Out-of-Distribution Detection Using Union of 1-Dimensional Subspaces

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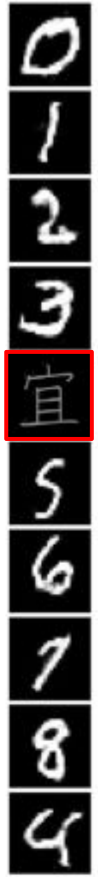
Joint work between University of Central Florida and University of Trento

https://github.com/zaeemzadeh/OOD
https://github.com/mmlab-cv/OOD_video

Out-of-distribution Detection

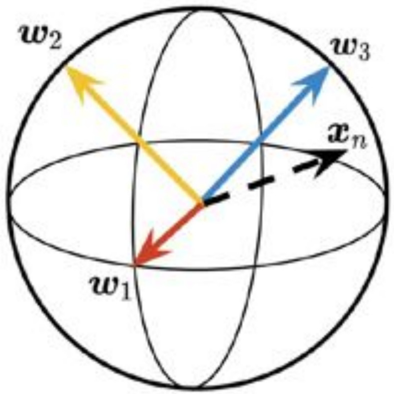
The goal of **out-of-distribution (OOD)** detection is to handle novel situations.

How can we make the in-distribution samples more distinguishable from OOD samples with unknown distribution?



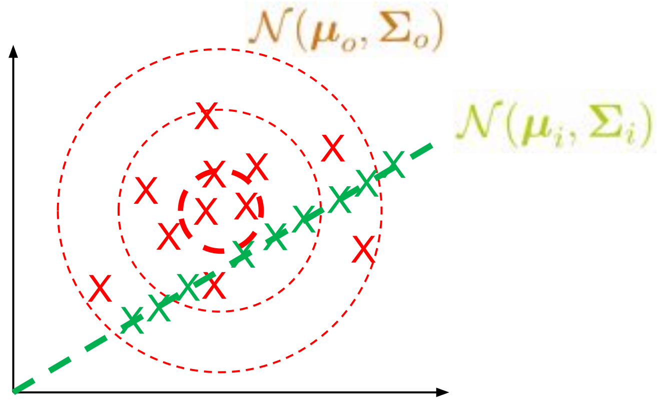
OOD Detection Using Union of 1D Subspaces

- Distribution-agnostic minimization of error
- No need for OOD samples to tune hyperparameters
- Does not rely on sample generation or reconstruction
- Easy to implement
- Modality-independent



Distribution-Agnostic Minimization of Error Probability

- Consider a binary classification problem:
- If one of the classes is degenerate, the detection can be performed with zero error probability.



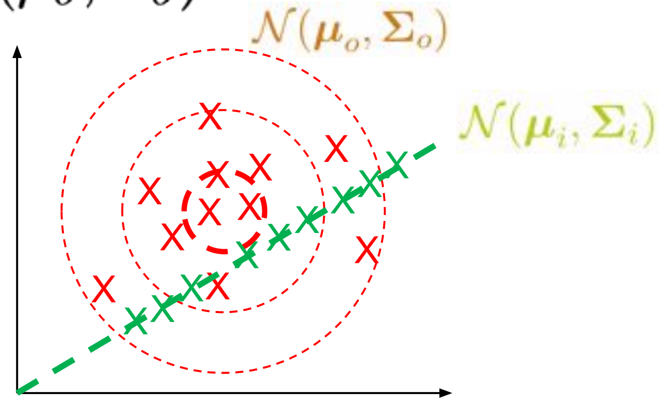
Distribution-Agnostic Minimization of Error Probability

p_i: The probability that the sample belongs to $\mathcal{N}(\mu_i, \Sigma_i)$

p_o: The probability that the sample belongs to $\mathcal{N}(\mu_o, \Sigma_o)$

$$\Delta = \mu_i - \mu_o$$

$$B = \frac{1}{8}\boldsymbol{\Delta}^T\left(\frac{\boldsymbol{\Sigma}_i + \boldsymbol{\Sigma}_o}{2}\right)^{-1}\boldsymbol{\Delta} + \frac{1}{2}\ln\left(\frac{\det\left(\frac{\boldsymbol{\Sigma}_i + \boldsymbol{\Sigma}_o}{2}\right)}{\sqrt{\det(\boldsymbol{\Sigma}_i)\det(\boldsymbol{\Sigma}_o)}}\right)$$

