LOCAL-PROMPT: EXTENSIBLE LOCAL PROMPTS FOR FEW-SHOT OUT-OF-DISTRIBUTION DETECTION

Fanhu Zeng[1, 2], **Zhen Cheng**[1, 2], **Fei Zhu**[3], **Hongxin Wei**[4], **Xu-Yao Zhang**[1, 2*]
[1]State Key Laboratory of Multimodal Artificial Intelligence Systems, Institute of Automation, Chinese Academy of Sciences
[2]School of Artificial Intelligence, University of Chinese Academy of Sciences
[3]Centre for Artificial Intelligence and Robotics, HKISI-CAS
[4]Department of Statistics and Data Science, Southern University of Science and Technology
{zengfanhu2022, chengzhen2019, zhufei2018}@ia.ac.cn
xyz@nlpr.ia.ac.cn, weihx@sustech.edu.cn

ABSTRACT

Out-of-Distribution (OOD) detection, aiming to distinguish outliers from known categories, has gained prominence in practical scenarios. Recently, the advent of vision-language models (VLM) has heightened interest in enhancing OOD detection for VLM through few-shot tuning. However, existing methods mainly focus on optimizing global prompts, ignoring refined utilization of local information with regard to outliers. Motivated by this, we freeze global prompts and introduce **Local-Prompt**, a novel coarse-to-fine tuning paradigm to emphasize regional enhancement with local prompts. Our method comprises two integral components: global prompt guided negative augmentation and local prompt enhanced regional regularization. The former utilizes frozen, coarse global prompts as guiding cues to incorporate negative augmentation, thereby leveraging local outlier knowledge. The latter employs trainable local prompts and a regional regularization to capture local information effectively, aiding in outlier identification. We also propose regional-related metric to empower the enrichment of OOD detection. Moreover, since our approach explores enhancing local prompts only, it can be seamlessly integrated with trained global prompts during inference to boost the performance. Comprehensive experiments demonstrate the effectiveness and potential of our method. Notably, our method reduces average FPR95 by 5.17% against state-of-the-art method in 4-shot tuning on challenging ImageNet-1k dataset, even outperforming 16-shot results of previous methods. Code is released at https://github.com/AuroraZengfh/Local-Prompt.

1 INTRODUCTION

Out-of-distribution (OOD) detection (Liu et al., 2020; Cheng et al., 2023b; Jaeger et al., 2022; Tao et al., 2022) aims to distinguish outliers, *i.e.*, samples that do not belong to known in-distribution (ID) classes. It is crucial for industries that require a high level of safety, such as face recognition (Lopez-Lopez et al., 2022) and autonomous driving (Filos et al., 2020). Most previous methods in the field of OOD detection handle the problem using single-modal methods and concentrate on post-hoc processing (Hendrycks & Gimpel, 2016; Wang et al., 2022) or leveraging outliers (Hendrycks et al., 2018; Jiang et al., 2024). However, they suffer from computational inefficiency or consuming data collection. Recently, as the emergence of vision-language models (Radford et al., 2021; Li et al., 2021) shows promising results in multi-modal tasks including image caption (Li et al., 2022a), video understanding (Xu et al., 2021), and so on, it is promising to exploit textual representations to improve performance of OOD detection given a vision-language model (Radford et al., 2021) as a prior model. Considering that zero-shot undergoes a domain gap between upstream and target distribution while full-tuning may pose threats to the learned representation, it is meaningful to explore few-shot learning for vision-language model in OOD detection, in which the detector is prohibited from real outliers and only has access to several ID images.

*Corresponding author.

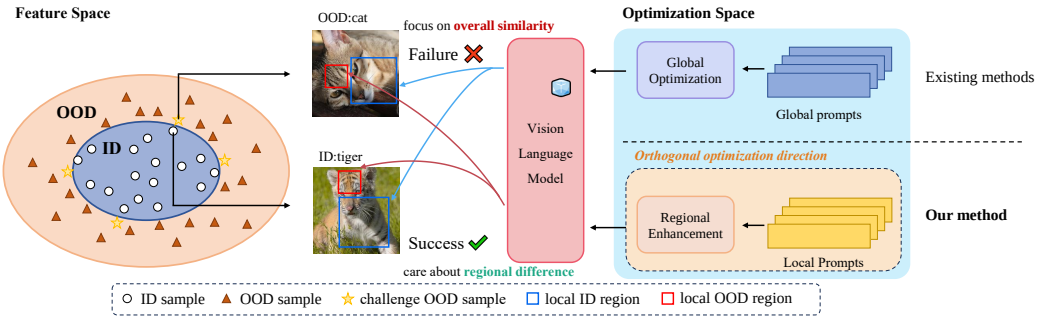

Figure 1: Comparison of prompt learning for OOD detection task. Prompts with global optimization may fail in challenging OOD samples as they are overall similar to ID samples and only have subtle regional differences. For example, cat and tiger are generally similar (blue boxes) and only differ in forehead (red box). Our approach with local outlier knowledge cares about region difference and tackles the issue to some extent.

The most challenging scene for OOD detection is that one hard OOD sample is similar to a known class on the whole and only has subtle differences locally, which naturally requires the detector to identify outliers through local outlier regions. However, existing research falls short of refining OOD task via rich local information when subtle OOD samples are exhibited in certain regions, as is shown in Fig. 1. Some methods merely focus on utilizing global features only (Ming et al., 2022) (blue boxes in Fig. 1), which ignores local features (red boxes in Fig. 1) and inevitably brings about coarse description. Others use the same prompts to match both global and local image features (Miyai et al., 2023b;a), so the gap between them may lead to inaccurate local outlier identification. Consequently, it is straightforward that enhancing regional information to empower the model with *local outlier knowledge* could be significant to OOD detection.

Motivated by the above observations, we focus on how to explicitly exploit regional-related knowledge, *i.e.*, the learned knowledge is determined by the position of regions, about not only known classes but also unknown samples, which has not been explored before. To tackle the issue, we propose **Local-Prompt**, which concentrates on enhancing local features solely and introduces extensible local prompts for fine local information utilization. Concretely, we decompose global and local prompts to exploit global and local features, and term prompts that interact with global/local features as global/local prompts. Then we propose two integral components: global prompt guided negative augmentation and local prompt enhanced regional regularization. Global prompt is frozen to provide guidance for generating negative augmentation, which could facilitate the exploitation of local outlier knowledge. Fine local prompt is designed for regional regularization to refine regional-related local prompts, which captures the fine local information to better distinguish OOD inputs. Moreover, we also propose corresponding regional-related evaluation metrics to leverage the power of local prompts for OOD detection.

Another advantage of our approach is that it orthogonally explores the benefits of local prompts shown in Fig. 1 and uses hand-crafted global prompts, *i.e.*, a photo of a {class}. Hence, it *is extensible to all existing global prompt designing methods* (Miyai et al., 2023a; Wang et al., 2023). Therefore, we can extend it by seamlessly replacing coarse global prompts with trained ones during inference to improve the performance.

Comprehensive experiments demonstrate the effectiveness of the proposed method. Specifically, our results outperform the state-of-the-art methods in both OOD detection (5.17% reduction on FPR95) and ID accuracy evaluation (1.02%) under 4-shot tuning by a large margin, exhibiting the superiority and the potential of enhancing local prompts for OOD detection and ID classification ability. We additionally carry out various analysis on and all quantitative outcomes and qualitative visualization validate effectiveness. We summarize our contributions as follows:

- We focus on enhancing local information with local prompts and propose a coarse-to-fine few-shot tuning paradigm. Specifically, we propose effective negative augmentation and regional regularization to learn local prompts with local outlier knowledge.
- We propose regional-related OOD score and ID classification metrics, which benefit from enhanced local prompts in OOD detection. Moreover, our method is orthogonal to global

prompt optimization methods and is extensible to get notable performance when integrated with trained local global prompts during inference.

- We conduct comprehensive experiments and achieve competitive results on various OOD detection datasets, demonstrating the superiority of our method. Notably, our 4-shot results on challenging ImageNet-1k even outperform 16-shot results of previous methods.

2 RELATED WORK

2.1 OUT-OF-DISTRIBUTION DETECTION WITH VISION-LANGUAGE MODEL

Out-of-distribution detection, as a crucial part of open environment (Zeng et al., 2024; Zhu et al., 2023b; Cheng et al., 2023b), has been widely studied in the past decades (Hendrycks et al., 2018; Cheng et al., 2023a; Shu et al., 2023; Zhu et al., 2023a; Liu et al., 2024). With the emergence of CLIP (Radford et al., 2021), which learns outstanding visual and textual representations pre-trained on large-scale image-text pairs and displays excellent ability in various downstream tasks, much attention has been paid to transferring vision-language model to OOD detection task (Fort et al., 2021; Ming et al., 2022; Esmaeilpour et al., 2022; Wang et al., 2023; Miyai et al., 2023a; Park et al., 2023; Bai et al., 2024). For instance, MCM (Ming et al., 2022) adopts the visual and textual representations extracted from CLIP encoders and applies softmax with temperature to better separate ID and OOD data. ZOC (Esmaeilpour et al., 2022) generates pseudo unseen class labels with additional modules and defines a novel confidence score accordingly. Clipn (Wang et al., 2023) enhances the discrimination of OOD samples with extra encoder and data (Sharma et al., 2018).

2.2 MULTI-MODAL FEW-SHOT PROMPT LEARNING

Since vision-language model like CLIP (Radford et al., 2021) achieves superior performance in numerous image-text tasks, many attempts have been made to explore few-shot tuning to leverage the power of large pre-trained models. There are mainly two lines of approaches, namely Adapter Learning (Zhang et al., 2021; Gao et al., 2023; Guo et al., 2023; Udandarao et al., 2023; Zhu et al., 2023c) and Prompt Learning (Zhou et al., 2022b; Bahng et al., 2022). Both of them froze the pre-trained encoders when fine-tuning a few additional parameters.

