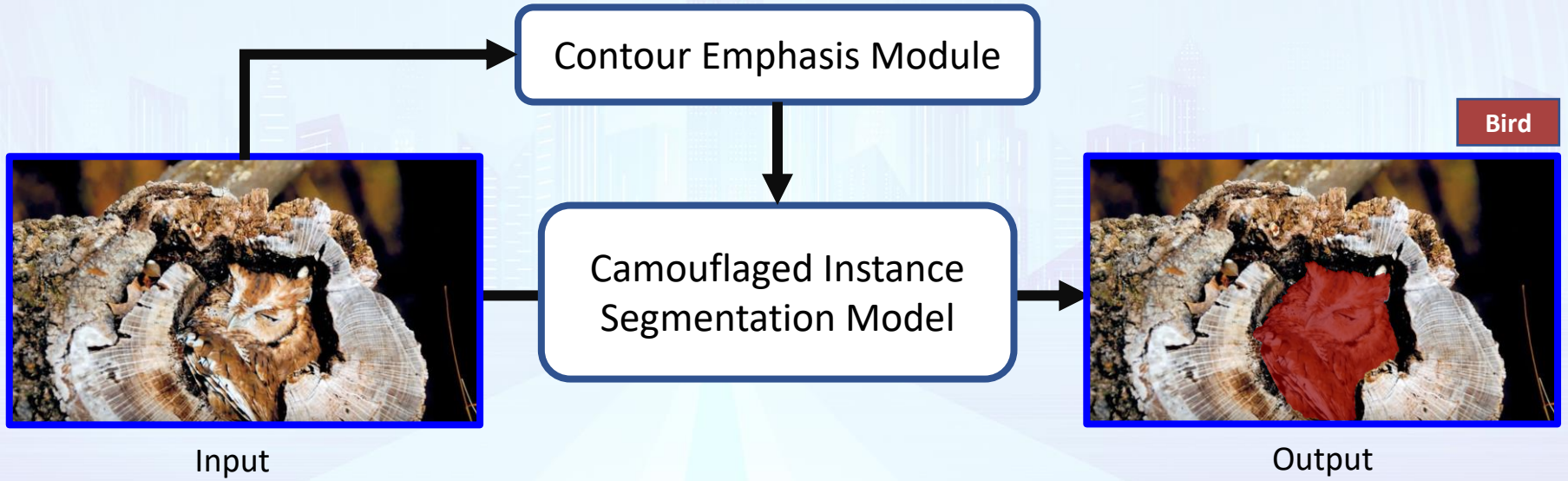
Focused challenge: Camouflaged instances are “visually transparent”, their colors and textures are similar to the background



Visual texture comparison among regions in a camouflaged image

1. Introduction

Contribution: we propose **Contour Emphasis** approach for **One-Stage Transformer-based Camouflage Instance Segmentation**, dubbed **CE-OST**