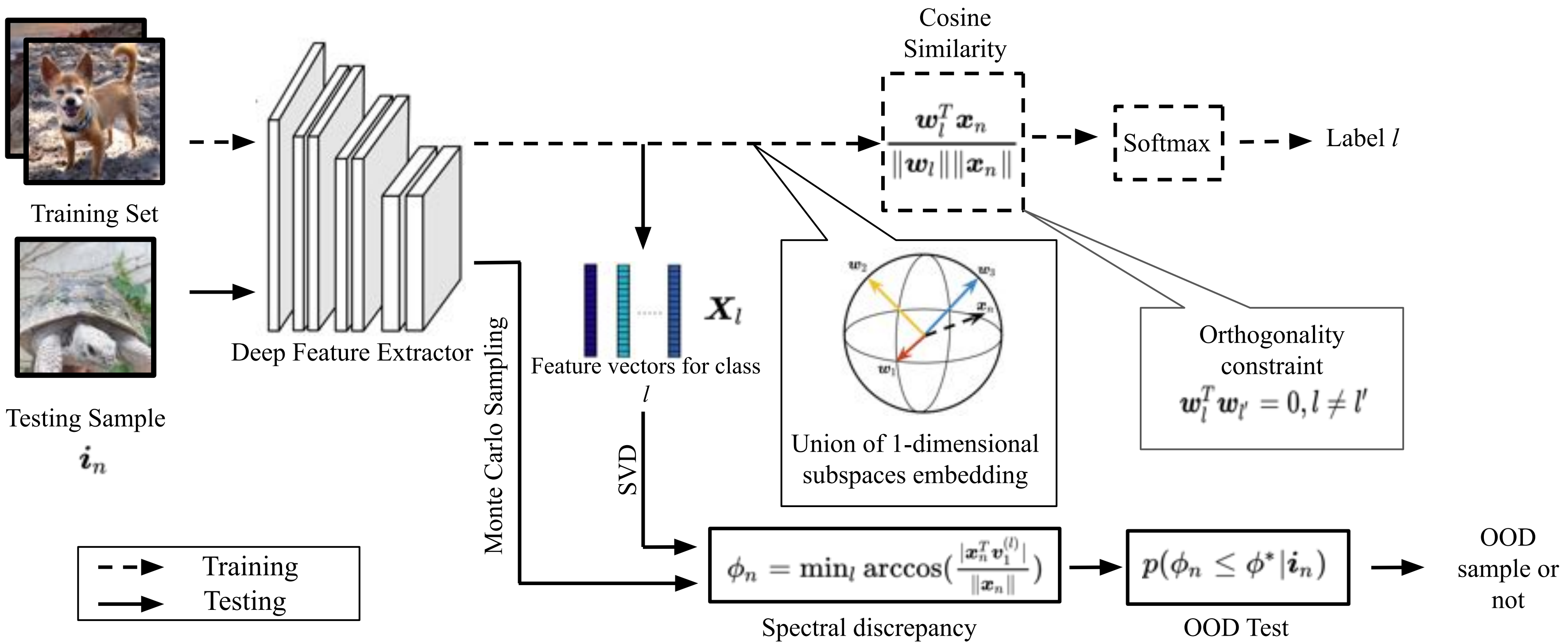


The classification error probability can be upper bounded by

$$p_e \leq \sqrt{p_i p_o}\, e^{-B}$$

The probability of error can be decreased by making the distribution of the known classes as compact as possible (e.g. *1D subspace*).