Prompt learning promotes the performance of vision-language model by enhancing the prompts in both visual (Jia et al., 2022; Bahng et al., 2022) and textual (Zhou et al., 2022b;a) aspects. A common practice is setting textual prompts learnable and forwarding them together with visual inputs. CoOp (Zhou et al., 2022b) replaces the hand-crafted prompts with contextual learnable embeddings and optimizes them during few-shot training. In our approach, we freeze global prompts and fine-tune local prompts individually.

2.3 GLOBAL AND LOCAL INFORMATION

In Vision Transformer (Dosovitskiy et al., 2020; Zeng & Yu), global tokens are specifically designed for image classification task (Touvron et al., 2021; He et al., 2022). They represent overall characteristics of images. Local tokens are utilized for dense prediction tasks including segmentation (Cheng et al., 2022; Strudel et al., 2021), object detection (Chen et al., 2022; Meng et al., 2021), and so on. The utilization of local features has been explored as well, such as pyramid features (Wang et al., 2021) and window attention (Liu et al., 2021; Li et al., 2022b; Liu et al., 2022).

In the field of OOD detection, global features are primarily employed and numerous studies have been conducted concerning local information (Miyai et al., 2023b;a; Zhang et al., 2023). GL-MCM (Miyai et al., 2023b) takes all tokens into consideration and uses the sum of global and local OOD scores to measure the confidence. LoCoOp (Miyai et al., 2023a) keeps global ID textual embeddings away from the interference of ID-irrelevant regions. However, all existing approaches take same prompts for all features. By contrast, our method directly enhances OOD detection with ID-related areas and refines local prompts to leverage local outlier knowledge.

3 PRELIMINARY

3.1 PROBLEM DEFINITION

Few-shot out-of-distribution detection. Formally, out-of-distribution detection can be viewed as a binary classification that the detector has to identify whether the input image is from ID or OOD space. Labeled training data is composed of $\mathcal{D}_{\text{train}}^{\text{in}} = \{(\boldsymbol{x}_i, y_i)\}_{i=1}^{n}$, where $\boldsymbol{x}_i$ is sampled *i.i.d.* from joint data distribution space $\mathcal{P}_{\mathcal{X}\mathcal{Y}^{\text{in}}}$ and $y_i \in \mathcal{Y}^{\text{in}}$. $\mathcal{Y}^{\text{in}} = \{1, \cdots, C\}$ is the label space of ID data and C is the number of classes. We transfer the definition of few-shot learning in classification to OOD detection to fine-tune given vision-language model instead of training from scratch. Under few-shot setting, a small proportion of images in each class (*e.g.*, 1, 4, or 16 images) are extracted for training. $\mathcal{Y}^{\text{out}}$ is the label space of OOD data and there is no overlap between ID and OOD label, *i.e.*, $\mathcal{Y}^{\text{in}} \cap \mathcal{Y}^{\text{out}} = \emptyset$. Typically, the model is unable to obtain any OOD data during training process.

The test dataset is a mixture of $\mathcal{D}_{\text{test}}^{\text{in}}$ and $\mathcal{D}_{\text{test}}^{\text{out}}$. When testing, OOD performance is evaluated by discriminating which distribution each sample comes from. A discriminant function is calculated to identify ID and OOD samples:

$$D(\boldsymbol{x}) = \begin{cases} \text{ID}, & S(\boldsymbol{x}) \geq \gamma \\ \text{OOD}, & S(\boldsymbol{x}) < \gamma \end{cases}, \tag{1}$$

where $S(\boldsymbol{x})$ is the confidence score function measuring the uncertainty and γ is the threshold.

Prompt learning with CLIP. CLIP (Radford et al., 2021) is compromised of image encoder E_{I} and text encoder E_{T}. Given an image I and a text T describing the corresponding image, they are extracted into feature embeddings, respectively. In prompt learning, textual prompts can be hand-crafted templates (Radford et al., 2021), *e.g.*, "a photo of {class}" or learnable context words (Zhou et al., 2022a), *e.g.*, $\boldsymbol{t}_c = [\boldsymbol{v}_1, \cdots, \boldsymbol{v}_L; \boldsymbol{v}_c]$, where $\boldsymbol{v}_i, (i = 1, \cdots, L)$ is the learnable embedding, and L is the length of context words. $\boldsymbol{v}_c$ $(c \in \{1, \cdots, C\})$ is the embedding of class name. Features of prompts are obtained from text encoder $E_{\text{T}}(\boldsymbol{t}_c) : \mathbb{R}^{(L+1)\times d} \to \mathbb{R}^{d}$. For simple notation, we use $\boldsymbol{t}_c$/ $\boldsymbol{t}$/ $\hat{\boldsymbol{t}}$ described below to represent features of prompts as text encoder is not the focus of the paper.

Image is first split into several patches with an additional class token embedding $\boldsymbol{x} \in \mathbb{R}^{(N+1)\times d}$. N and d denote the number of local tokens and hidden dimension, respectively. Both global and local visual features are then extracted from image encoder $[\boldsymbol{z}^{\text{g}}, \boldsymbol{z}^{\text{l}}] = E_{\text{I}}(\boldsymbol{x}) : \mathbb{R}^{(N+1)\times d} \to \mathbb{R}^{(N+1)\times d}$, where global features $\boldsymbol{z}^{\text{g}}$ and local features $\boldsymbol{z}^{\text{l}}$ represents overall features and patch-wise regional features, respectively.

In this paper, we denote global prompts and local prompts to hand-crafted/learnable prompts that interact with overall local features and fine local features, respectively.

OOD detection with CLIP. The MCM score (Ming et al., 2022) is defined as the maximum of similarity after softmax with temperature:

$$S_{\text{MCM}}(\boldsymbol{x}) = \max_{i} \frac{\exp(\text{sim}(\boldsymbol{z}^{\text{g}}, \boldsymbol{t}_i)/T)}{\sum_{j=1}^{C} \exp(\text{sim}(\boldsymbol{z}^{\text{g}}, \boldsymbol{t}_j)/T)}, \tag{2}$$

and GL-MCM score (Miyai et al., 2023b) considers local information. It applies softmax for local features as well and the maximum is selected as local MCM score. Final OOD score is the sum of MCM score and local MCM score:

$$S_{\text{GL-MCM}}(\boldsymbol{x}) = S_{\text{MCM}}(\boldsymbol{x}) + \max_{i,h} \frac{\exp(\text{sim}(\boldsymbol{z}_h^{\text{l}}, \boldsymbol{t}_i)/T)}{\sum_{j=1}^{C} \exp(\text{sim}(\boldsymbol{z}_h^{\text{l}}, \boldsymbol{t}_j)/T)}, \tag{3}$$

where $\boldsymbol{z}^{\text{g}}$ represents global feature and $\boldsymbol{z}_h^{\text{l}}$ $(h \in \{1, \cdots, N\})$ represents all extracted local features.

4 METHODOLOGY

We propose Local-Prompt, a coarse-to-fine paradigm to strengthen OOD detection with local outlier knowledge. We first present negative augmentation that leverages local and unknown outlier information. Then, we describe local prompt enhancement along with their training regularization and a regional OOD score for better regional information utilization. Finally, we extend our method to trained global prompts to boost the performance. Detailed structures are shown in Fig. 2.

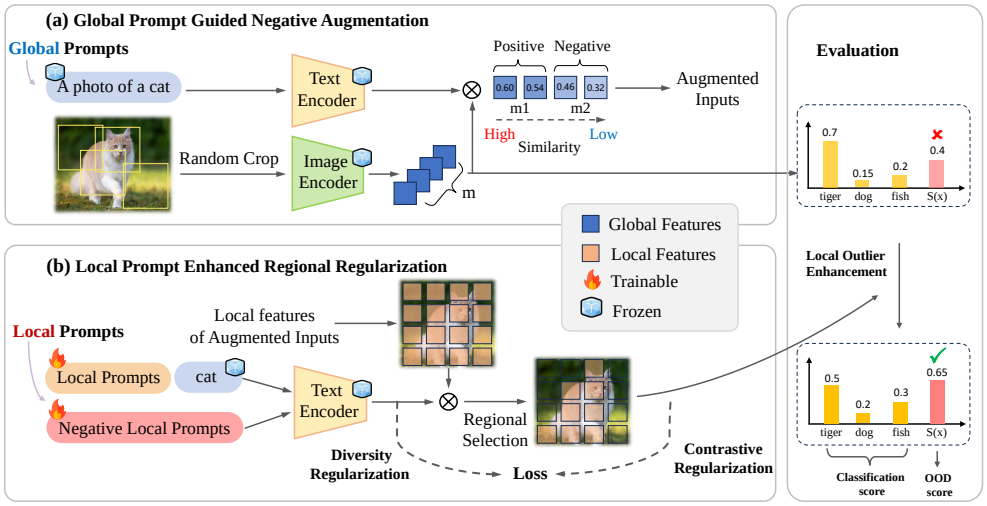

Figure 2: Detailed structure of the proposed Local-Prompt. Our method consists of global prompt guided negative augmentation and local prompt enhanced regional regularization. We froze global prompts to select regional augmented samples and enhance local prompts to learn regional-related representation that helps improve both ID accuracy and OOD detection.

