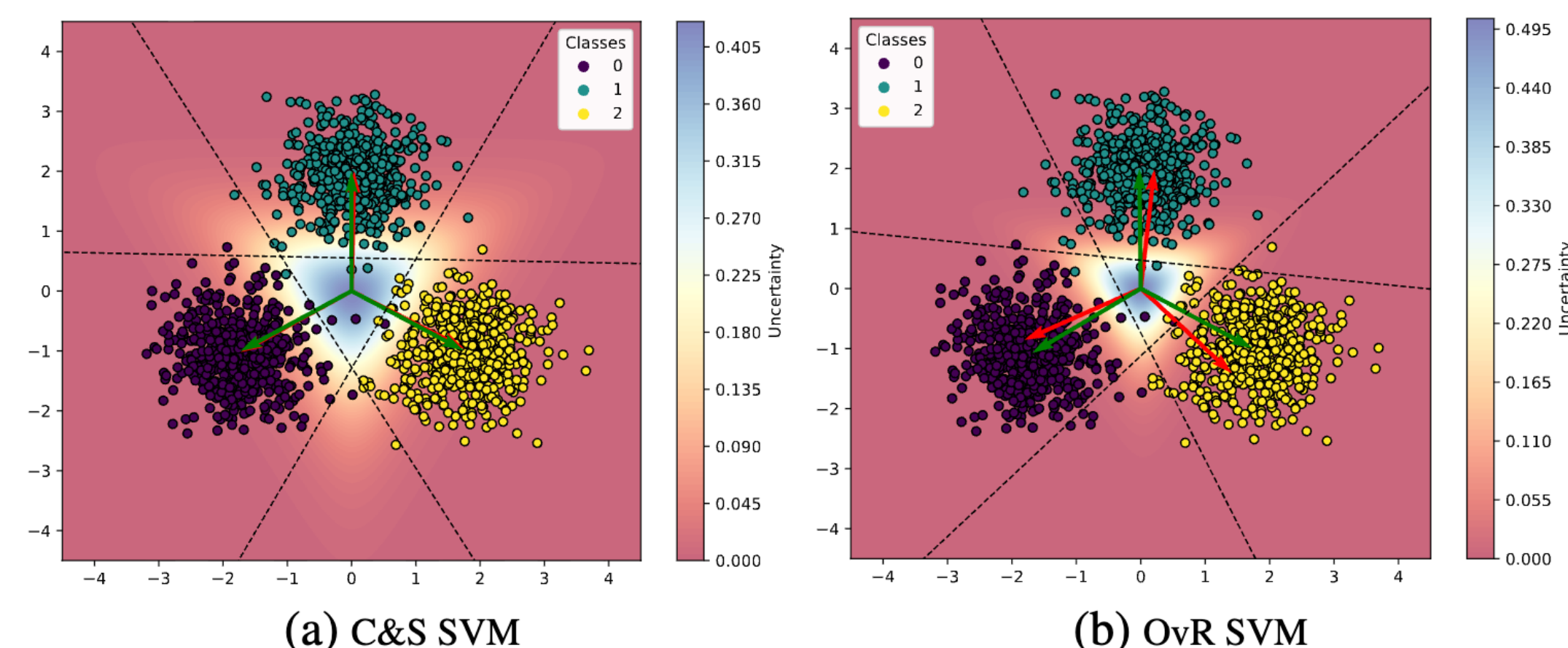


Motivation

Evidential Deep Learning estimates uncertainty by predicting a Dirichlet distribution. However, existing uncertainty measures are designed from a **probabilistic** perspective.

Key question: Are current uncertainty measures consistent with the **optimization** process?

Converge to a maximum-margin solution



Key observation: Minimizing UCE loss in EDL implicitly encourages a maximum-margin solution similar to C&S multi-class SVM.

Implicit maximum-margin solution

- C&S SVM solution: $w_j = \beta^{-1} \sum_{i=1}^N (\delta_{y_i,j} - \eta_{i,j}) x_i$
- UCE loss gradient: $\Delta w_j \propto \sum_i (\delta_{y_i,j} - b_{i,j}) \Psi(x_i)$

There exists an analogy between EDL gradient dynamics and the SVM dual solution.

