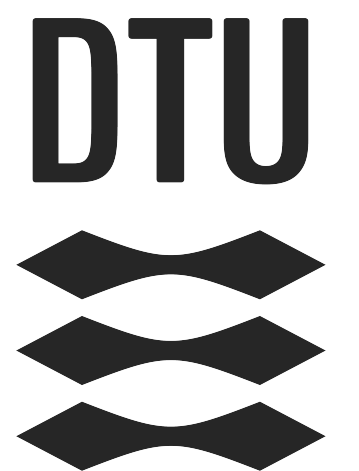


Bayesian Metric Learning for Uncertainty Quantification in Image Retrieval

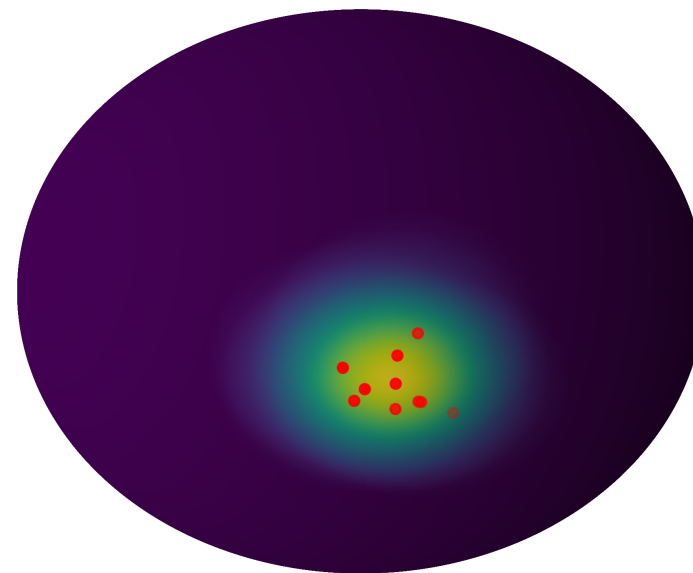
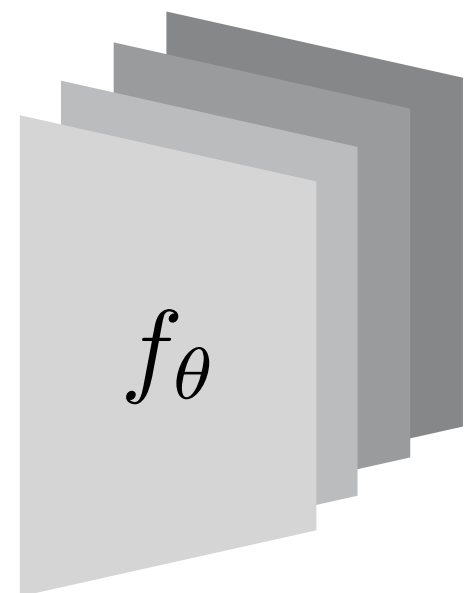
Frederik Warburg*, Marco Miani*, Silas Brack, Søren Hauberg

Technical University of Denmark



Laplacian Metric Lerner (LAM)