4.1 Global Prompt Guided Negative Augmentation

As it is costly and not always effective to rely solely on real outliers, one crucial problem for OOD detection is how to leverage imaginary local outlier knowledge to the detector. We propose to synthesize hard negative images to force the model to learn features with strong relation only to simulate outlier situations while avoiding the requirement of real OOD samples. To this end, we apply a simple and straightforward random crop augmentation to empower the detector with unknown (*i.e.*, OOD) information. Specifically, we randomly crop image input m times and use the hand-crafted template with corresponding class name, *i.e.*, $\boldsymbol{t}_c =$ "a photo of {class}", $c = \{1, \cdots, C\}$ as text inputs to calculate the image-text similarity with global features from image encoder. We then select m_1/m_2 images with the largest/least similarity, respectively. Images with the largest similarity can be seen as positive samples and those with the least similarity serve as hard negative samples. Notably, random crop is helpful to leverage local information in that local prompts can learn regional-related outlier information through space translation by means of random crop. Effectiveness of random crop is verified in Sec. 5.2.

Global prompts can be viewed as coarse guidance for negative augmentation standing for overall representation and are frozen in our framework. Motivated by previous observations(Ming et al., 2022; Miyai et al., 2023b), we simply use the basic global prompts during training and select augmented images as they are fairly good for extracting global features. Concretely, the global prompts are used to (1) guide the negative augmentation selection, which has been described above; (2) guide the global OOD score calculation for evaluation, as shown in Sec. 4.3.

It is worth emphasizing that our approach is orthogonal to all existing global prompt optimization strategies, *i.e.*, global prompts are built without tuning in our structure (Miyai et al., 2023a), so during inference, it is expected that extending the hand-crafted global prompts with carefully designed ones can promote the performance. Concretely, we replace hand-crafted global prompts with trained ones that have the same shape. Note that our main purpose is to decompose global and local prompts and showcase the effectiveness of local outlier enhancement for OOD detection. Therefore, we do not specifically select the template as it is not the focus of the paper.

4.2 Local prompt enhanced regional regularization

Once augmented inputs are decided, corresponding local features are then used to optimize local prompts to identify ID and OOD samples from the perspective of regional enhancement. We aim at utilizing the local features extracted from image encoder in a fine way to (1) learn regional-related prompts that better characterize local similarity for both ID and OOD regions; (2) enhance detection ability with refined local features. Specifically, we design local prompts $\boldsymbol{t}$ with learnable context

words to represent local textual information for each known class. Moreover, on account of the existence of OOD regions, we build a few local negative prompts $\hat{\boldsymbol{t}}$ to handle possible local outliers.

Contrary to previous global prompt optimization methods, local prompts that work on local features are expected to learn regional-related textual representations and be aware of outliers during training. To this end, we enhance local prompts through regional regularization, which consists of contrastive regularization and diversity regularization, to better distinguish between ID and OOD samples.

Contrastive regularization. We propose regional contrastive regularization to enhance local textual prompts for better local information utilization. It is composed of local loss and local negative loss. Given a positive sample of training image, local loss is employed to learn regional information of known classes:

$$\mathcal{L}_{\text{pos}}(\boldsymbol{x}, y) = -\log \frac{\mathcal{T}_k\{\exp(\text{sim}(\boldsymbol{z}_h^{\text{l}}, \boldsymbol{t}_y)/T)\}}{\sum_{i=1}^{\text{C}} \mathcal{T}_k\{\exp(\text{sim}(\boldsymbol{z}_h^{\text{l}}, \boldsymbol{t}_i)/T)\} + \sum_{i=1}^{\text{N}_{\text{neg}}} \mathcal{T}_k\{\exp(\text{sim}(\boldsymbol{z}_h^{\text{l}}, \hat{\boldsymbol{t}}_i)/T)\}}, \tag{4}$$

where $(\boldsymbol{x}, y)$ stands for training image-label pairs, $\mathcal{T}_k(\boldsymbol{x})$ is the sum of k largest elements in $\boldsymbol{x}$, k is regional number and T is the temperature. We use cosine similarity as the similarity metric:

$$\text{sim}(\boldsymbol{t}_i, \boldsymbol{t}_j) = \frac{\boldsymbol{t}_i \cdot \boldsymbol{t}_j}{\|\boldsymbol{t}_i\| \, \|\boldsymbol{t}_j\|}. \tag{5}$$

Similarly, given a hard negative sample of the image denoted as $\tilde{\boldsymbol{x}}$, local negative loss is defined to make the model aware of outliers:

$$\mathcal{L}_{\text{neg}}(\tilde{\boldsymbol{x}}) = -\log \frac{\sum_{i=1}^{\text{N}_{\text{neg}}} \mathcal{T}_k\{\exp(\text{sim}(\tilde{\boldsymbol{z}}_h^{\text{l}}, \hat{\boldsymbol{t}}_i)/T)\}}{\sum_{i=1}^{\text{C}} \mathcal{T}_k\{\exp(\text{sim}(\tilde{\boldsymbol{z}}_h^{\text{l}}, \boldsymbol{t}_i)/T)\} + \sum_{i=1}^{\text{N}_{\text{neg}}} \mathcal{T}_k\{\exp(\text{sim}(\tilde{\boldsymbol{z}}_h^{\text{l}}, \hat{\boldsymbol{t}}_i)/T)\}}. \tag{6}$$

Intuitively, contrastive regularization forces the model to focus on ID-related regions through random crop, and keep away from outlier-related regions through negative augmentation. We demonstrate the necessity of local negative loss to make margins for unknown categories in OOD detection in Sec.5.2.

Diversity regularization. As local negative prompts are randomly initialized, more regularization has to be imposed on them to ensure their diversity. Therefore, in addition to the proposed contrastive regularization, we apply a diversity regularization on local negative prompts, as follows:

$$\mathcal{L}_{\text{reg}} = \frac{1}{N_{\text{neg}}(N_{\text{neg}} - 1)/2} \sum_{1 \le i < j \le N_{\text{neg}}} \text{sim}(\hat{\boldsymbol{t}}_i, \hat{\boldsymbol{t}}_j), \tag{7}$$

where N_{neg} is the number of local negative prompts. Final Loss is a weighted sum of the above loss:

$$\mathcal{L}_{\text{total}} = \mathcal{L}_{\text{pos}} + \lambda_{\text{neg}} \mathcal{L}_{\text{neg}} + \lambda_{\text{reg}} \mathcal{L}_{\text{reg}}, \tag{8}$$

where λ_{neg} and λ_{reg} are the coefficients of the corresponding losses.

4.3 Regional OOD score

On consideration that regional information is especially enhanced during training, we propose Regional-MCM score to enhance OOD score beyond simple MCM and GL-MCM:

$$S_{\text{R-MCM}}(\boldsymbol{x}) = S_{\text{MCM}}(\boldsymbol{x}) + \mathcal{T}_k^{\text{mean}}\{\frac{\exp(\text{sim}(\boldsymbol{z}_h^{l}, \boldsymbol{t}_i)/T)}{\sum_{j=1}^{C} \exp(\text{sim}(\boldsymbol{z}_h^{l}, \boldsymbol{t}_j)/T) + \sum_{j=1}^{N_{\text{neg}}} \exp(\text{sim}(\boldsymbol{z}_h^{l}, \hat{\boldsymbol{t}}_j)/T)}\}, \tag{9}$$

where $\mathcal{T}_k^{\text{mean}}(\boldsymbol{x})$ is the mean of k largest elements in $\boldsymbol{x}$ and k represents regional number. Intuitively, Regional-MCM serves as a general form of GL-MCM that takes the k most similar regions into consideration and additionally contains local negative prompts, which is helpful to consider more than one certain region with high similarity and improve OOD detection ability. Effectiveness of the score is verified in Sec. 5.2.

As the proposed OOD score is only applicable for OOD detection, we further propose a local-aware score that assigns a score to each class and thus determines ID category with the largest score. Specifically, ID classification takes both global and local features into consideration:

$$h_i^{\text{g}}(\boldsymbol{x}) = \text{sim}(\boldsymbol{z}^{\text{g}}, \boldsymbol{t}_i), \tag{10}$$

Table 1: Results when ImageNet-1k is used as ID data. We compare the methods in different tuning manners. † represents the result by our re-implementation. **Bold** values represent the best results.

Method	iNaturalist		SUN		Places		Texture		**Average**	
	FPR95↓	AUROC↑	FPR95↓	AUROC↑	FPR95↓	AUROC↑	FPR95↓	AUROC↑	FPR95↓	AUROC↑
Zero-shot										
MCM	30.91	94.61	37.59	92.57	44.69	89.77	57.77	86.11	42.74	90.77
GL-MCM	15.18	96.71	30.42	93.09	38.85	89.90	57.93	83.63	35.47	90.83
Full-tuning										
MSP	54.05	87.43	73.37	78.03	72.98	78.03	68.85	79.06	67.31	80.64
Energy	29.75	94.68	53.18	87.33	56.40	85.60	51.35	88.00	47.67	88.90
KNN	29.17	94.52	35.62	92.67	39.61	91.02	64.35	85.67	42.19	90.97
NPOS	16.58	96.19	43.77	90.44	45.27	89.44	46.12	88.80	37.93	91.22
Textual-OE	29.61	94.74	57.12	87.34	66.82	83.71	79.29	77.76	58.21	85.88
Few-shot					4-*shot*					
CoOp	18.95	95.52	29.58	92.90	38.72	89.64	48.03	85.87	33.82	90.98
Local-Prompt	**9.65**	**97.87**	20.40	95.57	29.39	92.67	51.20	88.00	27.66	93.53
LoCoOp†	21.67	95.69	22.98	95.07	31.41	92.10	49.79	87.85	31.46	92.68
Local-Prompt+LoCoOp	12.81	97.29	**19.34**	**95.85**	**27.53**	**92.97**	**45.51**	**89.99**	**26.29**	**94.03**
					16-*shot*					
CoOp	14.60	96.62	28.48	92.65	36.49	89.98	43.13	88.03	30.67	91.82
Local-Prompt	8.71	98.10	23.97	94.85	32.50	92.32	47.93	89.04	28.27	93.58
LoCoOp	16.05	96.86	23.44	95.07	32.87	91.98	42.28	90.19	28.66	93.52
Local-Prompt+LoCoOp	**8.63**	**98.07**	**23.23**	**95.12**	**31.74**	**92.42**	**34.50**	**92.29**	**24.52**	**94.48**

$$h_i^{\mathrm{l}}(\boldsymbol{x}) = \mathcal{T}_k^{\mathrm{mean}}\{\exp(sim(\boldsymbol{z}_h^{\mathrm{l}}, \boldsymbol{t}_i)/T)\}, \tag{11}$$

where $h_i^{\mathrm{g}}(\boldsymbol{x})$, $h_i^{\mathrm{l}}(\boldsymbol{x})$ are global and local portions and i represents the category label. The score attached to each category is measured by:

$$f(y = i|\boldsymbol{x}) = h_i^{\mathrm{g}}(\boldsymbol{x}) * h_i^{\mathrm{l}}(\boldsymbol{x}), \tag{12}$$

each sample is then classified corresponding to the maximum score.