Methodology

The Optimization-Consistency Property

$$\mathcal{L}_{UCE}(x, y, W, \Psi) \leq \mathcal{L}_{UCE}(x', y', W, \Psi)$$

$$u(x; W, \Psi) \leq u(x'; W, \Psi).$$

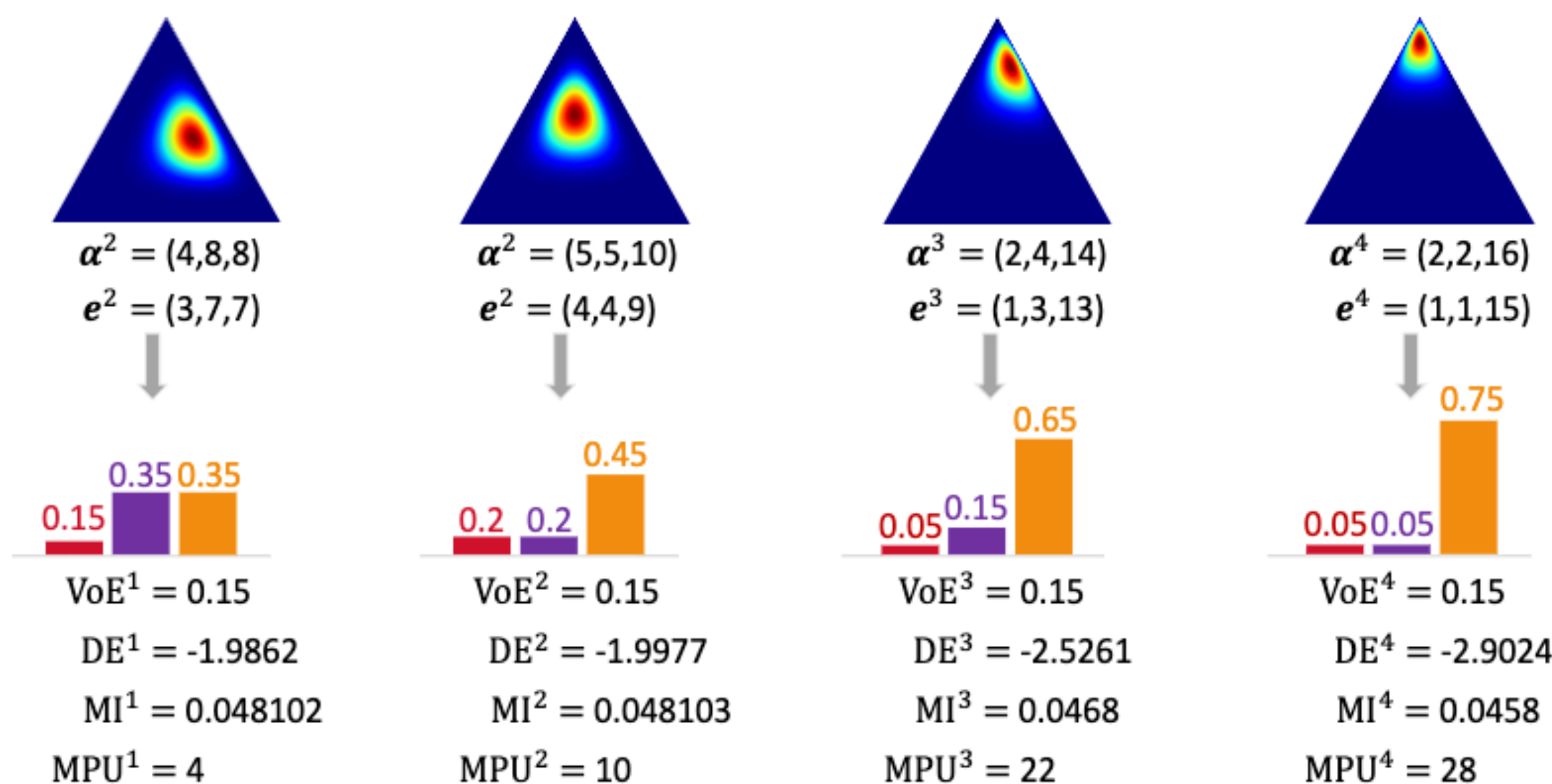
Key insight: A valid uncertainty measure should decrease as samples approach the global optimum of objective function.