$$f_{\theta} : \mathbb{R}^{HWC} \longrightarrow \mathcal{S}^Z$$



$$\theta \sim \mathcal{N}(\theta_t, H_{\theta_t}^{-1})$$

is a network parametrised by $\theta \in \Theta$

Laplace Approximation

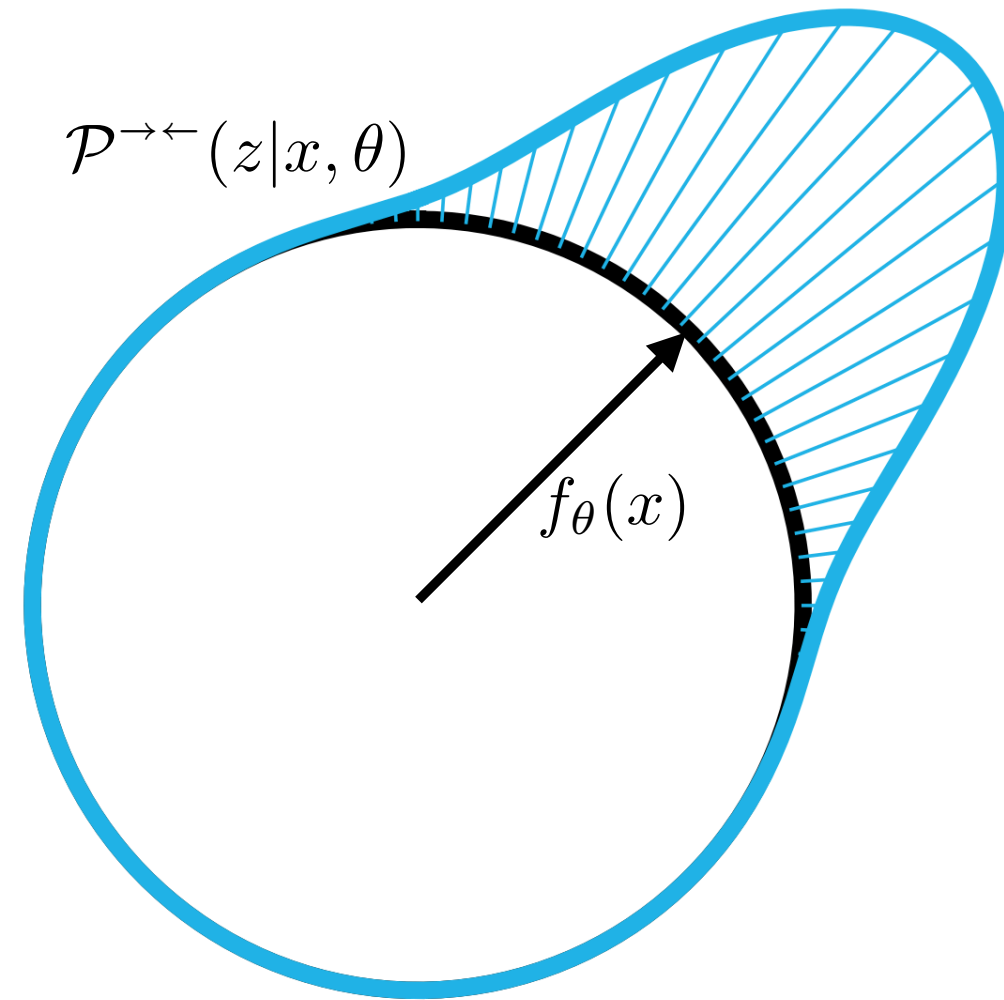
(Feasible thanks to *nnj* library)

Contrastive Loss

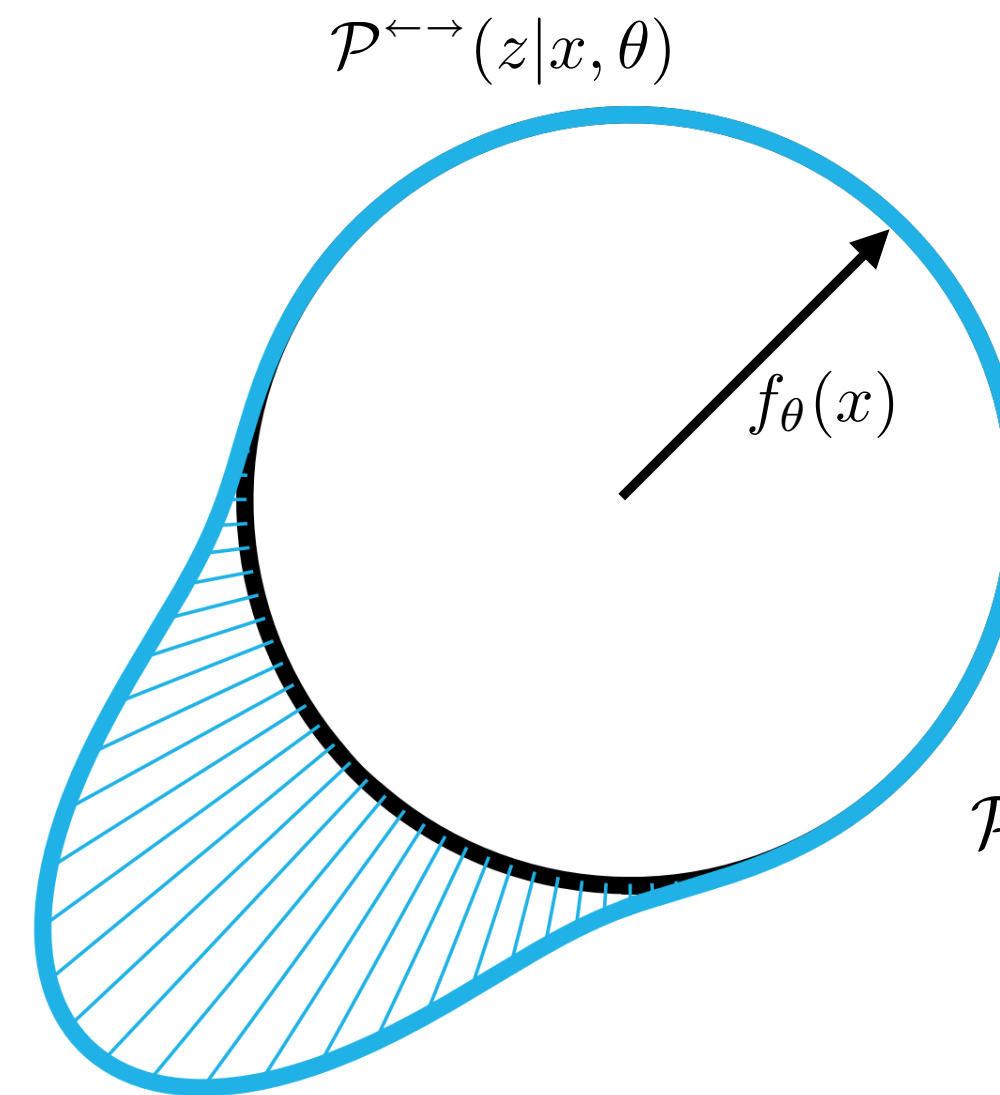
$$\mathcal{L}_{\text{con}}(\theta) = \frac{1}{2} \|f_{\theta}(x_a) - f_{\theta}(x_p)\|^2 + \frac{1}{2} \max(0, m - \|f_{\theta}(x_a) - f_{\theta}(x_n)\|^2)$$