5 Experiments

Datasets. Following existing works (Ming et al., 2022; Miyai et al., 2023b;a), large scale ImageNet-1K (Deng et al., 2009) along with a 100-category subset of it denoted as ImageNet-100 are used as ID dataset and OOD dataset is a combination of iNaturalist (Van Horn et al., 2018), SUN (Xiao et al., 2010), Places (Zhou et al., 2017) and Texture (Cimpoi et al., 2014). In addition, We also use two semantically similar subsets of ImageNet-1k, *i.e.*, ImageNet-10 and ImageNet-20, to evaluate near OOD detection performance (Ming et al., 2022). Detailed information is provided in Appendix A.

Implementation details. We use CLIP-Base/16 as the backbone. Image encoder, text encoder, and global prompts are frozen and only local prompts are learnable. We set one local prompt for each known category (1000 in total for ImageNet-1k). λ_{neg} and λ_{reg} are 5 and 0.5, respectively. As the stability of temperature T has been verified by previous research (Ming et al., 2022; Miyai et al., 2023b), we set T to be 1 by default. More details are shown in Appendix B.

Evaluation metrics. We report the following metrics for evaluation: (1) the area under the receiver operating characteristic curve (AUROC); (2) false positive rate of OOD samples when true positive rate of ID samples is 95% (FPR95); (3) in-distribution data classification accuracy (ID accuracy).

5.1 Main Results

ImageNet-1k as ID dataset. We report 4 and 16-shot results on four OOD datasets using ImageNet-1k as ID dataset. It can be seen in Tab. 1 that tuning local prompts only using hand-crafted global prompts can achieve competitive results, especially in datasets with challenging fine local textures like iNaturalist. Concretely, we get impressive progress in 4-shot tuning (outperforming by 3.80% on FPR95). In 16-shot setting, our approach gets competitive results as well. All results above strongly showcase the potential of regional enhancement for OOD detection as an orthogonal direction to global prompt optimization methods. Results of more shots are shown in Appendix C.

ID accuracy. In addition to OOD performance, it is also meaningful to evaluate ID accuracy as it is expected to ensure classification accuracy and separate outliers at the same time. However, weighing too much about separating outliers may narrow the inter-class distance, thus harming accuracy. Consequently, we evaluate ID accuracy for ImageNet-1k and the results shown in Tab. 2 conclude that

Table 2: ID accuracy evaluation using ImageNet-1k as ID data.

Method	Tuning Manner	ID accuracy
MCM	*zero-shot*	67.01
GL-MCM		67.01
KNN	*full-tuning*	79.64
NPOS		79.42
LoCoOp	4-*shot*	69.50
Local-Prompt		**70.52**
LoCoOp	16-*shot*	71.86
Local-Prompt		**74.24**

Table 3: Comparison results of near OOD detection tasks. We report 16-shot results for few-shot methods. Our method can achieve performance against other methods.

Method	ID / OOD	ImageNet-10 / ImageNet-20		ImageNet-20 / ImageNet-10		**Average**	
		FPR95↓	AUROC↑	FPR95↓	AUROC↑	FPR95↓	AUROC↑
MCM		5.00	98.71	12.51	97.70	8.75	98.21
GL-MCM		10.10	98.04	9.00	98.62	9.55	98.33
LoCoOp		11.20	97.49	12.00	97.79	11.60	97.64
Local-Prompt		**3.90**	**99.06**	**6.20**	**98.84**	**5.05**	**98.95**

Table 4: Experiments on ImageNet-100. 4-shot results are reported for few-shot tuning.

Method	iNaturalist		SUN		Places		Texture		**Average**	
	FPR95↓	AUROC↑	FPR95↓	AUROC↑	FPR95↓	AUROC↑	FPR95↓	AUROC↑	FPR95↓	AUROC↑
MCM	18.13	96.77	36.45	94.54	34.52	94.36	41.22	92.25	32.58	94.48
LoCoOp†	44.94	93.31	30.70	94.70	34.31	93.93	55.92	90.01	41.47	92.99
Local-Prompt	**6.99**	**98.05**	**24.34**	**96.03**	**26.04**	**95.49**	**36.32**	**93.67**	**23.42**	**95.81**

our method significantly surpasses previous methods (1.02% and 2.38%, respectively). It demonstrates that the proposed regional enhancement is also beneficial to improve OOD separation while increasing inter-class distance, which is of great significance for real application.

Extensive to global prompts. Benefiting from the convenient integration with well-trained global prompts, we *combine the advantage of trained global prompts* from LoCoOp (Miyai et al., 2023a) without further design (**Local-Prompt+LoCoOp**) and get further substantial improvements on all datasets. For example, we surpass the state-of-the-art method by a large margin (5.17% on FPR95 and 1.35% on AUROC), even against previous methods with 16 shots. Specifically, extending local prompts to global prompts is helpful to datasets with major global representations like Texture, verifying the compatibility and potential of local prompt optimization. It is notable that the extension process is seamless and can be integrated with any global optimization prompts, strongly showing the extensibility of our approach. Density map in Fig. 3 also illustrates the superiority of our method. More visualization can be found in Appendix D.

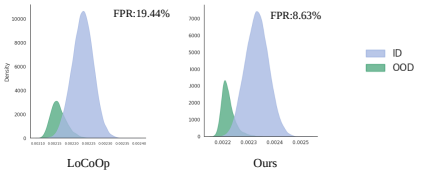

Figure 3: Comparison of density map on iNaturalist. Ours are more separable.

Near OOD detection tasks. Near OOD task typically evaluates semantically similar categories and is relatively more challenging. Following existing work (Ming et al., 2022), we conduct experiments on ImageNet-10 vs. ImageNet-20 to verify the effectiveness of the proposed approach. Results in Tab. 3 indicate that our method exceeds previous methods by a large margin. It can be observed that previous few-shot method fails in near OOD tasks. We attribute it to the refinement of local prompts by local outlier knowledge, which greatly assists in distinguishing semantically similar categories. By contrast, relying solely on global prompts may confuse the distribution. Therefore, it underlines that our local outlier enhancement approach is especially effective in semantically near OOD tasks.

ImageNet-100 as ID dataset. We also conduct experiments using ImageNet-100 as ID dataset. We compare with other zero-shot and few-shot methods and results are reported in Tab. 4. The substantial performance improvements (average 9.16% reduction on FPR95 and 1.33% promotion on AUROC) strongly demonstrate the effectiveness and transferability of our approach.

Comparison with outlier methods. NegLabel (Jiang et al., 2024) designs a novel scheme for OOD score with negative labels. It leverages real outlier information with negative labels from extensive corpus databases. This kind of knowledge helps to a great extent pointed out by OE (Hendrycks et al., 2018) and is inconsistent with real-world application, where negative categories are infinite. As can be seen from Tab. 5, we observe that **(1)** although without outlier, our model achieves better

Table 5: Comparison with NegLabel, which leverages powerful outlier samples.

Method	iNaturalist		SUN		Places		Texture		**Average**	
	FPR95↓	AUROC↑	FPR95↓	AUROC↑	FPR95↓	AUROC↑	FPR95↓	AUROC↑	FPR95↓	AUROC↑
NegLabel (w outlier)	1.91	99.49	20.53	95.49	35.59	91.64	43.56	90.22	25.40	94.21
Local-Prompt (w/o outlier)	8.63	98.07	23.23	95.12	31.74	92.42	34.50	92.29	**24.52**	**94.48**

Table 6: Effectiveness of each component in loss function.

