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Angular Gap:
Reducing the Uncertainty of Image Difficulty through Model Calibration

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Introduction

Curriculum learning (CL) needs difficulty scores to proceed from easy to hard. But how to estimate image difficulty and apply it into a CL framework?

- We propose Angular Gap, a measure of image difficulty estimated by angular distance of hyperspherical learning.
- To reduce estimation uncertainty, we introduce class-wise calibration as a post-training technique. Our experiments show that the calibrated Angular Gap can benefit CL.
- With calibrated Angular Gap, we further design a curriculum for cycle self training (CST) on the unsupervised domain adaptation (UDA) task.

Calibrating Angular Gap

With a validation set, class-wise calibration learns a δ that rectifies the angles of the hyperspace, as shown in Figure 1, bringing following advantages:

- Calibration reduces the expected calibration error (ECE) of a teacher model, thus reducing the uncertainty of difficulty estimation.
- Less uncertainty produces more trustworthy image difficulty and improves average downstream performance.
- The computation is efficient because δ is often light-weight and hyperspherical learning often converges swiftly.

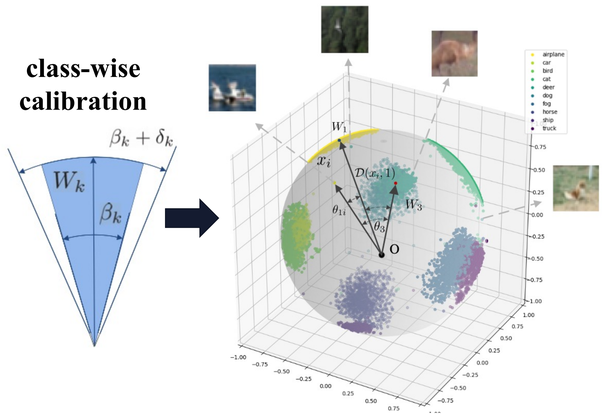


Figure 1 Geometric interpretation of model calibration on a spherical space. Class-wise calibration learns a vector $\boldsymbol{s}_d$ that adds δ_k to the angles of class k. This post-processing rectifies raw Angular Gap and generates more reliable data sequence for curriculum learning.

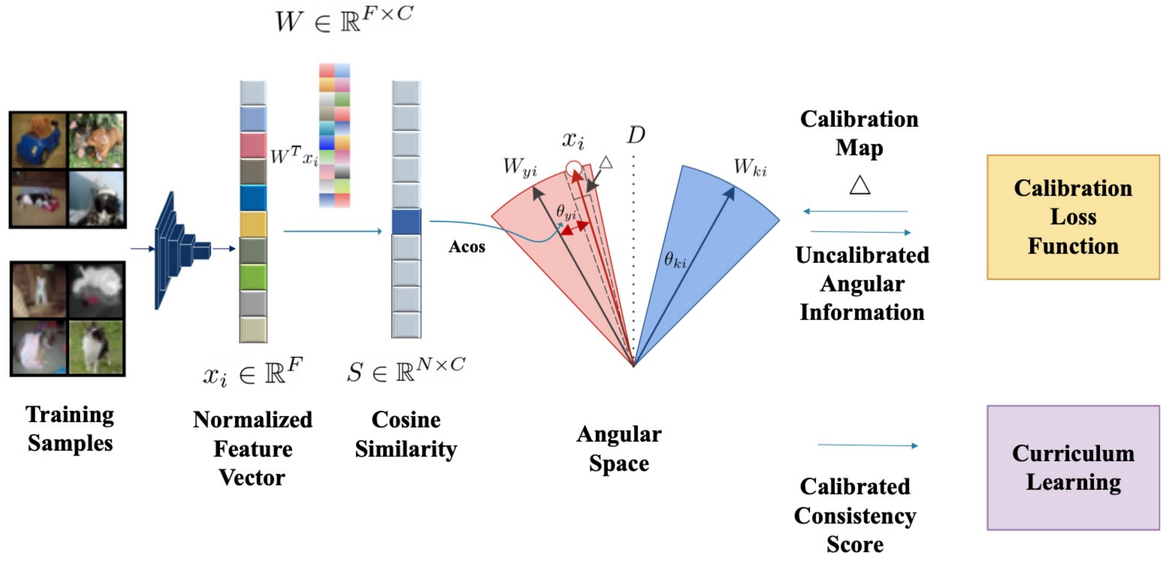
Experiments on UDA

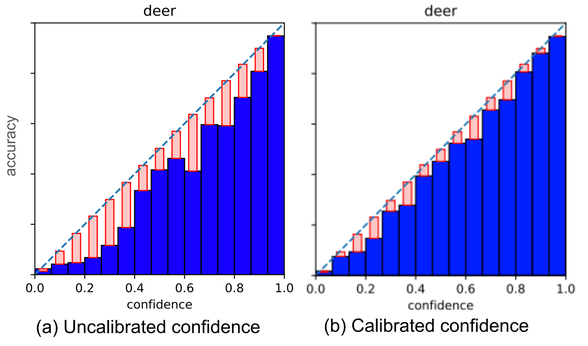
Dataset: VisDA2017 Metric: Accuracy

Curricular CST learns robust representation and outperforms recent baselines.

Method	Acc.	Method	Acc.
DANN	55.3	CBST	76.4
DAN	61.1	CRST	78.1
MSTN	65.0	FixMatch	76.7
JAN	65.7	CST	79.9
DSAN	74.8	FixBi	<u>87.2</u>
Curricular DSAN	75.4	Curricular CST	**88.1**

Angular Gap Framework





(a) Uncalibrated confidence (b) Calibrated confidence

Figure 2 The reliability diagrams visualize the calibration of ResNet18 by comparing predictive confidence (row) against observed accuracy (column). In general, class-wise calibration gives more reliable similarities for example difficulty estimation.

Summary

- We propose Angular Gap to estimate image difficulty and reduce its uncertainty with class-wise calibration.
- We build a class-wise calibrated Angular Gap based curriculum with CST for UDA.
- Model calibration produces more trustworthy similarities and therefore improves example difficulty estimation. Simply scaling up the model leads to unstable difficulty estimation.

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