attractive term

repulsive term



$$\mathcal{P}^{\rightarrow\leftarrow}(z|x, \theta) = c_{\kappa} \exp\left(-\kappa \frac{\|z - f_{\theta}(x)\|^2}{2}\right)$$

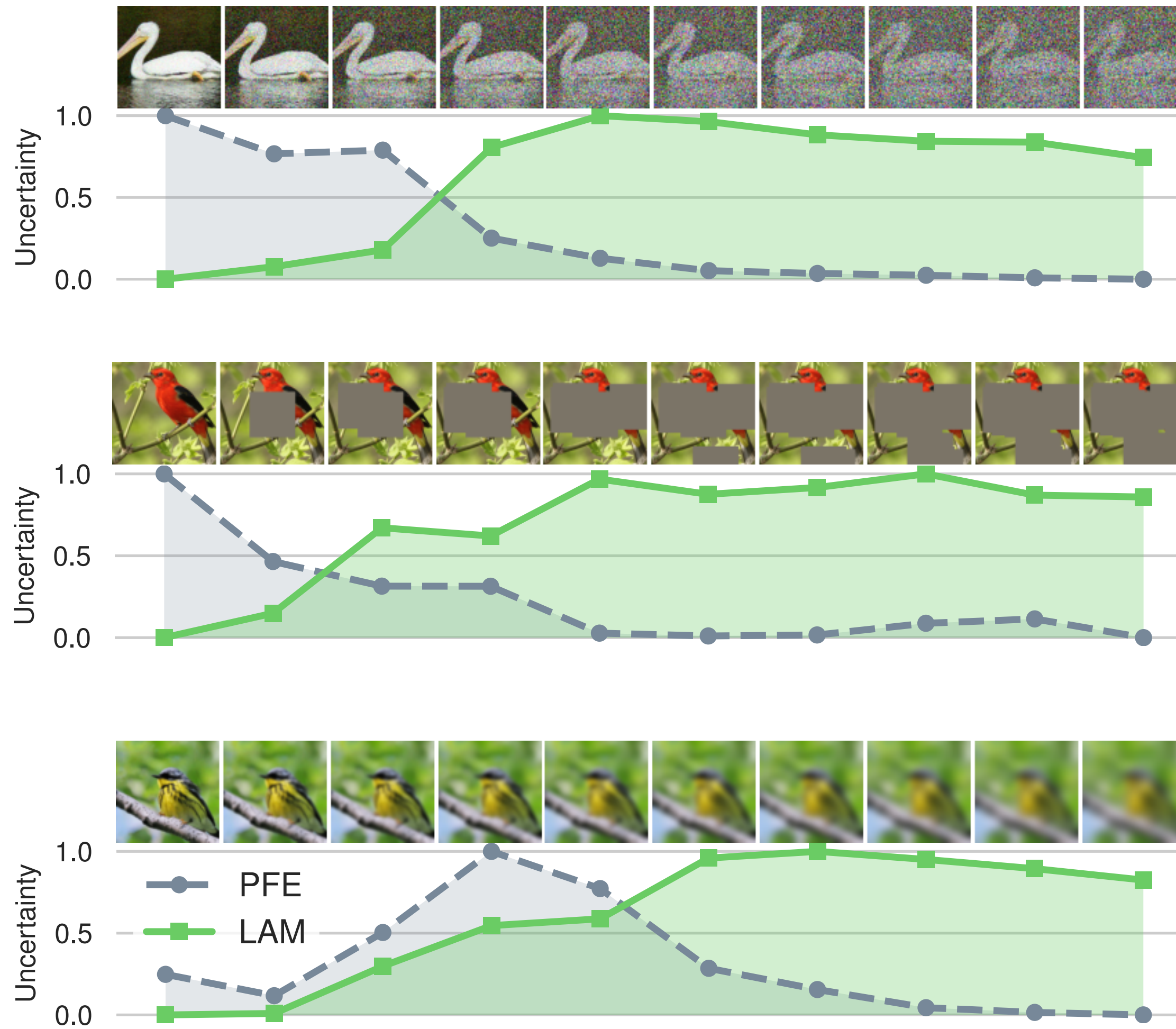


$$\mathcal{P}^{\leftarrow\rightarrow}(z|x, \theta) = c_{\kappa} \exp\left(-\kappa \frac{\|z + f_{\theta}(x)\|^2}{2}\right)$$