General idea of our contour emphasis framework contribution

2. Related work

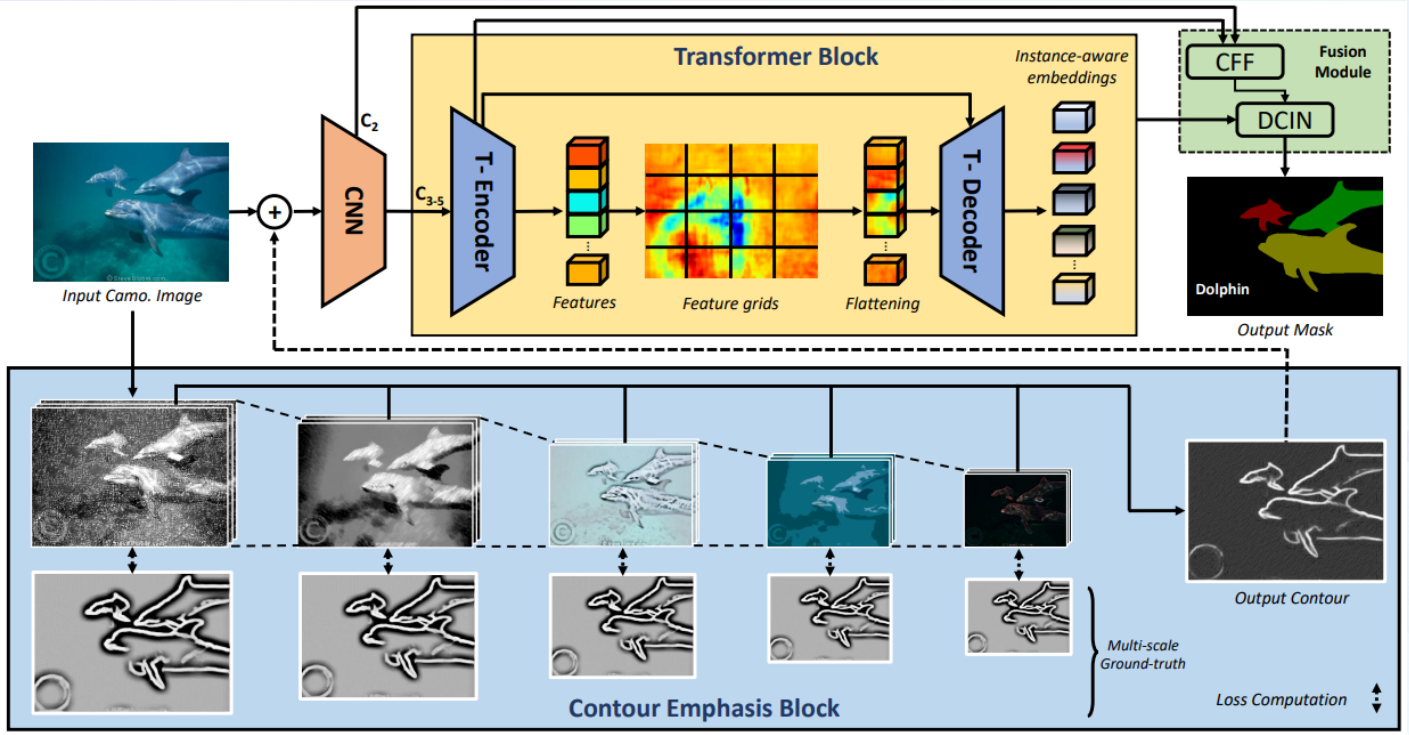
- **Camouflaged research** is attractive to the community with various tasks
- **Common approaches:** using Hand-crafted features and using Deep features
- **Instance segmentation models:** one-stage and two-stage architectures
- **Camouflaged Datasets:** COD10K, NC4K, CAMO, and CAMO++ are among the potential camouflage datasets with fine-grained annotations

Dataset	#Annot. Camo. Img.	#Meta-Cat.	#Obj. Cat.	Bbox. GT	Obj. Mask GT	Ins. Mask GT
CAMO [2]	1,250	2	8	×	✓	×
COD10K [19]	5,066	5	69	✓	✓	✓
NC4K [32]	4,121	5	69	✓	✓	✓
CAMO++ [31]	2,695	10	47	✓	✓	✓

Tab. Comparison among camouflage datasets (w/o non-camouflaged images)

3. Method

CE-OST has 2 main components:
- A Contour Emphasis Block
- A Transformer-based Instance Segmentation Block