Margin-aware Predictive Uncertainty (MPU)

$$MPU(\alpha) = (K - 1)\alpha_{\hat{y}} - \sum_{j \neq \hat{y}} \alpha_j$$

- ✓ Large margin \rightarrow confident prediction
- ✓ Small margin \rightarrow high uncertainty

Compare with previous UQ methods



Experiments

Out-of-distribution detection results

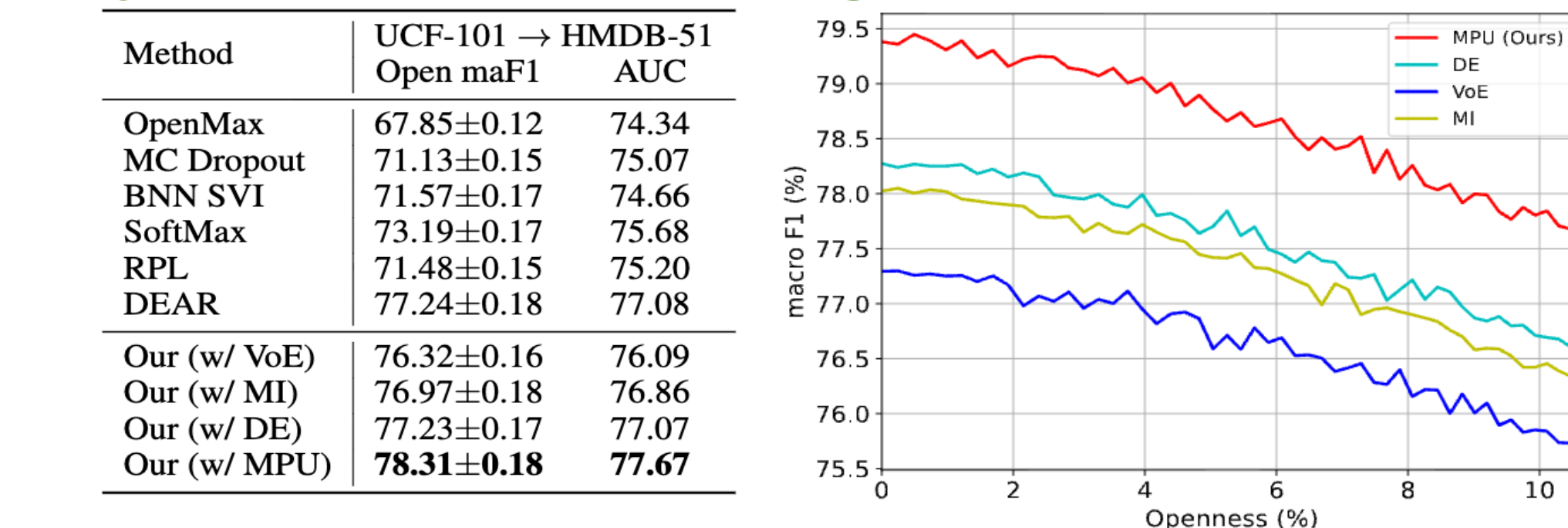
Method	\rightarrow SVHN	\rightarrow CIFAR100	\rightarrow GTSRB	\rightarrow Places365	\rightarrow Food101	Cls Acc	Mis Detect
MC Dropout	78.40±3.88	85.39±0.58	83.51±2.32	67.63±2.34	76.07±2.58	90.16±0.23	98.86±0.06
EDL	82.32±1.21	87.13±0.26	84.57±1.26	70.46±0.77	80.18±0.69	88.48±0.32	98.74±0.07
DUQ	81.44±4.63	85.38±0.37	83.35±4.30	66.20±3.61	75.87±4.40	89.39±0.13	97.98±0.34
PostN	83.76±0.46	87.07±0.94	84.83±1.67	71.79±2.36	78.83±2.53	87.82±0.06	97.46±0.06
NatPN	83.56±0.38	88.05±0.75	84.76±2.03	71.14±2.06	79.44±2.63	87.73±0.09	97.53±0.05
RED	82.85±2.35	87.84±0.54	85.30±3.31	70.78±2.33	79.91±1.92	89.43±0.28	98.82±0.09
Z-EDL	84.97±2.11	86.31±0.32	84.79±2.13	68.92±1.21	77.75±0.27	88.38±0.15	98.71±0.11
R-EDL	85.00±1.22	87.73±0.31	87.25±0.69	71.97±0.69	79.64±2.36	90.09±0.31	98.98±0.05
Re-EDL	89.94±1.40	88.31±0.16	90.53±2.04	73.42±1.05	80.83±1.72	90.13±0.25	98.81±0.05
Our /w VoE	48.96±8.96	66.45±1.73	69.64±2.18	43.21±3.00	45.65±2.26		96.63±0.32
Our /w MI	84.28±2.60	86.73±0.40	86.35±2.53	68.61±1.93	76.81±1.58		99.09±0.08
Our /w DE	87.32±1.20	88.11±0.34	87.30±2.40	70.91±1.58	78.64±1.40	93.35±0.25	99.31±0.06
Our /w MPU	87.36±0.91	88.92±0.31	88.71±1.85	72.82±1.24	79.79±1.35		99.41±0.04
Δ (MPU vs VoE)	+38.40	+22.47	+19.06	+29.69	+34.14		+2.78

