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Few-Shot Instance Segmentation: An Exploration in the Frequency Domain for Camouflage Instances

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Content

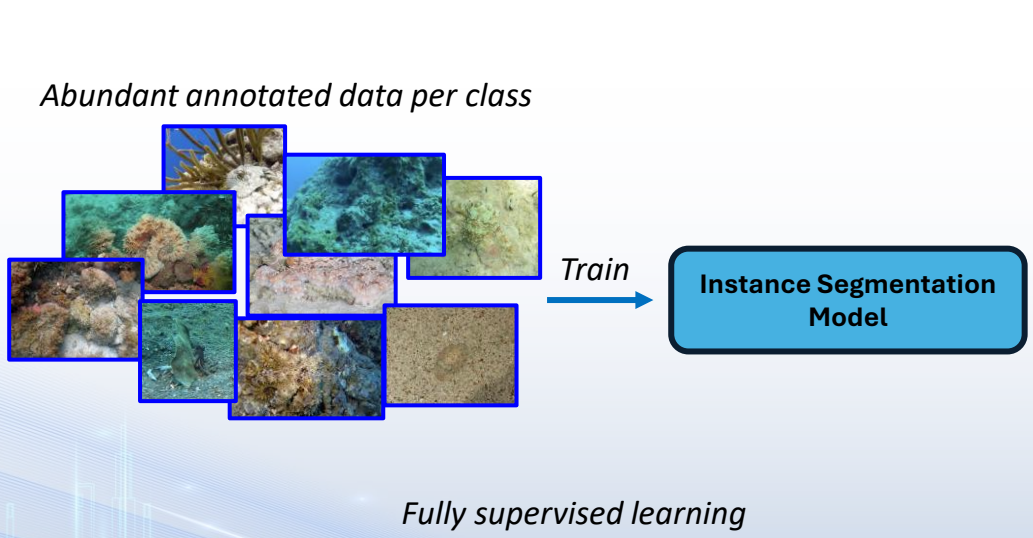
1. Introduction

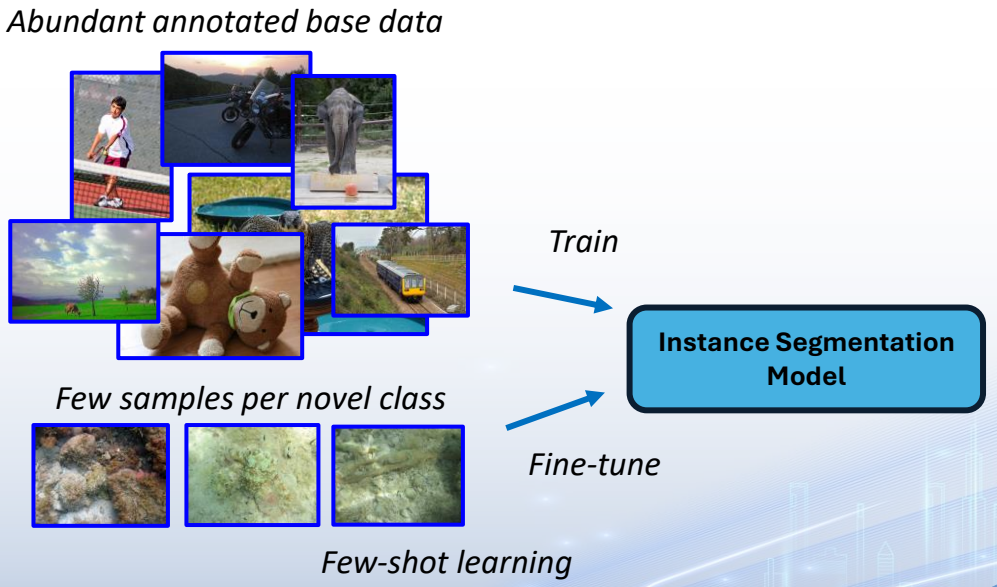
- **"Camouflage"** is **a defense mechanism** that animals use to **conceal their appearance** by blending in with their environment
- **Applications:** search-and-rescue work, wild species discovery and preservation, medical diagnostic, etc.