Proposition: The Contrastive loss is equal, up to an additive constant, to a negative log-likelihood

$$\log \mathcal{P}(\mathcal{D}|\theta) = -\mathcal{L}(\theta; \mathcal{D}) + c$$

Reliable stochastic embeddings

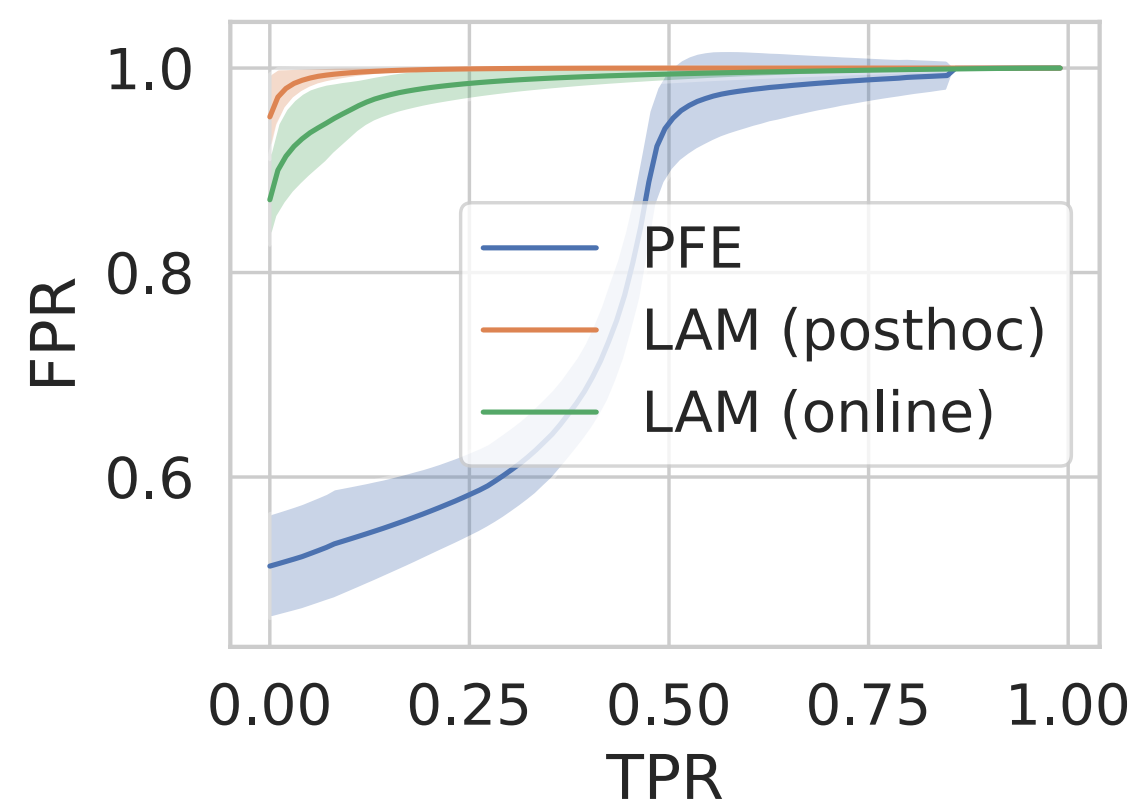


Embedding *uncertainty* for **corrupted** input image:

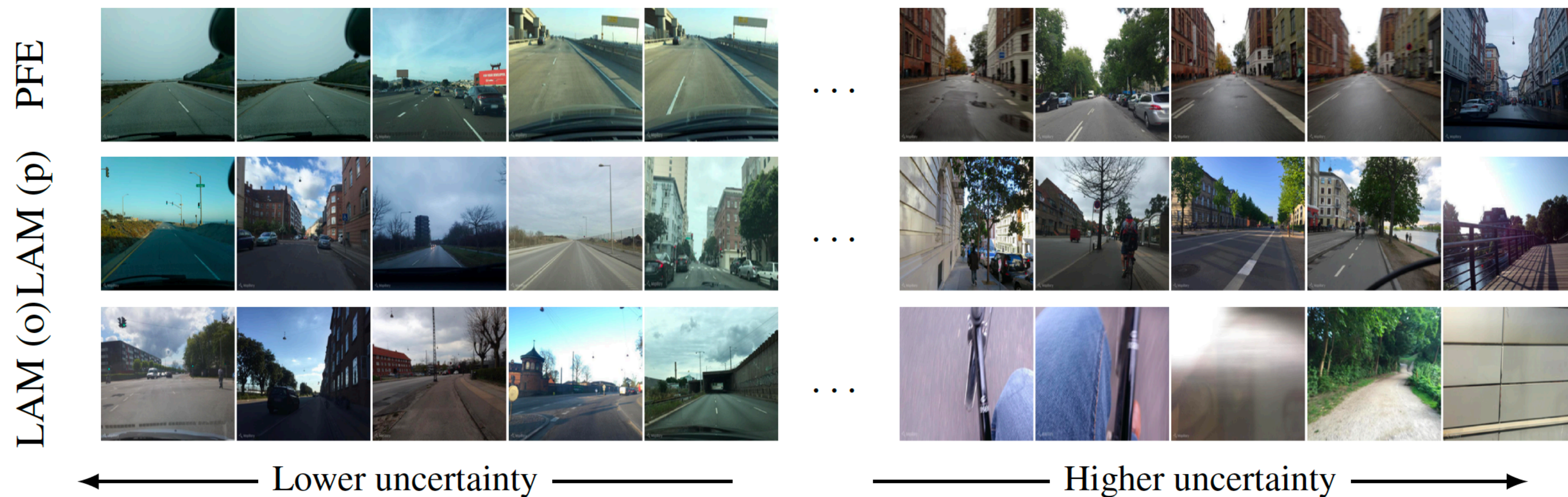
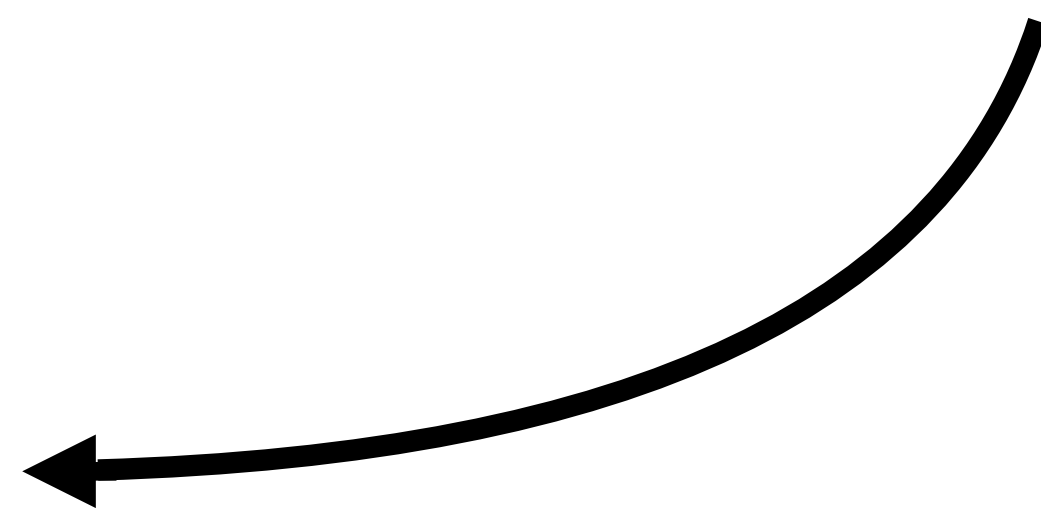
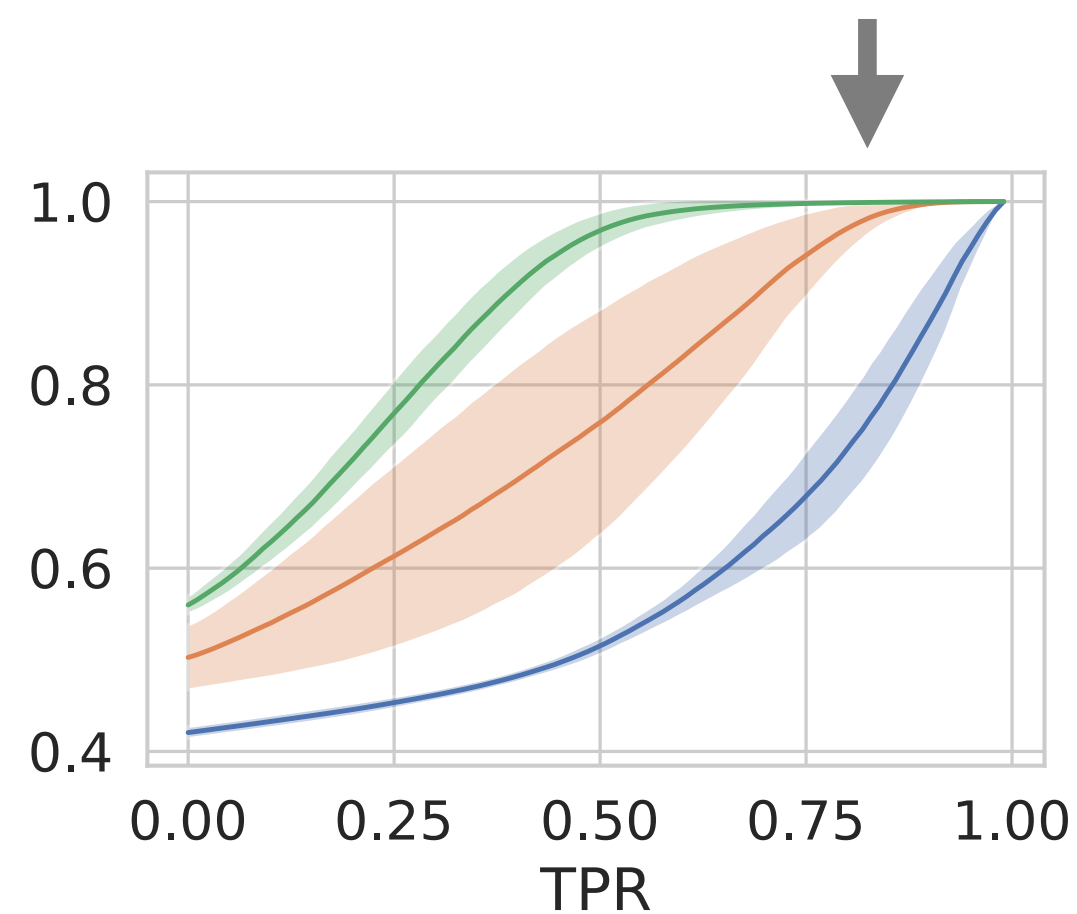
- noise
- occlusion
- blur