Method	CIFAR100 \rightarrow Places365				CIFAR100 \rightarrow Food101			
	MPU	DE	MI	VoE	MPU	DE	MI	VoE
EDL	45.45±1.47	45.52±1.52	45.52±1.52	45.52±1.52	68.54±2.19	68.87±2.46	68.89±2.51	68.89±2.51
Z-EDL	31.16±10.22	28.34±7.25	26.77±5.62	26.53±5.37	46.95±19.68	42.06±14.68	38.90±11.42	38.40±10.9
R-EDL	45.66±1.43	45.70±1.44	45.71±1.46	45.71±1.46	70.15±0.83	70.54±0.82	70.76±0.78	70.77±0.76
Re-EDL	43.88±2.10	43.92±2.13	43.91±2.14	43.91±2.14	69.99±1.30	70.46±1.46	70.50±1.48	70.50±1.48
PostN	31.88±3.40	33.04±4.54	18.05±3.12	31.64±3.79	47.55±5.98	50.19±7.84	22.79±4.45	46.85±5.82
PostN [†]	38.41±1.23	39.52±1.29	19.96±1.14	38.01±1.54	56.33±1.90	56.87±1.81	26.09±1.00	55.72±1.73
Our	49.62±1.05	45.01±1.40	33.27±0.91	27.83±0.37	68.34±0.89	66.75±2.03	55.40±2.18	44.72±1.27

Method	CIFAR100 \rightarrow CIFAR10				CIFAR-100 Mis Detect			
	MPU	DE	MI	VoE	MPU	DE	MI	VoE
EDL	72.75±1.02	72.70±1.10	72.67±1.12	72.67±1.12	91.05±0.29	90.56±0.32	90.48±0.33	90.47±0.33
Z-EDL	60.29±11.01	57.01±8.08	55.54±6.58	55.29±6.33	60.29±11.01	57.01±8.08	55.54±6.58	55.29±6.33
R-EDL	73.16±0.78	73.11±0.78	73.00±0.80	72.95±0.81	90.58±0.29	90.18±0.32	89.90±0.33	89.83±0.33
Re-EDL	71.69±1.49	71.55±1.63	71.52±1.65	71.51±1.65	90.92±0.26	90.36±0.29	90.26±0.29	90.26±0.29
PostN	59.89±5.42	62.15±7.55	41.76±6.56	59.06±7.92	79.75±5.34	81.06±5.12	44.16±4.56	78.45±1.53
PostN [†]	68.07±1.87	68.27±1.45	44.87±1.65	67.40±1.42	88.57±1.58	89.27±1.53	61.94±1.25	87.87±1.15
Our	76.05±0.49	74.55±0.48	65.77±0.88	58.72±1.35	94.34±0.25	90.34±0.90	80.71±1.11	76.41±1.13

Open-set action recognition results

Method	UCF-101 \rightarrow HMDB-51	
	Open maF1	AUC
OpenMax	67.85±0.12	74.34
MC Dropout	71.13±0.15	75.07
BNN SVI	71.57±0.17	74.66
SoftMax	73.19±0.17	75.68
RPL	71.48±0.15	75.20
DEAR	77.24±0.18	77.08
Our (w/ VoE)	76.32±0.16	76.09
Our (w/ MI)	76.97±0.18	76.86
Our (w/ DE)	77.23±0.17	77.07
Our (w/ MPU)	78.31±0.18	77.67



Uncertainty distribution visualization