Exemplary camouflaged samples extracted from CAMO-FS dataset

1. Introduction

- **Few-shot Camouflage Instance Segmentation (Few-shot CIS)** is formulated as a two-stage training task:
  - **Base training phase** on abundant annotated data of *general domain*
  - **Novel fine-tuning phase** on **few-shot sample** of *novel domain*





1. Introduction

Focused challenge: color space image augmentation **fails due to the similar representation of the input camouflage image**

Contribution: we propose a **few-shot camouflage instance segmentation** via an **instance-aware frequency-based augmentation**, dubbed **FS-CAMOFreq**

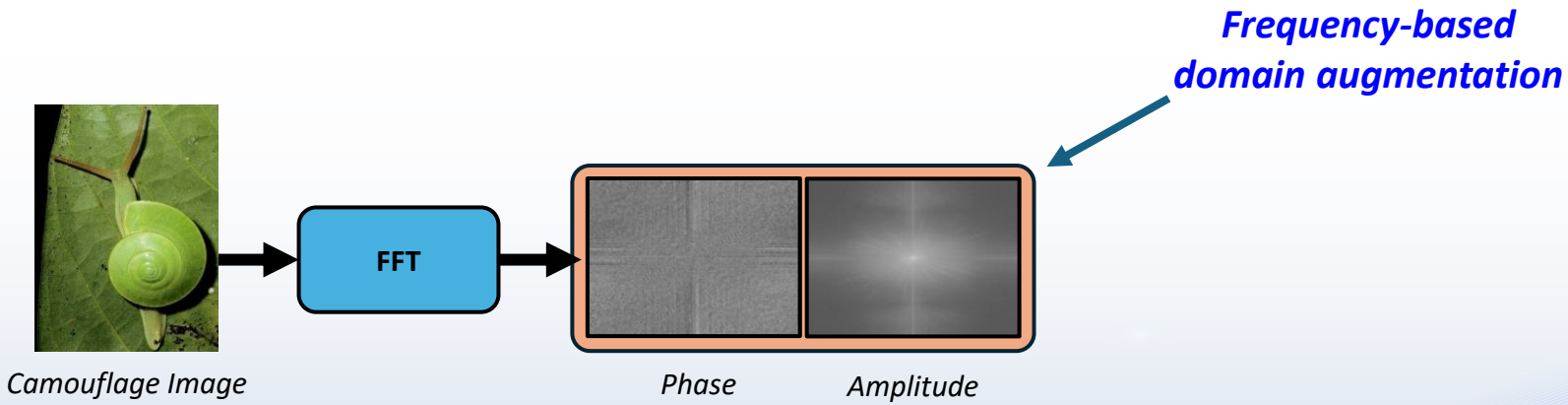


Fig. Breaking a camouflage image into the frequency domain by a phase and an amplitude component via Fast Fourier Transform FFT.

2. Related work

- **Image Segmentation Research**
- **Few-shot Learning in Image Segmentation:** general and camouflage domain
- **Data Enhancement in Camouflage Image Segmentation**
- **Few-shot Camouflaged Datasets for Instance Segmentation**

Dataset	Year	Venue	Type	#Annot. Camo. Img.	#Meta-Cat.	#Obj. Cat.	Bbox. GT	Obj. Mask GT	Ins. Mask GT	Few-shot
CamouflagedAnimals	2016	ECCV	Video	181	-	6	×	✓	✓	×
MoCA	2020	ACCV	Video	7,617	-	67	✓	×	×	×
CHAMELEON	2018	-	Image	76	-	-	×	✓	×	×
CAMO	2019	CVIU	Image	1,250	2	8	×	✓	×	×
COD	2020	CVPR	Image	5,066	5	69	✓	✓	✓	×
NC4K	2021	CVPR	Image	4,121	5	69	✓	✓	✓	×
CAMO++	2022	TIP	Image	2,695	10	47	✓	✓	✓	×
CAMO-FS	2024	IEEE ACCESS	Image	2,852	10	47	✓	✓	✓	✓