Loss	iNaturalist		SUN		Places		Texture		**Average**	
	FPR95↓	AUROC↑	FPR95↓	AUROC↑	FPR95↓	AUROC↑	FPR95↓	AUROC↑	FPR95↓	AUROC↑
Baseline ($\mathcal{L}_{\text{pos}}$)	11.64	97.59	26.81	94.59	34.50	91.59	50.46	87.84	30.85	92.90
$+\mathcal{L}_{\text{neg}}$	9.84	97.88	24.37	94.97	32.84	91.94	50.02	88.32	29.27	93.27
$+\mathcal{L}_{\text{neg}} + \mathcal{L}_{\text{reg}}$	9.39	97.97	24.20	95.10	32.13	92.21	49.37	88.66	**28.77**	**93.48**

Table 7: Influence of different negative augmentation strategies.

	iNaturalist		SUN		Places		Texture		**Average**	
	FPR95↓	AUROC↑	FPR95↓	AUROC↑	FPR95↓	AUROC↑	FPR95↓	AUROC↑	FPR95↓	AUROC↑
Baseline	11.18	97.68	23.30	95.25	30.97	92.44	50.44	87.89	28.97	93.31
+cutout	17.47	96.64	26.17	94.73	34.38	91.84	54.84	86.88	33.21	92.52
+gaussian noise	11.32	97.59	25.70	94.39	34.99	91.71	51.06	88.15	30.76	92.96
+random crop	9.39	97.97	24.20	95.10	32.13	92.21	49.37	88.66	**28.77**	**93.48**

average performance against NegLabel; **(2)** our method achieves better balance between different kinds of OOD datasets, which strongly validates the effectiveness of incorporating local information and strengthens its application in diverse and infinite read-world scenarios.

5.2 Ablation Study

We conduct various and comprehensive ablation studies to investigate the effectiveness of each component. We train a 4-shot model to showcase the function of components and hyper-parameters unless otherwise stated. More studies about training time and coefficient are shown in Appendix C.

Effectiveness of loss components. We conduct experiments to analyze the effectiveness of each loss component and results in Tab. 6 imply that local prompts optimization (baseline) achieves comparable results with global prompts optimization methods, strongly demonstrating the effectiveness of our proposed regional enhancement strategy. Furthermore, taking hard negative samples together with local negative prompts $\hat{\boldsymbol{t}}$ to optimize OOD-considered representation is beneficial to the distinction of outliers. Outcome without regularization loss is better in FPR95 but slightly inferior in AUROC. Considering overall performance and the fact that the optimization of $\hat{\boldsymbol{t}}$ relies heavily on the initialization without regularization, we reserve regularization loss for stability and convergence.

Influence of negative augmentation strategy. We conduct experiments to analyse the influence of negative augmentation strategy. In Tab. 7, baseline does not employ augmentation. Cutout and random crop are used as augmentation, respectively. It is concluded that improper augmentation is unfavorable to detection ability. By contrast, random crop is helpful to enhance regional-related representation and distinguish outliers, which confirms our analysis above.

Number of local negative prompts. The number of local negative prompts N_{neg} stands for local outlier knowledge the model learns from negative augmentation. Results in Tab. 8 indicate that the performance is positively related to N_{neg}. However, larger N_{neg} requires more computational resources. Considering both computational cost and performance, the number 300 is selected.

OOD score strategy. We compare our proposed OOD score with existing scores (Ming et al., 2022; Miyai et al., 2023b) on 16-shots. We also remove local negative prompts in our OOD score to analyse their effectiveness. Results in Fig. 4 imply that our regional OOD score attains better performance than existing strategy, displaying the strength of regional enhancement. Moreover, the performance is further promoted when negative prompts are introduced. We attribute it to possible outlier leverage through negative prompts.

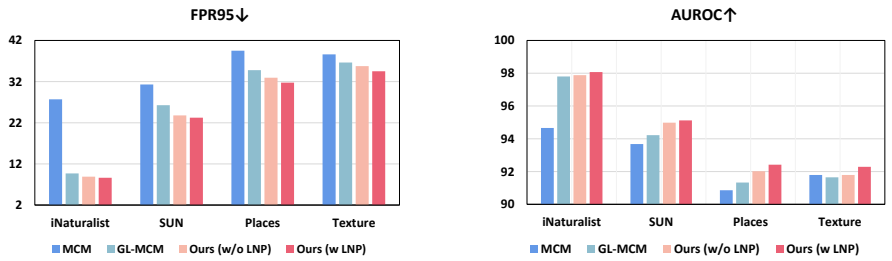

Figure 4: Ablation study of different OOD score strategies. LNP denotes local negative prompts.

Table 8: Influence of different number of local negative prompts.

N_{neg}	iNaturalist		SUN		Places		Texture		**Average**	
	FPR95↓	AUROC↑	FPR95↓	AUROC↑	FPR95↓	AUROC↑	FPR95↓	AUROC↑	FPR95↓	AUROC↑
100	9.02	98.00	24.71	94.82	32.77	91.87	48.81	88.50	28.82	93.30
200	9.65	97.90	22.58	95.26	32.03	92.18	49.85	88.00	28.52	93.33
300	9.39	97.97	24.20	95.10	32.13	92.21	49.37	88.66	28.77	93.48

5.3 VISUALIZATION

Visualization of local prompts. We give a detailed explanation of local prompts and visualize the regions that attract attention from local prompts and local negative prompts. Visualization is shown in Fig. 5 in the order of original picture, ID-related, and several typical OOD-related areas. It implies that local prompts concentrate on ID regions and local negative prompts are helpful to extract ID-irrelevant, *i.e.*, outlier areas corresponding to certain semantics. For instance, local negative prompts successfully focus on sky, sea, and beach, respectively in pirate ship, which is beneficial to enhance OOD detection ability through local and unknown knowledge leverage.

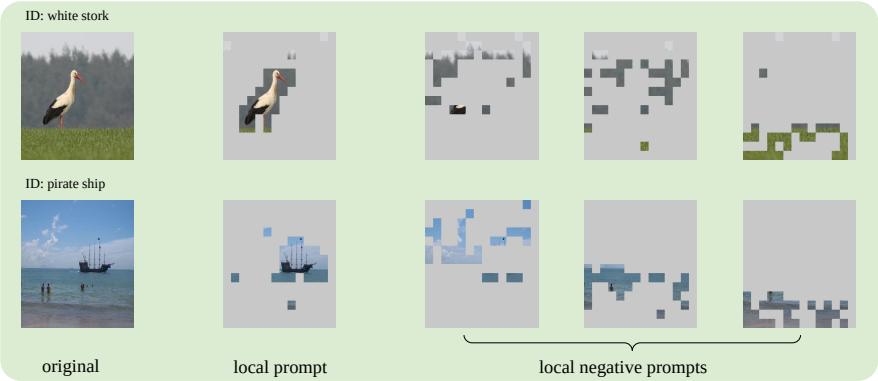

Figure 5: Visualization of ID and OOD related regions. Local prompts and local negative prompts successfully focus on ID-related and OOD-related regions, respectively, which helps OOD detection.

Visualization of hard OOD samples. We showcase several hard OOD samples that previous global-based method fails to detect, while our method with local enhancement successfully discriminates the outlier. For example, in the first image, previous global-based method fails to detect the outlier as it is similar to ID category ocean liner on the whole, with only subtle difference mechanical devices on the deck indicating that it is actually an icebreaker (also demonstrated by the iceberg next to it). The same phenomenon are also observed other examples.

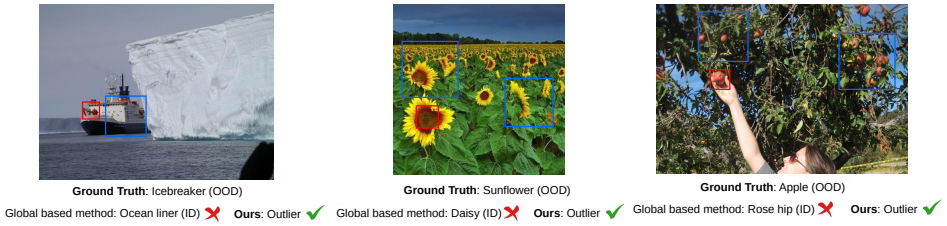

Figure 6: Examples of outlier from SUN dataset that fails to be detected by previous global-based method, and our method with local enhancement successfully discriminates them with subtle differences in certain regions.

6 CONCLUSION

In this paper, we investigate the relationship between global and local prompts for few-shot OOD detection. Concentrating on enhancing outlier knowledge for better local textual representation utilization, we decompose global and local features using respective prompts. We use straightforward negative augmentation to leverage local outlier knowledge and propose local prompts to enhance regional information by means of regional regularization. We also propose regional-related evaluation metric to enrich the detector with local outlier information. Moreover, our approach is extensible to well-trained global prompts to get better performance. We conduct various experiments and superior results underline the effectiveness of our method. We hope our method can provide a new perspective on studying local prompts for OOD detection tasks based on vision-language models.

ACKNOWLEDGEMENT

This work is supported by National Science and Technology Major Project (2022ZD0116500), National Natural Science Foundation of China (62222609, 62076236), and CAS Project for Young Scientists in Basic Research (YSBR-083).

REFERENCES

Hyojin Bahng, Ali Jahanian, Swami Sankaranarayanan, and Phillip Isola. Exploring visual prompts for adapting large-scale models. *arXiv preprint arXiv:2203.17274*, 2022.

Yichen Bai, Zongbo Han, Bing Cao, Xiaoheng Jiang, Qinghua Hu, and Changqing Zhang. Id-like prompt learning for few-shot out-of-distribution detection. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*, pp. 17480–17489, 2024.

Qiang Chen, Xiaokang Chen, Gang Zeng, and Jingdong Wang. Group detr: Fast training convergence with decoupled one-to-many label assignment. *arXiv preprint arXiv:2207.13085*, 2022.

Bowen Cheng, Ishan Misra, Alexander G Schwing, Alexander Kirillov, and Rohit Girdhar. Masked-attention mask transformer for universal image segmentation. In *Proceedings of the IEEE/CVF conference on computer vision and pattern recognition*, pp. 1290–1299, 2022.

Zhen Cheng, Xu-Yao Zhang, and Cheng-Lin Liu. Unified classification and rejection: A one-versus-all framework. *arXiv preprint arXiv:2311.13355*, 2023a.

