Method for the MUAD Challenge:

Robust Energy Score with BN Adaptation

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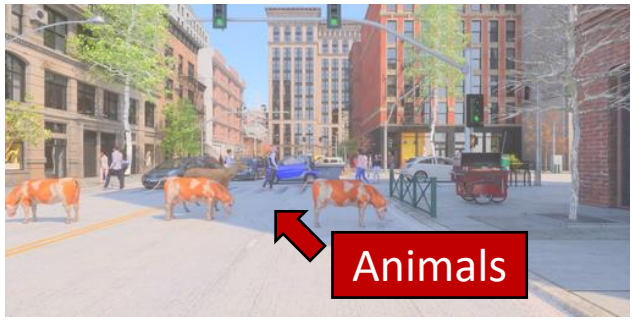
Introduction

- **Setting**: Both unknown domains and unknown objects could exist during testing.
- **Goal**: Dense OOD detection with potential domain-shifts.
- **Strategy**: Test-Time Adaptation (TTA).

(a) Image with unknown domain.



(b) Image with unknown object.

Motivation & Main Idea

- **Motivation:** Directly applying some existing TTA techniques could typically hurt the performance of OOD detection.
  - E.g. the transductive batch normalization (TBN) method [1,2].
- **Main Idea:** Identify whether an input image is from the seen or unseen domain and perform model adaptation accordingly.

[1] Nado, Zachary, et al. "Evaluating prediction-time batch normalization for robustness under covariate shift." arXiv preprint (2020).
[2] Zhitong Gao, et al. “ATTA: Anomaly-aware Test-Time Adaptation for Out-of-Distribution Detection in Segmentation”, NeurIPS (2023).

Selective Batch Normalization (SBN)

1. Estimate the probability of input image being generated from unseen domain.
   - Utilizing the distribution distance between the deep features of test and training data in the Normalization layers of the segmentation network.

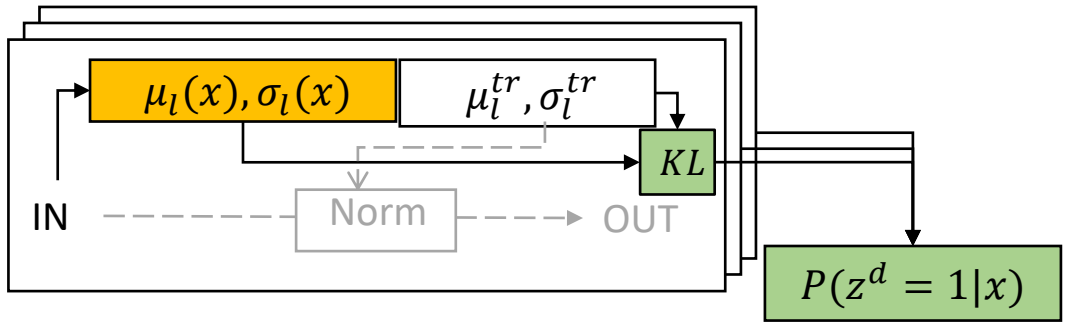
Running mean and standard deviation.

Domain-shift Probability:

$$P(z^d = 1|x) = h_{a,b}\left(\sum_{l=1}^{L}\left(KL(N(\mu_l(x), \sigma_l(x))||N(\mu_l^{tr}, \sigma_l^{tr}))\right)\right)$$

$h_{a,b}$: $\mathrm{sigmoid}((x+a)/b)$

The mean and standard deviation for each test input x



Selective Batch Normalization (SBN)

2. Update the BN statistics of the network according to the probability.
   - Mixing the original BN statistics with the test statistics.

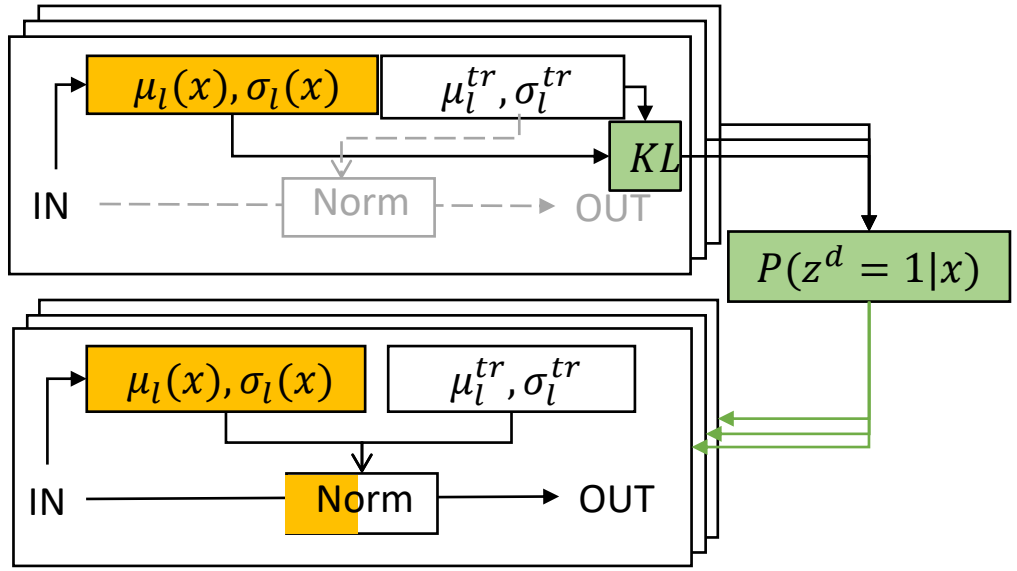
Domain-shift Probability

$$\hat{\mu}_l = P(z^d = 1|x) * \mu_l(x) + P(z^d = 0|x) * \mu_l^{tr}$$

$$\hat{\sigma}_l^2 = P(z^d = 1|x) * \sigma_l^2(x) + P(z^d = 0|x) * (\sigma_l^{tr})^2$$

Test statistics

Original statistics



IN: BN input; OUT: BN output.