Out of Distribution detection

On out-of-distribution (**OoD**) data we measure the Area Under Receiver Operator Curve (AUROC), and Area Under Precision-Recall Curve (AUPRC)

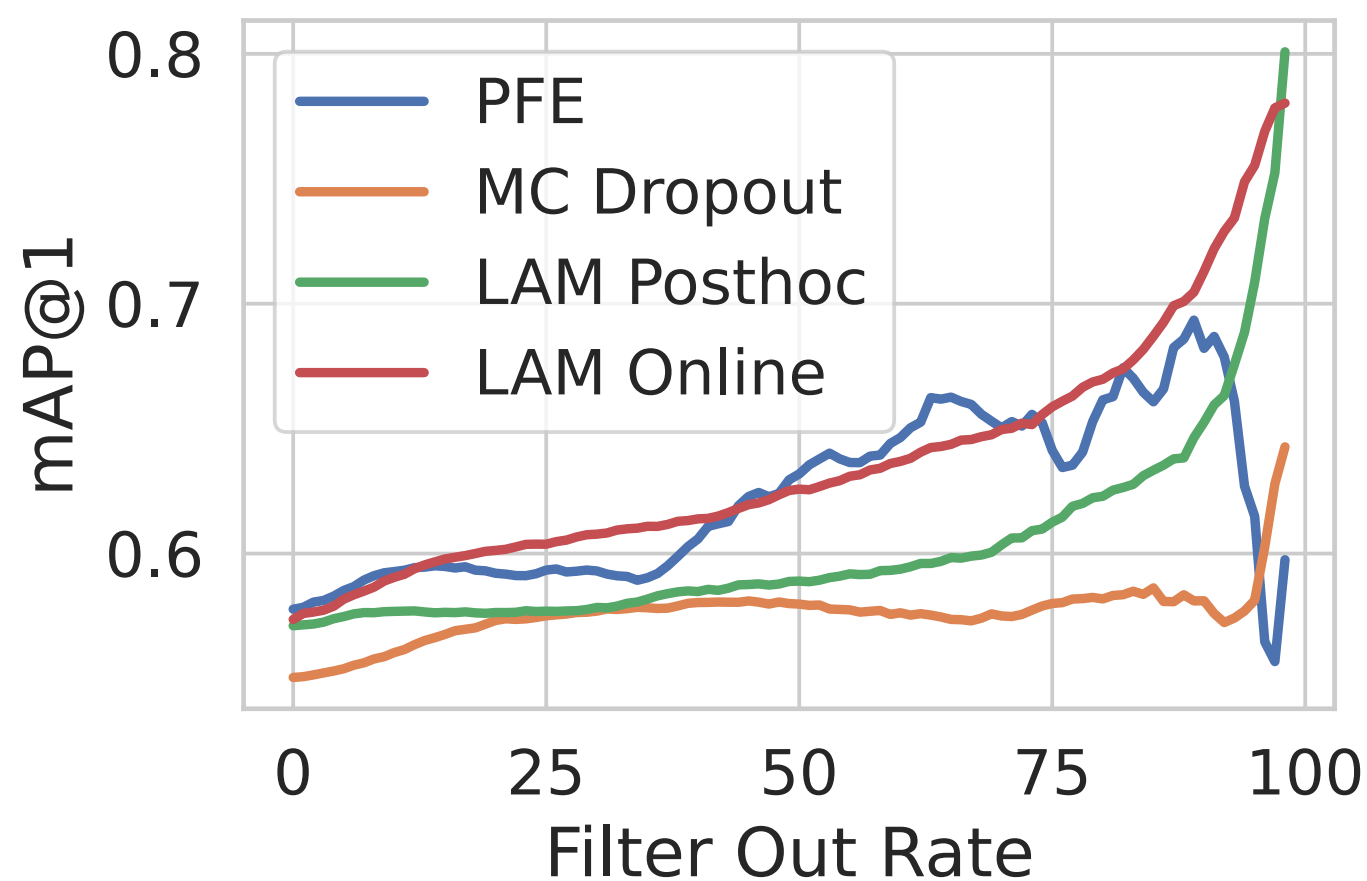