Zhen Cheng, Fei Zhu, Xu-Yao Zhang, and Cheng-Lin Liu. Average of pruning: Improving performance and stability of out-of-distribution detection. *arXiv preprint arXiv:2303.01201*, 2023b.

Mircea Cimpoi, Subhransu Maji, Iasonas Kokkinos, Sammy Mohamed, and Andrea Vedaldi. Describing textures in the wild. In *Proceedings of the IEEE conference on computer vision and pattern recognition*, pp. 3606–3613, 2014.

Jia Deng, Wei Dong, Richard Socher, Li-Jia Li, Kai Li, and Li Fei-Fei. Imagenet: A large-scale hierarchical image database. In *2009 IEEE conference on computer vision and pattern recognition*, pp. 248–255. Ieee, 2009.

Alexey Dosovitskiy, Lucas Beyer, Alexander Kolesnikov, Dirk Weissenborn, Xiaohua Zhai, Thomas Unterthiner, Mostafa Dehghani, Matthias Minderer, Georg Heigold, Sylvain Gelly, et al. An image is worth 16x16 words: Transformers for image recognition at scale. In *International Conference on Learning Representations*, 2020.

Sepideh Esmaeilpour, Bing Liu, Eric Robertson, and Lei Shu. Zero-shot out-of-distribution detection based on the pre-trained model clip. In *Proceedings of the AAAI conference on artificial intelligence*, volume 36, pp. 6568–6576, 2022.

Angelos Filos, Panagiotis Tigkas, Rowan McAllister, Nicholas Rhinehart, Sergey Levine, and Yarin Gal. Can autonomous vehicles identify, recover from, and adapt to distribution shifts? In *International Conference on Machine Learning*, pp. 3145–3153. PMLR, 2020.

Stanislav Fort, Jie Ren, and Balaji Lakshminarayanan. Exploring the limits of out-of-distribution detection. *Advances in Neural Information Processing Systems*, 34:7068–7081, 2021.

Peng Gao, Shijie Geng, Renrui Zhang, Teli Ma, Rongyao Fang, Yongfeng Zhang, Hongsheng Li, and Yu Qiao. Clip-adapter: Better vision-language models with feature adapters. *International Journal of Computer Vision*, pp. 1–15, 2023.

Ziyu Guo, Renrui Zhang, Longtian Qiu, Xianzheng Ma, Xupeng Miao, Xuming He, and Bin Cui. Calip: Zero-shot enhancement of clip with parameter-free attention. In *Proceedings of the AAAI Conference on Artificial Intelligence*, volume 37, pp. 746–754, 2023.

Kaiming He, Xinlei Chen, Saining Xie, Yanghao Li, Piotr Dollár, and Ross Girshick. Masked autoencoders are scalable vision learners. In *Proceedings of the IEEE/CVF conference on computer vision and pattern recognition*, pp. 16000–16009, 2022.

Dan Hendrycks and Kevin Gimpel. A baseline for detecting misclassified and out-of-distribution examples in neural networks. In *International Conference on Learning Representations*, 2016.

Dan Hendrycks, Mantas Mazeika, and Thomas Dietterich. Deep anomaly detection with outlier exposure. In *International Conference on Learning Representations*, 2018.

Paul F Jaeger, Carsten Tim Lüth, Lukas Klein, and Till J Bungert. A call to reflect on evaluation practices for failure detection in image classification. In *The Eleventh International Conference on Learning Representations*, 2022.

Menglin Jia, Luming Tang, Bor-Chun Chen, Claire Cardie, Serge Belongie, Bharath Hariharan, and Ser-Nam Lim. Visual prompt tuning. In *European Conference on Computer Vision*, pp. 709–727. Springer, 2022.

Xue Jiang, Feng Liu, Zhen Fang, Hong Chen, Tongliang Liu, Feng Zheng, and Bo Han. Negative label guided ood detection with pretrained vision-language models. In *The Twelfth International Conference on Learning Representations*, 2024.

Junnan Li, Ramprasaath Selvaraju, Akhilesh Gotmare, Shafiq Joty, Caiming Xiong, and Steven Chu Hong Hoi. Align before fuse: Vision and language representation learning with momentum distillation. *Advances in neural information processing systems*, 34:9694–9705, 2021.

Wei Li, Linchao Zhu, Longyin Wen, and Yi Yang. Decap: Decoding clip latents for zero-shot captioning via text-only training. In *The Eleventh International Conference on Learning Representations*, 2022a.

Yanghao Li, Hanzi Mao, Ross Girshick, and Kaiming He. Exploring plain vision transformer backbones for object detection. In *European Conference on Computer Vision*, pp. 280–296. Springer, 2022b.

Weitang Liu, Xiaoyun Wang, John Owens, and Yixuan Li. Energy-based out-of-distribution detection. *Advances in neural information processing systems*, 33:21464–21475, 2020.

Yangyang Liu, Yi Chen, Fei Yin, and Cheng-Lin Liu. Context-aware confidence estimation for rejection in handwritten chinese text recognition. In *International Conference on Document Analysis and Recognition*, pp. 134–151. Springer, 2024.

Ze Liu, Yutong Lin, Yue Cao, Han Hu, Yixuan Wei, Zheng Zhang, Stephen Lin, and Baining Guo. Swin transformer: Hierarchical vision transformer using shifted windows. In *Proceedings of the IEEE/CVF international conference on computer vision*, pp. 10012–10022, 2021.

Ze Liu, Han Hu, Yutong Lin, Zhuliang Yao, Zhenda Xie, Yixuan Wei, Jia Ning, Yue Cao, Zheng Zhang, Li Dong, et al. Swin transformer v2: Scaling up capacity and resolution. In *Proceedings of the IEEE/CVF conference on computer vision and pattern recognition*, pp. 12009–12019, 2022.

Eric Lopez-Lopez, Xose M Pardo, and Carlos V Regueiro. Incremental learning from low-labelled stream data in open-set video face recognition. *Pattern Recognition*, 131:108885, 2022.

Depu Meng, Xiaokang Chen, Zejia Fan, Gang Zeng, Houqiang Li, Yuhui Yuan, Lei Sun, and Jingdong Wang. Conditional detr for fast training convergence. In *Proceedings of the IEEE/CVF International Conference on Computer Vision*, pp. 3651–3660, 2021.

Yifei Ming, Ziyang Cai, Jiuxiang Gu, Yiyou Sun, Wei Li, and Yixuan Li. Delving into out-of-distribution detection with vision-language representations. *Advances in Neural Information Processing Systems*, 35:35087–35102, 2022.

Atsuyuki Miyai, Qing Yu, Go Irie, and Kiyoharu Aizawa. Locoop: Few-shot out-of-distribution detection via prompt learning. *arXiv preprint arXiv:2306.01293*, 2023a.

Atsuyuki Miyai, Qing Yu, Go Irie, and Kiyoharu Aizawa. Zero-shot in-distribution detection in multi-object settings using vision-language foundation models. *arXiv preprint arXiv:2304.04521*, 2023b.

Sangha Park, Jisoo Mok, Dahuin Jung, Saehyung Lee, and Sungroh Yoon. On the powerfulness of textual outlier exposure for visual ood detection. In *Thirty-seventh Conference on Neural Information Processing Systems*, 2023.

Alec Radford, Jong Wook Kim, Chris Hallacy, Aditya Ramesh, Gabriel Goh, Sandhini Agarwal, Girish Sastry, Amanda Askell, Pamela Mishkin, Jack Clark, et al. Learning transferable visual models from natural language supervision. In *International conference on machine learning*, pp. 8748–8763. PMLR, 2021.

Piyush Sharma, Nan Ding, Sebastian Goodman, and Radu Soricut. Conceptual captions: A cleaned, hypernymed, image alt-text dataset for automatic image captioning. In *Proceedings of the 56th Annual Meeting of the Association for Computational Linguistics (Volume 1: Long Papers)*, pp. 2556–2565, 2018.

Yang Shu, Xingzhuo Guo, Jialong Wu, Ximei Wang, Jianmin Wang, and Mingsheng Long. Clipood: Generalizing clip to out-of-distributions. 2023.

Robin Strudel, Ricardo Garcia, Ivan Laptev, and Cordelia Schmid. Segmenter: Transformer for semantic segmentation. In *Proceedings of the IEEE/CVF international conference on computer vision*, pp. 7262–7272, 2021.

Leitian Tao, Xuefeng Du, Jerry Zhu, and Yixuan Li. Non-parametric outlier synthesis. In *The Eleventh International Conference on Learning Representations*, 2022.

Hugo Touvron, Matthieu Cord, Matthijs Douze, Francisco Massa, Alexandre Sablayrolles, and Hervé Jégou. Training data-efficient image transformers & distillation through attention. In *International conference on machine learning*, pp. 10347–10357. PMLR, 2021.

Vishaal Udandarao, Ankush Gupta, and Samuel Albanie. Sus-x: Training-free name-only transfer of vision-language models. In *Proceedings of the IEEE/CVF International Conference on Computer Vision*, pp. 2725–2736, 2023.

Grant Van Horn, Oisin Mac Aodha, Yang Song, Yin Cui, Chen Sun, Alex Shepard, Hartwig Adam, Pietro Perona, and Serge Belongie. The inaturalist species classification and detection dataset. In *Proceedings of the IEEE conference on computer vision and pattern recognition*, pp. 8769–8778, 2018.

Haoqi Wang, Zhizhong Li, Litong Feng, and Wayne Zhang. Vim: Out-of-distribution with virtual-logit matching. In *Proceedings of the IEEE/CVF conference on computer vision and pattern recognition*, pp. 4921–4930, 2022.