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

3. Method

FS-CAMOFreq has 2 main components:

- Instance-Aware Frequency-Based Data Enhancement
- Few-shot Instance Segmentation Pipeline

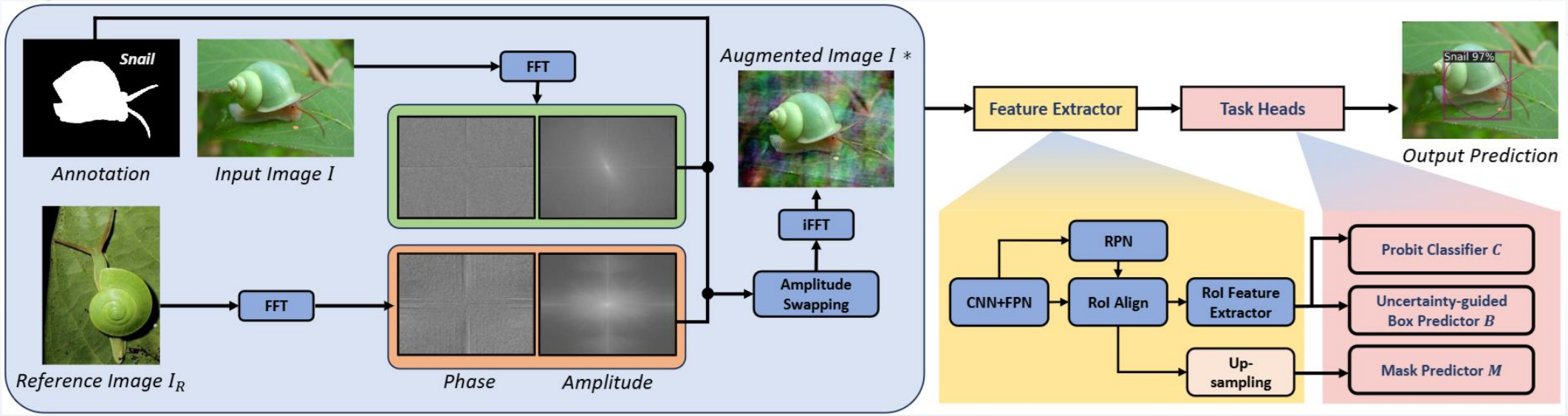
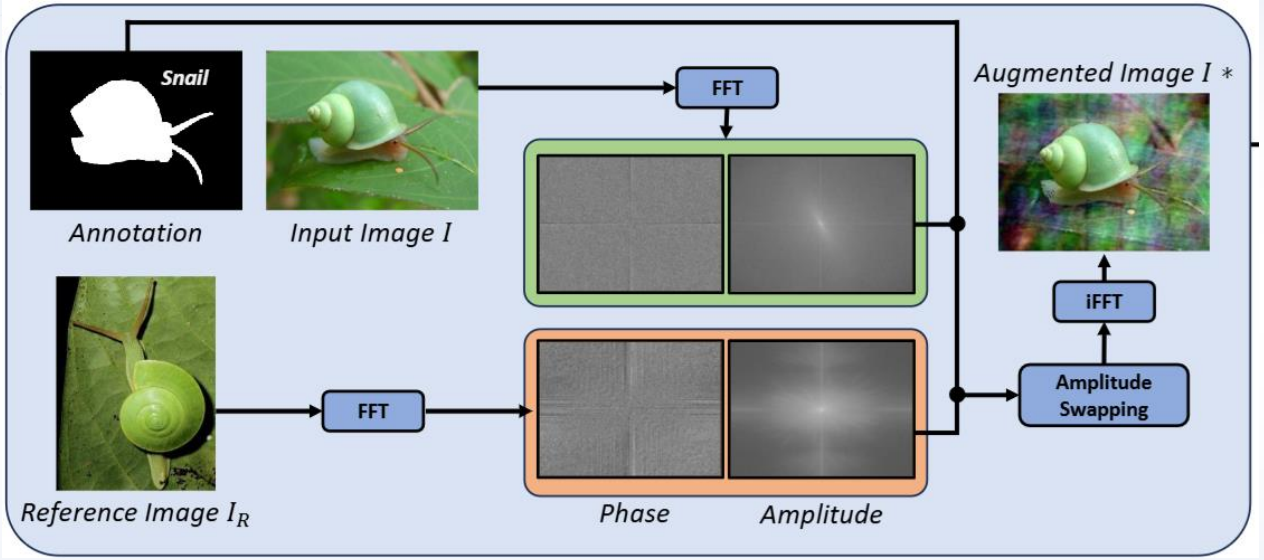