ROC on FashionMnist and Cifar-10

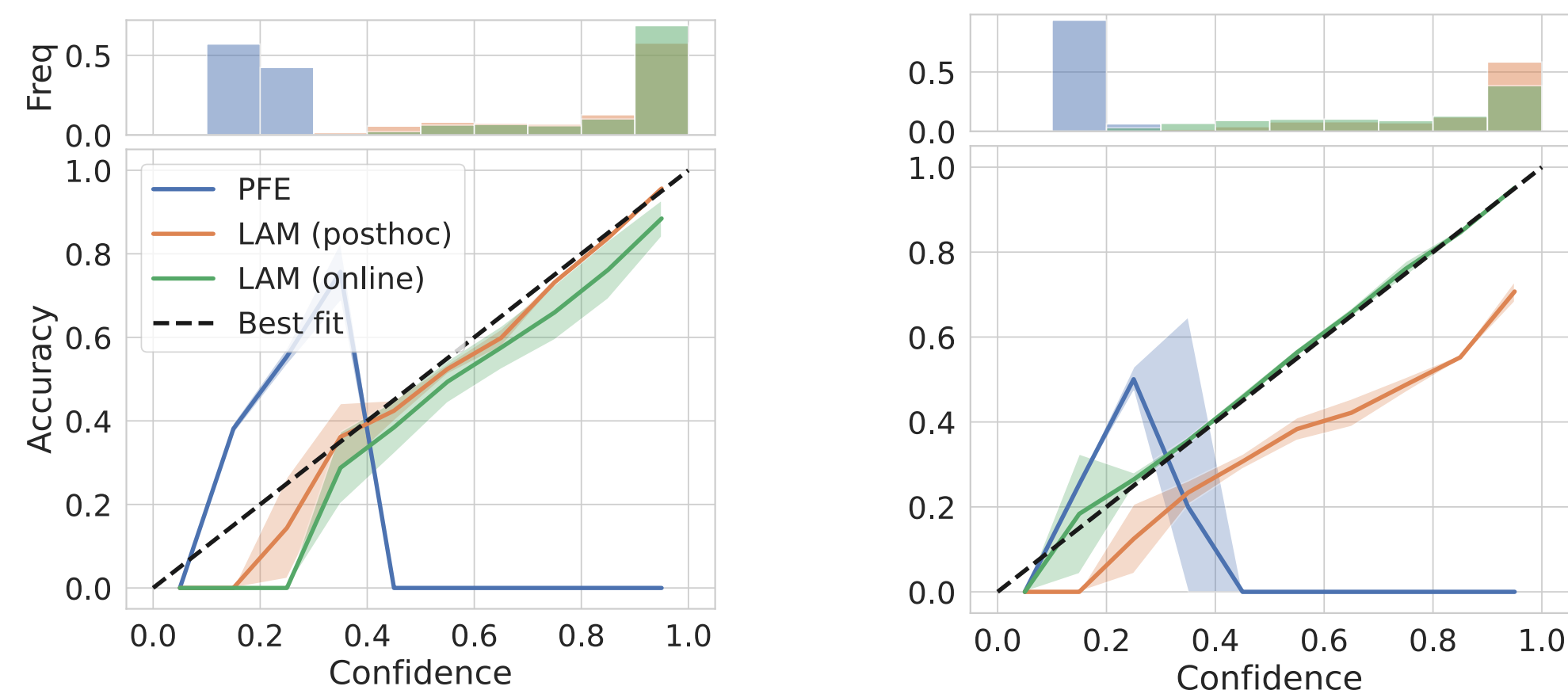


Calibrated Uncertainties

On in-distribution (ID) data we measure *Area Under the Sparsification Curve* (AUSC) and *Expected Calibration Error* (ECE)