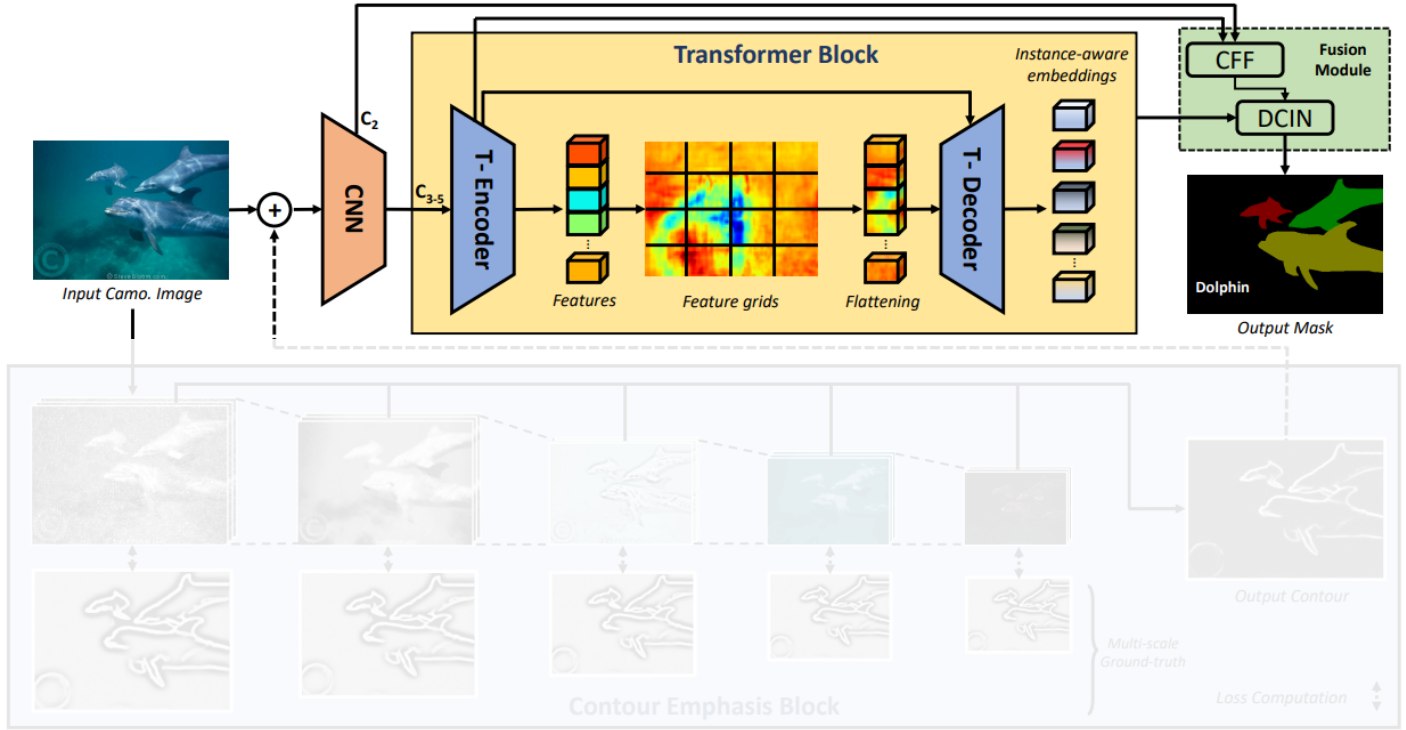


Overall our CE-OST framework: Contour Emphasis for One-Stage Transformer-based Camouflage Instance Segmentation

CE-OST enhances the contour features at image-level to boost the performance the camouflaged instance segmentation model

3. Method

A Transformer-based Instance Segmentation Block: relied on Transformer architecture with self-attention mechanism