OOD Detection Using Union of 1-Dimensional Subspaces



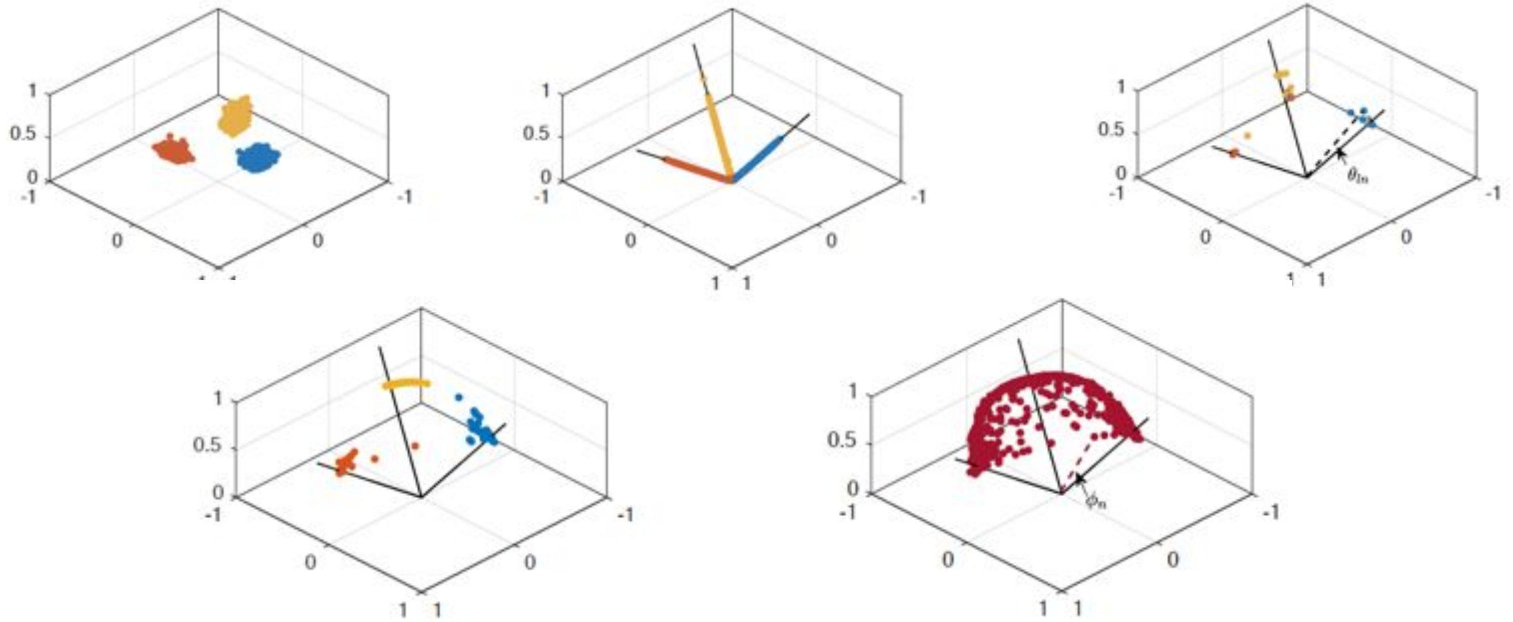
Experiments

3-dimensional visualization of the features extracted from CIFAR10

w/o Cosine similarity | w/ Cosine similarity | w/ Cosine similarity (normalized)

Training Set

Test Set



In-distribution | Out-of-distribution

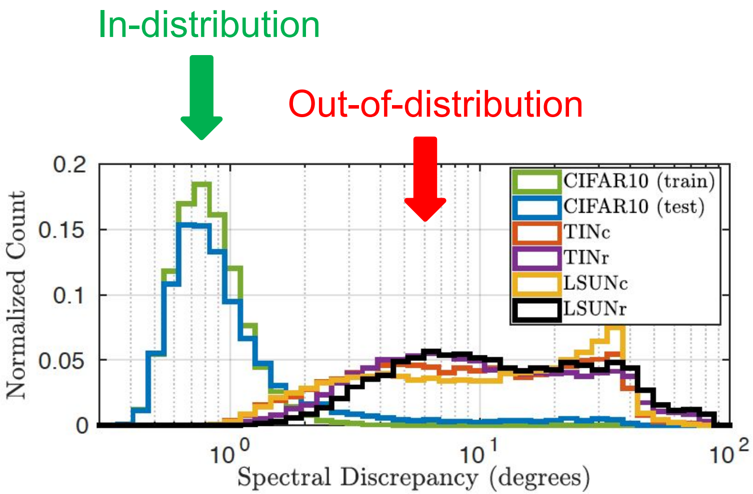
Experiments: Image Classification

The proposed spectral discrepancy measure can effectively distinguish between the ID (CIFAR10) and OOD samples.

AUROC: Area under receiver operating characteristic curve

AUPR: Area under precision recall curve

FPR/TPR: False/True Positive Rate



Training dataset	OOD dataset	FPR at 95% TPR ↓	Detection Error ↓	AUROC ↑	AUPR In ↑	AUPR Out ↑
		Softmax. Pred. [12]/OLTR [24]/ Ours				
CIFAR10	TINc	38.9/25.6/**9.0**	21.9/14.8/**6.8**	92.9/91.3/**98.1**	92.5/93.2/**98.2**	91.9/88.3/**98.1**
	TINr	45.6/28.8/**7.6**	25.3/15.8/**6.2**	91.0/90.3/**98.5**	89.7/92.3/**98.6**	89.9/87.1/**98.4**
	LSUNc	35.0/21.3/**2.8**	20.0/13.0/**3.7**	94.5/92.9/**99.4**	95.1/94.4/**99.4**	93.1/90.8/**99.4**
	LSUNr	35.0/21.7/**3.4**	20.0/13.2/**3.8**	93.9/92.6/**99.3**	93.8/94.4/**99.4**	92.8/90.0/**99.3**

OOD detection can be improved by making the known classes as compact as possible.

Experiments: Video Classification

Our method can generalise for multiple modalities (images, videos)

New baseline for OOD detection on action recognition in videos on UCF 50 and UCF 101 datasets

Training dataset	**OOD dataset**	**FPR at 95% TPR** ↓	**Detection Error** ↓	**AUROC** ↑	**AUPR In** ↑	**AUPR Out** ↑
		SoftMax. Pred. (Baseline) [12]/ SoftMax. Pred. (Orthogonal Subs.) [12]/ Ours				
UCF50	UCF51	86.3/82.44/**71.6**	36.8/36.1/**30.0**	66.0/68.3/**75.7**	89.8/**90.1**/74.3	25.6/27.8/**72.5**
HMDB25	HMDB26	**82.0**/85.2/84.5	41.8/44.5/**40.8**	59.7/56.4/**61.9**	**88.9**/87.6/65.4	20.4/19.7/**56.6**

Conclusions

- We can improve the OOD detection performance by engineering the distribution of in-distribution samples
- Our approach does not have hyperparameters, does not need extra information, and can be easily applied to existing methods with minimal change.
- Our approach is modality-independent and can be applied to different input types

Thank You!

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