Implementation

- **Segmentation Model:** A provided pretrained Deeplab v3+ model on the MUAD training set.
- **SBN Adaptation:** Detects and mitigates the effects of unknown domains by adapting the batch normalization (BN) layers.
- **OOD Detection:** Energy Score.

Results on MUAD dataset

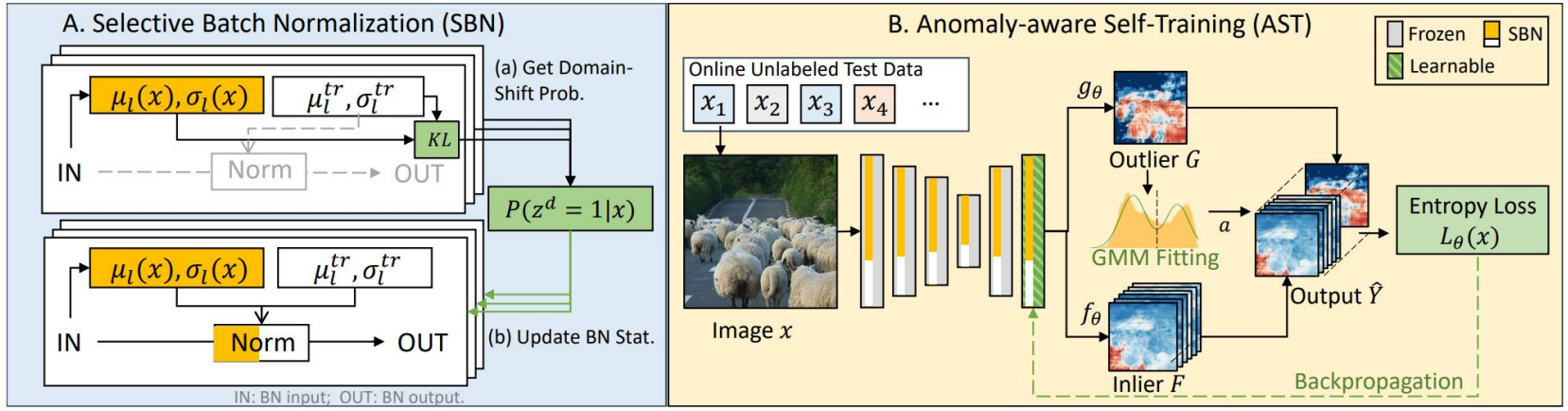
#	User Name	mAUROC ↑	mAUPR ↑	mFPR ↓	mECE ↓	mIoU ↑
1	zuoyi	**0.9516**	0.6053	0.1722	NA	0.4887
2	arui	0.9515	**0.6379**	**0.1499**	0.0726	0.5123
3	bee	0.9149	0.6072	0.2230	0.0698	0.5340
4	MahouShoujo	0.9094	0.3520	0.2391	NA	0.3837
5	rac	0.8510	0.4435	0.3983	0.0603	**0.6454**
6	zachtian	0.8393	0.2196	0.3850	0.1075	0.3274
7	Tonnia	0.8393	0.2745	0.4196	NA	0.4599
8	drop08	0.8356	0.2502	0.3898	0.0942	0.4558
9	Shyam671	0.8341	0.3038	0.3091	**0.0531**	0.3817
10	xtz	0.8280	0.4767	0.3536	0.1540	0.5049
11	Team_Rocket	0.7673	0.1821	0.4720	0.1855	0.3796
12	h.m	0.7644	0.2031	0.4512	0.1657	0.4134
13	HPeter	0.7429	0.1712	0.5204	0.3116	0.3656
14	Janes_migadel	0.7418	0.1806	0.5880	0.1799	0.2848
15	Yuehua.DING	0.7411	0.1641	0.5020	0.2165	0.3668
16	dens03	0.7399	0.1884	0.4787	0.2521	0.3764
17	Baseline	0.7337	0.1790	0.5253	0.2880	0.3690
18	NathLaMenace	0.7337	0.1790	0.5253	0.2880	0.3690
19	Sp4n	0.7091	0.1907	0.7499	0.0970	0.5309

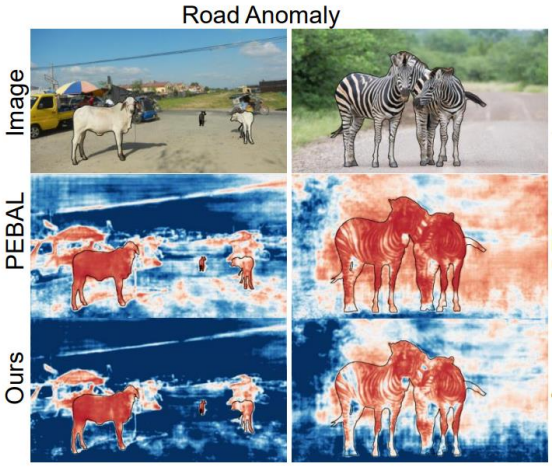
The method is simple and powerful:

- It achieves good results on the benchmark, much better than the baseline method.

Extension

- Method: Anomaly-aware Self-Training.
- Benchmarks: Road Anomaly, Fishyscapes, SegmentMeIfYouCan, Lost & Found, etc.
- Baseline methods: PEBAL, Max-logit, Energy, Meta-OOD, Max-Softmax, etc.





For more information, please refer to our paper or come to my poster!

- ATTA: Anomaly-aware Test-Time Adaptation for Out-of-Distribution Detection in Segmentation, NeurIPS (2023).

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Thanks for listening!