Fig. Overview of our FS-CAMOFreq framework exploiting the instance-ware frequency-based enhancement in few-shot camouflage instance segmentation.

FS-CAMOFreq employs the Instance-Aware Frequency-Based Data Enhancement to enhance the visibility of the camouflage instance from the background in Few-shot Instance Segmentation

3. Method

Instance-Aware Frequency-Based Data Enhancement



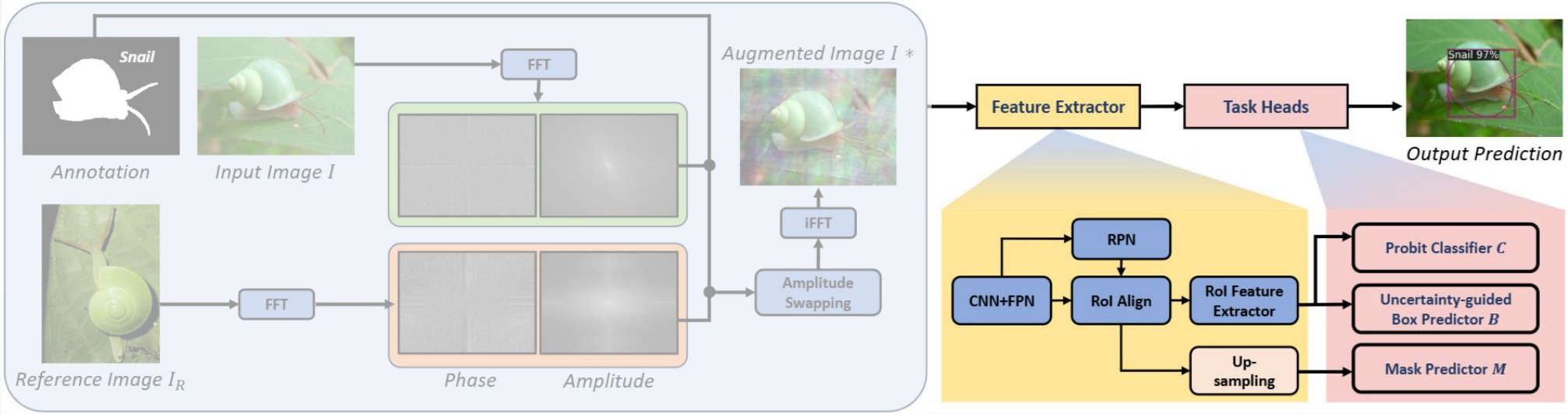
Focus: Instance-Aware Frequency-Based Data Enhancement

- We **swap the amplitude of the background** (where mask $M = 0$) with that of the reference image I_R, while keeping **the original foreground amplitude and phase unchanged**

➔ To **amplify the visual contrast** between the instance and its background to make the camouflaged object more distinguishable