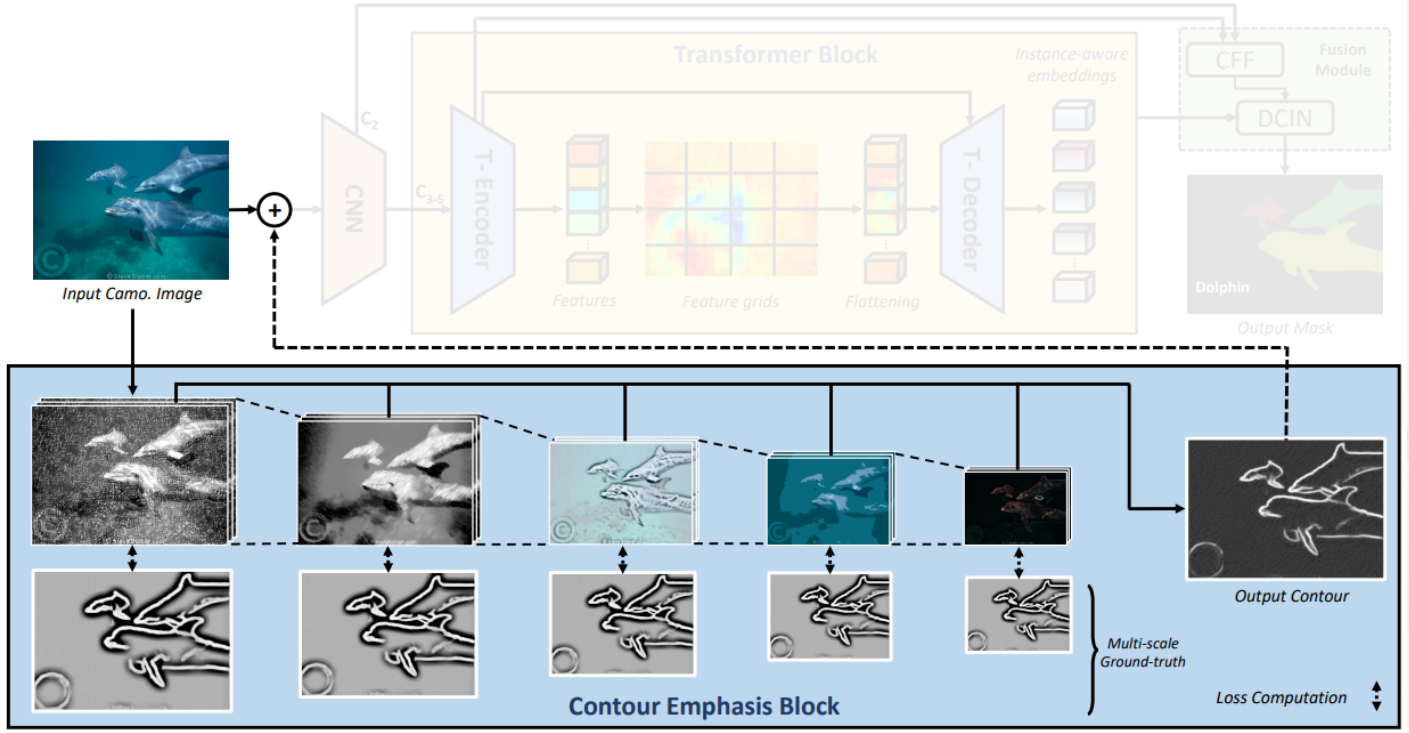


Focus: Transformer Block

- Inspired by OSFormer, a one-stage Transformer architecture
- Pre-trained backbones from OSFormer: ResNet-50, ResNet-101, SwinT, PVT
- Precise positional embeddings, necessary for instance segmentation

3. Method

Contour Emphasis Block: a multi-scale CNN (VGG-16 backbone) learning to perform edge detection*, then fuse them with the original camouflaged image



Focus: Contour Emphasis Block

- CE Block is pretrained on BSD500, a dataset for edge detection
- Total loss is the summary of Cross-entropy loss computed at each scale
- The final output contour is combined with the original image thanks to a **Grid-Condition**

