Uncertainty Aware Semi-Supervised Learning on Graph Data

Xujiang Zhao[1], Feng Chen[1], Shu Hu[2], Jin-Hee Cho[3]

[1]The University of Texas at Dallas, [2]University at Buffalo, SUNY, [3]Virginia Tech

Types of uncertainty

1

Epistemic **uncertainty (a.k.a. model/parameter uncertainty)**

- Measures what model doesn't know
- Due to **limited data and knowledge**

Aleatoric **uncertainty (a.k.a. data uncertainty)**

- Measures what you can't understand from the data
- Due to **randomness**

→ Probabilistic Uncertainty

2

Vacuity **uncertainty** (a.k.a. ignorance)

- Measures uncertainty due to **a lack of evidence**

Dissonance **uncertainty**

- Measures uncertainty due to **conflicting evidence**

→ Evidential Uncertainty

[1] Alex Kendall and Yarin Gal. **What Uncertainties Do We Need in Bayesian Deep Learning for Computer Vision?** NIPS 2017.
[2] Audun Jøsang, Jin-Hee Cho, and Feng Chen. **Uncertainty Characteristics of Subjective Opinions.** FUSION 2018.

Evidential Uncertainty

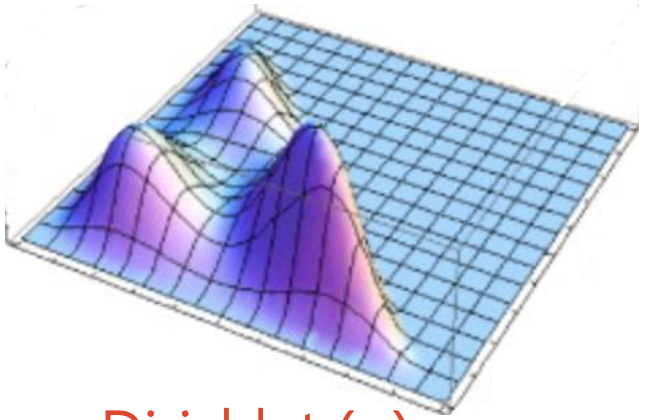
Task: 3 class image classification

Training Data: Dog ($e_1 = 10$ images) Cat ($e_2 = 10$ images) Pig ($e_3 = 10$ images)

$e = [e_1, \ldots, e_K]$ Evidence (Historical observations)

$\alpha = e + 1$

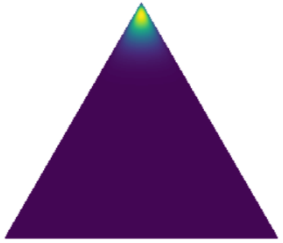
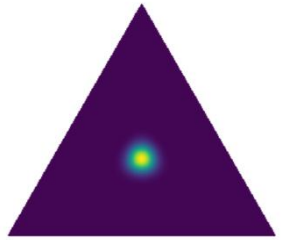
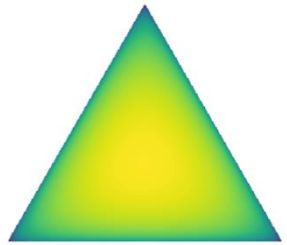
Subjective Opinion



Dirichlet (α)

A subjective opinion modeled based on `Subjective Logic' which uses Dirichlet distribution to measure multiple dimensions of uncertainty in classification tasks