3. Method

Few-shot Instance Segmentation Pipeline

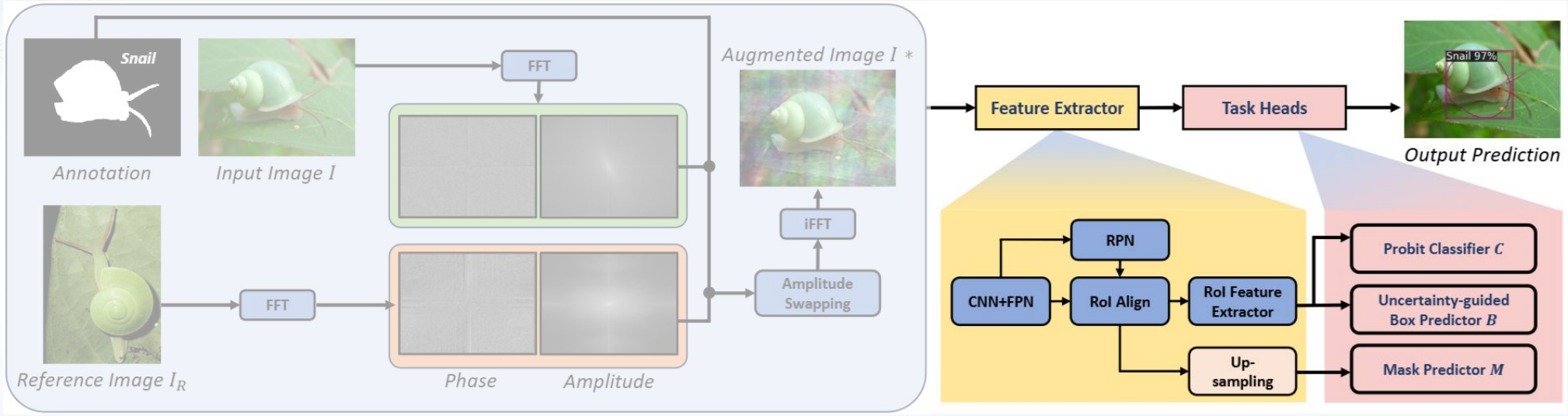


Focus: Instance-Aware Frequency-Based Data Enhancement

Following FS-CDIS[4] and CamoFA[13], our **FS-CAMOFreq** framework exploits the frequency-based data enhancement in an instance-aware manner.

3. Method

Few-shot Instance Segmentation Pipeline



Focus: Instance-Aware Frequency-Based Data Enhancement

Our **FS-CAMOFreq** formulates the **few-shot CIS** task with:

- **Base training phase**: on **80** COCO classes
- **Novel fine-tuning phase**: on **47** CAMO-FS classes with 1, 2, 3, 5 shots per novel class

4. Experiments

- **Successfully employ frequency-based enhancement** in **few-shot learning** on **camouflage instance segmentation** domain
- Our **FS-AMOFreq improves over the SoTA FS-CDIS**[7] in both tasks on CAMO-FS benchmark

Tab. State-of-the-art comparison on CAMO-FS dataset. The chosen backbones are COCO-80 FPN-ResNet-101.

Model		nAP						nAP50						nAP75					
Method	Backbone/ Num. of shots	Instance Segmentation			Object Detection			Instance Segmentation			Object Detection			Instance Segmentation			Object Detection		
		1	5	Avg.	1	5	Avg.	1	5	Avg.	1	5	Avg.	1	5	Avg.	1	5	Avg.
MTFA [3]	COCO-80 ResNet-50	2.48	6.40	4.44	1.98	6.17	4.08	4.24	9.89	7.07	4.12	9.94	7.03	2.38	8.04	5.21	1.47	6.40	3.94
M-RCNN [28]		4.08	8.29	6.19	2.82	6.18	4.50	6.91	13.89	10.40	6.78	13.92	10.35	4.34	8.18	6.26	1.45	4.51	2.98
iFS-RCNN [2]		4.17	6.38	5.28	3.92	6.60	5.26	6.19	10.02	8.11	6.23	10.15	8.19	4.93	7.32	6.13	4.47	7.17	5.82
MTFA [3]	COCO-80 ResNet-101	3.66	5.95	4.81	2.93	5.84	4.39	5.37	8.67	7.02	5.86	9.13	7.50	4.09	6.94	5.52	2.20	6.04	4.12
M-RCNN [28]		4.39	10.09	7.24	3.03	7.79	5.41	7.58	15.41	11.50	7.53	15.86	11.70	4.53	11.90	8.22	1.42	5.34	3.38
iFS-RCNN [2]		4.27	7.80	6.04	3.79	8.08	5.94	5.98	11.35	8.67	5.92	11.52	8.72	4.75	9.15	6.95	4.46	9.24	6.85
FS-CDIS-ITL* [4]		5.35	9.35	7.35	4.71	10.36	7.54	7.80	14.01	10.91	7.85	14.40	11.13	6.04	11.57	8.81	5.51	11.32	8.42
FS-CDIS-IMS* [4]		2.99	9.03	6.01	2.74	8.44	5.59	4.62	12.48	8.55	4.81	13.18	9.00	3.36	9.82	6.59	2.98	9.69	6.34
							Our performance												
Baseline FS-CAMOFreq †	COCO-80 ResNet-101	5.55	8.21	6.88	5.34	8.82	7.08	8.42	12.07	10.25	8.49	12.86	10.68	6.19	9.58	7.89	5.98	9.22	7.60
FS-CAMOFreq (ours)		**5.71**	**8.31**	**7.01**	**5.56**	**8.89**	**7.23**	**8.50**	**11.72**	**10.11**	**8.56**	**12.11**	**10.34**	**6.46**	**9.53**	**8.00**	**6.25**	**9.49**	**7.87**