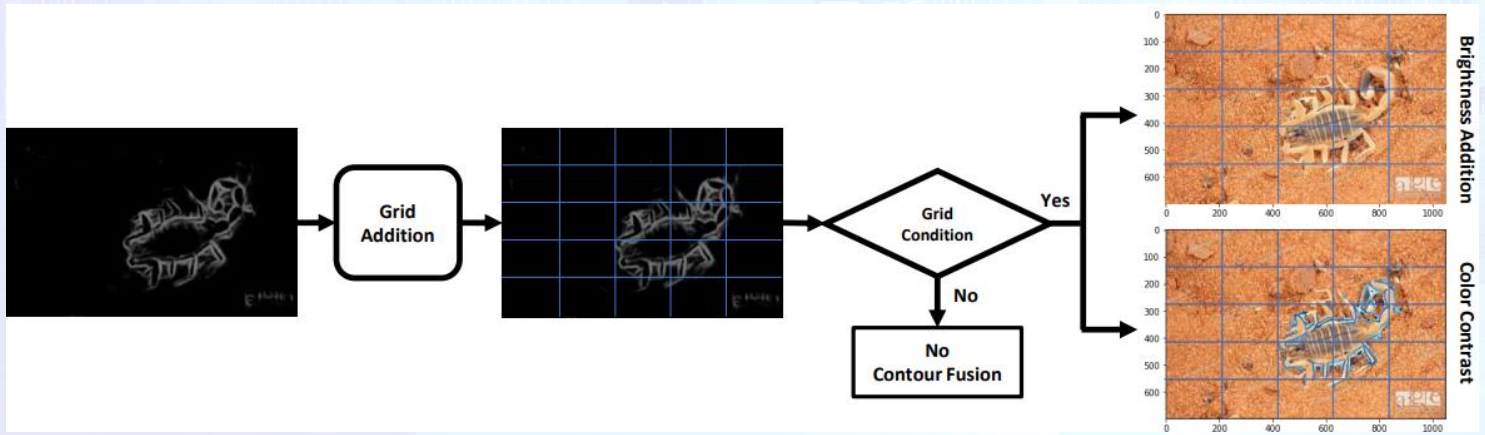
*S. Xie and Z. Tu, "Holistically-nested edge detection," in ICCV, 2015

3. Method

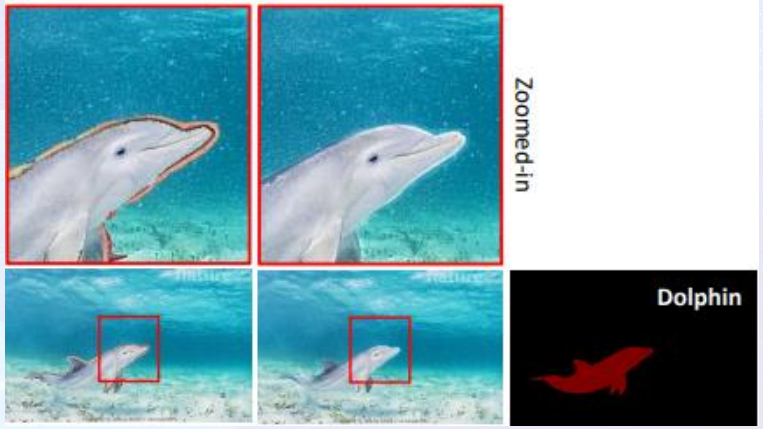
Grid-Condition: A grid 5×5 is applied to each image. Not boundary fusion if the number of eliminated cells is over half. A cell is eliminated if the number of pixels in the detected boundary area covers over a half area of the cell.