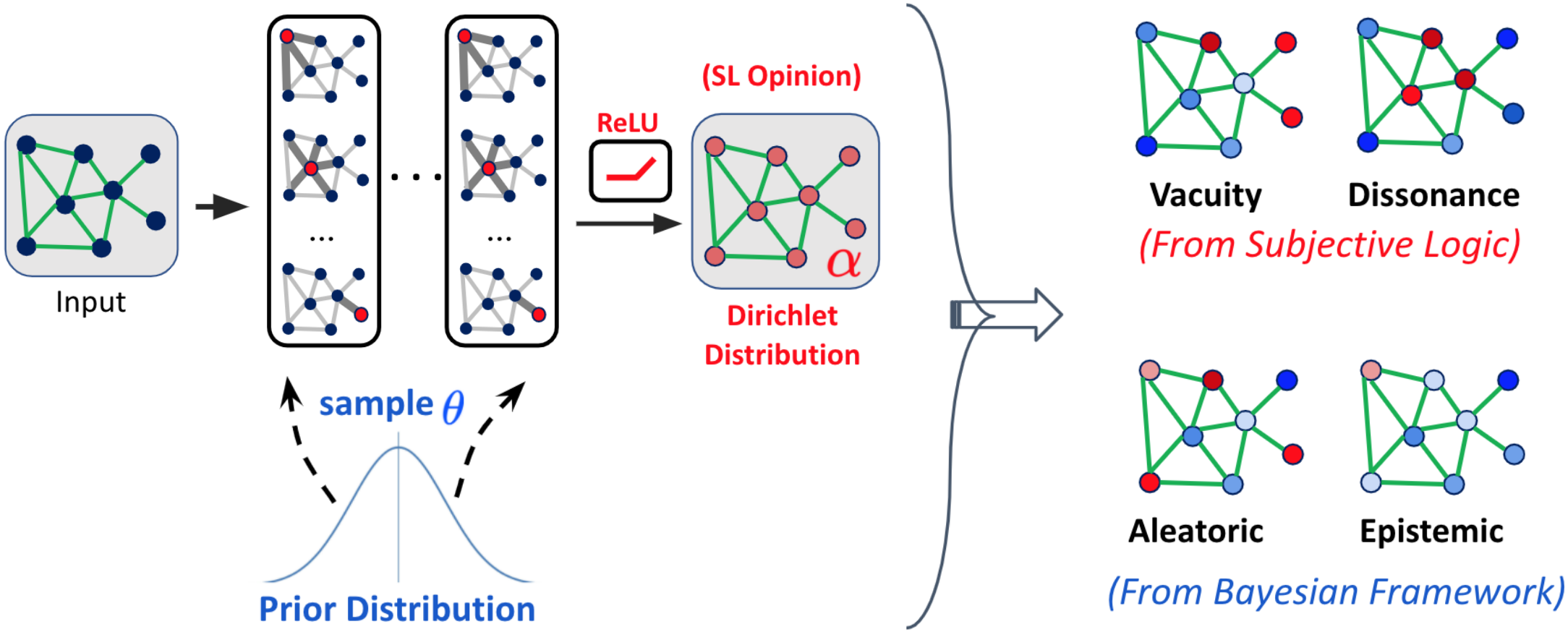
Why Evidential Uncertainty?

	Confidence Prediction	Conflict Prediction	Out-of-Distribution
			
Dirichlet Distribution	$\alpha = [11, 1, 1]$	$\alpha = [11, 11, 11]$	$\alpha = [1, 1, 1]$
Expected Probability	$p = [0.83, 0.083, 0.083]$	$p = [1/3, 1/3, 1/3]$	$p = [1/3, 1/3, 1/3]$
	Low Uncertainty	High Dissonance (conflicting evidence)	High Vacuity (lack of evidence)
Test image			