* *denotes the FS-CDIS results built on top of iFS-RCNN [2]*

† *denotes our reproduced baseline FS-CDIS iFS-RCNN [2], [4] on our upgraded CUDA version 12.4*

4. Experiments – Ablation study

Tab. Ablation study of our FS-CAMOFreq on instance region augmentation evaluated on CAMO-FS

FS-CAMOFreq	Detection			Segmentation		
Num. of shots	nAP	nAP50	nAP75	nAP	nAP50	nAP75
1	5.63	8.38	6.44	5.31	8.44	5.97
2	5.64	8.10	6.56	5.65	8.36	6.49
3	4.94	7.17	5.71	5.16	7.35	5.78
5	6.12	9.01	6.59	6.84	9.64	7.53
Avg.	**5.58**	**8.17**	**6.33**	**5.74**	**8.45**	**6.44**

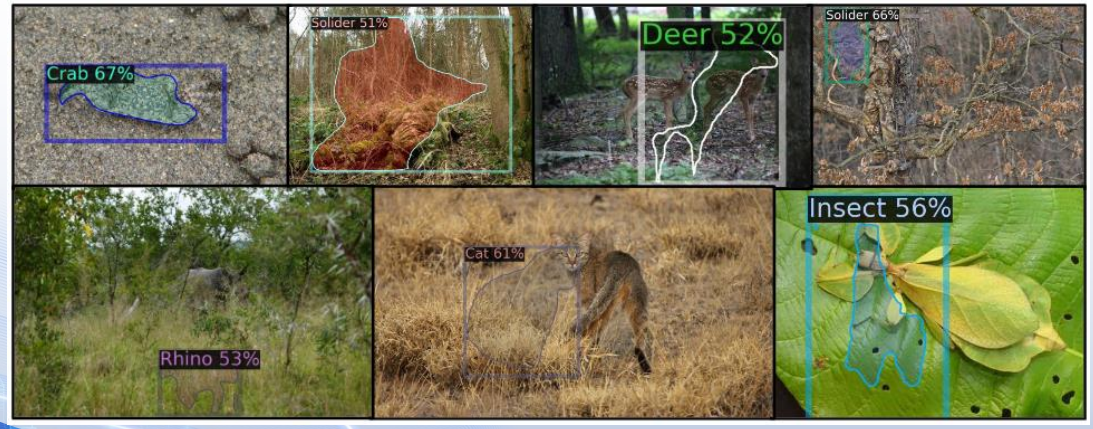


Fig. Visualization results of our FS-CAMOFreq on the CAMO-FS

- This inverse setting results in **performance degradation**
- Altering foreground features disrupts camouflage cues, leading to **model confusion** and **reduced accuracy**

5. Conclusion

In this work:

- We proposed **FS-CAMOFreq –** a novel framework that enriches image representations through **instance-aware frequency domain augmentation**
- Extensive experiments on theCAMO-FS benchmark validate the superiority of our approach over existing state-of-the-art baselines

In the future:

- Explore the adaptive frequency-based enhancement approach
- Extend our framework to other dense prediction tasks under limited supervision

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