Two ways of enhancement:

- **Brightness Addition:** add **pixel-wise value** to the original image
- **Color Contrast:** add **pixel wise contrast value** to the original image



Our Grid-Condition to control the Contour Emphasis



Exemplary contour emphasized images on CAMO++

4. Experiments

- State-of-the-art comparison among **one-stage** and **two-stage methods**
- Our CE-OST achieved the highest AP score at 43.2% on COD10K and 45.1% on NC4K thanks to the contour emphasizing

Method		COD10K			NC4K		
		AP	AP50	AP75	AP	AP50	AP75
Two-Stage	Mask R-CNN [41]	28.7	60.1	25.7	36.1	68.9	33.5
	MS R-CNN [43]	33.3	61.0	32.9	35.7	63.4	34.7
	Cascade R-CNN [44]	29.5	61.0	25.9	34.6	66.3	31.5
	HTC [47]	30.9	61.0	28.7	34.2	64.5	31.6
	BlendMask [46]	31.2	60.0	28.9	31.4	61.2	28.8
	Mask Transfiner [64]	31.2	60.7	29.8	34.0	63.1	32.6
One-Stage	YOLACT [49]	29.0	60.1	25.3	37.8	70.6	35.6
	CondInst [65]	34.3	67.9	31.6	38.0	71.1	35.6
	QueryInst [66]	32.5	65.1	28.6	38.7	72.1	37.6
	SOTR [67]	32.0	63.6	29.2	34.3	65.7	32.4
	SOLOv2 [51]	35.2	65.7	33.4	37.8	69.2	36.1
	OSFormer [30]	42.0	71.3	42.8	44.4	73.7	45.1
	CE-OST (Ours)	**43.2**	**72.2**	**44.1**	**45.1**	**74.0**	**46.4**

Tab. State-of-the-art comparison on COD10K and NC4K dataset. The chosen backbone is the common ResNet-101.

4. Experiments – Ablation Study

- **PVT backbone stably holds the best performance** as its multi-scale feature extractor can well handle the various scales of CAMO++
- **CAMO++** is the most intensive dataset, following by NC4K and COD10K

Method	Base-Model	COD10K			NC4K			CAMO++		
		AP	AP50	AP75	AP	AP50	AP75	AP	AP50	AP75
OSFormer	ResNet-50 [59]	41.0	71.1	40.8	42.5	72.5	42.3	19.0	33.8	18.3
	ResNet-50-550 [59]	-	-	-	-	-	-	20.1	36.3	19.3
	ResNet-101 [59]	42.0	71.3	42.8	44.4	73.7	45.1	20.6	34.4	20.2
	PVTv2-B2-Li [60]	47.2	74.9	49.8	-	-	-	27.7	44.7	27.9
	Swin-T [61]	47.7	78.6	49.3	-	-	-	22.3	36.6	21.8
CE-OST (Color Contrast)	ResNet-50 [59]	41.6	70.7	42.3	42.4	71.4	42.6	20.1	34.2	19.6
	ResNet-50-550 [59]	35.9	65.2	34.3	41.1	70.9	41.1	20.6	35.7	20.0
	ResNet-101 [59]	43.2	72.2	44.1	45.1	74.0	46.4	21.7	36.6	21.3
	PVTv2-B2-Li [60]	48.4	75.7	51.3	51.4	77.9	55.0	28.5	45.3	29.9
	Swin-T [61]	49.1	78.0	52.1	50.5	78.9	53.1	22.7	37.6	22.4
CE-OST (Brightness Addition)	ResNet-50 [59]	41.2	69.0	41.6	42.4	71.1	42.9	20.2	34.8	19.5
	ResNet-50-550 [59]	35.9	65.2	34.6	40.8	71.1	40.3	21.0	37.1	20.3
	ResNet-101 [59]	42.4	70.8	43.7	44.2	73.1	45.0	21.1	34.4	20.9
	PVTv2-B2-Li [60]	47.9	74.6	50.5	51.1	77.3	54.9	27.9	45.1	29.2
	Swin-T [61]	49.0	78.5	51.4	50.8	79.3	53.9	22.7	38.4	23.1