Hualiang Wang, Yi Li, Huifeng Yao, and Xiaomeng Li. Clipn for zero-shot ood detection: Teaching clip to say no. In *Proceedings of the IEEE/CVF International Conference on Computer Vision*, pp. 1802–1812, 2023.

Wenhai Wang, Enze Xie, Xiang Li, Deng-Ping Fan, Kaitao Song, Ding Liang, Tong Lu, Ping Luo, and Ling Shao. Pyramid vision transformer: A versatile backbone for dense prediction without convolutions. In *Proceedings of the IEEE/CVF international conference on computer vision*, pp. 568–578, 2021.

Jianxiong Xiao, James Hays, Krista A Ehinger, Aude Oliva, and Antonio Torralba. Sun database: Large-scale scene recognition from abbey to zoo. In *2010 IEEE computer society conference on computer vision and pattern recognition*, pp. 3485–3492. IEEE, 2010.

Hu Xu, Gargi Ghosh, Po-Yao Huang, Dmytro Okhonko, Armen Aghajanyan, Florian Metze, Luke Zettlemoyer, and Christoph Feichtenhofer. Videoclip: Contrastive pre-training for zero-shot video-text understanding. In *Proceedings of the 2021 Conference on Empirical Methods in Natural Language Processing*, pp. 6787–6800, 2021.

Fanhu Zeng and Deli Yu. M2m-tag: Training-free many-to-many token aggregation for vision transformer acceleration. In *Workshop on Machine Learning and Compression, NeurIPS 2024*.

Fanhu Zeng, Fei Zhu, Haiyang Guo, Xu-Yao Zhang, and Cheng-Lin Liu. Modalprompt: Dual-modality guided prompt for continual learning of large multimodal models. *arXiv preprint arXiv:2410.05849*, 2024.

Ji Zhang, Lianli Gao, Bingguang Hao, Hao Huang, Jingkuan Song, and Hengtao Shen. From global to local: Multi-scale out-of-distribution detection. *IEEE Transactions on Image Processing*, 2023.

Renrui Zhang, Rongyao Fang, Wei Zhang, Peng Gao, Kunchang Li, Jifeng Dai, Yu Qiao, and Hongsheng Li. Tip-adapter: Training-free clip-adapter for better vision-language modeling. *arXiv preprint arXiv:2111.03930*, 2021.

Bolei Zhou, Agata Lapedriza, Aditya Khosla, Aude Oliva, and Antonio Torralba. Places: A 10 million image database for scene recognition. *IEEE transactions on pattern analysis and machine intelligence*, 40(6):1452–1464, 2017.

Kaiyang Zhou, Jingkang Yang, Chen Change Loy, and Ziwei Liu. Conditional prompt learning for vision-language models. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*, pp. 16816–16825, 2022a.

Kaiyang Zhou, Jingkang Yang, Chen Change Loy, and Ziwei Liu. Learning to prompt for vision-language models. *International Journal of Computer Vision*, 130(9):2337–2348, 2022b.

Fei Zhu, Zhen Cheng, Xu-Yao Zhang, and Cheng-Lin Liu. Openmix: Exploring outlier samples for misclassification detection. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*, pp. 12074–12083, 2023a.

Fei Zhu, Xu-Yao Zhang, Zhen Cheng, and Cheng-Lin Liu. Revisiting confidence estimation: Towards reliable failure prediction. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 2023b.

Xiangyang Zhu, Renrui Zhang, Bowei He, Aojun Zhou, Dong Wang, Bin Zhao, and Peng Gao. Not all features matter: Enhancing few-shot clip with adaptive prior refinement. *arXiv preprint arXiv:2304.01195*, 2023c.

APPENDIX

A DATASET DETAILS

ImageNet-10 contains 10 classes of ImageNet-1k, including military aircraft (n04552348), sports car (n04285008), brambling (n01530575), Siamese cat (n02123597), impala (n02422699), Greater Swiss Mountain Dog (n02107574), American bullfrog (n01641577), garbage truck (n03417042), common sorrel horse (n02389026) and container ship (n03095699).

ImageNet-20 is a 20-class subset in ImageNet-1k. Concretely, they are schooner (n04147183), canoe (n02951358), balloon (n02782093), tank (n04389033), missile (n03773504), high-speed train (n02917067), starfish (n02317335), spotted salamander (n01632458), smooth newt (n01630670), newt (n01631663), zebra (n02391049), European green lizard (n01693334), Nile crocodile (n01697457), Arctic fox (n02120079), grey wolf (n02114367), brown bear (n02132136), moped (n03785016), steam locomotive (n04310018), space shuttle (n04266014) and snowmobile (n04252077).

ImageNet-100 is the same 100-class subset of ImageNet-1k as MCM (Ming et al., 2022) to have a fair comparison with previous vision-language based OOD detection methods. Detail categories are provided in https://github.com/deeplearning-wisc/MCM.

B TRAINING DETAILS

Number of learnable context words is 16. We use SGD optimizer to train the model with 30 epochs. Learning rate is 2×10^{-3} with a cosine schedule and batch size is 256. m is set to 24 by default. We empirically set positive/negative augmentation to be 8/1, which are discussed thoroughly below. Training and testing k are 50 and 10, respectively in main results. We use one single NVIDIA A6000 to run all experiments. The reported results are averaged for three runs. Extra experimental results are shown below.

C MORE EXPERIMENTAL RESULTS

Experiments of different shots. We use ImageNet-1k as ID dataset in the main experiment. For training, we use different shots, *i.e.*, numbers of images from each class, following few-shot setting. For evaluation, we use validation set of ImageNet-1k, which is composed of 50000 images from 1000 categories. Results are shown in Tab. 9.

Influence of coefficient. Both λ_{neg} and λ_{reg} determine the importance of the corresponding loss. We report average FPR95 and AUROC to show the trend when the coefficients vary. The results in Tab. 10 indicate that the performance tends to be stable when the coefficients are in a wide range. During the entire ablation process, the results are relatively robust when the ratio of the two corresponding coefficients is approximately within $[2, 10]$, with performance drop under extreme cases ($\lambda_{\text{neg}} = 0.1$ and 50). For $\lambda_{\text{neg}} = 50$, the loss for local prompts is neglected, resulting in severe

Table 9: More few-shot experimental results on ImageNet-1k.

Method	iNaturalist		SUN		Places		Texture		**Average**	
	FPR95↓	AUROC↑	FPR95↓	AUROC↑	FPR95↓	AUROC↑	FPR95↓	AUROC↑	FPR95↓	AUROC↑
					4-*shot*					
CoOp	18.95	95.52	29.58	92.90	38.72	89.64	48.03	85.87	33.82	90.98
LoCoOp	21.67	95.69	22.98	95.07	31.41	92.10	49.79	87.85	31.46	92.68
Local-Prompt	9.65	97.87	20.40	95.57	29.39	92.67	51.20	88.00	27.66	93.53
					8-*shot*					
CoOp	15.23	96.69	27.78	93.08	35.93	90.22	48.26	85.91	31.80	91.47
LoCoOp	16.34	96.47	22.40	94.96	31.86	91.83	42.20	89.81	28.20	93.27
Local-Prompt	10.17	97.83	19.82	95.42	30.83	92.54	48.26	88.47	27.27	93.56
					16-*shot*					
CoOp	14.60	96.62	28.48	92.65	36.49	89.98	43.13	88.03	30.67	91.82
LoCoOp	16.05	96.86	23.44	95.07	32.87	91.98	42.28	90.19	28.66	93.52
Local-Prompt	8.71	98.10	23.97	94.85	32.50	92.32	47.93	89.04	28.27	93.58

Table 10: Influence of different coefficient in loss function.

		iNaturalist		SUN		Places		Texture		**Average**	
		FPR95↓	AUROC↑	FPR95↓	AUROC↑	FPR95↓	AUROC↑	FPR95↓	AUROC↑	FPR95↓	AUROC↑
λ_{neg}	0.1	17.64	95.97	27.18	94.76	34.45	91.41	48.82	86.89	32.02	92.25
	2	9.47	97.97	24.11	94.99	32.28	92.07	47.94	88.86	28.45	93.47
	5	9.39	97.97	24.20	95.10	32.13	92.21	49.37	88.66	28.77	93.48
	10	10.19	97.83	23.46	95.26	31.59	92.31	49.57	88.81	28.70	93.55
	50	34.09	92.06	42.34	88.63	50.88	83.52	62.47	85.70	47.44	87.48
λ_{reg}	0.2	9.83	97.88	24.60	94.92	32.65	92.10	49.82	88.63	29.22	93.38
	0.5	9.39	97.97	24.20	95.10	32.13	92.21	49.37	88.66	28.77	93.48
	1	11.24	97.67	25.87	94.77	33.54	91.89	48.38	88.97	29.75	93.32

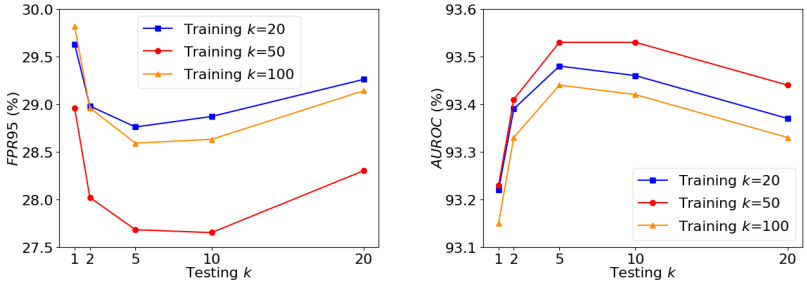

Figure 7: Results on different values of k for training and inference.

performance drop. For $\lambda_{\text{neg}} = 0.1$, the local negative prompts are over-regularized by diversity constraints. The effectiveness of the proposed loss can be further verified accordingly.