Different Vacuity

Sample probability

Uncertainty Aware Framework

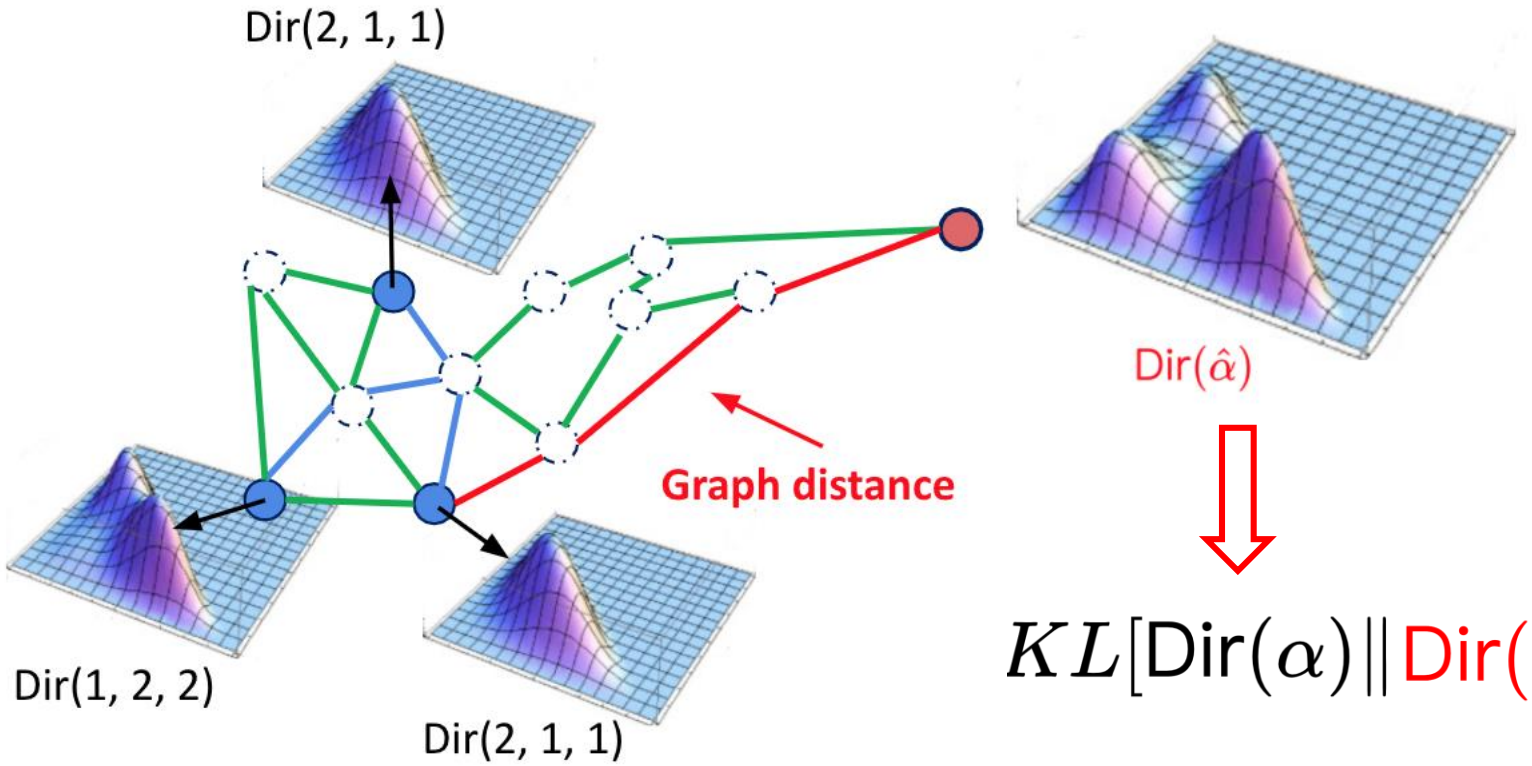


Subjective Bayesian GNN

Multiple Uncertainties

Graph-Based Kernel Dirichlet Estimation

Predict node-level Dirichlet more accurately

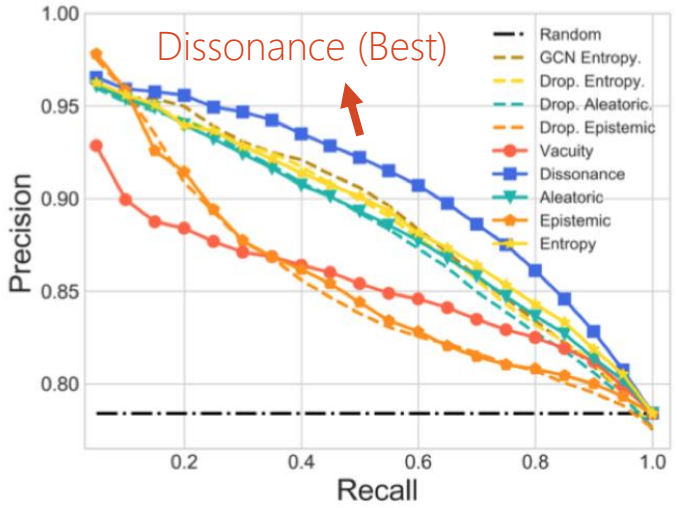


$$KL[\mathrm{Dir}(\alpha)\|\mathrm{Dir}(\hat{\alpha})]$$

High vacuity occurs when testing node far away from training nodes.