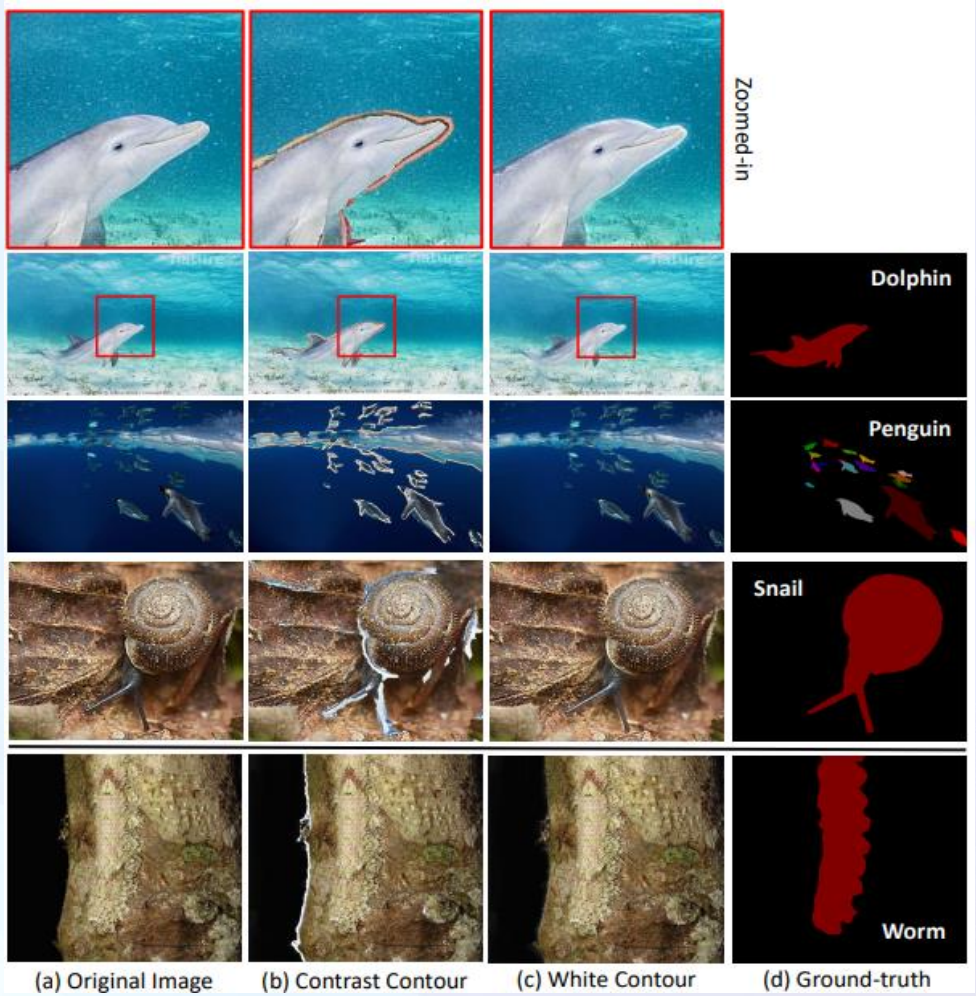
**The first, second, and third best results are marked in red, blue, and green, respectively.*

Tab. Ablation study on different base models on COD10K, NC4K, and CAMO++.

Qualitity visualization result on the CAMO++ testing set on our CE-OST-PVT. The confidence threshold is 0.5.

4. Experiments – Ablation Study

- **Color Contrast shifts the color values to another value in the contrast range**, bringing better distinguished contour views compared to Brightness Addition
- The contour emphasis is **highly affected** by the contour detection results



Exemplary contour emphasized images on CAMO++. The first rows are the zoomed-in regions.

5. Conclusion

In this work:

- We proposed **CE-OST framework –** a **Contour Emphasis** approach for **One-Stage Transformer-based model** to address the instance segmentation task on camouflaged images
- Experimental results proves our SOTA results among the surveyed methods on CAMO++, NC4K, and COD10K datasets

In the future:

- Train the camouflaged specific Edge Detection model
- Extend our idea to other specific domains of medical imaging where the instances carry camouflaged features

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