Sparsification Curves on MSLS monotonically increase for LAM



Calibration Error on FashionMnist and Cifar-10, LAM is near-perfect

		IMAGE RETRIEVAL			OoD		CALIBRATION	
		mAP@1 ↑	mAP@5 ↑	mAP@10 ↑	AUROC ↑	AUPRC ↑	AUSC ↑	ECE ↓
FashionMNIST	Deterministic	0.78 ± 0.01	0.73 ± 0.01	0.72 ± 0.01	—	—	—	—
	Deep Ensemble	0.69	0.62	0.59	0.41	0.46	0.61	0.04
	PFE	0.78 ± 0.00	0.74 ± 0.00	0.72 ± 0.00	0.53 ± 0.03	0.46 ± 0.01	0.65 ± 0.01	0.26 ± 0.02
	HIB	0.69 ± 0.08	0.63 ± 0.09	0.61 ± 0.09	0.60 ± 0.12	0.60 ± 0.11	0.65 ± 0.08	0.54 ± 0.08
	MC dropout	0.76 ± 0.03	0.71 ± 0.03	0.70 ± 0.03	0.93 ± 0.03	0.93 ± 0.03	0.84 ± 0.06	0.03 ± 0.04
	LAM (post-hoc)	0.78 ± 0.00	0.74 ± 0.00	0.72 ± 0.00	0.96 ± 0.02	0.96 ± 0.02	0.86 ± 0.01	0.03 ± 0.00
	LAM (online)	0.81 ± 0.00	0.77 ± 0.01	0.76 ± 0.01	0.98 ± 0.01	0.98 ± 0.01	0.89 ± 0.01	0.02 ± 0.00
	CIFAR10	Deterministic	0.66 ± 0.00	0.59 ± 0.00	0.58 ± 0.00	—	—	—
Deep Ensemble	0.66	0.61	0.59	0.42	0.67	0.72	0.02	
MC dropout	0.46 ± 0.01	0.37 ± 0.01	0.34 ± 0.01	0.60 ± 0.03	0.76 ± 0.02	0.61 ± 0.01	0.05 ± 0.00	
HIB	0.11 ± 0.01	0.07 ± 0.00	0.05 ± 0.00	0.44 ± 0.17	0.70 ± 0.1	0.29 ± 0.03	0.04 ± 0.02	
PFE	0.66 ± 0.00	0.60 ± 0.00	0.58 ± 0.00	0.21 ± 0.02	0.56 ± 0.01	0.56 ± 0.01	0.11 ± 0.01	
LAM (post-hoc)	0.66 ± 0.00	0.60 ± 0.00	0.58 ± 0.00	0.50 ± 0.11	0.69 ± 0.07	0.81 ± 0.01	0.23 ± 0.01	
LAM (online)	0.66 ± 0.01	0.60 ± 0.00	0.57 ± 0.01	0.78 ± 0.04	0.85 ± 0.03	0.83 ± 0.01	0.01 ± 0.00	

		IMAGE RETRIEVAL			OoD		ID
		mAP@1 ↑	mAP@5 ↑	mAP@10 ↑	AUROC ↑	AUPRC ↑	AUSC ↑
CUB200	Deterministic	0.62 ± 0.01	0.48 ± 0.01	0.42 ± 0.01	—	—	—
	Deep Ensemble	0.21	0.11	0.07	0.47	0.55	0.21
	PFE	0.62 ± 0.01	0.5 ± 0.01	0.43 ± 0.01	0.44 ± 0.16	0.5 ± 0.08	0.61 ± 0.02
	HIB	0.33 ± 0.04	0.19 ± 0.02	0.14 ± 0.02	0.54 ± 0.12	0.61 ± 0.1	0.31 ± 0.07
	MC dropout	0.61 ± 0.00	0.48 ± 0.00	0.42 ± 0.00	0.73 ± 0.08	0.68 ± 0.07	0.63 ± 0.01
	LAM (post-hoc)	0.65 ± 0.01	0.52 ± 0.01	0.45 ± 0.01	0.56 ± 0.16	0.61 ± 0.11	0.66 ± 0.03
	LAM (online)	0.61 ± 0.00	0.48 ± 0.00	0.42 ± 0.00	0.80 ± 0.03	0.75 ± 0.03	0.63 ± 0.01
	LFW	Deterministic	0.44 ± 0.00	0.68 ± 0.00	0.65 ± 0.00	—	—
Deep Ensemble	0.36	0.57	0.54	0.52	0.64	0.33	
PFE	0.44 ± 0.00	0.68 ± 0.00	0.65 ± 0.00	0.03 ± 0.02	0.41 ± 0.0	0.49 ± 0.01	
MC dropout	0.42 ± 0.00	0.65 ± 0.01	0.63 ± 0.01	0.03 ± 0.01	0.41 ± 0.0	0.46 ± 0.01	
LAM (post-hoc)	0.44 ± 0.01	0.68 ± 0.01	0.65 ± 0.00	0.65 ± 0.14	0.72 ± 0.11	0.45 ± 0.03	
LAM (online)	0.46 ± 0.00	0.71 ± 0.00	0.69 ± 0.00	0.71 ± 0.22	0.78 ± 0.17	0.50 ± 0.02	

Thank you!

and see you at the poster session Tue 12 Dec 5:15 pm