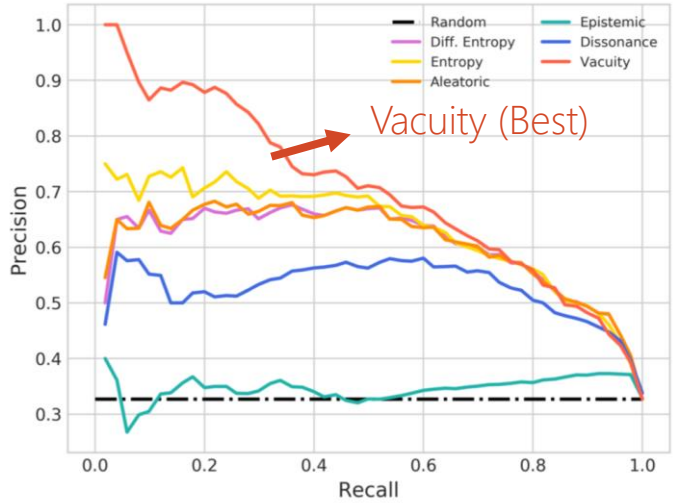
Experiment Result

Misclassification Detection



(c) PR curves on Pubmed

OOD Detection



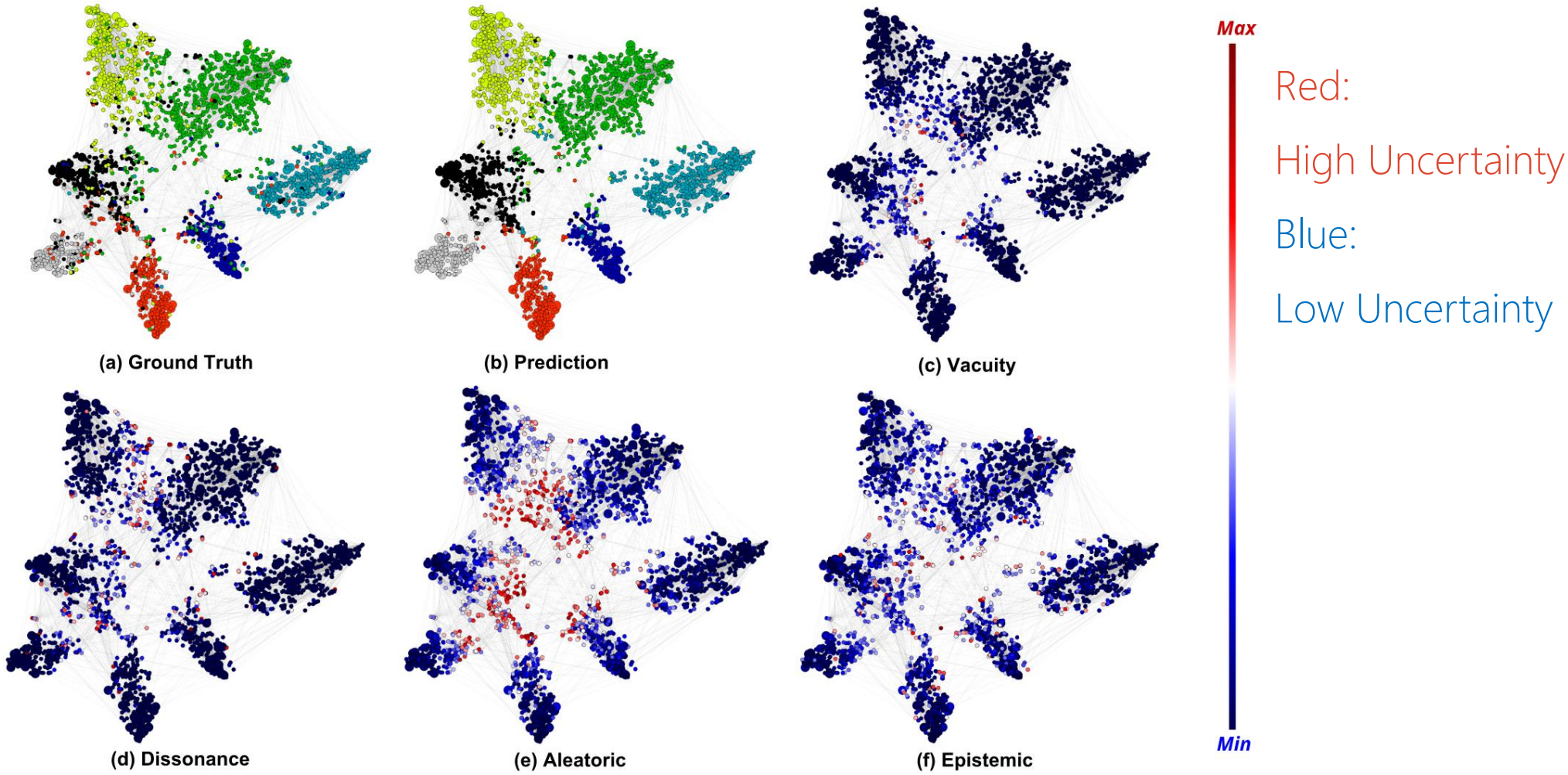
(b) PR curves on Amazon Computers

Misclassification ← High Uncertainty → Out-of-distribution

Correct Prediction ← Low Uncertainty → In distribution

Visualization

Different color represent class label



Red: High Uncertainty

Blue: Low Uncertainty

Extension to other Deep Learning Model (CNN)

Replace GKDE to other method to estimation prior Dirichlet Distribution.