Regional number. Regional number k expresses the extent to which local prompts pay attention to areas. As regional information is not always ID or OOD-related, the selection of regional number k largely determines performance. During training, Regions are selected to emphasize suitable ID-related regions (outlier regions when hard negative images) and learn regional-related local prompts. During inference, k is relatively smaller to guarantee the confidence of the selected region for metric calculation. We conduct various experiments on different values of k during both training and testing. Curves shown in Fig. 7 illustrate that for both k during training and inference, larger k will confuse confidence of the boundary between ID and OOD regions, while smaller k fails to extract precise regional-related textual representations, which corresponds to our analysis. We underline that varying k brings in subtle differences and even simplified outcome without careful selection of k still achieves better results than previous approaches.

Extra training time. We extend the training time to analyse the benefits of longer training. It can be seen in Tab. 11 that 30 epochs is sufficient to get superior representations in few-shot prompt tuning and longer training time does not necessarily bring about the improvements of performance. By contrast, LoCoOp (Miyai et al., 2023a) requires 50 epochs and it indicates that our approach is well and fast converged, which is in line with the purpose of few-shot learning.

Number of negative augmentation. The number of negative augmentation influences the performance. It can be seen in Tab. 12 that setting negative augmentation to be 1 achieves obviously better results. A potential reason for the phenomenon is that random crops of original images are hard enough for the detector to learn local outlier information and too much negative augmentation may confuse the learning process. Consequently, we choose the least similar image as the negative augmentation.

Table 11: Influence of longer training time.

epoch	iNaturalist		SUN		Places		Texture		**Average**	
	FPR95↓	AUROC↑	FPR95↓	AUROC↑	FPR95↓	AUROC↑	FPR95↓	AUROC↑	FPR95↓	AUROC↑
30	9.39	97.97	24.20	95.10	32.13	92.21	49.37	88.66	28.77	93.48
50	9.60	97.83	23.71	95.05	32.31	92.02	48.47	88.68	28.52	93.40

Table 12: Influence of negative augmentation number.

N	iNaturalist		SUN		Places		Texture		**Average**	
	FPR95↓	AUROC↑	FPR95↓	AUROC↑	FPR95↓	AUROC↑	FPR95↓	AUROC↑	FPR95↓	AUROC↑
1	9.39	97.97	24.20	95.10	32.13	92.21	49.37	88.66	28.77	93.48
8	10.31	97.80	25.18	94.96	33.36	92.06	51.32	87.64	30.04	93.12

Table 13: Comparison with ID-like.

Method	iNaturalist		SUN		Places		Texture		**Average**	
	FPR95↓	AUROC↑	FPR95↓	AUROC↑	FPR95↓	AUROC↑	FPR95↓	AUROC↑	FPR95↓	AUROC↑
ID-like	8.98	98.19	42.03	91.64	44.00	90.57	25.27	94.32	30.07	93.68
Ours	12.81	97.29	19.34	95.85	27.53	92.97	45.51	89.99	**26.29**	**94.03**

Comparison with ID-like. We additionally compare with ID-like (Bai et al., 2024), and the results shown in Tab. 13 reveal that our model achieves better average performance against ID-like, demonstrating the utility of our local information enhancement strategy.

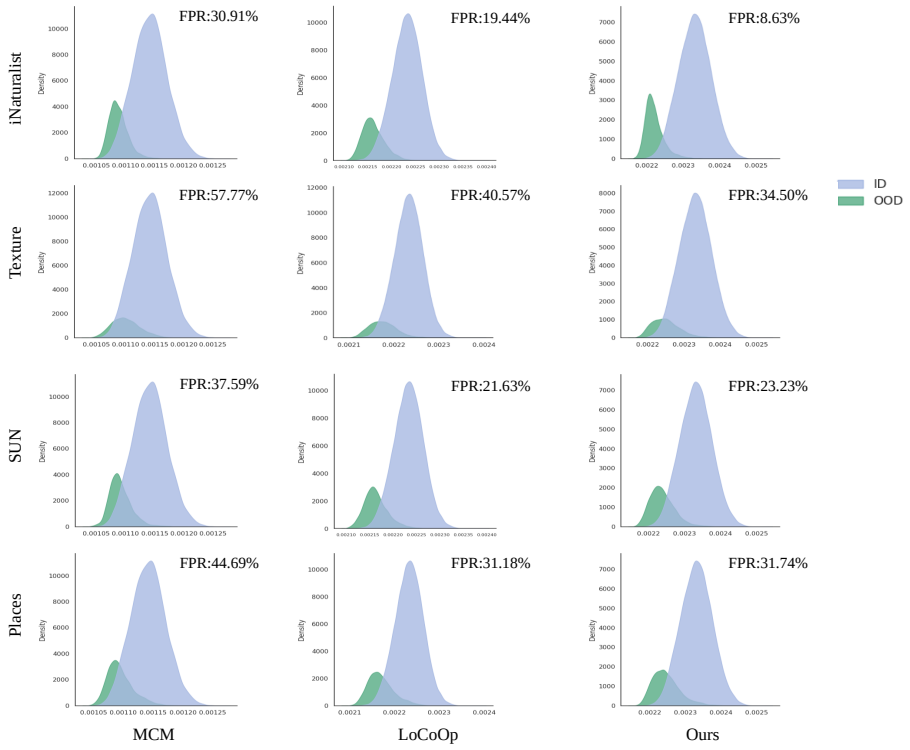

Figure 8: Density map of different OOD datasets measured by various methods.

D VISUALIZATION AND ANALYSIS

Visualization of heatmaps. we additionally include heatmaps maps of typical images to illustrate the attention of our methods. It can be seen in Fig. 9 that our method accurately focuses on ID regions despite the interference of complex background surroundings, *e.g.*, tabby cat, lion and leonberg with complex background of grassland, which showcases the effectiveness of pseudo background augmentation serving as local outlier. Moreover, our method also captures multi-objects, *e.g.*, the ships on the sea (third picture on the first row), strongly validating the usefulness of local enhancement in the framework.

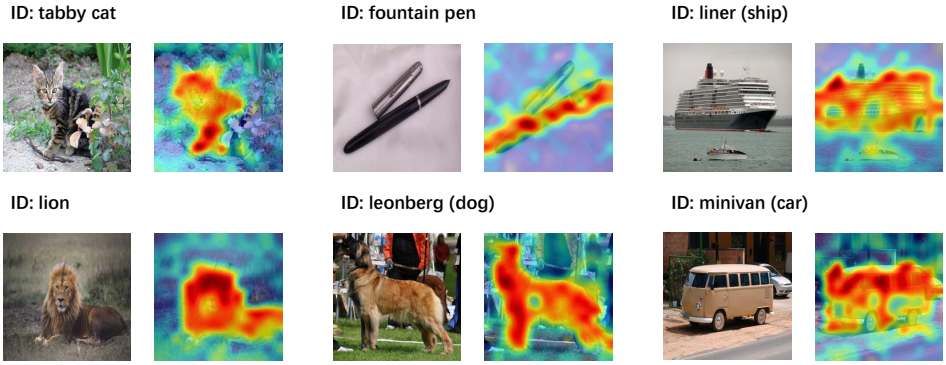

Figure 9: Visualization of heatmaps.

Table 14: The top-k average similarity of both ID-dataset and OOD datasets with local prompts.

k	10	20	50
w/o local enhancement			
ID-dataset	0.297	0.286	0.272
OOD-datasets	0.280	0.276	0.261
w local enhancement			
ID-dataset	0.312	0.306	0.282
OOD-datasets	0.273	0.266	0.249

More visualization. We visualize the density map of 4 OOD datasets, *i.e.*, iNaturalist, SUN, Places and Texture and compare them with typical existing methods. Fig. 8 exhibits that our approach is capable of distinguishing ID and OOD samples with more confidence and has obviously less overlap between them than previous zero-shot and few-shot methods. It strongly demonstrates the effectiveness and potential of our local prompt based method.

Similarity of enhanced regions. We calculate the top-k average similarity of both ID-dataset and OOD datasets with local prompts to qualitatively showcase the effectiveness of local enhancement. It can be clearly seen in Tab. 14 that the method without local enhancement has no obvious boundary between ID and OOD datasets (0.272 for top-50 and 0.276 for top-20), which may confuse the model when detecting hard outlier samples where subtle difference occurs in certain regions of the image. By contrast, our method appears to be more discriminant and has an obvious boundary between them (0.282 for ID and 0.273 for OOD). It additionally demonstrates the core problem that current method encounters and our method of refining local regions successfully addresses the issue to some extent.

E LIMITATIONS AND FUTURE WORK

Training time. The primary limitation of our work is that it may require more training time due to negative augmentation. However, as few shot tuning paradigm for vision-language model is efficient and time-saving, it will not be the bottleneck of the model. Practically, we fine-tune CLIP on one single NVIDIA A6000 and 4-shot tuning only needs 4 hours.

Joint training of both global and local prompts. In our work, we mainly concentrate on the effectiveness of local prompts as an enhancement and set global prompts frozen/from existing methods. We believe that exploiting the connection between global and local features is promising. Therefore, we are in an effort to explore the advantage of training global and local prompts jointly.

Expansion to other recognition tasks. In this work, we focus on OOD detection for classification task. It will be an interesting topic to handle other vision tasks in open-world such as segmentation and object detection. However, existing methods also merely deal with one task at a time. Nevertheless, we believe the proposed local prompts can be generally useful as long as the applied tasks have rich local information.